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March 13, 2026

Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL A1A 5B2

Attention: Colleen Jones
Assistant Board Secretary

Re: Application for Approval of Capital Expenditures for Section Replacement and Weld Refurbishment for Bay d'Espoir Hydroelectric Generating Facility Penstock 3

Please find enclosed Newfoundland and Labrador Hydro's ("Hydro") application for approval of capital expenditures for section replacement and weld refurbishment of Penstock 3 at the Bay d'Espoir Hydroelectric Generating Facility ("Bay d'Espoir"). This project is required for the safe and reliable operation of Penstock 3 in Bay d'Espoir. Project execution is expected to take three years with an estimated project cost of $77,462,128. This application also contains a request for approval to proceed with certain aspects of the work in advance of the overall project approval ("Early Execution") to allow for regulatory review of the application without resulting in delays to the overall construction timeline for the proposed project. The Early Execution capital expenditures for which approval is requested are estimated at $1,942,814.

Need for Refurbishment

The current operational status of Penstock 3 in Bay d'Espoir is not a viable long-term solution to meet Hydro's mandate to provide safe, least-cost, reliable power. Inspections on Penstock 3 in 2018 led to 1,030 m of weld refurbishment, and annual inspections on the penstock continue to identify signs of wear, corrosion, and stress-related issues. As with Bay d'Espoir Penstock 1, for which section replacement and weld refurbishment were approved in Board Order No. P.U. 6(2023), recent inspections of Penstock 3 have revealed additional cracking in welds previously repaired within the 11.1 mm (7/16 in.) steel section. The operational flexibility of Bay d'Espoir Units 5 and 6 has been limited to mitigate the ongoing risk of penstock failure.

Further details regarding the condition of Penstock 3, the review and analysis of options, and the recommended solution are provided in Schedule 1 to the application and its associated attachments.

Timing of Application

Deferral of this work would pose a significant system reliability risk given the penstock's condition and scheduling constraints, which require execution of this project during the planned outage period in 2027. The timing of the 2025 inspections meant that this project proposal could not be included in the 2026 Capital Budget Application, and the timelines for necessary approvals preclude including this project in the 2027 Capital Budget Application, for which Board approval would not be expected until the end of 2026. Additionally, awaiting the completion of the Penstock 1 project allowed lessons learned from that project to be incorporated into the planned execution of Penstock 3 and enabled Hydro to maximize efficiencies, reducing costs and risks to the benefit of customers. Refurbishment of Penstock 3

is urgently required to ensure ongoing safe, reliable service from Bay d'Espoir and to enable Hydro to continue meeting established planning criteria and satisfying current customer requirements. Based on the above, Hydro decided to proceed with this proposal as a supplemental capital project.

Early Execution Approval

To meet and avail of the 2027 outage window, both to ensure the Penstock 3 issues are expeditiously addressed and to avoid implications for Hydro's scheduled capital improvements and maintenance plan for other assets that could directly impact system reliability and capital costs, Hydro will need to begin certain aspects of the project in 2026. As time is also needed for the Board and any intervenors to review and consider Hydro's application, Hydro is requesting approval for Early Execution expenditures. Hydro is not requesting the recovery of any expenditures related to the Early Execution prior to the Board's approval of the overall project. Details regarding the Early Execution expenditures and the necessity of its approval are provided in Schedule 1 to this application, in particular Sections 3.1 and 6.1. Approval of Early Execution expenditures is needed prior to April 20, 2026, the estimated end of the bid period for the steel supply required for the project.

This application contains commercially sensitive information regarding the budget and other contractual aspects of the proposed projects. An unredacted version of the report is being provided to the Board on a confidential basis. The parties will be provided with a version in which this information has been redacted. Hydro requests that this information be kept confidential and not be made publicly available. Hydro requests that the Board use the redacted version for posting to its website.

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO



Shirley A. Walsh
Senior Legal Counsel, Regulatory
SAW/sk

Encl.

ecc:

Board of Commissioners of Public Utilities
Jacqui H. Glynn
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Board General

Island Industrial Customer Group
Paul L. Coxworthy, Stewart McKelvey
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Consumer Advocate
Adrienne H.Y. Ding, O'Dea Earle
Justin W. King, O'Dea Earle

Section Replacement and Weld Refurbishment

Bay d'Espoir Penstock 3

March 12, 2026

An application to the Board of Commissioners of Public Utilities

newfoundland labrador hydro

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IN THE MATTER OF the *Electrical Power Control Act, 1994*, SNL 1994, Chapter E-5.1 ("*EPCA*") and the *Public Utilities Act*, RSNL 1990, Chapter P-47 ("*Act*"), and regulations thereunder; and

IN THE MATTER OF an application by Newfoundland and Labrador Hydro ("Hydro") for approval of capital expenditures for section replacement and weld refurbishment of Penstock 3 at the Bay d'Espoir Hydroelectric Generating Facility, pursuant to Subsection 41(3) of the *Act.*

To: The Board of Commissioners of Public Utilities ("Board")

THE APPLICATION OF HYDRO STATES THAT:

A. Background

1. Hydro, a corporation continued and existing under the *Hydro Corporation Act, 2024*, is a public utility within the meaning of the *Act* and is subject to the provisions of the *EPCA*.

2. Hydro is the primary generator of electricity in Newfoundland and Labrador. The largest of Hydro's hydroelectric generating facilities on the Island is located at Bay d'Espoir. The Bay d'Espoir Generating Facility ("Bay d'Espoir") provides 613 MW of electrical capacity and 2,560 GWh of energy annually to the Island Interconnected System. It consists of four penstocks that supply water to the seven generating units. Penstock 3 supplies water to Units 5 and 6 in the Bay d'Espoir Powerhouse 1 and is an integral component of the 153 MW of generation from these two units.

3. Penstock 3 has been in service for over 55 years. After four ruptures occurred on Penstock 1 between 2016 and 2019 that resulted in Bay d'Espoir Units 1 and 2 being unavailable for service for extended periods of time, Hydro conducted level 2 condition assessments on all three penstocks that serve Powerhouse 1.

4. Since 2016, Hydro has engaged three different engineering consultants, Hatch Ltd. ("Hatch"), SNC-Lavalin Group Inc. ("SNC-Lavalin"), and Kleinschmidt Associates ("Kleinschmidt"), to provide

support for failure investigations, condition assessments, life extension option analysis, and Front-End Engineering and Design ("FEED") work. The various reports completed by these consultants are included with this application as attachments to Schedule 1.

5. In 2021, Kleinschmidt performed a comprehensive review of four life extension options for Penstocks 1, 2, and 3. Hydro sought Kleinschmidt's recommendations to support Hydro's determination of the most prudent and justifiable investment decision based on the risk, reliability, construction costs, schedule, and viability of each option.

6. In 2022, Hydro had identified Penstock 1 as the most critical of the three penstocks due to the history of weld failures and ruptures in recent years and requested approval from the Board for capital expenditures necessary for section replacement and weld refurbishment. Approval was received from the Board in April 2023, and replacement and refurbishment were completed with the penstock returning to service in December 2025.

7. During the review of Penstock 1, acknowledging that Penstocks 2 and 3 would require similar refurbishment projects at some point in the future, both penstocks were included in the FEED analysis to enable Hydro to understand risks, cost, and execution strategies to better inform its capital planning. Hydro continued to conduct annual inspections of Penstocks 2 and 3 to assess their condition and determine the appropriate timing for capital investment, while avoiding ruptures similar to those experienced on Penstock 1.

8. As with Penstock 1, recent inspections of Penstock 3 have revealed additional cracking in welds previously repaired within the 11.1 mm (7/16 in.) steel section. Based on the results of these annual inspections, Hydro implemented a more prescriptive operating regime for Units 5 and 6.[1] Under this operating regime, Units 5 and 6 are limited to a minimum unit loading of 50 MW once dispatched and are not cycled or shut down as part of normal system operations. These operating measures are intended to manage asset condition risk while maintaining system reliability.

[1] A similar prescriptive operating regime, including minimum loading limits and restrictions on cycling, was previously implemented for Units 1 and 2 due to the rupture history and condition of Penstock 1 and remained in place until capital refurbishment work was substantially complete in 2025.

9. The options for Penstock 3 are discussed throughout the attached Schedule 1, as well as in Kleinschmidt's report, enclosed as Attachment 1 to Schedule 1. Kleinschmidt's analysis of the four options for the life extension of Penstock 3 determined that Option 3, section replacement and weld refurbishment, would provide the greatest level of risk mitigation and the highest level of reliability among the available options. It is the only option that would adequately address the peaking and fatigue issues in the 17-ft. diameter section and allow Units 5 and 6 to return to normal operation.

10. In Board Order No. P.U. 6(2023) regarding Hydro's application for section replacement and weld refurbishment of Penstock 1, the Board found that while the proposed course of action was the most expensive alternative, it had the lowest risk rating and highest level of reliability. The Board found that the proposed section replacement and weld refurbishment of Penstock 1 were reasonable and necessary to ensure the delivery of safe, reliable service at the lowest possible cost and should be approved. The information and evidence provided herein is consistent with that provided in the Penstock 1 proceeding, and Hydro believes support a similar conclusion.

11. Project execution is anticipated to take three years. Due to the timing of the inspections in 2025 that were necessary to obtain the required information to inform Hydro's capital planning for the penstock as well as Hydro's decision to await the completion of the work on Penstock 1 to identify and incorporate the experience on that project as efficiencies on the proposed Penstock 3 project, Hydro was unable to include this proposal in the 2026 Capital Budget Application.

12. Due to the criticality of this penstock to the system and the necessity of coordinating this work with other ongoing projects at Bay d'Espoir as well as outage planning and ensuring works are completed before winter-load periods, Hydro determined that work must begin earlier in 2026 and cannot apply in the 2027 Capital Budget Application for which an order would not be available before the end of 2026. Therefore, Hydro has presented this project as a supplemental capital budget application.

13. Additionally, due to the time sensitivities for this project, as part of this application, Hydro is seeking initial early approval for capital expenditures to allow critical scopes of work to proceed while the process of review of the overall project proposal continues ("Early Execution").

14. The request to proceed with Early Execution work in advance of full project approval is to allow Hydro to maintain the overall project schedule and budget and to mitigate the related risks to the system and risk of project cost increases to project costs. The Early Execution work comprises raw steel procurement and line relocation, the expenditures for which will become necessary in April 2026. Further detail regarding the Early Execution work is provided in Sections 3.1 and 6.1 of Schedule 1 to this application. Hydro is not requesting recovery of any expenditures related to the Early Execution prior to Board approval of the overall project.

B. Application

15. Bay d'Espoir Units 5 and 6 provide 153 MW of generation to the Island Interconnected System with the water delivered by Penstock 3. To ensure the safe and reliable operation of Bay d'Espoir Penstock 3, as with the previously approved Penstock 1, Hydro recommends proceeding with Kleinschmidt's recommendation of section replacement and weld refurbishment, as it is reasonable and necessary to ensure the delivery of safe, reliable service at the lowest possible cost.

16. Project execution is expected to take three years. The project description and schedule are detailed in Sections 6.0 and 8.0 of Schedule 1, respectively, and are included within the Basis of Schedule provided as Attachment 12 to Schedule 1 of this Application.

17. The estimated capital cost of the project is $77,462,128. Details regarding the calculation of this planned project budget are contained in Section 7.0 and in the Basis of Estimate provided as Attachment 11 to Schedule 1. The customer rate impact of this project is detailed in Section 7.8 of Schedule 1.

18. The proposed Early Execution budget, detailed in Table 9 in Section 7.2.1 of Schedule 1, is $1,942,814 and is included in the estimated capital cost of the project noted above.

19. Hydro submits that the proposed capital expenditures are necessary to ensure that Hydro can continue to provide service which is safe and adequate and just and reasonable as required by Section 37 of the *Act.*

C. Hydro's Request

20. Hydro requests that the Board make an Order pursuant to Section 41(3) of the *Act* approving the capital expenditures necessary for the Early Execution work, as more particularly described in this application, necessary to maintain the overall project schedule and budget of the proposed section replacement and weld refurbishment of Bay d'Espoir Penstock 3.

21. Hydro further requests that the Board make an Order pursuant to Section 41(3) of the *Act* approving the capital expenditures necessary for the section replacement and weld refurbishment of Bay d'Espoir Penstock 3, as more particularly described in this application.

D. Communications

22. Communications with respect to this Application should be forwarded to Shirley A. Walsh, Senior Legal Counsel, Regulatory for Hydro.

DATED at St. John's in the province of Newfoundland and Labrador on this 12th day of March 2026.

NEWFOUNDLAND AND LABRADOR HYDRO



Shirley A. Walsh
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Schedule 1

Application Overview

Penstock 3 Section Replacement and Weld Refurbishment

Bay d'Espoir

newfoundland labrador hydro

Penstock 3 Section Replacement and Weld Refurbishment

Location: Bay d'Espoir Hydroelectric Generating Facility

Investment Classification: Renewal

Asset Category: Hydraulic Plant

Cost: $77,462,128

Executive Summary

The Bay d'Espoir Hydroelectric Generating Facility ("Bay d'Espoir"), located on the south coast of Newfoundland and Labrador, is the largest hydroelectric generating facility in the Island Interconnected System. The station, from which service began in 1967, relies on penstocks to supply water to each generating unit. In total, four penstocks supply water to seven units. Bay d'Espoir Powerhouse 1, consisting of Units 1 through 6, is fed by Penstocks 1, 2, and 3.

From 2016 to 2019, Bay d'Espoir Penstock 1 experienced four ruptures, resulting in Units 1 and 2 being unavailable for service for extended periods and significant unplanned expenditure. In 2018, in response to the investigations and consultant recommendations regarding Penstock 1, an annual inspection program began on all three penstocks, given their similarities in age, design, and construction. The results of these inspections have led to substantial weld refurbishment across all penstocks, including 1,030 m of weld refurbishment on Penstock 3 in 2018. Annual inspections on Penstock 3 continue to identify signs of wear, corrosion, and stress-related issues.

Penstock 3 serves as an integral component of Units 5 and 6. Together, these units supply 153 MW of generation and are required for Newfoundland and Labrador Hydro ("Hydro") to meet current customer requirements.

Since 2016, Hydro has engaged three engineering consultants—Hatch Ltd. ("Hatch"), SNC-Lavalin Group Inc. ("SNC-Lavalin"), and Kleinschmidt Associates ("Kleinschmidt")—to support failure investigations, condition assessments, and life extension options analysis. All three consultants agree that, when considering the complete data set across multiple failure investigations, the root cause of the cracking found in the penstocks was high stresses in the longitudinal weld seams due to peaking, exacerbated by preferential corrosion and cyclic stresses. Like Penstock 1, recent inspections of Penstock 3 have

revealed additional cracking in welds previously repaired within the 11.1 mm (7/16 in.) steel section. Considering the current condition of Penstock 3, an operating regime has been in place that constrains unit loading to a minimum of 50 MW up to the unit maximum and reduces overall cycling. Hydro believes that capital investment is required to mitigate the ongoing risk of penstock failure.

In 2021, Hydro engaged Kleinschmidt to perform a comprehensive review of four life extension options for all three penstocks[1] and provide recommendations to allow Hydro to make prudent and justifiable investment decisions based on the risk, reliability, construction costs, schedule, and viability of each option. The options included:

- Option 1: Status quo;
- Option 2: Weld refurbishment;
- Option 3: Section replacement and weld refurbishment; and
- Option 4: Weld reinforcement.

Kleinschmidt's analysis of the four options for the life extension of Penstock 3 determined that Option 3, section replacement and weld refurbishment, would provide the greatest level of risk mitigation and the highest level of reliability among the available options.

To ensure the safe and reliable operation of Penstock 3, Hydro recommends proceeding with Kleinschmidt's recommendation of Option 3. Section replacement and weld refurbishment is the most technically feasible option that provides reliable service at least cost and is the only option that restores Penstock 3 to unconstrained operation, including Units 5 and 6 it serves.[2] Project execution is anticipated to take three years with an estimated cost of $77,462,128.

Deferral of this work would pose a significant system reliability risk given the penstock's condition and scheduling constraints, which require execution of this project during the planned outage period in 2027. The timelines for the work and for the necessary approval preclude including this project in the 2027 Capital Budget Application, for which approval from the Board of Commissioners of Public Utilities

[1] "Decision Support Package: Penstocks 2 & 3 - FEED - Kleinschmidt Associates – November 2021," provided as Attachment 1 to Schedule 1 of this application.
[2] *Supra f.n. 1.*

("Board") would not be expected until the end of 2026. Additionally, the timing of the 2025 inspections meant that this project proposal could not be included in the 2026 Capital Budget Application.

The critical nature of the Penstock 3 condition, as noted above, also meant that the Penstock 3 project application can not be held and filed as part of the 2028 Capital Budget Application. The condition of Penstock 3 poses a risk to system reliability. Delaying the commencement of project execution until 2028 would also pose risks in terms of interface with other ongoing projects, outage planning, and ensuring works are completed before winter-load periods.

The timing of this project is set to align with outages associated with other projects, such as the planned overhaul of Bay d'Espoir Unit 5, which will be proposed in Hydro's 2027 Capital Budget Application. Due to the project's time sensitivities, as part of this application, Hydro is requesting approval to proceed with certain aspects of the work in advance of overall project approval ("Early Execution") capital expenditures to proceed with critical scopes of work. The work involved in Early Execution includes, but is not limited to: (i) procurement of raw steel for the sections of the penstock that will be replaced, and (ii) relocation of an existing distribution line adjacent to Penstock 3. The intent is to proceed with Early Execution work in advance of full project approval to allow Hydro to maintain the overall project schedule and budget and mitigate risks to the system and risks of increases to project costs. The Early Execution approval is required by late April 2026,[3] while full project approval is required by the end of August 2026.[4]

[3] Refer to Section 3.1, Table 1, 'Application Approved by Board (Early Execution)' milestone (20-Apr-2026).
[4] Refer to Section 3.1, Table 1, 'Application Approved by Board (Full Project Approval)' milestone (24-Aug-2026).

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Attachment 13: "Project Execution Strategy and Plan: Penstock No. 1 - Bay d'Espoir Hydro Site," Kleinschmidt Associates, March 2022

1.0 Introduction

Bay d'Espoir currently provides 613 MW of electrical capacity and 2,560 GWh of energy annually. The existing facility includes seven generating units installed across two powerhouses, and relies on four steel penstocks, buried along their lengths, to supply water to the generating units. Bay d'Espoir Powerhouse 1 consists of six 75 MW units (Units 1–6) fed by Penstocks 1–3, with each penstock controlling the flow of water to two units. Each set of units is fed through a bifurcation system in the penstock located near the powerhouse.

The penstocks were constructed from a series of steel cans[5] that vary in length and plate thickness. Penstock 3 is approximately 1,200 m in length and generally ranges in diameter from 5.2 m (17 ft.) at the intake to 4.1 m (13.5 ft.) at the Powerhouse bifurcation. The steel used ranges in thickness from 11.1 mm (7/16 in.) near the intake to 42.9 mm (1-11/16 in.) at the Powerhouse bifurcation.

Penstock 3 (see Figure 1), serving Units 5 and 6, has been in service for over 55 years. It is currently identified as having the most urgent need for life-extension work, based on condition assessments revealing recurring weld degradation in critical sections. Deferral of this work would pose significant system reliability risks given the penstock's condition, as well as scheduling constraints requiring the execution of this project during the planned outage period in 2027.[6]

[5] Each penstock is constructed of many cans, each constructed individually by welding two halves together horizontally along the longitudinal axis of the can, then welded end-on-end using a circumferential weld. A typical can is approximately 2.7 m (9 ft.) in length.
[6] Schedule constraints resulting from Hydro's generation outage schedule and planned works at Bay d'Espoir over the next number of years.

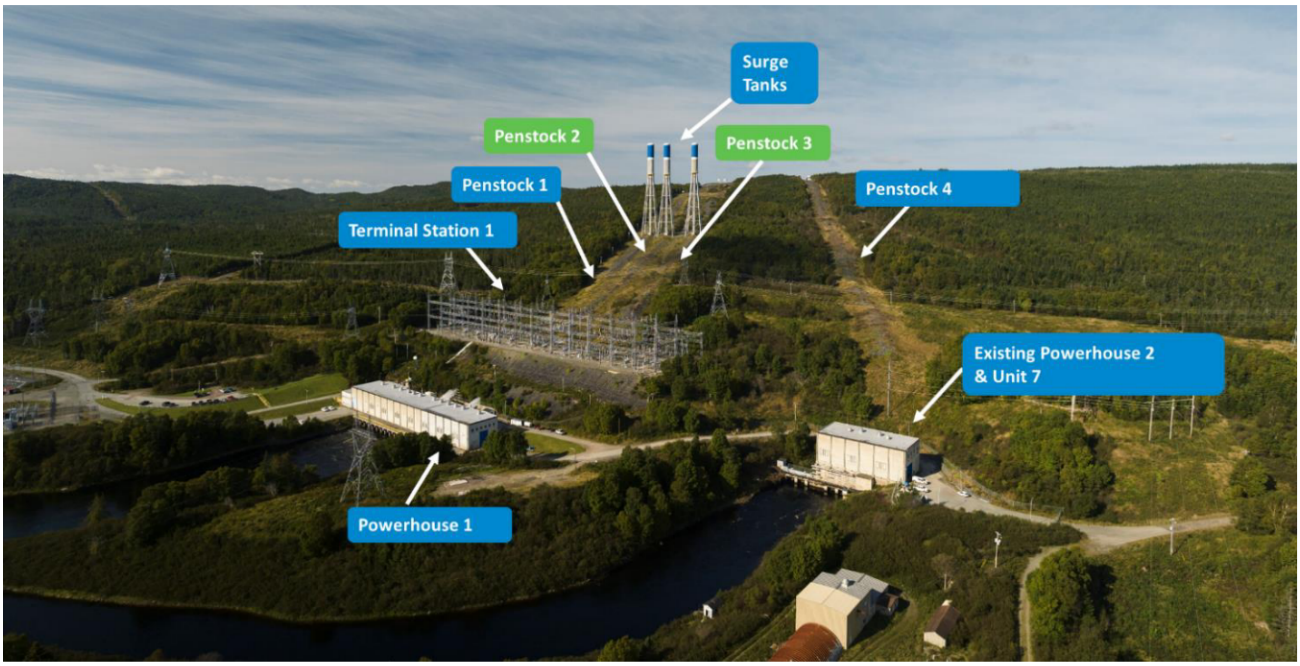

Figure 1: Bay d'Espoir Powerhouses 1 and 2, Surge Tanks, and Buried Penstocks

2.0 Background

From 2016 to 2019, Bay d'Espoir Penstock 1 experienced four ruptures within the 17-ft. diameter section of penstock, resulting in Units 1 and 2 being unavailable for service for extended periods of time.[7]

Due to the ruptures on Penstock 1, level 2 condition assessments[8] were conducted on all three penstocks. The results of these condition assessments led to substantial weld refurbishment of Penstock 3, including 1,030 m of weld refurbishment in 2018, resulting in an unexpected cost of approximately $4,740,000 and an outage extension of approximately eight weeks.[9]

[7] These ruptures and subsequent investigations are more specifically described in Penstock 1 Section Replacement and Weld Refurbishment application for capital expenditure, "Penstock 1 Section Replacement and Weld Refurbishment – Bay d'Espoir Hydroelectric Generating Facility," Newfoundland and Labrador Hydro, December 7, 2022.
[8] A level 2 condition assessment is undertaken by a professional or certified specialist having the knowledge, skill, and experience in the design, construction, and operation of the facility type, and may require knowledge and use of specialized equipment in the assessment of the facility. Level 2 condition assessments are much more thorough than level 1 condition assessments and often involve dismantling the equipment. This type of condition assessment provides sufficient detail to clearly define the work required to address identified deficiencies, to enable an accurate cost estimate [Association for the Advancement of Cost Engineering ("AACE") Class 3] to be made, and a clear description to be provided of the scope of the restoration/repairs/replacement/removal for the work to be done.
[9] Refer to the discussion in Section 4.3.1 of this application for additional details.

In 2021, Kleinschmidt conducted a comprehensive review of four life-extension options for the three penstocks. Kleinschmidt's recommendations were provided to support Hydro's determination of the most prudent and justifiable investment decision based on the risk, reliability, construction costs, schedule, and viability of each option. Hydro identified Penstock 1 as the most critical of the three penstocks at that time due to the history of ruptures in recent years. The capital expenditure for the section replacement and weld refurbishment of Bay d'Espoir Penstock 1 was approved by the Board in April 2023. Replacement and refurbishment are completed, with Penstock 1 returning to service in December 2025.

As part of the Bay d'Espoir Penstock 1 proceeding, it was acknowledged that similar life extension work would be required for Penstocks 2 and 3. Hydro has continued to conduct annual inspections of Penstocks 2 and 3 to assess their condition and determine the appropriate timing for capital investment while avoiding similar ruptures experienced on Penstock 1.

The substantial assessments and resulting decision support packages, option analysis, and cost estimates provided herein are similar to those provided in the proceeding before the Board regarding Penstock 1. Hydro notes that in that proceeding, and through Board Order No. P.U. 6(2023), the Board found that while the section replacement and weld refurbishment option was the most expensive alternative, it had the lowest risk rating and the highest level of reliability. The Board acknowledged that the option ". . . mitigates the risk of a rupture over the long term which would mitigate potentially substantial repair and replacement energy costs and reliability impacts."[10] The Board found that the proposed section replacement and weld refurbishment of Penstock 1 were reasonable and necessary to ensure the delivery of safe, reliable service at the lowest possible cost and should be approved. The information and evidence provided herein is consistent with that provided in the Penstock 1 proceeding, and Hydro believes support a similar conclusion.

3.0 Justification

Repeated inspections and condition assessments over the past several years have consistently identified significant and recurring issues on Penstock 3, including extensive weld indications, evidence of peaking,

[10] Board Order No. P.U. 6(2023), p. 7.

and reoccurring defects in previously repaired locations.[11] These findings have directly led to sustained operating restrictions on Units 5 and 6, including minimum load requirements and limits on cycling, thereby reducing operational flexibility and increasing system risk. Despite ongoing annual maintenance and targeted weld repairs, the continued emergence of new and recurring indications demonstrates that incremental refurbishment is no longer sufficient to manage the asset's condition. Given the cumulative inspection evidence, the operational constraints now required to manage risk, and the increasing frequency of findings within the critical 11.1 mm section, capital intervention is necessary to restore the penstock to reliable service and mitigate the growing risk of failure. Since Penstock 3 is a critical component for supplying 153 MW of generation on the island, refurbishment is required to ensure reliable operation and availability of the asset.

Based on the execution of the replacement and refurbishment project for Penstock 1, Hydro estimates that an eight-month outage will be required during the construction phase of the Penstock 3 scope. It is not feasible for Hydro to refurbish more than one penstock, such as Penstock 2 and 3, in a single construction season without risking customer outages. Furthermore, executing refurbishment and repair works on two penstocks concurrently poses potential resource concerns, site bottlenecking, and safety concerns due to close interfaces. Additionally, delays in any concurrent work could pose a risk of having two penstocks out during the winter readiness period (beyond December 1). While Penstock 2 and 3 both exhibit signs of wear, corrosion, and potential stress-related issues, Penstock 3 presents a more immediate risk to reliability. This is due to the extent, urgency, and frequency of weld indications as well as their reoccurrence in previously repaired locations. This assessment is supported by Kleinschmidt's ongoing annual inspections and the resulting recommendations. To meet peak customer demand and winter readiness requirements, Hydro proposes proceeding with the Penstock 3 project; however, refurbishment of Penstock 2 is planned to follow as soon as practicable, in line with consultants' recommendations from routine inspections and assessments.

In consideration of the Long-Term Asset Plan for Bay d'Espoir, and compounding outage impacts on the Island Interconnected System, Hydro's Long-Term Asset Planning team has identified the 2027 construction season as the optimal window for refurbishment work. This timing aligns with other

[11] Weld indications refer to any mark, signal, or measurement detected during an inspection of a weld. These can represent harmless conditions (e.g., weld geometry, instrument noise, etc.), or actual defects. In the context of the penstock inspections, weld indications, identified via non-destructive testing methods, pertain to defects attributed to known stress contributors, such as peaking, cyclic loading, and weakening of base material in the weld heat-affected zone.

planned outages on the Island Interconnected System over the coming years and the need to ensure system reliability ahead of other major upcoming works. To meet the 2027 outage window, detailed engineering design must start in 2026. By undertaking this project now, Hydro aims to prevent costly unplanned future failures, maintain the full operational capacity of Bay d'Espoir during peak periods, and ensure an uninterrupted power supply to customers. However, to allow detailed engineering to start in 2026 while review of Hydro's proposed Penstock 3 project is underway, Hydro would require Board approval of the necessary Early Execution capital expenditures.

3.1 Early Execution

As Hydro has noted previously, and will discuss further herein, refurbishment of Penstock 3 is urgently required to ensure ongoing safe, reliable service from Bay d'Espoir and to enable Hydro to continue meeting established planning criteria and satisfying current customer requirements.

To meet and avail of the 2027 outage window, Hydro will need to begin detailed engineering in 2026. This will ensure the Penstock 3 issues are expeditiously addressed and to avoid implications for Hydro's scheduled capital improvements and maintenance plan for other assets that could directly impact system reliability and capital costs. As time is also needed for the Board and any intervenors to review and consider Hydro's application, Hydro is requesting approval to proceed with Early Execution. This work predominantly consists of items related to raw steel procurement and line relocation work at the site. Table 1 highlights the key milestones within the Early Execution period. Hydro is not requesting the recovery of any expenditures related to the Early Execution prior to the Board's approval of the overall project.

Table 1: Penstock 3 Project Early Execution Schedule Summary

Milestone	End Date
Application Submitted to Board (including Early Execution)	12-Mar-2026
Prepare Invitation to Tender (Steel Supply)	26-Mar-2026
Application Approved by Board (Early Execution)	20-Apr-2026
Bid Period (Steel Supply)	20-Apr-2026
L2 Distribution Line (Engineering Design)	21-Apr-2026
Evaluate Contract Proposals (Steel Supply)	27-Apr-2026
Award Contract (Steel Supply)	4-May-2026
Steel Supply	[redacted]
Application Approved by Board (Full Project Approval)	24-Aug-2026
Distribution Line Work (Site Work)	[redacted]

The ability to proceed with Early Execution work in advance of project approval will allow Hydro to maintain the overall project schedule and budget and mitigate risks to the system and to project costs.

4.0 Asset Overview

4.1 Asset Background

Bay d'Espoir Penstock 3 is a buried steel penstock approximately 1,200 m long, tapering from 5.2 m (17 ft.) in diameter at the intake to 4.1 m (13.5 ft.) in diameter at the Powerhouse bifurcation. It then narrows again within the bifurcation to 2.2 m (7.25 ft.) before tying into the spherical valves of each unit. Penstock 3 was designed with a rated flow of 99.2 m^3/s (3500 cfs).

The penstock steel plate ranges in thickness from 11.1 mm (7/16 in.) at the intake to 42.9 mm (1-11/16 in.) at the bifurcation. Penstock 3 was fabricated using multiple grades of steel, including ASTM A285 and CSA G40.8B, the same types used in Penstocks 1 and 2, as well as OX522-D. Penstock 3 was built with varying slopes between its bends, including a minimum slope of 0.3% at the intake and a maximum slope of 36.5% just before the bifurcation, where it crosses underneath the terminal station and terminates at the powerhouse. See Figure 2 for a conceptual layout of Penstock 3.

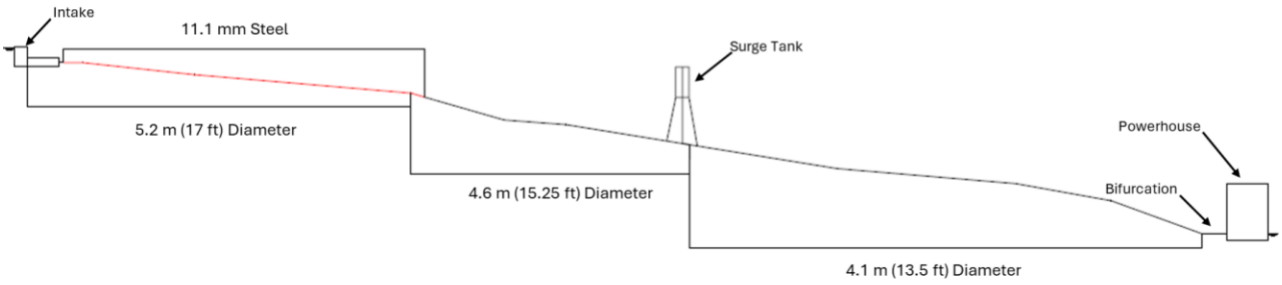

Figure 2: Penstock 3 Conceptual Layout

The first 31.7 m of steel penstock is encased in concrete as it transitions from the intake under the power canal embankment. From the toe of the dam, approximately 40 m of the penstock sits in a narrow, blasted rock trench that extends 3 m to 4 m above the top of the penstock cover. The penstock cover in this region varies in thickness from 1.0 m to 2.5 m above its obvert.[12] Beyond this area, the penstock maintains a minimum cover of 0.6 m, including 0.3 m of riprap, until reaching the terminal station.

4.2 Historical Reliability

Annual inspections of Penstock 3 continue as part of Hydro's condition-based asset management program. These inspections have identified weld indications in recent years, which have informed enhanced monitoring, maintenance activities, and operating decisions. Fortunately, due to the ongoing inspection and repair work, Penstock 3 has not experienced a rupture, and Units 5 and 6 have not incurred unplanned outages due to Penstock 3 failure; however, extended outages have been required periodically to complete inspection and repair activities.

Based on the results of annual inspections of Penstock 3, Hydro implemented a more prescriptive operating regime for Units 5 and 6.[13] Under this operating regime, Units 5 and 6 are limited to a minimum unit loading of 50 MW, up to the unit maximum once dispatched and are not cycled or shut down as part of normal system operations. These operating measures are intended to manage the risk

[12] The uppermost inner surface of the penstock.
[13] A similar prescriptive operating regime, including minimum loading limits and restrictions on cycling, was previously implemented for Units 1 and 2 due to the rupture history and condition of Penstock 1 and remained in place until capital refurbishment work was substantially complete in 2025.

of asset condition while maintaining system reliability. Minimum unit loadings introduce operational constraints, such as limiting the ability to dispatch unit output to meet system demands, manage system hydrology, or reduce unit output to mitigate the risk of frazil ice under conducive environmental conditions.

As part of its Asset Management Program, Hydro must balance system demand with the condition of its assets. Given the critical role of Bay d'Espoir in meeting customer demand, the system has limited operational flexibility, which in turn limits Hydro's ability to maintain prescriptive operating restrictions concurrently across multiple penstocks on a sustained basis.

4.3 Asset Condition

4.3.1 2018 Condition Assessment and Life Extension Options

In 2018, Hydro hired Hatch to complete a comprehensive condition assessment of Penstock 3. Hatch was tasked with the completion of the condition assessment, as well as the preparation of three reports to provide refurbishment/life extension alternatives to ensure the long-term reliable operation of the penstocks:

- Report 1:[14] An initial summary report of the findings of the condition assessment to better understand the condition of the penstocks prior to the 2018–2019 winter operating season.
- Report 2:[15] The final condition assessment report, which would include the complete findings of the inspection, as well as a wide variety of potential penstock refurbishment/life extension alternatives (with order of magnitude cost estimates) for Hydro's review.
- Report 3:[16] A detailed report on three potential life extension options for the penstocks (with preliminary cost estimates), selected by Hydro from the variety of options presented in Report 2.

[14] "Final Report for Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3," Hatch Ltd., December 13, 2018, provided as Attachment 2 to Schedule 1 of this application.
[15] "Final Report for Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3," Hatch Ltd., March 28, 2019, provided as Attachment 3 to Schedule 1 of this application.
[16] "Final Report for Penstock No.'s 1, 2 and 3 Life Extension Options," Hatch Ltd., July 26, 2019, provided as Attachment 4 to Schedule 1 of this application. Redactions contained in this report were completed by Hatch.

Bay d'Espoir Level 2 Condition Assessment of Penstocks 1, 2, and 3 (Report 1)

In 2018, following the ruptures of Penstock 1, Hydro hired Hatch to complete a level 2 condition assessment on Penstocks 2 and 3, which included inspection of the longitudinal welds, 3D scanning, and metallurgical analysis. The Penstock 3 weld inspection frequency was one in every ten cans for the total length of the penstock. When welds that warranted refurbishment were discovered during inspection, a further five cans upstream and five cans downstream of this area were subject to the same level of inspection. The end of the refurbishment areas was determined when five cans passed inspection, both upstream and downstream of the refurbished can. The assessment found weld indications in 44.8% of all longitudinal welds. This resulted in approximately 1,030 m of longitudinal weld being refurbished, including approximately 700 m in the 11.1 mm (7/16 in.) section. This assessment was originally planned to take place over a three-day period during a planned two-week outage; however, due to the overall condition and required weld repairs, the outage was extended to approximately eight weeks.

In addition to the linear indications in the longitudinal welds, Hatch also noted preferential corrosion of the Heat-Affected Zone ("HAZ") and longitudinal weld seam peaking.

Condition Assessment and Refurbishment Options of Penstocks 1, 2, and 3 (Report 2)

Report 2 was issued by Hatch in March 2019 and presented a variety of life extension alternatives with details on risks, benefits, feasibility, and cost estimates. Hydro reviewed these alternatives with a variety of stakeholders and eliminated several options for technical and/or cost reasons. Three alternatives were selected for further study:

- Option 1: Weld Refurbishment – Comprehensive weld refurbishment of the penstocks and application of an internal coating.
- Option 2: Section Replacement – Replacement of the 17-ft. diameter portion of the penstock, which has been subject to failure, as well as weld refurbishment and application of an internal coating for the remainder of the penstock.
- Option 3: Weld Reinforcement – Comprehensive weld refurbishment and reinforcement of the longitudinal weld seams of the penstocks, as well as application of an internal coating.

Life Extension Options for Penstocks 1, 2, and 3 (Report 3)

Report 3, issued by Hatch in July 2019, further developed and evaluated the three selected alternatives. Hatch recommended proceeding with Option 1, as the weld refurbishments and change in operating procedures appeared to have been successful in stabilizing the weld failures. Work was recommended for completion within the next five years.

In March 2020, Hatch issued a revised version of its conclusions in Report 3 following the September 2019 Penstock 1 rupture.[17] Since the rupture occurred on a previously refurbished weld seam in the 17-ft. diameter section of Penstock 1, concerns arose about the long-term reliability of the weld refurbishment method proposed in Option 1. After carefully reviewing the data collected since Report 3 was issued, Hatch revised its recommended life-extension strategy for Penstock 1 to Option 2.

For Penstock Nos. 2 and 3, refurbishment Option 1 was still selected as the preferred refurbishment strategy, as these two penstocks had not shown signs of failure in the rewelded longitudinal seams.

4.3.2 Follow-Up Condition Assessments[18]

2019 Assessments

In 2019, the surge tank transition was observed to be wet during the initial inspection, but no seepage was noted.[19] One month later, a 1.2 m deep sinkhole was discovered downstream of the surge tank concrete, on the left side of Penstock 3. Kleinschmidt's 2019 analysis concluded that the penstock does not meet acceptable factors of safety at the joints.[20]

2021 Assessments

In 2021, active but light seepage was identified through the welded joints at the penstock-to-surge tank transition.[21] Efflorescence and water were observed coming into the penstock from the exterior. This indicated the presence of full-depth cracks at the weld locations and further reinforced the need for penstock refurbishment. Kleinschmidt's ensuing 2021 analysis recommended replacement of the 17-ft.

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[17] "Final Report for Penstock No.'s 1, 2 and 3 Life Extension Options," Hatch Ltd., March 13, 2020, provided as Attachment 5 to Schedule 1 of this application. Redactions contained in this report were completed by Hatch.
[18] Penstock 3 was not inspected in 2020 due to the COVID-19 pandemic.
[19] "Penstock No. 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstocks 1-3 Inspection Project," Kleinschmidt, November 2019, provided as Attachment 6 to Schedule 1 of this application.
[20] *Supra f.n. 19.*
[21] "Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project," Kleinschmidt Associates, December 2021, provided as Attachment 7 to Schedule 1 of this application.

diameter section of Penstock 3 to remove the risk of future failure during operation.[22] Since then, Kleinschmidt has completed annual condition assessments on Penstock 3 utilizing the same weld inspection frequency detailed in Section 4.3.1.

2022 Assessments

The 2022 inspection[23] had found similar issues with the surge tank transition, as noted in the 2021 inspection, but only found one indication in a circumferential weld. Both the circumferential weld and the surge tank repairs were completed in 2023.

2023 Assessments

Beginning in 2023, inspection findings increasingly identified weld indications in previously refurbished locations, necessitating renewed repair activity and resulting in a rising trend in inspection-related expenditures. Indications found in previously repaired welds suggest that the weld repairs may have a limited life expectancy, which reflects the increasing difficulty of sustaining acceptable risk levels through incremental repairs alone. The 2023 inspection had identified nine cans with weld indications.[24] Eight of the nine cans were in the 11.1 mm (7/16 in.) thick section.

2024 Assessments

The 2024 inspection identified six cans with weld indications; all cans were in the 11.1 mm (7/16 in.) section, and all but one had been previously repaired.[25]

2025 Assessments

Most recently, during the 2025 inspection,[26] another 13 cans were identified with indications. Those that require weld repair were located within the 11.1 mm (7/16 in.) section, and all cans had been previously refurbished.[27]

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[22] *Supra f.n. 21.*
[23] "Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project," Kleinschmidt Associates, September 2022, provided as Attachment 8 to Schedule 1 of this application.
[24] "Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project," Kleinschmidt Associates, January 2024, provided as Attachment 9 to Schedule 1 of this application.
[25] "Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project," Kleinschmidt Associates, December 2024, provided as Attachment 10 to Schedule 1 of this application.
[26] The 2025 inspection report is still in draft form.
[27] The remaining cans could have the crack ground out without reducing the integrity of the weld.

Overall, since 2023, additional weld indications have been found during these annual inspections. An example of such indications is shown in Figure 3.



Figure 3: Weld Failure Can 59N, Penstock 3

Where inspection findings warranted, corrective actions, including targeted weld repairs and associated planned outages, were undertaken to manage identified risks and maintain continued operation. Table 2 summarizes the inspection, repair, outage, and expenditure history for Penstock 3.

Table 2: Penstock 3 Work History & Expenditures

Date	Event	Outage Duration (weeks)	Cost ($000)
2017	Annual Inspection	2	60.5
2018	Annual Inspection and Weld Repairs	8	4,743.2
2019	Annual Inspection	2	59.1
2021	Annual Inspection	2	68.2
2022	Annual Inspection	2	64.4
2023	Annual Inspection and Weld Repairs	3	652.1
2024	Annual Inspection and Weld Repairs	2	680.8
2025	Annual Inspection	3	110.1
		Total	**6,438.4**

4.4 Condition-Based Remaining Life

Based on inspection findings and continued evaluation, Kleinschmidt estimated that the penstock plating has an additional 50 years of useful service life. However, due to the condition of the existing welds and the short life of weld repairs in the 17-ft. diameter section of the penstock, Kleinschmidt has recommended replacing this section. The remaining welds will need to be refurbished, and the interior coated before the steel deteriorates further. In 2025, Kleinschmidt recommended replacing the 17-ft. sections and that the remainder of the penstock undergo extensive weld replacement within the next 5 years.

5.0 Options Analysis

In 2021, Hydro engaged Kleinschmidt to complete a study for Bay d'Espoir Penstock Life Extension. The scope of this study was to complete a comprehensive review of the three options for the life extension of Penstock 3,[28] earlier developed in Report 3 (Hatch),[29] as well as the status quo option. This review would provide a more detailed analysis of items such as risk, cost, and technical matters, enabling Kleinschmidt to recommend to Hydro which life extension option to pursue. The options, including the status quo, were:

- Option 1: Status Quo – No refurbishment of the penstock with continued operational maintenance procedures only. Repairs are completed on an as-needed basis.
- Option 2: Weld Refurbishment – Refurbishment of deteriorated circumferential and longitudinal weld seams, including resurfacing and recoating of the penstock interior. Refurbished welds will be selected after inspection of all welds.
- Option 3: Section Replacement and Weld Refurbishment – Replacement of the 17-ft. diameter section of penstock plus weld refurbishment and recoating of the interior of the smaller diameter sections of penstock. All welds will be inspected.

[28] The comprehensive review completed by Kleinschmidt included an analysis of the life extension options for Penstocks 2 and 3, which is provided as Attachment 1 to Schedule 1 of this application. Page v of the report lists all consultant reports discussed in this application, including those that contain information on the investigation results for Penstock 3.
[29] *Supra f.n. 15.*

- Option 4: Weld Reinforcement – Refurbishment of deteriorated welds, recoating of the entire interior of the penstock and reinforcement of the longitudinal and circumferential welds in the 17-ft. diameter penstock section with reinforcing plates.

In evaluating the life extension options for Penstock 3, Kleinschmidt considered risk, reliability, construction costs, schedule, and viability. Cost estimates for the different options[30] were based on an AACE Class 4[31] Cost Estimate, and high-level construction schedules were developed. Additional information on the analysis can be found in the Decision Support Package: Penstock 2 & 3, prepared by Kleinschmidt.[32]

5.1 Option 1: Status Quo

This option involves maintaining the existing state of Penstock 3. While annual penstock inspections, maintenance, weld refurbishments, and other repairs will be performed as needed, no life-extension measures will be implemented. While Penstock 3 has not experienced any ruptures, numerous weld indications have been identified during recent inspections, and weld repair remains necessary each year. This includes repair of previously repaired welds, as recommended by previous inspections and analyses. From a system reliability perspective, Hydro does not consider Option 1 to be a viable strategy.

Depending on the nature of the failure and the time of year, various consequences may result. A minor failure in the summer months may be repaired promptly at a cost of approximately $100,000 to $200,000[33] with minimal lost energy costs. A minor failure during peak winter demand would take longer to repair and result in the loss of 153 MW from the system, at a time when it is needed the most. The costs associated with a failure during peak winter demand would also be significantly higher than those during the summer months. Hydro estimates that the cost to replace 153 MW with generation from the Holyrood Thermal Generating Station ("Holyrood TGS") would be approximately $120/MWh.[34]

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[30] Option 1 does not include any life extension rehabilitation work and therefore was not evaluated for rehabilitation cost.
[31] AACE Class 4 estimates require an increased level of engineering. Accuracy is expected to be in the ranges of -15%/-30% and +20%/+50% with a 50% level of confidence.
[32] *Supra f.n. 1.*
[33] Hydro has completed repairs, on average, in approximately two to three weeks when conditions allowed. Mitigation measures to reduce the repair time have been implemented. The repair costs are typical based on Hydro's experience with Penstock 3.
[34] Analysis based on Bay d'Espoir Units 1 and 2 production data from the previous five years, January to March. Economic offsets via the Maritime Link and Labrador-Island Link were not considered. Assumed a Holyrood TGS Derated Adjusted Forced Outage Rate of 15%. Assumed Holyrood TGS full production during these months. Cost of Bunker C is based on the June 2022 rate ($147/bbl.).

Assuming the repair could be completed in four weeks, this could cost $12.5 million for replacement energy and repairs, and could also impact downstream assets, outage durations, and repair costs. This could have significant impacts on customers, both through reliability impacts and recovery of these additional costs.

Based on Kleinschmidt's Risk Assessment[35] and Hydro's reliability analysis, the status quo is not a viable option as it does not meet its mandate to provide safe, least-cost, reliable power.

5.2 Option 2: Weld Refurbishment

This option would replace deteriorated welds with new welds and install a protective coating on the interior of the penstock. The scope of work includes a thorough inspection of all interior longitudinal and circumferential weld seams in Penstock 3 to identify deterioration. Specialized scaffolding will be required to access welds in the upper half of the penstock for inspection and refurbishment.[36] Significant abrasive cleaning will occur following weld refurbishment to obtain the desired surface condition for coating application. A coating will be applied on the interior of the penstock using an approved coating system, limiting the progression of corrosion in both the steel and base metal.[37] All refurbishment and coating work will be inspected by qualified third-party inspectors.

Kleinschmidt recommends that annual inspections continue under this option to monitor welds and the coating system, given the remaining peaking issues in the welds of the 17-ft. diameter section of the penstock. This will limit Bay d'Espoir's operational flexibility.

This option does not address the design issues related to peaking and fatigue, and operational constraints will remain. A risk of failure remains, as it was assumed that only 50% of the welds would be repaired. Risk remains that a non-refurbished weld may fail in the next 30 years, especially considering the level of corrosion and cracks found in existing refurbished/repaired welds.

Hydro does not consider Option 2 a technically viable life-extension option over a 30-year period due to remaining uncertainty about reliability, even with significant capital investment. Again, this option will

[35] Included as Appendix B of Attachment 1 to Schedule 1 of this application.
[36] For estimating purposes, Kleinschmidt used engineering judgement and assumed that 50% of all welds will require refurbishment.
[37] A new penstock coating system is expected to require recoating in approximately 15–20 years, depending on the surface preparation and service life of the product.

not fully mitigate current operational constraints and return the Penstock to normal operation. This is further detailed through Kleinschmidt's Risk Assessment.

5.3 Option 3: Section Replacement and Weld Refurbishment

This option would replace all 11.1 mm (7/16 in.) thick sections of the penstock with new steel sections. The new 17-ft. diameter steel penstock section would be designed to meet current standards and fully remediate weld peaking issues in this section of penstock. Condition assessments could be reduced to a more appropriate, less frequent inspection cycle.

The new 17-ft. diameter steel penstock sections will be fabricated and coated off-site. Site work on Penstock 3 will commence with excavation, demolition, and disposal of the existing 17-ft. diameter section of the steel penstock. The new penstock sections will then be installed, and the penstock interior will be coated. Hydro anticipates that the new 17-ft. diameter penstock section will have an operational life of 80–100 years.[38]

Based on recent inspections[39] and findings, including Hydro's experience on the refurbishment of Penstock 1, Hydro intends to replace all 11.1 mm (7/16 in.) thick sections, not just those 11.1 mm (7/16 in.) thick sections associated with the 17-ft. diameter sections. This adds approximately 12.0 m (39.2 ft.) to the length of the penstock recommended for replacement. Hydro believes this is prudent and critical to address fatigue and stress-related issues in all 11.1 mm (7/16 in.) thick sections of the penstocks while consultants and contractors are mobilized to do the work.[40]

Replacing the entirety of Penstock 3 is not required for reliable operation. Recommendations support replacing all 11.1 mm (7/16 in.) sections. The remaining sections of penstock would see weld refurbishment and interior coating, as noted in Option 2. As stated in Option 2, the thicker downstream 15-ft. and 13.5-ft. diameter penstock sections have performed well and do not experience the same weld peaking and fatigue issues. By implementing a planned refurbishment and following operational

[38] American Society of Civil Engineers. (2012). Manuals and Reports on Engineering Practice No. 79, *Steel Penstocks* (2nd Edition).
[39] The 2025 inspection report is still in draft form.
[40] As Hydro noted in its application for approval of changes to the budget and scope of the Penstock 1 project, the findings from the inspection of that penstock that had been completed after the approval of the project, supported a recommendation by Kleinschmidt that additional sections where the steel was the same thickness (11.1 mm or 7/16 in.) as the section originally proposed for replacement should also be replaced to ensure long-term reliability of the penstock. In Board Order P.U. 26 (2024), the Board found that the additional scope of work continued to be necessary to ensure that Hydro could continue to provide service which is safe and adequate and just and reasonable.

and maintenance guidelines, Hydro anticipates these sections of penstock would have an operational life of 30–50 years.

Hydro has identified Option 3 as the lowest cost, technically feasible option, which would return the penstock to safe and reliable operations, eliminating current operational constraints. This option presents the lowest risk while providing the highest reliability, as evidenced by the Risk Assessment.

5.4 Option 4: Weld Reinforcement

This option would include replacing deteriorated welds and installing a protective coating system on the interior of the penstock (same construction sequence as Option 2), with the addition of reinforcement to the penstock interior. This would be completed using fillet welds around a flat bar to attach it over the newly refurbished welds, providing protection and reducing weld peaking.[41] After the reinforcement plates were installed, the protective coating system would be applied to the interior of the penstock, including the plates.

Kleinschmidt recommends that annual inspections continue under this option to monitor welds and the coating system, given the remaining peaking issues in the welds of the 17-ft. diameter section of the penstock. This will limit Bay d'Espoir's operational flexibility and preclude the return of Units 5 and 6 to normal operation for the next 30 years.

As stated in Option 2, the thicker downstream 15-ft. and 13.5-ft. diameter penstock sections have performed well and, with planned refurbishment and adherence to operational and maintenance guidelines, should have an operational life of 30–50 years.

The Risk Assessment concluded that the addition of reinforcement does not provide sufficient value to justify the approximately $8,000,000 added expense over Option 2. Moreover, the significant quantity of cracks discovered in previously repaired welds and in the new reinforcing plate welds in 2021 still imposes operational constraints following Option 4 refurbishment.

[41] Similar weld reinforcement was previously installed for Penstock 1 in 2017.

Hydro does not consider Option 4 a technically viable life-extension option over a 30-year period. Existing deficiencies related to the design of Penstock 3 remain, including peaking and fatigue, continued penstock out-of-roundness, and steel plate thickness issues in the 17-ft. section.

5.5 Risk Assessment

5.5.1 Option 1: Status Quo

Through the risk assessment completed by Kleinschmidt,[42] various risk items were identified as they relate to Option 1. The items with the highest score (16) and second-highest score (12) in the rating system were the risk of minor failures[43] and the risk of excessive corrosion requiring full interior coating.

If Penstock 3 is not refurbished, there remains considerable inherent risk of failure, particularly in the 17-ft. diameter section. Previous inspections have reported corrosion and weld cracks requiring urgent repairs. Overall probability of failure due to weld peaking, pitting corrosion in the weld HAZ, and loss of base-metal thickness remains considerably high.

Hydro's Capital Risk Evaluation outcomes for Option 1 are provided in Table 3. As there is no up-front capital cost associated with Option 1, and this option does not provide any significant risk mitigation, Risk-Spend Efficiency ("RSE") for this option is not applicable.

Table 3: Capital Risk Evaluation for Option 1

	Impact	Likelihood	Score
Pre-Execution	5	4	**20**
Post-Execution	5	4	**20**
		Risk Mitigated	**0**
		FEED Cost Estimate ($ Millions, Escalated to 2026 Dollars)	[redacted]
		RSE	**N/A**

5.5.2 Option 2: Weld Refurbishment

The risk assessment completed by Kleinschmidt concluded that the risk of weld failure would be reduced due to weld refurbishments, including mitigations such as enhanced cleaning and coating,

[42] Included as Appendix B of Attachment 1 to Schedule 1 of this application.
[43] Minor failures were defined as a localized failure at a weld in the 17-ft. diameter section of the penstock, causing a temporary outage, but no significant damage to the surrounding infrastructure.

thereby limiting overall corrosion progression. Still, the risks posed by material loss (large diameter-to-thickness ratio) and weld peaking will not be mitigated by implementing Option 2 measures.

As part of Option 2, it is assumed that only 50% of the welds would be refurbished. Thus, a risk remains that a non-refurbished weld may fail in the next 30 years. Cracks in refurbished welds found in 2021 in Penstock 1 and a failure of a refurbished weld in 2019 in Penstock 1[44] indicate that there is also a risk that the refurbished welds will fail. The impacts are reduced because the likelihood of multiple failures over 30 years is lower.

However, minor risks are present, such as resurfacing and coating of the penstock. Coating-related risks are attributed to the quality of the surface preparation and of the coating system selected for the project. Due to the expected high humidity within the penstock, the large surface area to cover, and the penstock's rough condition, a small or minor localized coating failure is likely to occur following construction, although the overall impact would be low due to strict quality processes.

Kleinschmidt has recommended against moving forward with Option 2. Even with significant capital investment, the risk of weld failures in the 17-ft. section and uncertainty around reliability will remain. Hydro's Capital Risk Evaluation outcomes for Option 2 are provided in Table 4.

Table 4: Capital Risk Evaluation for Option 2

	Impact	Likelihood	Score
Pre-Execution	5	4	**20**
Post-Execution	5	3	**15**
		Risk Mitigated	**5**
		FEED Cost Estimate ($ Millions, Escalated to 2026 Dollars)	[redacted]
		RSE	[redacted]

5.5.3 Option 3: Section Replacement and Weld Refurbishment

The risk assessment completed by Kleinschmidt concluded that Option 3 has the lowest risk rating, as it is the only option to fully address the design issues for the 17-ft. section and return units to normal operation. Option 3 mitigates design issues, including out-of-roundness, wall thickness, flexibility, weld

[44] Failure of a refurbished weld in 2019 in Penstock 1, as well as cracks found in refurbished welds in Penstock 1 in 2021.

peaking, and weld corrosion. This would lift operational constraints, allowing a return to normal operations and increased operational flexibility.

Another advantage of Option 3 is that inspections could be reduced to occur every 3–5 years to assess the coating condition and welds. Long-term maintenance and monitoring costs are expected to be the lowest of the refurbishment options.

Risks pertain to pre-construction and construction, which can be effectively mitigated to a lower risk profile, as discussed in the risk assessment. The number of weld refurbishments will significantly decrease if the 17-ft. diameter penstock section is replaced. The welds associated with the 17-ft. section would be a known quantity, very unlikely to change, and thus the overall risk to the budget and schedule due to uncertainty in the number of weld repairs would be reduced compared to Option2.

Hydro's Capital Risk Evaluation outcomes for Option 3 are provided in Table 5.

Table 5: Capital Risk Evaluation for Option 3

	Impact	Likelihood	Score
Pre-Execution	5	4	**20**
Post-Execution	5	1	**5**
		Risk Mitigated	**15**
		Cost Estimate ($ Millions, Escalated to 2026 Dollars)	[redacted]
		RSE	[redacted]

5.5.4 Option 4: Weld Reinforcement

The risk assessment concluded that while Option 4 is similar to Option 2 in terms of risk, the main benefit of Option 4 is that the weld reinforcement mitigates weld peaking by covering the refurbished welds and increasing stiffness in the weld area. However, if operational restrictions are lifted, cyclic pressure loadings will increase, and the risk of plate failure becomes likely over a 30-year period. The toe of the fillet welds used to attach the plates is susceptible to cyclic loading, increasing the likelihood of weld failure. There is a high probability that failures of the weakened material or cracks will develop due to fatigue from the cyclical nature of the loads.

Moreover, constructability risks exist with the design of the plates. The plates are heavy and are to be welded at various locations. Lifting in plates, securing, and welding to the penstock pose challenges and safety concerns that would have to be duly addressed.

While issues with weld peaking are mitigated, Option 4 is still not the recommended option as per Kleinschmidt's analysis. It does not fully address fatigue-related issues; therefore, lifting operational constraints would not be recommended. The added expense of the plates was also deemed to be unjustified.

Hydro's Capital Risk Evaluation outcomes for Option 4 are provided in Table 6.

Table 6: Capital Risk Evaluation for Option 4

	Impact	Likelihood	Score
Pre-Execution	5	4	**20**
Post-Execution	5	3	**15**
		Risk Mitigated	**5**
		FEED Cost Estimate ($ Millions, Escalated to 2026 Dollars)	[redacted]
		RSE	[redacted]

5.6 Least-Cost Evaluation

A comparison of the four options based on Kleinschmidt's up-front estimated budget and risk assessment is provided in Table 7.

Table 7: Comparison Summary for Penstock 3 ($)[45]

	Option 1	Option 2	Option 3	Option 4
Capital Budget	0	[redacted]	77,462,128	[redacted]
Return to Normal Operations?	No. It does not address the existing deficiencies related to the Penstock design (peaking and fatigue). Annual inspections must continue to monitor welds.	No. It does not address the existing deficiencies related to the Penstock design (peaking and fatigue). Annual inspections must continue to monitor welds.	Yes. Addresses existing deficiencies, and replaced sections would be designed to current standards. Inspections are reduced to every 3–5 years.	No. It does not address the existing deficiencies related to the Penstock design (peaking and fatigue). Annual inspections must continue to monitor welds.
RSE	N/A	[redacted]	[redacted]	[redacted]

[45] Cost estimates for Options 2 and 4 were conservatively escalated to 2026 dollars utilizing Hydro corporate assumptions.

5.7 Recommended Alternative

Kleinschmidt recommends proceeding with Option 3 to ensure the safe and reliable operation of Penstock 3 and the units it serves. Through a detailed risk assessment process, it was concluded that Option 3 would present the lowest level of risk and would be the only possible solution that would allow normal operation of the penstock and Units 5 and 6, thus providing the highest level of reliability.

Hydro's Capital Risk Evaluation indicates that Option 3 presents the greatest risk mitigation. This is the only option that adequately addresses the peaking and fatigue issues in the 17-ft. diameter section and returns Units 5 and 6 to normal operation. Due to the high number of weld failures in both original and refurbished welds in the 17-ft. diameter section of Penstock 3 in recent years, replacing this section provides a level of reliability that cannot be achieved with the other options. It is anticipated that the new penstock section will see an operational service life of 80 years.

As outlined in this application, Early Execution activities must be initiated in 2026 to adequately progress the replacement and refurbishment work for Penstock 3. Deferring the implementation of Option 3 would likely result in longer-than-anticipated penstock outages for repairs and an increased likelihood of penstock rupture, leading to significant unplanned outages and expenditures. A penstock rupture during the winter months could prove costly if replacement energy is required to make up the system load and would compromise the reliability of the Island Interconnected System. Hydro agrees with Kleinschmidt's recommendation, as Option 3 was identified as the only option which would return the penstock to reliable operations.

5.7.1 Risk of Asset Stranding

Hydro's *Reliability and Resource Adequacy Study Review* proceeding has identified the need for additional supply to meet Hydro's future generation needs. As Penstock 3 feeds Units 5 and 6 with a combined total generating capacity of 153 MW, it is a critical component of the Island Interconnected System and is required for Hydro to provide adequate generation for the foreseeable future. As a result, the risk of asset stranding is low.

6.0 Scope of Work

The Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment Project will involve implementing the recommended Option 3 to return Penstock 3 to reliable, normal operation. Work will

commence by engaging a third-party consultant to complete all technical design work and to provide project support for the duration of the work. The design, fabrication, and coating of the replacement penstock sections are expected to be completed off-site and shipped to Bay d'Espoir in advance of construction.

Site work on Penstock 3 will begin with excavation, demolition, and off-site disposal of the existing penstock sections. Earthworks will follow to prepare for cranes to lift the new penstock cans onto the newly placed bedding material. Field welding will then join the penstock cans together, utilizing an expected combination of semiautomatic and manual welding processes for efficiency and an expected combination of external and internal bracing to maintain the penstock shape and alignment. Backfill will be placed and compacted around the new sections of penstock concurrently with the placement of those sections and the completion of their joints.

The remaining length of Penstock 3 will undergo a complete inspection of all weld seams to verify their condition. Any refurbishment work required to return the welds to good condition will be completed, followed by abrasive blasting and the application of a protective coating to the penstock interior.

It is anticipated that various site infrastructure and construction support activities will be required, such as distribution line re-routes, laydown areas and construction access routes.

6.1 Early Execution Scope for Penstock 3

Early Execution capital expenditure has been identified as necessary to ensure that the time required for the Board's and any potential intervenors' review does not impact the project's timelines and maintain the proposed schedule and estimate. Maintaining the currently proposed schedule will reduce and/or eliminate key project risks as identified earlier in this document. The Early Execution scope includes but is not limited to:

- Engagement with steel suppliers for the supply of raw steel plate for the replacement sections of Penstock 3; and
- Re-location of an existing distribution line adjacent to Penstock 3.

The project control schedule assumes a [redacted] time to procure the necessary steel plate for the replacement section of the penstock. The steel must be available [redacted] [redacted] Market conditions for steel availability and lead times can be heavily influenced

by extraneous factors (e.g., markets, politics) and therefore can be difficult to predict. Approval of Early Execution is critical to mitigate the risk associated with steel availability and lead times.

[redacted] This will support the timely completion of the penstock design, de-risk potential challenges associated with constructability, alleviate having additional resources present at the construction site during the key construction, and, imperatively, mitigate overall cost and schedule impact should there be a delay in receiving project approval and the relocation scope be prolonged. [redacted] there is considerable risk to critical construction scopes, jeopardizing completion within the 2027 outage window.

7.0 Project Cost and Assumptions

The cost estimating structure for this project is designed to ensure financial robustness and risk preparedness.

The project capital cost estimate includes the following:

- Base cost estimate, which includes prices for direct costs, such as equipment, materials, etc., and indirect costs, such as Hydro's management, engineering, and consultant services, personnel expenses, sunk costs, insurance, and Engineering, Procurement, and Construction Management ("EPCM") costs; and
- Contingency, to account for uncertainties outside of the Hydro's control—these are the "known unknowns" that are within the project scope (e.g., additional weld remediation).

The sum of these costs makes up the project capital cost estimate. To establish the Planned Project Budget, the following is also included:

- Interest during Construction ("IDC"), to account for the cost of borrowing during project construction; and
- Escalation, which accounts for anticipated increases in labour costs and material prices over the course of execution of a multi-year project.

As part of the Major Projects' estimate development practices, Hydro has calculated the Management Reserve applicable to this project. Section 7.7 contains additional details on the development of the

Management Reserve amount. Hydro has determined not to request approval of the additional reserve, as discussed in Section 7.7.

7.1 Quantitative Risk Analysis

A Quantitative Risk Analysis ("QRA") is defined as a "risk analysis used to estimate a numerical value (usually probabilistic) on risk outcomes wherein risk probabilities of occurrence and impact values are used directly. . ."[46] For the Penstock 3 project, the Hydro project management team conducted a QRA.

Throughout the process, the QRA team reviewed various elements of the estimate and reached consensus on the expected variability for each element. This variability range could be for the item's cost, or for an element of the item's cost, such as quantity or production rates. This variability defines the probabilistic ranges used in the model for the Monte Carlo Simulation ("MCS").

This MCS is performed simultaneously for a variety of items across the entire estimate. The outcomes of all calculations and analyses provide a statistical probability curve of outcomes for the overall project. Picking a point on this curve provides the probabilistic outcome at that point, also called the P-value.

These QRA sessions collected data for the execution of the work and were modelled using an industry-standard statistical modelling tool. The output of this tool provides a range of outcomes to inform the project management team on recommended values for Contingency and Management Reserve.

7.2 Estimated Amount

The capital cost estimate was developed by Hydro based on the costs for Penstock 1, with adjustments for lessons learned, scope and quantity differences, actual contract costs, and appropriate unit rates. The estimate is deemed Class 3 per the AACE Recommended Practice (RP) No. 69R-12.[47]

The estimated cost for the Penstock 3 Section Replacement and Weld Refurbishment project is $77,462,128, including life-to-date costs and estimated direct construction costs, indirect costs, contingency, escalation, and IDC.[48] This estimate is deemed to have an accuracy range of [redacted] The Basis of Estimate, provided as Attachment 11 to this schedule, provides a breakdown of the project

[46] Association for the Advancement of Cost Engineering International. (2026). Recommended Practice (RP) 10S-90, *Cost Engineering Terminology, p. 107*.
[47] Association for the Advancement of Cost Engineering International. (2020). Recommended Practice (RP) 69R-12, *Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for Hydropower Industries*.
[48] Approval of Management Reserve is not requested for this project; further details can be found in Section 7.7.

budget. A summary of estimated costs is provided in Table 8. Further discussion of the underlying assumptions and individual cost estimate components is provided in the following sections.

Table 8: Summary of Estimated Costs ($2024)

Component	Estimated Cost
Direct Construction Costs	[redacted]
Hydro's Indirect Costs	
Subtotal Base Cost Estimate	
Project Contingency	
Subtotal Base Estimate (with Contingency)	
Escalation	
Interest During Construction	
Total Cost Estimate	**77,462,128**

The overall costs for the Penstock 3 project have increased compared to Penstock 1. This is mainly due to [redacted]

7.2.1 Early Execution Budget

The costs associated with this Early Execution scope total $1,942,814, the details of which are set out in Table 9. Hydro is not requesting the recovery of any expenditures related to the Early Execution prior to the Board's approval of the overall project.

Table 9: Early Execution Budget ($)

Description	Amount
Material Supply	[redacted]
Labour	
Contract Work	
Indirect Costs	
Contingency	
Escalation	
Interest During Construction (IDC)	
Total	**1,942,814**

7.3 Assumptions

The assumptions underpinning project execution and estimating are contained in the Basis of Estimate, Basis of Schedule, and relevant Project Execution Strategy and Plan, provided within Attachments 11, 12, and 13 to this schedule, respectively. Some of the key assumptions include:

- An adequate labour supply is available;
- [redacted]
- There will be no labour disruptions during the execution of the works;
- No abnormal (i.e., outside of normal observed statistical history) weather events occur during construction;
- Regulatory approvals will be generally granted as assumed in the project schedule; and
- [redacted]

It should be noted that some of these assumptions have been identified as strategic risks, and a related Management Reserve has been considered for them.

7.4 Base Cost Estimate

The Base Cost Estimate is stated in 2024 dollars, with Escalation and IDC calculated based on a cost profile that follows the project schedule. The Base Cost Estimate comprises direct construction costs and Hydro's indirect costs, as detailed in the sections that follow.

7.4.1 Direct Construction Costs

The Penstock 3 estimate for direct construction costs is largely based on [redacted] from the substantial completion of the Penstock 1 project. Lessons learned through the substantial completion of Penstock 1 have been incorporated progressively throughout the preparation of this application. A lessons learned process will be followed through as part of the project close-out of Penstock 1,[49] and will be used to further inform execution planning and cost control during the delivery of Penstock 3.

[49] Penstock 1 project closeout anticipated in the third quarter of 2026.

Since vendor pricing or actual costs were used as the basis of construction costs, indirect costs such as site services, contractor overhead, etc., for the construction contractor are included within these items and were not considered separately.

The Base Cost encompasses all key project phases, including estimates for:

- Mobilization, demobilization, and facilities cost;
- Penstock replacement;
- Penstock rehabilitation;
- Performance security;
- Steel supply; and
- External construction consultants.

7.4.2 Indirect Costs

Hydro's indirect costs include those for Hydro Owner's team and an EPCM consultant. The cost estimate includes labour costs, as well as additional elements such as travel to and accommodations in the Bay d'Espoir area, insurance, Hydro support during construction and commissioning, and various corporate costs. The estimate for the EPCM consultant is based on the expected cost for Penstock 3 under a site-wide EPCM contract.[50]

7.5 Contingency

Contingency is defined as "an amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs."[51]

Hydro reviewed the project scope in detail and assigned potential low and high percentages to individual estimate items, as shown in Attachment 11. These percentages were then used in an MCS-based QRA to develop a cumulative distribution curve from which a contingency value is calculated. The cumulative distribution curve shows the expected cost for each probability level. The P50 value indicates

[50] The EPCM is contracted to support other projects at the Bay d'Espoir site, including Penstock 3, Unit 7, and Unit 8.
[51] Association for the Advancement of Cost Engineering International. (2026). Recommended Practice (RP) 10S-90, *Cost Engineering Terminology*, p. 32.

the dollar amount at which there is a 50% probability that the total base costs are below that amount. Contingency is then calculated as the P50 value minus the base amount.

7.6 Escalation and Interest During Construction

7.6.1 Escalation

There are a variety of methods for estimating escalation factors, but the commonality is an attempt to predict future economic and market conditions. This projection becomes increasingly difficult over longer-term periods. Hydro has developed a standardized approach to escalation projections, which is utilized on all its projects, including Penstock 3. The escalation factors for Penstock 3 were provided by Hydro's Financial Department and applied to the committed costs for the years 2025 to 2028.

7.6.2 Interest During Construction

Hydro uses a standard method to calculate IDC, which is applied to capital expenditures, including this cost estimate.

7.7 Management Reserve

Management Reserve is defined as "an amount added to a cost estimate to allow for discretionary management purposes outside of the defined scope of the project, as otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency, or that cannot be effectively managed using contingency."[52]

During the development of the estimate for this project, Hydro created a strategic risk register and assigned low-, expected-, and high-cost ranges to each risk. These ranges were then used in an MCS-based QRA to determine a Management Reserve value for those risks. Consistent with the Commission of Inquiry Respecting the Muskrat Falls Project's recommendations, the Management Reserve is calculated at a P85 probability. This P-value is presented to the Steering Committee as a recommendation, and the Steering Committee makes the final selection of the P-value for the management reserve.

[52] Association for the Advancement of Cost Engineering International. (2026). Recommended Practice (RP) 10S-90, *Cost Engineering Terminology*, p. 82.

Management Reserve consists of two components:

- Management Reserve on base cost, which is calculated as the difference between the P85 and [redacted] values in the total cost MCS; and
- Management Reserve on strategic risk.

The total calculated Management Reserve for this project is approximately [redacted]

Hydro has considered the purpose of the Management Reserve, and the particular context of this application, [redacted]

The costs for the Penstock 3 project, like those for Penstock 1, are mostly contained within a single construction contract. This makes it easier for potential bidders to estimate the available funding for the contract from the publicly available approved budget. The Penstock 1 project was recently completed, with an approved budget publicly available, and it is also publicly known that the project finished within budget. [redacted]

[redacted] Hydro notes that although Management Reserve should always be calculated to fully understand the potential impact of strategic risks on the cost, the decision to request approval of it as part of the project's authorized cost should be made on a case-by-case basis, considering all risks associated with the specific project. For projects that are unusual, complex, infrequent, or involve multiple contracts, or for which the calculated Management Reserve is high, Hydro believes it is appropriate and even necessary to seek Board approval of Management Reserve as part of the approved Authorized Cost.

7.8 Customer Rate Impact

The incremental revenue requirement for the Penstock 3 Section Replacement and Weld Refurbishment project is estimated to be approximately [redacted][53] in 2028, the first full year in service. This increase in revenue requirement would represent a [redacted][54] wholesale rate increase relative to the 2019 Test Year and [redacted][55] retail increase. However, the Government of Newfoundland and Labrador's ("Government") rate mitigation plan limits Hydro's annual rate increases on the Island Interconnected System to [redacted] for retail rates up to and including 2030. This annual rate increase includes the impact of all of Hydro's costs and would encompass any revenue requirement associated with this project in those years. Details on the structure and applicability of rate mitigation post-2030 remain under consideration.

8.0 Project Schedule

The Project Control Schedule ("PCS") for Penstock 3 is a Class 3, Level 2 schedule (as per AACE RP 37R-06). It has been built by leveraging both historical data as well as Penstock 1 task durations. The PCS contains activities that develop a full project view of the scope, categorized as: deliverables for project management, regulatory activities required for project approval, execution activities to forecast engineering, procurement/fabrication, construction and commissioning. The Basis of Schedule (Attachment 12) provides further details on the development of the project schedules.

As this project progresses and consultants and contractors are awarded scopes, the level of detail in the activities will be increased. Additionally, now that the overall construction of the Penstock 1 Life Extension Project is substantially complete, the actual construction durations, productivity rates, sequencing, and outage performance achieved on that project have been incorporated to inform and refine the Penstock 3 schedule, improving confidence in the planned execution approach and critical path assumptions.

The overarching critical path for Penstock 3 is calculated to run through the 2027 construction season, which assumes that Penstock 3 can be taken offline only during the non-winter load period.

[53] Based on an estimated service life of 70 years and a [redacted] incremental weighted average cost of capital.
[54] [redacted] ÷ $603.7 million (2019 Test Year Island Interconnected Revenue Requirement) = [redacted]
[55] [redacted] × 70% (estimated pass through to retail level) = [redacted]

8.1 Project Major Milestones

Table 10 contains a listing of the project's major milestones.

Table 10: Project Major Milestones

Milestone Description	Date
EPCM (LNTP[56]) Award	Q1 2026
Early Execution Regulatory Approval	Q2 2026
Steel Supply Contract Award	Q2 2026
Full Regulatory Approval	Q3 2026
Construction Contract Award	Q3 2026
Completion of Construction	Q4 2027

8.2 Scheduling Constraints and Considerations

The planned work for Penstock 3 is subject to several constraints, including approvals, material availability and lead times, weather conditions, and coordination with other facilities during construction.

8.2.1 Approvals

There are several risks that could impact the execution schedule. The project schedule assumes time for a thorough review and evaluation of the project through a regulatory proceeding necessary to obtain Board approval by early in the third quarter of 2026. Hydro will request Board approval of the Early Execution scope discussed herein to enable project continuity while allowing the time necessary for the overall regulatory proceeding.[57] Again, it is imperative that [redacted] to de-risk the overall schedule and limit potential cost increases. Delays in receiving regulatory approval for the Early Execution Scope beyond the end of April 2026 would affect overall project approval and delay the award of the construction contract, increasing the risk of a project delay of up to two years. As noted previously, Hydro is not requesting recovery of any expenditures related to the Early Execution until the Board approves the overall project. The Early Execution expenditures form part of the overall estimated budget and will be recovered from customers as part of the project's cost recovery, if the overall project is approved.

[56] Limited Notice to Proceed (LNTP).
[57] The Early Execution scope includes the request for approval of expenditures for steel procurement and distribution line reroutes that are needed to maintain both project cost and schedule.

8.2.2 Material Availability and Lead Times

The PCS utilizes a [redacted] time to procure the necessary steel plate for the replacement section of the penstock and [redacted] Market conditions for steel availability and lead times can be heavily influenced by the political climate and, therefore, difficult to predict. Approval of Early Execution is critical to mitigate the risk associated with steel availability and lead times.

8.2.3 Line Relocations

The line relocation scope must [redacted] as to progress the project schedule through maturation of the penstock design and overall constructability, to alleviate additional burden and safety concerns from having extra resources on site during the critical construction period, and imperatively, to de-risk schedule and cost by ensuring that line work is not delayed into the critical 2027 outage window and construction period. Approval of Early Execution is critical to mitigate the risk associated with delayed line relocation works.

8.2.4 Weather Conditions

The construction phase is planned to be executed during non-winter periods to manage construction costs. Delays to the project schedule due to weather, [redacted] could push construction into the colder months, further slowing production.

8.2.5 Coordination with Existing Facilities

Certain portions of the planned work require coordination with existing facilities, most notably the major unit overhaul scheduled for 2027.

9.0 Risks and Risk Management

9.1 Project Risk Management Overview

Over the life of the project, risks and associated risk treatments will be identified, analyzed, and continuously monitored and reviewed in accordance with Hydro's Risk Management Framework.

The purpose of the project Risk Management Framework is to provide a structured approach for identifying, assessing, managing, and monitoring potential risks that could influence the successful delivery of the project. It serves as a roadmap to proactively manage uncertainties, minimize negative

impacts, and maximize opportunities, ensuring that project objectives related to scope, time, cost, health and safety, environment, and quality are protected. Through clear risk identification, prioritization, and response planning, the Risk Management Framework aims to enhance decision-making, allocate resources efficiently, and foster a culture of risk awareness, ultimately supporting project success and alignment with organizational goals.

In support of risk management, Hydro continues to employ QRA, as outlined in Section 7.1. This is done as part of prudent project management practice, ensuring that key risks are highlighted, analysed, and their impacts are both qualified and quantified. The QRA process also directly influences information necessary to develop a robust, informed project estimate, including the basis for developing contingency and management reserve estimates.

The goal is to support the project's successful completion by managing uncertainties in a way that aligns with the organization's risk tolerance and strategic objectives.

9.2 Key Risk Management Activities

The risk management process is generally carried out through the following key risk management activities:

- Risks and opportunities are identified based on input from the project team, consultants, key stakeholders, as well as lessons learned from similar past projects;
- Qualitative and/or quantitative risk analysis is performed for identified risks to determine their consequence type, severity and likelihood;
- Appropriate treatment plans to respond to the risks are developed, with defined risk owners; and
- Risks and reporting of risks are monitored and reviewed on a regular basis so that the appropriate audience is informed, and any required updates are made.

The risk management process is iterative and follows a continuous improvement approach throughout the project life cycle.

9.3 Current Risk Mitigation Status

During the FEED phase, a preliminary Risk Register has been developed.[58] This document captures all identified risks, such as timely approval, weather conditions, unforeseen conditions, their analysis, and corresponding treatment plans.

9.3.1 Risks to Schedule Execution

Several risks could impact the successful execution of the project schedule, including timely approval and weather conditions.

- Timely Approval: A delay in project approval can delay the award of the construction contractor and thus penstock fabrication, which could introduce significant delays of up to two years should the Penstock 3 outage window be missed. This is particularly critical as Unit 7 Life Extension and the unit outage are scheduled for 2028, and the Penstock 3 outage cannot occur concurrently.
- Weather Conditions: Weather patterns outside of the statistical norms for the area could adversely affect construction. These conditions may not only cause delays but also increase costs due to the need for additional measures such as heating, snow removal, or temporary structures.

9.3.2 Unforeseen Conditions:

The condition of the penstock welds and steel could require additional efforts to refurbish, beyond the reasonably foreseeable amount, causing delays to project schedules and impacting return-to-service dates.

9.3.3 Early Execution Works

Proceeding with Early Execution work in advance of the overall project approval provides meaningful risk mitigation by protecting the overall estimated project schedule and budget. Early Execution enables Hydro to procure critical raw materials and complete necessary distribution line re-routes in advance of award of the fabrication and construction contract, thereby securing schedule certainty, reducing safety and logistical risks and maintaining control of the overall project budget. This approach to steel

[58] Provided as Appendix B of Attachment 1 to Schedule 1 of this application.

procurement also [redacted]

[redacted]

10.0 Conclusion

The current operational status of Penstock 3 in Bay d'Espoir is not a viable long-term solution to meet Hydro's mandate to provide safe, least-cost, reliable power. Penstock 3 serves as an integral component of Bay d'Espoir, supplying Units 5 and 6, and therefore requires refurbishment to ensure continued reliable operation.

Hydro has engaged multiple consultants since 2016 to conduct a series of condition assessments and inspections on Penstocks 1, 2, and 3. Since 2018, Hydro has engaged consultants to conduct annual inspections of Penstocks 1, 2, and 3 to mitigate the risk of penstock rupture. These inspections have identified multiple, recurring weld indications in Penstock 3, including cracking in previously repaired welds.

Through failure investigations and the development of life extension options, Hydro has engaged three engineering consultants: Hatch, SNC-Lavalin, and Kleinschmidt. Considering the complete data set across multiple failure investigations, the root cause of cracking in Penstock 1 was confirmed to be weld peaking combined with corrosion and cyclic stresses. Given these circumstances and the similarity among the three Powerhouse 1 penstocks, Hydro and Kleinschmidt analyzed four life-extension options for Penstock 3, considering the risk, reliability, construction costs, schedule, and technical viability of each option. Based on the risk analysis and Hydro's reliability analysis, Kleinschmidt recommended Section Replacement and Weld Refurbishment as the preferred alternative. The other options considered were deemed not technically viable for life extension due to the high risk of future weld failures and the associated significant cost impacts. Furthermore, the other options do not enable a full return to normal operations for Penstock 3 and Units 5 and 6. Based on historical experience, which has shown failures in previously refurbished welds, Options 1, 2, and 4 will not mitigate the issues experienced in the 11.11 mm (7/16 in.) penstock section, and uncertainty around reliability will exist even after significant capital investment.

Hydro supports Kleinschmidt's recommendation and project execution plan and proposes executing the section replacement and weld refurbishment of Penstock 3 during the 2026–2028 timeframe to address

the peaking and fatigue issues, extend the service life of the penstock and return Units 5 and 6 to normal operation.

To ensure the project maintains schedule and cost, an Early Execution scope, with associated capital funds, has been requested as part of this application to progress critical scopes and de-risk the overall construction schedule and budget. Hydro is not requesting the recovery of any expenditures related to the Early Execution prior to the Board's approval of the overall project.

Schedule 1, Attachment 1

Decision Support Package: Penstocks 2 & 3

Bay d'Espoir Hydro Site

Front End Engineering and Design

Kleinschmidt Associates

November 21, 2021



Decision Support Package: Penstocks 2 & 3

Bay d'Espoir Hydro Site

Front End Engineering and Design

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
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November 2021

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NL Hydro) is evaluating four options regarding the long-term life extension of Bay d'Espoir Penstocks 1, 2, and 3. This Decision Support Package was developed to facilitate NL Hydro's decision-making process for Penstock 2 and 3 with regards to which option to move forward with in their evaluation process. The Decision Support Package provides an evaluation of the costs, benefits, viability, reliability, life expectancy, and risks associated with each option for Penstock 2 and 3. A Risk Assessment Report was developed from the risk workshop to identify risks for each life extension option associated with Penstock 2 and 3 and is appended to and summarized in this Decision Support Package.

The options evaluated for the life extension of Penstocks 2 and 3 are as follows:

- ***Option 1*** (No Rehabilitation) - No refurbishment of the penstock with continued operational and maintenance procedures only. Repairs completed on an as needed basis.
- ***Option 2*** (Weld refurbishment) - Refurbishment of deteriorated circumferential and longitudinal weld seams including resurfacing and recoating of the penstock interior. Refurbished welds will be selected after inspection of all welds.
- ***Option 3*** (Section Replacement)- Replacement of the 17-foot diameter section of penstock plus weld refurbishment and recoating of the interior of the smaller diameter sections of the penstock. All welds will be inspected.
- ***Option 4*** (Weld Reinforcement) - Refurbishment of deteriorated welds, recoating of the entire interior of the penstock and reinforcement of the longitudinal and circumferential welds in the 17-foot diameter penstock section with reinforcing plates.

Construction Cost

Construction costs were reviewed and compared for the three refurbishment options. Option 1 was not included in the construction cost review as no refurbishments will be completed for this option. An independent AACE Class 4 Cost Opinion for the three rehabilitation options was developed for the purpose of providing a comparison and update on the previously developed 2020 Hatch estimate (Hatch, 2020). A summary of the Kleinschmidt cost opinion and investigation into the direct costs compared to the

2020 Hatch Cost Opinion is provided in Section 3.0. The primary observation when comparing the 2021 and 2020 cost opinions is that the two estimates, while not the same, are very similar and reside well within the AACE Class 4 accuracy range of each other. While the 2020 and 2021 cost opinions differ, the range of accuracy overlapping suggests a correlation between the two sets of estimates that verifies that the two cost opinions support each other as reasonable representations of the expected price to complete the work.

Penstock 2	Option 2	Option 3	Option 4
Hatch 2020	**$27,450,000**	**$52,290,000**	**$36,230,000**
Kleinschmidt 2021	**$29,715,700**	**$53,495,600**	**$38,016,200**

Penstock 3	Option 2	Option 3	Option 4
Hatch 2020	**$25,860,000**	**$47,090,000**	**$34,700,000**
Kleinschmidt 2021	**$28,248,700**	**$53,204,600**	**$36,780,200**

Project Execution and Schedule

High level project execution items are outlined in Section 4 and are used to inform the project schedules developed and presented in Section 5. Items included in the project execution for Option 2, which is used as the base case, include:

- Contractor Weld Plan/Procedure
- Equipment
- Site Access
- Penstock Access
- Engineered Scaffolding
- Base Metal Inspection
- Weld Inspection
- Excavation for Full Penetration Welds
- Weld Repair
- Interior Penstock Surface Preparation
- Recoating Interior of Penstock

- Weld Repair and Coating Inspections

Option 3 adds the following nine items to the project execution that needed to be accounted for in the project schedule:

- Fabrication/Shipping of new penstock sections ("cans")
- Site Crane
- Laydown Area
- Demo of Existing Penstock
- Bedding Material
- Environmental
- New Penstock Installation
- Pressure testing
- Site Restoration

Compared to Option 2, Option 4 adds the following four items to the project execution that need to be accounted for in the project schedule:

- Steel bar fabrication
- Working/Laydown Area
- Installation of Flat Bar
- Fillet Welds for Flat Bar

General construction schedules were developed using the project execution details for the three different refurbishment options. Each schedule was created using a May to November construction timeframe. See Figures 5.1, 5.2 and 5.3 in Section 5 for project Gantt charts.

The presented schedules are based on a 5-day X 10-hour shift work week. Welding activities will utilize two 10 hour shifts per day to meet the outage schedule constraints and allow time for the coating to be applied. The time to complete the weld repairs was calculated by using the total estimated weight of the weld material for each option and using a deposition rate per hour. Based on expert input from Skarborn Engineering, Flux-cored arc welding is expected to be the welding process utilized by the contractors providing competitive bids. Based on the information at hand, with a weld material deposition rate of approximately 8 lbs/hr and a 20% Operation Factor, we expect a crew

of 10 welders per shift will be necessary to achieve this schedule. Accommodating 10 welders will require 10 specialized adjustable scaffold systems and adequate access and ventilation necessary to support spacing the welders over the length of the penstock. Based on this assessment, it is expected that each refurbishment option can be completed in a single construction season. Option 3 involves the replacement of the 17-foot diameter section of the penstock. An important schedule consideration for this option is lead time on the delivery of the penstock cans to site. Based on our experience Hydro can expect a 6 to 8-month lead time on the penstock delivery.

We have assumed at this point that the work for Penstock 2 and Penstock 3 is completed as two separate jobs and there are no shared costs. We have allowed that the access for Penstock 2 is more challenging than for Penstock 3 and has resulted in a slight increase in cost. More challenging access and construction was accounted for by utilizing a higher indirect/direct ratio in the costing of Penstock 2 as discussed in Section 3.3 of this report.

Risk Assessment

A risk assessment was developed to evaluate risks associated with the various aspects of the four life extension options for Penstock 2 and 3 and is documented in Appendix B. Risks were identified for the four options in a risk registry with impact severity and probability of occurrence documented for each risk item. The risks identified for each option were evaluated and an analysis performed to facilitate a comparison of the relative risk level for each option.

It was demonstrated that Option 1 is the highest risk option due to the probability of multiple failures (estimated at one every other year) and associated significant repair costs over the next 30 years. Option 1 had two risk items with ratings of 16, the highest risk rating possible in the 4 x 4 matrix. Based on the level of risk associated with Option 1, with its elevated probability of failure historically demonstrated by 4 failures in 5 years, new cracks discovered in 2021 during dewatered inspection, and high consequence, it is recommended that this option be ruled out as it exceeds what should be tolerated for risk. There are no mitigating measures for Option 1 that can adequately reduce the elevated risks without implementing Options 2, 3, or 4.

It is shown that Option 3 has the lowest risk rating and adequately mitigates the peaking and fatigue issues, allowing operational constraints to be lifted. Options 2 and 4 have a similar risk profile but rank higher in risk than Option 3 because they do not completely

mitigate the peaking, fatigue, and design issues in the 17-foot diameter section of penstock.

Summary

Option 3 has the lowest risk and provides the most future reliability The reliability increase is obtained by replacing the problematic 17-foot diameter section with a new penstock section.

From a construction cost point of view Option 2 is the least cost solution, allowing that Option 1 is not considered a viable solution. Option 2 is about 60% less than Option 3 and 30% less than Option 4. Option 2 however does not completely address design concerns in the 17-foot diameter section, and it is not recommended to lift operational constraints following the Option 2 refurbishment.

The discovery of cracking in previously repaired welds and in the new reinforcing plate welds of Penstock 1 during a planned dewatered inspection in May of 2021 supports the need to maintain operational constraints following an Option 2 or Option 4 refurbishment. New cracks in previously repaired welds in 14 cans of the 17-foot diameter section of Penstock 1 raise questions and concerns regarding the service life of the weld repairs as the repairs were less than 5-years old. The new cracks in Penstock 1 were discovered following the first risk assessment workshop and the initial draft of the Penstock 1 risk assessment report but are being referred to in this report because the newly discovered cracks add valuable insight into the potential longevity and serviceability of Options 2 and 4. It should be noted that the last failure during operation of Penstock 1 was in a previously repaired weld also in the 17-foot diameter section. While these observations are from Penstock 1, the three penstocks are identical from a design and operation standpoint.

The difference between Option 2 and Option 4 is the addition of the reinforcing plates over the repaired welds. We feel that these plates do not add enough value to support the additional expense over Option 2. The plates would be welded on the penstock with fillet welds which are susceptible to cracking at the toe from cyclic loading. This has been observed during the 2021 inspection where five reinforcing plates in Penstock 1 were found to exhibit extensive cracking at the toe of the fillet welds.

For long term maintenance Option 3 is preferred with a new 17-foot diameter penstock section and associated new bedding and drainage. The requirement for inspections, maintenance, and repairs is expected to be significantly reduced for Option 3 compared to Options 2 and 4.

It is our opinion that Option 3 is the most viable option based on future reliability. As can be interpreted from recent identified cracks in 14 cans in Penstock 1 and the most recent failure in 2019, the refurbished welds and the reinforcing plates do not have the reliability or life expectancy that would provide trouble free operation for the next 30 years. Yearly inspections would be required, and operational constraints implemented for Options 2 and 4 along with weld repairs expected every 3 to 5 years based on what we have observed in the short time the existing repairs have been in place for Penstock 1.

A risk assessment workshop was carried out to study the risk of failure of Penstock 2 and 3 and to assess construction risks for all refurbishment options for both penstocks. Both Penstock 2 and 3 were inspected previously, including the weld refurbishments completed in 2016/2017. In 2018, the refurbished welds in Penstock 2 did not show signs of degradation. However, corrosion and cracking of the welds in the heat affected zones (HAZ) were identified in Penstock 3 during the 2018 inspection with the welds displaying less corrosion downstream of the surge tank. On average, upstream of the surge tank, cracks were 4 to 5 millimeters in depth which is 36-45% of the plate thickness. The refurbished welds in Penstock 3 did not show signs of degradation.

Penstock 2 was inspected in 2021 and no degradation of the previous weld repairs were identified. Penstock 3 was not inspected in 2020 but will be inspected in August 2021.

The risk of a minor failure occurring for Penstock 2 and 3 was given a risk rating of 12, which is reduced from the risk rating of 16 assigned to Penstock 1. The team determined there was less risk of a minor failure of Penstock 2 and 3 because no failures have occurred to date.

It is important to note that there was no sign of degradation of the repaired welds in Penstock 1 during the August 2018 inspection; however, multiple cracks were found in the repaired welds in 2021.

Despite the reduction in failure risk of Penstock 2 and 3 compared to Penstock 1, Option 3 is the recommended option for refurbishment for both Penstock 2 and 3 as well. Although Option 3 has the highest initial rehabilitation cost, it is expected to have the lowest long term maintenance costs, it has the lowest risk rating, the highest reliability, and is the only option that adequately addresses the design issues in the 17-foot diameter section, it is also the only option that removes operational constraints returning the site to normal operations. Based on this it is our opinion that Option 3 will provide the required asset integrity and reliability at best value to rate payers.

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1.0 INTRODUCTION

This report is part of the front-end engineering design support for the long-term life planning of Penstock 2 and 3 at the Bay d'Espoir (BDE) Hydro Site. Newfoundland and Labrador Hydro's (NL Hydro) primary objective is to make prudent and justifiable investment decisions regarding the long-term life of the BDE penstocks to provide asset integrity and reliability at best value to rate payers. With this object in focus, additional assessments and analysis of risks and costs have been developed to supplement prior studies to provide a more detailed understanding of the life extension options.

On May 21, 2016, a 600-millimeter crack in Penstock 1 was found 260 meters downstream of the intake (Figure 1.1). The exterior of the penstock was exposed, and the crack to propagate along the longitudinal weld seam. The crack was inspected and repaired. Subsequent failures in September 2016 and November 2017 prompted extensive investigations and inspections to determine the root cause of the failures of Penstock 1. Since Penstock 2 and 3 are of similar vintage, design and construction, there was concern of further weld failures in all three penstocks.



Figure 1.1 May 2016 Crack

In the spring of 2019, an area of cracking was discovered in the heat affected zone of a previously refurbished weld in Penstock 1 (shown in Figure 1.2).



Figure 1.2 2019 Cracks Above and Below Previously Repaired Weld

Refurbishment options were prepared by Hatch and submitted to NL Hydro and four options were chosen for further consideration. The four refurbishment options are:

1. No refurbishment or replacement (Status Quo/Do Nothing).
2. Refurbishment of the deteriorated welds, resurfacing, and recoating of the penstock interior.

3. Replacement of the 17-foot diameter section of penstock with a new penstock designed to current standards. Refurbishment of the deteriorated welds, resurfacing and recoating of the penstock interior on the remainder of the existing penstock.
4. Refurbishment of the deteriorated welds, additional reinforcement of the refurbished welds with steel plates, and resurfacing and recoating of the interior of the penstocks.

This report includes a summary of Kleinschmidt's investigation into the direct costs of refurbishment and provides a review of previous cost estimates while adding and updating costs as appropriate to refine the costing with available data. High level schedules for the execution of each option have been developed and incorporate discussions during the risk assessment workshop for Penstock 2 and 3. The reliability of the proposed penstock refurbishment options including consideration of potential risks and estimated life expectancy of the penstocks is discussed. The results of the Risk Assessment Workshop for Penstock 2 and 3 are summarized in Section 6.0.

The overall Decision Support Package is intended to assemble and review relevant data with the goal to provide a clear justified recommendation for a preferred option for each penstock that evaluates costs, risks, reliability, and life expectancy. This report summarizes and compares each option for Penstock 2 and 3. Information gathered, methodologies, rationale, justifications, assumptions, and sources of information are documented in the report.

The level of detail used in this report for this phase of the project is intended to provide a clear comparison of the options while avoiding unnecessary details and information not required at this stage. Once an option is chosen, a thorough and detailed discussion and assessment of the execution for that option will be provided in the next phase of this project.

A separate Decision Support Package was developed for Penstock 1 because the multiple operational failures of Penstock 1, that did not happen with Penstocks 2 or 3, created the urgency and impression that Penstock 1 should be handled separately as it may have different risks, results, and recommendations.

NL Hydro is expected to select the preferred option for Penstock 2 and 3 Life Extension based on the Decision Support Package which will include the Risk Assessment and Cost Benefit Analysis results. This will be Decision Gate 2.

2.0 DESCRIPTION OF OPTIONS

Four options are being considered for Penstock 2 and 3, one status quo option and three refurbishment options. These options have been developed and discussed in previous reports and are refined here for the current studies and this report. A comparison of costs, schedule, risks, and reliability are discussed in the following sections.

2.1 Option 1 – No Rehabilitation

For Option 1 no life extension measures will be implemented over the next 30 years. Operational and maintenance procedures will continue, and repairs will be completed on an as needed basis.

A summary list of items considered in this report include:

- Penstock 2 and 3 have not failed; however, corrosion and cracking of the weld material has been identified during past inspections and refurbishments were completed by placing new weld and reinforcement plates.
- The greatest benefit of Option 1 is the short-term economic benefits associated with no major capital investment for repairs or replacement of Penstock 2 and 3. This benefit is offset by the risks and associated costs of potential failures and emergency repairs. The Team identified there is a reduced risk of penstock failure for Penstock 2 and 3 compared to Penstock 1; however, there remains a high probability of weld failures over the next 30 years.
- The current operational restrictions represent a negative aspect which would continue. These restrictions are intended to limit cyclic loads on the penstock weld seams but restrict Hydro's flexibility in operating the units at Bay d'Espoir.
- Internal surface corrosion will progress leading to shell thickness loss and corrosion of the weld material increasing the likelihood of failure as the penstock continues to age.
- There is an increased risk of catastrophic failure, prolonged outages to complete the repairs, other equipment damage, loss of generation revenue, and increased frequency of inspections.
- Public and worker safety, environmental and social damages, damage to other local infrastructure are risks that are considered for this option.

2.2 Option 2 – Weld Refurbishment

Option 2 is considered the standard repair option as it is intended to simply replace deteriorated welds with new welds and has the lowest construction cost. This option includes:

- Inspect longitudinal and circumferential weld seams to determine those requiring refurbishment (50% repair rate is the baseline assumption in this report).
- Refurbish deteriorated weld seams using modified repair procedure (repairing welds from both sides, interior and exterior, whenever possible).
- Abrasive blasting of the interior surface of the penstock.
- Coat interior of the penstock (specifically with a MC-Zinc primer – one coat; MC-Tar moisture cure urethane -two coats).

A summary list of items considered in this report include:

- A significant portion of the longitudinal weld seams of Penstock 2 and 3 were previously inspected and repaired. These will require further inspection and possibly further repair.
- The interior surface will be cleaned, and a coating applied to mitigate corrosion. The penstock interior will need to be recoated in approximately 15 years depending on the surface preparation, application environmental conditions and service life of the product. There is a risk that a second coating will not be applied to clean near white metal due to the limited thickness and corrosion of the steel. The first coating will require significant abrasive cleaning that will slightly thin the steel plate. There is enough thickness to do this once down but may not be enough thickness to do this a second time in 15 years. A second coating can be applied but may require a different material and likely a less effective surface preparation.
- This option limits the large up front capital investment compared to a complete penstock replacement.
- A significant disadvantage to this option is that there will be no remediation to the existing deficiencies related to the design of the penstock, such as the existing out of roundness and steel plate thickness concerns of the upper 17-foot diameter section, or the peaking related stresses.
- Future dewatered inspections will still be required periodically to monitor the coating condition.
- Recoating of exterior of the penstock and drainage improvements are not included in this option.

2.3 Option 3 – Section Replacement and Weld Refurbishment

Option 3 includes the most extensive refurbishment and has the highest construction cost. This option includes:

- Replace the 17-foot diameter section of Penstock 2 and 3.
    - Results of the previous penstock analysis determined the 17-foot diameter section of the penstocks had the most areas of concern compared to the smaller diameter sections. The 17-foot diameter sections of Penstock 2 and 3 are made of a different steel material and also have notable peaking stresses, and more weld deterioration found when compared to the rest of the penstock length. It is more economical to replace the problematic section of the penstocks instead of the entire length. There is no identified need to replace the remaining length of each penstock. The new penstock sections would be designed to meet current standards which would fully remediate the out of roundness, weld peaking and plate thickness issues for the replaced section of penstock.
- Refurbish the remaining sections of the penstock as noted in Option 2.

A summary list of items considered in this report include:

- The main advantage of this option is the mitigation of the design deficiencies of the existing 17-foot diameter sections of Penstock 2 and 3, and correcting out of roundness, wall thickness, flexibility, weld peaking, and weld corrosion. The new 17-foot diameter section would be designed to current standards.
- Remediation would include new bedding, drainage, and cover.
- The primary disadvantage is the higher cost for materials and installation when compared to Options 2 and 4.

2.4 Option 4 – Weld Reinforcement

Option 4 starts with Option 2 and adds reinforcing plates over the welds. This option includes:

- Refurbish Penstock 2 and 3 as noted in Option 2.
- Reinforce the longitudinal and circumferential welds for both penstocks in the 17-foot diameter penstock section with reinforcing plates.

A summary list of items considered in this report include:

- Potential savings associated with only reinforcing the longitudinal welds as these experience higher stresses and have a history of repair needs when compared to the circumferential welds. There is less benefit associated with installing reinforcing plates on the circumferential welds and this may not be worth the investment.
- The reinforcing plates will strengthen the joints.
- The reinforcing plates introduce edges that may impact the performance of the coating but can be mitigated by rounding the ends.
- Interior versus exterior installation of the reinforcing plates requires consideration.
- A significant portion of the longitudinal weld seams were previously inspected and repaired. These will require further inspection and possibly further repair.
- The interior surface will be cleaned, and a coating applied to mitigate corrosion. The penstock interior will need to be recoated in approximately 15 years depending on the surface preparation, application environmental conditions and service life of the product. There is a risk that a second coating will not be applied to clean near white metal due to the limited thickness and corrosion of the steel. The first coating will require significant abrasive cleaning that will slightly thin the steel plate. There is enough thickness to do this once down but may not be enough thickness to do this a second time in 15 years. A second coating can be applied but may require a different material and likely a less effective surface preparation.
- This option limits the large up front capital investment compared to a complete penstock replacement.
- A significant disadvantage to this option is that there will be no remediation to the existing deficiencies related to the design of the penstock, such as the existing out of roundness and steel plate thickness concerns of the upper 17-foot diameter section, or the peaking related stresses.
- Future dewatered inspections will still be required periodically to monitor the coating condition.
- Recoating of exterior of the penstock and drainage improvements are not included in this option.

3.0 COST COMPARISON

An independent cost opinion of the three rehabilitation alternatives was requested by NL Hydro to establish increased cost confidence for the ongoing evaluation of the three alternatives. One purpose of the independent cost opinion was to remove any perception of bias that may be present in the original estimate due to the use of unit cost data resulting from the emergency repairs, which are thought to reflect higher costs due to the urgent response nature of the work and are thought to not be entirely reflective of the market price for the upcoming rehabilitation being executed under planned circumstances.

3.1 Options Analysis

Kleinschmidt performed a cost evaluation for three of the four options for both Penstock 2 and 3. We compared the results of the Kleinschmidt cost assessment with the assessment presented in the Hatch "*Penstock No's 1, 2 and 3 Life Extension Options*" Report (Hatch, 2020a).

Below, a discussion of the options is presented, identifying relevant assumptions that were made by Hatch in their assessment and presenting Kleinschmidt's approach to developing the Cost Opinions of the three options evaluated. Some assumptions, such as the development of unit rates, made by Hatch that differ from Kleinschmidt's evaluation are identified in the discussion of the options.

The comparison of the cost evaluations is presented below in Table 3.1 and 3.2 for Penstock 2 and Table 3.3 and 3.4 for Penstock 3.

3.1.1 Option 1

As discussed above in Section 2.1, Option 1 does not include any life extension rehabilitation work. Operational and maintenance procedures will continue, and repairs will be completed on an as needed basis. As such, this option was not evaluated for rehabilitation cost.

3.1.2 Option 2

Option 2 includes the thorough inspection of Penstocks 2 & 3 longitudinal and circumferential welds and refurbishment of all deteriorated welds. Hatch considered the length of all welds in the penstocks and subtracted the length of repaired longitudinal

welds from the total length. They then considered a 50 percent refurbishment rate of the remaining longitudinal welds. Circumferential welds were considered to have an increase in refurbishment cost compared to the longitudinal welds. Kleinschmidt's assessment considered 50% of all longitudinal and circumferential welds to establish the weld quantity.

The interior of the penstocks are assumed to be recoated for corrosion prevention. Highlights of Hatch's refurbishment costing assumptions are as follows:

1. The assumption is that another 40 years' service life is possible with the implementation of weld refurbishment and recoating life extension measures.
2. Hatch did not consider inflation in the cost estimates but did consider a staged or scheduled approach to the repairs requiring multiple outages.
3. All weld seams are assumed to be inspected, and repairs carried out for all deteriorated welds. For costing purposes, a 50% refurbishment rate was considered for all remaining non refurbished longitudinal and circumferential weld seams.
4. It was assumed that abrasive blasting will be used to resurface the interior of the entire length of penstock before a three-coat paint system was applied.
5. The unit rates for welding were based on previous emergency weld repairs completed at the site.

3.1.3 Option 3

The refurbishment recommendation for Option 3 includes replacement of the 17-foot diameter section of penstock with an interior corrosion prevention coating and refurbishment of the deteriorated welds in the remaining sections of penstock. Weld refurbishment and coating assumptions for the remaining section of penstock are consistent with Option 2.

1. Hatch identified construction risks such as shipping and constructability of a large diameter penstock to a remote site, which may increase project costs.
2. It was assumed that the penstock bedding and drainage improvements would be required to ensure adequate drainage around the new penstock section.
3. Refurbishment of the welds and recoating of the remaining penstock sections will be performed as identified in Option 2.

3.1.4 Option 4

In Option 4, refurbishment of the welds and interior coating will follow the same procedure as outlined for Option 2. However, the longitudinal and circumferential weld seams will be reinforced with plates like the repairs completed in 2017. See Option 2 for assumptions regarding weld refurbishment and recoating.

1. Plates will be installed over the repaired weld seams to provide protection and stiffening. The estimate assumes the plates will be cut and rolled to the same radius as the penstock, fitted and welded using fillet welds.
2. Fillet weld inspections are performed using Magnetic Particle Testing and Visual Testing.
3. For the fillet welds Hatch assumed that half the fillet welds were out of position welds while half of the welds were considered "normal". Out of position welds were considered to cost four times that of normal welds.

3.2 Hatch Cost Opinion - 2020

Opinions of costs were presented for the three refurbishment options. Hatch developed AACE Class 4 cost estimates for each option utilizing costing information and pricing provided by local companies involved in recent emergency repairs. Additional budgetary estimates were provided to Hatch by local fabricators and painting contractors, and these were utilized in the cost estimate assumptions for each option.

3.3 Kleinschmidt Cost Opinion - 2021

Kleinschmidt developed an independent AACE Class 4 Cost Opinion for the three rehabilitation options as requested for the purpose of providing a comparison and update on the previously developed Hatch estimate. The Kleinschmidt cost opinion was developed based on AACE Recommended Practice (RP) 69R-12: Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Hydropower Industry, a Class 4 Cost Estimate is appropriate when:

- The maturity level of project definition deliverables (expressed as a percentage of complete definition) is in the 1% to 15% range.
- The intended End Usage (purpose) of the Cost Estimate is for project study or feasibility.

The expected accuracy range of a Class 4 Cost opinion is:

- Low: -15% to -30%
- High: +20% to +50%

The state of technology, availability of applicable reference cost data, and other risks affect the expected accuracy range. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of P50 contingency for a given scope.

A summary of the Hatch and Kleinschmidt Cost Opinions are presented below in Table 3.1 and 3.2 for Penstock 2, and Table 3-3 and 3-4 for Penstock 3 for comparison discussions.

Table 3-1 Hatch Cost Estimate for Option 2, 3 and 4 (March 2020)

Penstock 2	Option 2	Option 3	Option 4
Total Direct	**$19,890,000**	**$34,860,000**	**$26,250,000**
EPCM (12% of Direct)	$2,390,000	$4,180,000	$3,150,000
Temporary Site Facilities and Services (3% of Direct)	$600,000	$1,050,000	$790,000
Owner's Cost (5% of Direct)	$990,000	$1,740,000	$1,310,000
Total Indirect Cost	**$3,980,000**	**$6,970,000**	**$5,250,000**
Owner's Contingency (% of Direct + Indirect)	$3,580,000	$10,460,000	$4,730,000
Total Cost	**$27,450,000**	**$52,290,000**	**$36,230,000**

Table 3-2 Kleinschmidt Cost Estimate Summary for Option 2, 3 and 4

Penstock 2	Option 2	Option 3	Option 4
Total Contractor Direct & Indirect	$19,798,000	$36,195,000	$25,463,000
Contractor's Profit and Contingency (12% each)	$4,752,000	$8,686,000	$6,112,000
Opinion of Contractors Probable Price	$24,550,000	$44,881,000	$31,575,000
Owner's Cost (Engineering, Site Management, Project Management and Tendering)	$1,289,700	$1,636,600	$1,482,200
Owner Contingency (15% of direct + indirect)	$3,876,000	$6,978,000	$4,959,000
Total Recommended Budget	**$29,715,700**	**$53,495,600**	**$38,016,200**

Table 3-3 Hatch Cost Estimate for Option 2, 3 and 4 (March 2020)

Penstock 3	Option 2	Option 3	Option 4
Total Direct	**$18,740,000**	**$31,390,000**	**$25,140,000**
EPCM (12% of Direct)	$2,250,000	$3,770,000	$3,020,000
Temporary Site Facilities and Services (3% of Direct)	$560,000	$940,000	$750,000
Owner's Cost (5% of Direct)	$940,000	$1,570,000	$1,260,000
Total Indirect Cost	**$3,750,000**	**$6,280,000**	**$5,030,000**
Owner's Contingency (% of Direct + Indirect)	$3,370,000	$9,420,000	$4,530,000
Total Cost	**$25,860,000**	**$47,090,000**	**$34,700,000**

Table 3-4 Kleinschmidt Cost Estimate Summary for Option 2, 3 and 4

Penstock 3	Option 2	Option 3	Option 4
Total Contractor Direct & Indirect	$18,770,000	$35,990,000	$24,597,000
Contractor's Profit and Contingency (12% each)	$4,504,000	$8,638,000	$5,904,000
Opinion of Contractors Probable Price	$23,274,000	$44,628,000	$30,501,000
Owner's Cost (Engineering, Site Management, Project Management and Tendering)	$1,289,700	$1,636,600	$1,482,200
Owner Contingency (15% of direct + indirect)	$3,685,000	$6,940,000	$4,797,000
Total Recommended Budget	**$28,248,700**	**$53,204,600**	**$36,780,200**

The primary observation when comparing the two cost opinions is that the expected accuracy ranges (-15% to +20%) of the two sets of estimates overlap. While the Hatch and Kleinschmidt cost opinions differ, the range of accuracy of the two Class 4 Cost Opinions overlap suggesting a correlation between the two estimates that verifies that the two cost opinions support each other as being reasonable representations of the expected price to complete the work given the current project definition. The primary differences between the two cost opinions are examined below:

1. The mobilization/demobilization values used by Kleinschmidt were determined as 5% of the direct costs associated with each option, while Hatch used 10% plus a fee for a crane and contractor Live Out Allowance (LOA). As, a result Hatch's mobilization/demobilization cost is higher.
2. The longitudinal weld refurbishment costs estimated by Kleinschmidt are lower than the values provided by Hatch. Hatch used pricing information from local

contractors and the deposition rate costs per meter for emergency repairs previously completed at the BDE site to develop a direct unit price per foot for the welds. Kleinschmidt utilized a weight of weld per foot estimation based upon information provided by Skarborn Engineering given the penstock thickness and condition and assuming the use of the Flux-cored arc welding process to complete the welds. NL Hydro expressed concern that the use of pricing from previous emergency repairs may build in an inherent error due to the nature of pricing for the emergency repairs. Kleinschmidt built up welding unit rates based on expert opinion and estimations for the rate (lb/hr) of weld deposition provided by Skarborn Engineering. Labour rates applied to the unit pricing utilized the information presented in previous Hydro solicitations from a local contractor (Cahill). Using this information, a deposit rate and unit cost per pound were determined.

3. Kleinschmidt assumed that 50% of welds would require refurbishment. Based on the expert advice of Skarborn Engineering, it is assumed that 70% of welds that require repair will require full penetration welds. Skarborn' recommendation was that these full penetration welds would require access from both inside and outside the penstock shell. Kleinschmidt's cost opinion takes the excavation cost for this additional expected penstock shell exposure on the outside into consideration. The actual quantity of welds that will require refurbishment cannot be determined until adequate inspection is performed immediately prior to the start of rehabilitation. This unknown represents both a schedule and cost risk that cannot be quantified at this time. NL Hydro may consider holding an additional specific Owner Contingency to account for this uncertainty.
4. Hatch's surface preparation and coating estimate was lower than Kleinschmidt's estimate. Hatch utilized a $20 per square foot cost based on an estimate provided by local contractors for a 3-coat paint system by Wasser. Kleinschmidt utilized a $51.60 per square foot cost based upon previous projects that Kleinschmidt has been involved. This unit cost includes surface preparation, coating (specifically with a MC-Zinc primer – one coat; MC-Tar moisture cure urethane - two coats)., and cleanup of the existing penstock. It is not clear that the Hatch unit rate included surface preparation and cleanup.
5. Kleinschmidt's new penstock supply cost for Option 3 includes the cost of coating which was not included in Hatch's estimate. Hatch utilized a quote for steel plate based upon a thickness of 0.625-inch. Kleinschmidt has also used a thickness of 0.625-inch, this increase of penstock thickness will provide higher damage resistance during transportation as well as longevity during operation.

6. Hatch's cost estimate for Option 4 included the use of pre-bent, 2-foot-wide steel plates to reinforce the refurbished welds. Kleinschmidt in collaboration with Skarborn Engineering, determined that the need to bridge the new weld repair and heat affected zone did not necessitate such a large pre-formed steel plate. Kleinschmidt's cost opinion therefore includes a 6-inch-wide steel plate which does not require pre-bending to be installed. This resulted in reduced costs for the reinforcing steel plates in comparison to the Hatch estimate.
7. Hatch utilized an owner contingency of 25% for Option 3. Kleinschmidt maintained the same 15% owner's contingency for all options.

During the Risk workshops, a risk of limited availability of accommodations during the construction season and the possibility that a construction camp may be required was discussed. Should this risk be realized, it will apply an equal cost to all options that are being assessed and will not impact the selection of a preferred alternative. The current Kleinschmidt Cost Opinion does not include this potential cost.

Note regarding current COVID 19 related material price volatility.

Due to high volatility in material pricing within the current market conditions in the large-scale construction industry, contractor bids may be at a premium due to the high demand and low contractor availability. This premium and any additional markups that the bidding contractors may apply to their submittal has not been considered in the opinion of cost. The opinion of cost provided is assumed to be in a market with adequate contractor supply and standard profit margins as seen in historic large scale hydroelectric construction projects. Material and commodity pricing for items such as steel, concrete and timber are currently experiencing large price spikes due to supply and demand effects in the current market conditions. These large fluctuations are difficult to predict and for this reason, Kleinschmidt has applied pricing that is consistent with regular historic market conditions and trends.

The results of the opinion of construction cost for Penstocks 2 & 3 reflect that of Penstock 1 with slight variations as expected. These variations are a result of differences in quantities and access between the three penstocks. The direct unit rates were kept consistent for all three penstocks. Penstock 2 is located between Penstock 1 and Penstock 3, resulting in more challenging access and construction which was accounted for by utilizing a higher indirect/direct ratio (0.38 for Penstocks 1 & 3, 0.40 for Penstock 2). Another reason for the difference in opinion of construction cost is due to the varying lengths of each penstock diameter. For example, Penstock 3 has a shorter 15'-3" diameter section but slightly longer 17' and 13.5' diameter sections. This results in different quantities between the three penstocks and in turn, different final costs.

4.0 PROJECT EXECUTION

Option 1 is excluded from the project execution section as life extension measures of the penstock will not be implemented for this option. For Option 1, general penstock maintenance will continue over a 30-year period and weld repairs will be completed only if a weld failure occurs or if a weld defect is identified during yearly dewatered inspections.

4.1 Option 2 – Weld Refurbishment

The construction risks are lower for Option 2 compared to Option 3 and 4. The inspections, cleaning, coating and much of the weld refurbishments will be completed inside the penstock; therefore, adverse weather conditions and other external site works will present reduced schedule risk on the work inside the penstock. Full penetration welds, estimated to be 70% of all the weld repairs, will require excavation and exterior welding and will carry a risk of schedule impact from adverse weather conditions. NL Hydro opted not to man a 24-hour shift schedule during previous repairs; therefore, Kleinschmidt assumes that a maximum of two shifts a day will be possible for completion of the weld inspections and repairs.

Penstocks 2 and 3 turbine unit outages are limited to low demand and low flow periods; therefore, the construction schedule will preferably be limited to the period between May and November.

Kleinschmidt assumes that restrictions will be in place for site access and restricted areas will be well delineated at the start of the project. It is understood, following the Risk Assessment Workshop, that there is limited availability for worker accommodations in Bay d'Espoir and that a temporary construction camp may be required close to the hydro site. Such a camp would reduce crew travel time to the site and potentially increase project efficiency. Neither the current Cost Opinion or Schedule include the set up and operation of a temporary construction camp.

Site specific safety procedures shall be adhered to, and job hazard assessments (JHA) carried out daily or if change occurs on site/shift change.

Execution considerations are discussed below.

1. *Site Access:* Restricted site areas will be clearly demarcated for the contractor. The signage will reduce the risk of damage to other infrastructure such as crossing over operational penstocks.
2. *Equipment:* Laydown areas for equipment and materials such as generator set up, equipment, and consumables for grinding and welding will be determined preconstruction. Spill kits will be available for on site for refueling.
3. *Penstock Access:* We assume temporary access holes will be cut through the side of the existing penstock shell. These larger access holes will greatly improve workflow and material handling. The access holes will be repaired upon completion of the weld inspections and repairs. Excavation of the soil cover will be required in the area where the new access points are to be located.
4. *Scaffolding*: Scaffolding will be required to access welds at the upper half of the penstock for inspection and repair. Scaffolding will also be required to support the interior cleaning, coating preparation and coating application.
5. *Base Metal:* Inspections of the base metal should be completed before construction and after cleaning. Ultrasonic thickness testing of the steel will need to be performed to confirm remaining plate thickness is adequate to resist loads.
6. *Weld Inspection*: Inspections and weld refurbishment schedules/shifts can be staggered, and inspections can progress ahead of the welders. It is uncertain as to how many welds will require repairs; however, it was assumed for this study that 50 percent of the longitudinal welds, and 50 percent of the circumferential welds will require refurbishment. The actual quantity of welds that will require refurbishment cannot be determined until adequate inspection is performed immediately prior to the start of rehabilitation. This unknown represents both a schedule and cost risk that cannot be quantified at this time.
7. *Weld Repair:* Grinding/gouging of the identified weld defects will be completed. A gap for full penetration weld repairs is assumed to be 10 mm, and additional welding will be required if the gap exceeds 10 mm. The repairs may be completed on longitudinal or circumferential welds (automatic or semi-automatic welding procedures should be considered).
8. *Weld Repair and Coating Inspections:* Qualified third-party weld inspectors (CSA W178.2) will perform non-destructive testing (NDT) and provide quality assurance/quality control (QA/QC) (magnetic particle testing). A qualified NACE inspector will complete inspection of the paint coating thickness and adhesion.
9. *Interior Penstock Surface Preparation:* For efficiency, the crews preparing the interior surface for coating can proceed after the weld defects have been ground off and the welds have been refurbished. Weld inspections must be completed

before the interior surface is prepped. The surface preparation will conform with the requirements of the coating system selected during design.

10. *Recoating Interior of Penstock:* Recoating of interior penstock surface will be completed with an approved coating following a rigorous product and application review. The new coating will be tested to adhere to the penstock surface and selected based on performance with application during humid conditions. Automation or unmanned paint coating applications may be considered for efficiency. A NACE coating inspector will be required to perform adhesion tests and dry film thickness measurements.
11. *Excavation for Full Penetration Welds*: Where a full penetration weld is required, access to complete the weld is required from the outside of the penstock. Excavation will proceed at the exterior of the penstock to expose the area to be welded. The excavation locations will not be known until after the weld tests are complete. The excavated area will be reinstated and compacted to the existing soil density or better.
12. *Contractor Weld Plan/Procedure:* Contractor will be responsible for welding procedure and weld distortion mitigation plan. Weld material will be the responsibility of the contractor.

4.2 Option 3 – Section Replacement and Weld Refurbishment

The scope of work in Option 3 includes the same scope discussed in Option 2 for all areas of the penstock except for the 17-foot diameter section which is replaced with a new 17-foot diameter penstock. Here, the additional scope and differing considerations for Option 3 are discussed. A design to replace the 17-foot diameter section of Penstock 2 & 3 will be completed in advance of the construction to allow for material procurement and construction tendering processes. Execution and procurement discussion items are presented below.

1. *Fabrication/Shipping:* Fabricated penstock "cans" manufactured off site, should be third party inspected at the fabrication shop to confirm compliance with current standards. (Local fabricators should be considered to reduce shipping costs and duration). Due to flatbed size limitations by the Newfoundland Department of Transportation, an escort may be required to ship the large diameter penstock sections. The new penstock will be coated in the shop except exposed metal areas at locations of field welding.
2. *Site Crane*: Crane pads will need to be constructed adjacent to the upper section of Penstock 1 & 3. A crane with a longer lift radius will be required for Penstock 2 as it is in between Penstocks 1 and 3, making access more challenging. Where

possible the crane will utilize the access road along the penstock length, the crane will be mobilized to the site and access routes should be well delineated before construction commences. Hoisting and rigging shall be preplanned and completed by a certified crew.

3. *Laydown Area:* A suitable lay down area will need to be identified for storage of the new fabricated sections of penstock, other materials, and heavy equipment.
4. *Demo of Existing Penstock:* The area around the penstocks will be excavated to expose the existing penstock for removal. Slopes shall be maintained at 2H:1V. The existing 17-foot diameter penstock cans will be demolished and removed. It will be the contractor's responsibility to remove the old sections of penstock from the site.
5. *Bedding Material:* The bedding material will be disturbed during removal of the penstock. Removal and replacement of much of the bedding material is expected to achieve required specifications for bedding and drainage.
6. *Environmental:* Environmental measures for erosion control will be required and monitored throughout the project.
7. *New Penstock Installation:* The penstock will be installed on the newly rehabilitated bedding material. Field welds should be reduced if possible and/or semiautomatic welding processes should be utilized for efficiency. Existing penstock out of roundness issues will need to be confirmed for fit up (dimensions confirmed). Spiders can be used to keep penstock shape for alignment purposes during welding procedures. Welding is assumed as full penetration butt welds with a backing bar. A steel thimble section may be required depending upon the condition of the existing penstock and degree of out of roundness at each end of the new penstock installation. Soil will be compacted around the new section of penstock to standard compaction design limits. Compaction around the haunches and spring line will require hand compaction equipment.
8. *Pressure testing*: Pressure testing of the new penstock section will take place prior to burial.
9. *Site Restoration*: All excavated areas will be restored and reseeded as required.

4.3 Option 4 – Weld Reinforcement

Option 4 includes the same construction procedures as Option 2 (See Option 2 for construction sequence). The welds will be further reinforced by welding flat bar over the newly refurbished welds to provide protection and reduce weld peaking. Here, the additional scope and differing considerations for Option 4 are discussed.

1. *Steel bar fabrication:* Steel bar will be procured in standard lengths and cut to suit on site. Steel bar shall be ordered well in advance of proposed construction.
2. *Working/Laydown Area:* Proper working area for cutting bar (if required) will need to be established adjacent to the existing penstock.
3. *Installation of Flat Bar:* A work method will be developed by the contractor to safely lift bar sections into place at the weld locations to be reinforced. The procedure will be implemented to reduce the potential for dropping the bar sections and causing a potential injury.
4. *Fillet Welds Steel Flat Bar:* Fillet welds will be used around the flat bar for attachment over the refurbished welds. Fillet welds will be inspected by a third-party welding inspector. A distortion/warping plan shall be developed by the contractor and submitted to the owner.

5.0 CONSTRUCTION SCHEDULE

General construction schedules were developed using the project execution details for the three different refurbishment options in Section 4.0. Each schedule was created using a May to November timeframe (approximately seven months) for comparison purposes. We assumed that there is no delay in mobilization of equipment and that all materials are delivered to site at the project start. Specific tasks can be completed concurrently with proper staging to increase schedule efficiency. See Figures 5.1, 5.2 and 5.3 below for project Gantt charts of the three alternatives.

The presented schedules are based on a 5-day X 10-hour shift work week. Completion of the work will be facilitated by predesigned and pre-manufactured adjustable access scaffolding, intended to support the optimal position of welders and weld inspectors over the length of the penstock. One scaffold assembly will be provided for each of the 10 expected welding crews. Multiple crews will also be utilized to perform the inspections in a timely duration.

Welding activities will utilize two 10 hour shifts per day to meet the outage schedule constraints and allow time for the coating to be applied. The time to complete the weld repairs was calculated by using the total estimated weight of the weld material for each option and using a deposition rate per hour. Based on expert input from Skarborn Engineering, Flux-cored arc welding is expected to be the welding process utilized by the contractors providing competitive bids. Based on the information at hand, with a weld material deposition rate of approximately 8 lbs/hr and a 20% Operation Factor, we expect a crew of 10 welders per shift will be necessary to achieve this schedule. Accommodating 10 welders will require 10 specialized adjustable scaffold systems and adequate access and ventilation necessary to support spacing the welders over the length of the penstock.

Surface preparation and cleanup will be separated from the application of the interior coating by approximately 3 weeks to allow the dirty work to advance and the clean work to not be impacted by ongoing preparation and clean-up work. It may prove necessary to also separate the coating application from the other activities by utilizing a night shift for the surface preparation and cleanup work.

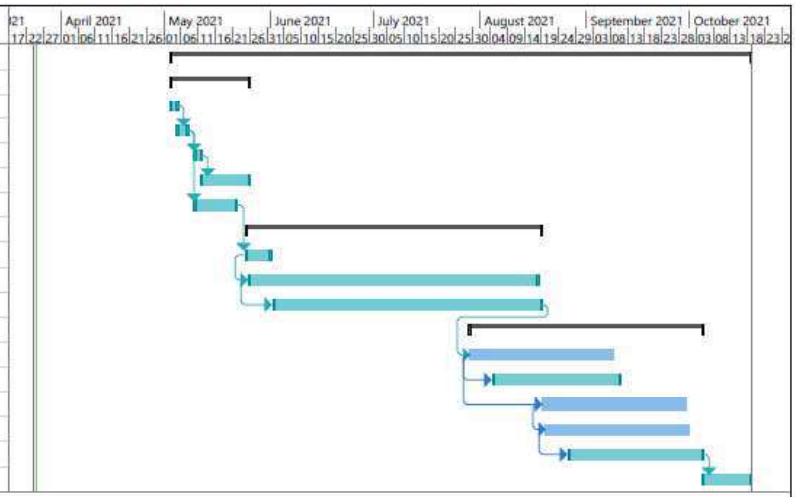
Based on this assessment It is expected that each refurbishment option can be completed in a single construction season.

The duration for constructing the 17-foot diameter penstock sections, approximately 1245 feet (379.5 meters) in length for Penstock 2 and 1294 feet (394.4 meters) for Penstock 3, was developed based on experience gained on previous installations of similar size penstocks.

A review of the schedules indicates that each of the three rehabilitation options investigated can be completed in a May to November construction timeframe. The schedules assume the availability of 20 welding crews (2 shifts, 10 crews per shift); a welding crew defined as one welder and the required support workers to maintain that welder on a full-time welding pace, to be able to meet these schedule constraints. These schedules assume that only 50% of the existing welds will require rehabilitation. Until a thorough inspection of all welds is completed, it is uncertain if this assumption is accurate or not. The identification of a significantly higher percentage of welds that require rehabilitation would result in an increased outage duration to complete the work. Hydro may wish to consider planning on two seasons of outages to mitigate the risk that the outage would carry beyond the May to November timeframe. Such planning would necessitate additional weld inspections, mobilization and other indirect construction costs that would naturally increase the overall project cost beyond that of the increased direct unit cost for the weld quantities.

Availability and delivery of the new penstock sections for Option 3 will require adequate pre-engineering and long lead procurement to ensure delivery to site when needed.

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Option 2 Weld Refurbishment and Recoating**	**121 days**	**Mon 5/03/21**	**Mon 10/18/21**	
2		**Mobilization**	**17 days**	**Mon 5/03/21**	**Tue 5/25/21**	
3		Deliveries to Site	2 days	Mon 5/03/21	Tue 5/04/21	
4		Site Trailers	3 days	Wed 5/05/21	Fri 5/07/21	3
5		Penstock Access	2 days	Mon 5/10/21	Tue 5/11/21	4
6		Air Quality Equipment Installation	10 days	Wed 5/12/21	Tue 5/25/21	5
7		Construct/Install Scaffolding/Staging	10 days	Mon 5/10/21	Fri 5/21/21	4
8		**Weld Repairs**	**62 days**	**Tue 5/25/21**	**Wed 8/18/21**	
9		Existing Weld Inspection (all penstock sections)	5 days	Tue 5/25/21	Mon 5/31/21	7FS+1 day
10		Weld Repairs (two shifts)	60 days	Wed 5/26/21	Tue 8/17/21	9SS+1 day
11		Welding QC (Qualified Weld Inspector)	56 days	Wed 6/02/21	Wed 8/18/21	10SS+5 days
12		**Interior Coating**	**48 days**	**Thu 7/29/21**	**Mon 10/04/21**	
13		Interior Surface Preparation	30 days	Thu 7/29/21	Wed 9/08/21	11FS-15 days
14		Cleanup	27 days	Thu 8/05/21	Fri 9/10/21	13SS+5 days
15		Apply Coating	30 days	Thu 8/19/21	Wed 9/29/21	13SS+15 days
16		Coating Inspection by Qualified NACE Inspector	30 days	Fri 8/20/21	Thu 9/30/21	15SS+1 day
17		Touchup and Repairs	27 days	Fri 8/27/21	Mon 10/04/21	16SS+5 days
18		Site Restoration/Demobilization	10 days	Tue 10/05/21	Mon 10/18/21	17

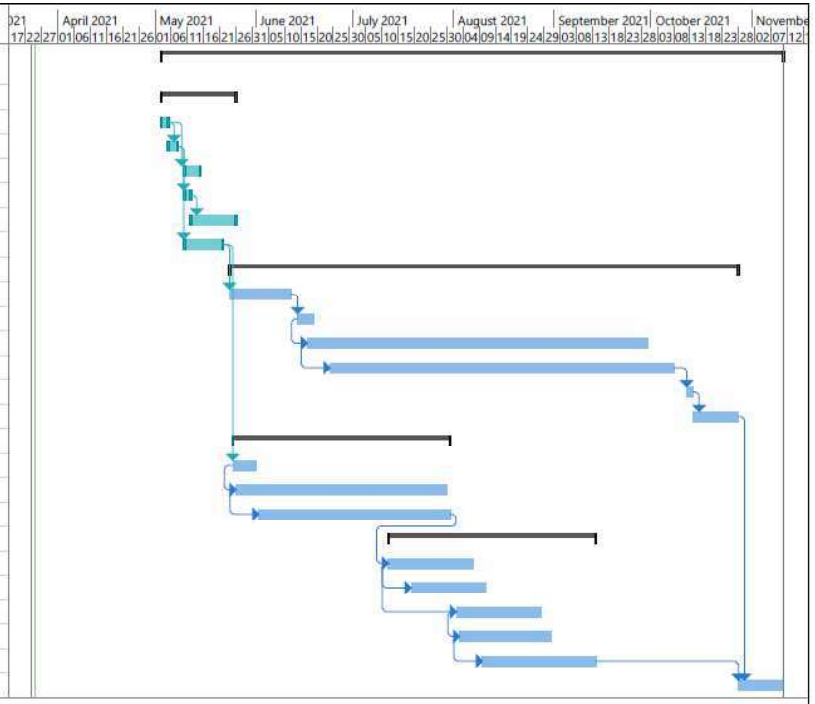


Project: Option 2
Date: Thu 3/25/21

Task | Split | Milestone | Summary
Project Summary | Inactive Task | Inactive Milestone | Inactive Summary
Manual Task | Duration-only | Manual Summary Rollup | Manual Summary
Start-only | Finish-only | External Tasks | External Milestone
Deadline | Progress | Manual Progress

Figure 5.1 Option 2 Weld Refurbishment and Recoating

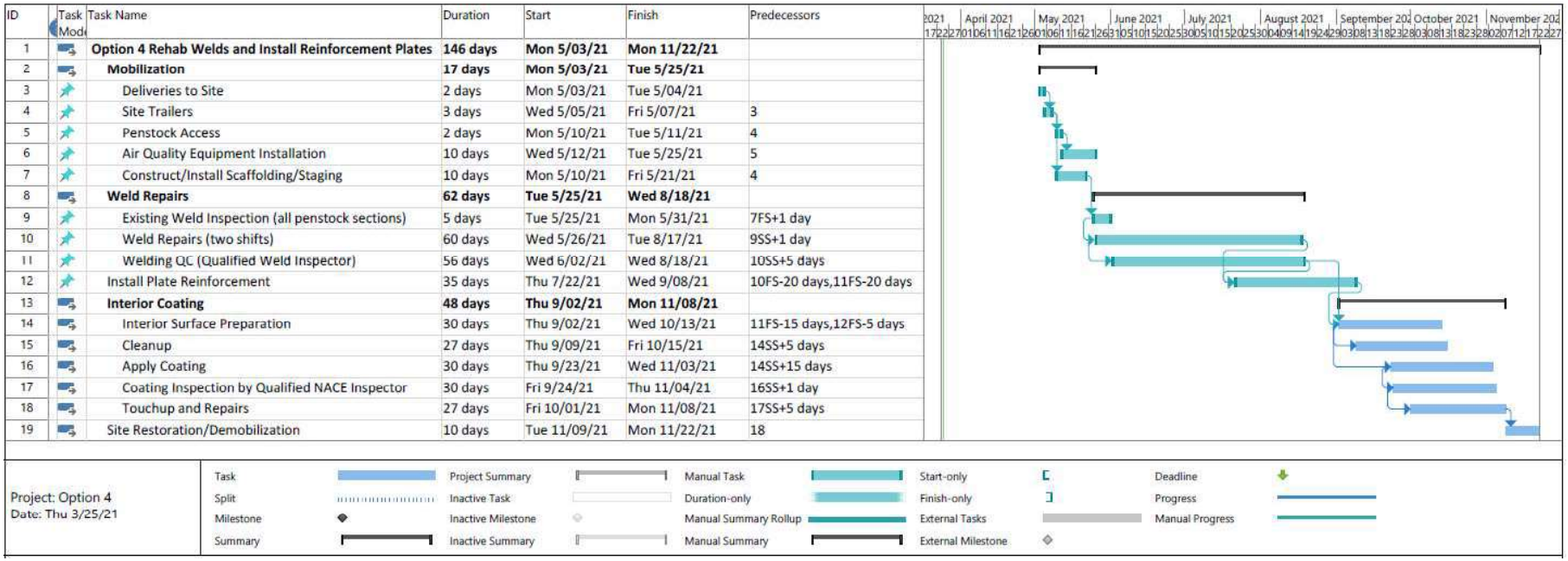
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Option 3 Replacement 17 ft Diameter Penstock & Weld Refurbishment**	**138 days**	**Mon 5/03/21**	**Wed 11/10/21**	
2		**Mobilization**	**17 days**	**Mon 5/03/21**	**Tue 5/25/21**	
3		Deliveries to Site	2 days	Mon 5/03/21	Tue 5/04/21	
4		Site Trailers	3 days	Wed 5/05/21	Fri 5/07/21	3
5		Crane Mobilization	5 days	Mon 5/10/21	Fri 5/14/21	3
6		Penstock Access	2 days	Mon 5/10/21	Tue 5/11/21	4
7		Air Quality Equipment Installation	10 days	Wed 5/12/21	Tue 5/25/21	6
8		Construct/Install Scaffolding/Staging	10 days	Mon 5/10/21	Fri 5/21/21	4
9		**Install New 17 ft Diameter Section of Penstock**	**113 days**	**Mon 5/24/21**	**Wed 10/27/21**	
10		Excavation, Demo and Removal of Existing Penstock	15 days	Mon 5/24/21	Fri 6/11/21	8
11		Repair Bedding Material	5 days	Mon 6/14/21	Fri 6/18/21	10
12		Install New Sections of Penstock (two crews)	75 days	Thu 6/17/21	Wed 9/29/21	11SS+3 days
13		Weld Inspections	76 days	Thu 6/24/21	Thu 10/07/21	12SS+5 days
14		Pressure Test New Penstock	2 days	Tue 10/12/21	Wed 10/13/21	13FS+2 days
15		Compact Soil Around New Penstock	10 days	Thu 10/14/21	Wed 10/27/21	14
16		**Weld Repairs**	**49 days**	**Tue 5/25/21**	**Fri 7/30/21**	
17		Existing Weld Inspection (all penstock sections)	5 days	Tue 5/25/21	Mon 5/31/21	8FS+1 day
18		Weld Repairs (two crews)	47 days	Wed 5/26/21	Thu 7/29/21	17SS+1 day
19		Welding QC (Qualified Weld Inspector)	43 days	Wed 6/02/21	Fri 7/30/21	18SS+5 days
20		**Interior Coating**	**46 days**	**Mon 7/12/21**	**Mon 9/13/21**	
21		Interior Surface Preparation	20 days	Mon 7/12/21	Fri 8/06/21	19FS-15 days
22		Cleanup	17 days	Mon 7/19/21	Tue 8/10/21	21SS+5 days
23		Apply Coating	20 days	Mon 8/02/21	Fri 8/27/21	21SS+15 days
24		Coating Inspection by Qualified NACE Inspector	20 days	Tue 8/03/21	Mon 8/30/21	23SS+1 day
25		Touchup and Repairs	25 days	Tue 8/10/21	Mon 9/13/21	24SS+5 days
26		Site Restoration/Demobilization	10 days	Thu 10/28/21	Wed 11/10/21	25,15



Project: Option 3
Date: Thu 3/25/21

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Figure 5.2 Option 3 Replacement 17-foot Diameter Penstock and Weld Refurbishment



ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Option 4 Rehab Welds and Install Reinforcement Plates**	**146 days**	**Mon 5/03/21**	**Mon 11/22/21**	
2		**Mobilization**	**17 days**	**Mon 5/03/21**	**Tue 5/25/21**	
3		Deliveries to Site	2 days	Mon 5/03/21	Tue 5/04/21	
4		Site Trailers	3 days	Wed 5/05/21	Fri 5/07/21	3
5		Penstock Access	2 days	Mon 5/10/21	Tue 5/11/21	4
6		Air Quality Equipment Installation	10 days	Wed 5/12/21	Tue 5/25/21	5
7		Construct/Install Scaffolding/Staging	10 days	Mon 5/10/21	Fri 5/21/21	4
8		**Weld Repairs**	**62 days**	**Tue 5/25/21**	**Wed 8/18/21**	
9		Existing Weld Inspection (all penstock sections)	5 days	Tue 5/25/21	Mon 5/31/21	7FS+1 day
10		Weld Repairs (two shifts)	60 days	Wed 5/26/21	Tue 8/17/21	9SS+1 day
11		Welding QC (Qualified Weld Inspector)	56 days	Wed 6/02/21	Wed 8/18/21	10SS+5 days
12		Install Plate Reinforcement	35 days	Thu 7/22/21	Wed 9/08/21	10FS-20 days,11FS-20 days
13		**Interior Coating**	**48 days**	**Thu 9/02/21**	**Mon 11/08/21**	
14		Interior Surface Preparation	30 days	Thu 9/02/21	Wed 10/13/21	11FS-15 days,12FS-5 days
15		Cleanup	27 days	Thu 9/09/21	Fri 10/15/21	14SS+5 days
16		Apply Coating	30 days	Thu 9/23/21	Wed 11/03/21	14SS+15 days
17		Coating Inspection by Qualified NACE Inspector	30 days	Fri 9/24/21	Thu 11/04/21	16SS+1 day
18		Touchup and Repairs	27 days	Fri 10/01/21	Mon 11/08/21	17SS+5 days
19		Site Restoration/Demobilization	10 days	Tue 11/09/21	Mon 11/22/21	18

Figure 5.3 Option 4 Rehab Welds and Install Reinforcement Plates

6.0 RISK AND RELIABILITY

The risk assessment in this phase of the study is intended to highlight and evaluate the consequential risks associated with each alternative. The highlighted risks were used to compare the options. A risk assessment workshop was conducted to identify and evaluate risks associated with the various aspects of the life extension options. A risk report was created to present the methodology, analysis, and findings of the risk assessment and is attached as Appendix B. The risk report is summarized here in context of comparing the options.

6.1 Risk Assessment Methodology Summary

The risk assessment workshop, the most important step in the risk assessment process, was conducted with a multi-disciplinary team comprised of various relevant technical backgrounds. The workshop team included engineering consultants with specialties in penstocks, welding, construction, and hydropower, and NL Hydro representatives from engineering, operations, and management. The risk workshop team worked together to identify and describe risks and then determine consequences and likelihood of occurrence to ultimately develop a risk rating for each risk item. Identified risks were recorded in a risk registry (Appendix B) with impact severity and probability of occurrence documented.

The risk assessment methodology is discussed in detail in the Risk Report in Appendix B. A 4 by 4 matrix was utilized to develop a rating for each risk item. The risk matrix is illustrated Figure 6.1. The matrix value is matched to the likelihood description and the numerical ranges for the impacts in Table 6.1

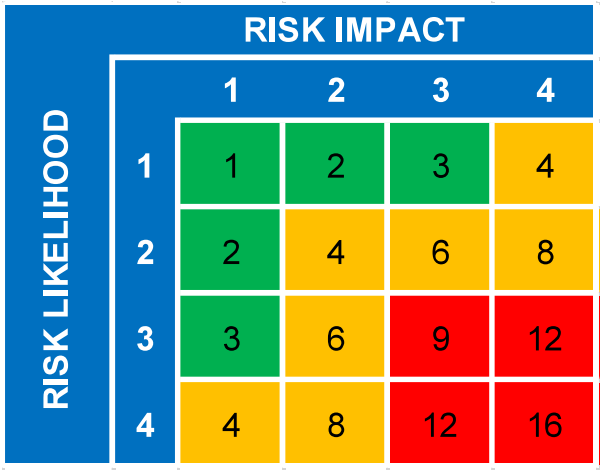


Figure 6.1 Risk Assessment Matrix

Table 6-1 Matrix Value Interpretation

Matrix Value	Likelihood	Cost Impact	Schedule Impact	Other Impact
1	Very Unlikely	$0 to $100K	0 Weeks to 2 weeks	Little
2	Somewhat Unlikely	$100K to $500K	2 Weeks to 1 Month	Some
3	Somewhat Likely	$500K to $5M	1 Month to 4 Months	Significant
4	Highly Likely	$5M +	4+ Months	Ruinous

The risk rating values obtained from the risk matrix are grouped into three categories.

- Low risks have a value between 1 and 3,
- Moderate risks have values between 4 and 8,
- High risks are values between 9 and 16.

If the risk rating is Low, no risk mitigating action is needed. Moderate risks will be managed using appropriate risk response and mitigating actions. Risks rated as High require risk mitigation to reduce the rating to an acceptable risk rating of 8 or lower. It is imperative that high risk items are mitigated down to an acceptable risk rating.

6.2 Summary of Risks

The following summarizes the risk identification and evaluation for Penstock 2 and 3. This section concentrates on the consequential risks and mitigation requirements. For a more detailed review see the Risk Assessment Report for Penstock 2 and 3.

Option 1 – No Refurbishment

If Penstock 2 and 3 are not refurbished there remains an inherent risk of failure, especially in the upper 17-foot diameter section. Past inspections revealed that there was corrosion and weld cracks requiring repairs to be completed; however, no failures of Penstock 2 or 3 occurred. There is a higher probability of failure due to weld peaking, pitting corrosion in the heat affected zone, high penstock diameter to thickness ratio, brittle failure (steel not meeting Charpy requirements), and overall general corrosion.

The general risk types associated with Option 1 include:

- Penstock failure (multiple failure modes are possible and are discussed)
- Operational risks
- Societal or environmental risks
- Safety risks
- Financial risks

The risk assessment team identified twenty-three risk items for Option 1, with one having the highest possible risk rating of 16 (risk item 1-09), and another having the second highest risk rating of 12 (risk item 1-01). These two items are the risk of minor failures and the risk of excessive corrosion requiring full interior coating, items 1-01 and 1-09 respectively in the Risk Registry. Risk item 1-01 has a high probability of occurrence and a likely cost between $500K and $5M. Risk item 1-09 has a high probability of occurrence and high costs exceeding $5M.

Table 6-2 Penstock 2 and 3 Risk Rating - Corrosion

ID	Risk Title	Risk Description	Risk Rating
1-01	***Minor Failure*** Rupture at weld upstream of Surge Tank	Localized failure in 17ft dia. section creating a minor leak which causes a temporary outage. There is no damage to the surrounding infrastructure. Only one can is affected.	12
1-09	General Corrosion	Base metal corrosion (Not in heat affected zone). Penstock interior corrodes to the point that a coating system is required to prevent unacceptable material loss.	16

Minor failures were defined as a localized failure at a weld in the 17-foot diameter section of the penstock causing a temporary outage, but no significant damage to the surrounding infrastructure (Figure 1.1 and Figure 1.2, Section 1.0). For the risk assessment it was assumed that one penstock "can" length is affected with a small leak or breach. A "can" in this report is defined as a section of penstock from one circumferential weld to the next circumferential weld and averages about 9 feet long. Based on recent performance it was assumed that over a 30-year period more than one minor failure could occur. For impact estimation it was estimated that a failure could occur once every two years. The potential for multiple failures over the next 30 years drove the cost and operational impacts higher as well as societal risks such as negative public perception at the local and provincial level.

Corrosion was also identified as a significant issue. Corrosion and pitting will continue without a coating for the interior of the penstock which creates high likelihood that the corrosion will continue over the next 30 years to the point that a coating system is going to be required to prevent unacceptable material loss, or corrodes to the point of failure in the base metal or heat affected zone.

Other general risks identified for Option 1 include:

- Larger (medium and major) failures at various locations that cause increasing levels of damage but have less probability of occurrence based on past performance and method of failure,
- Failures under the switchyard that can go undetected until the soil erosion expends to the point the switchyard settles or collapses into a void.
- Operational constraints which is an ongoing issue will remain if Option 1 is selected.
- Drainage and foundation erosion risks that can lead to settlement and damage of the penstock.

Option 2 – Weld Refurbishment and Coating

Option 2 includes cleaning and application of a protective coating along the entire penstock, and repair of the deteriorated welds. For this risk assessment the number of welds repaired were assumed to be approximately fifty percent of the longitudinal welds and fifty percent of the circumferential welds. The larger diameter to thickness ratio and weld peaking issues will not be mitigated with the implementation of Option 2 life

extension measures. However, the risk of weld failure will be reduced due to weld refurbishments and cleaning and coating which will limit the progression of corrosion of the steel in the heat affected zone and the base metal.

The team developed 58 risks for Option 2 with various construction risks and post construction failure scenarios. Six high risk items were found with five risk items having a risk rating of 9, and one risk item having a risk rating of 12, for option two. Four of the Six high risk items were construction related and two were pre-construction related. Five out of the six identified high-risk items were able to be mitigated down to a lower rating. Further analysis and comparison of the data is provided in the Risk Report in Appendix B.

The key differences between Option 1 and Option 2 in terms of risk is the reduction of the failure related and corrosion related risk ratings and the addition of the construction related risks. The risk likelihood of a minor penstock failure in the 17-foot section after weld refurbishments and recoating of the interior surface of the penstock was rated as unlikely for Option 2 which is a significant change from Option 1 (highly likely). It was assumed that only fifty percent of the welds would be refurbished so a small risk remains that a non-refurbished weld may fail in the next 30 years. Cracks in refurbished welds found in 2021 in Penstock 1 and a failure of a refurbished weld in 2019 in Penstock 1 indicate that there is risk that the refurbished welds will fail. The impacts are reduced as the chances of multiple failures over 30 years is reduced.

Risk of failure due to the progression of corrosion throughout the penstock base metal and heat affected zone of the welds is mitigated by resurfacing and recoating the penstock. However, associated risks with resurfacing and coating of the penstock is added to the assessment. Coating related risks can be attributed to quality of the surface preparation and of the coating system selected for the project. Strict QA and QC practices can be implemented to mitigate coating related risks and coating tests can be undertaken before coating the entire penstock to see how each coating performs. Moisture cured urethanes can be applied in high humidity conditions or there are epoxy paint systems that may be suitable.

Due to the expected high humidity within the penstock, the large surface area to cover, and the current rough condition of the penstock the risk likelihood of a small or minor localized coating failure is thought to be likely to occur following construction, but the impact to the project will be minimal because of strict QA and QC processes and coating thickness and adhesion measurements during application that should limit the likelihood,

quantity, and size of localized coating failures. Small repairs will not significantly impact the overall schedule and budget of the project as repairs can be planned around scheduled outages and would not require an outage just for the spot repairs. If a significant coating failure occurs, such as if the coating does not adhere or is not suitable for the application, the cost impacts associated with cleaning and recoating would be significant. The risk likelihood is rated as unlikely for a significant large scale coating failure as it is expected the coating product will be thoroughly researched and tested before the interior surface is recoated.

In addition to risks associated with Option 1 and penstock failures listed above, construction related risks were identified for Option 2. The construction phase is expected to run from May to November. Construction risks involving workforce, schedule, safety, environment, financial constraints, and other potential risks are listed in Section 4.4 of the Risk Report.

There were five items for Option 2 that have a pre-mitigation risk rating of 9 with three items related to construction and two items related to pre-construction. One risk item had a pre-mitigation risk rating of 12 related to construction. These high-risk items are listed in Table 6.3.

Table 6-3 Option 2 - Construction High Risk Rating

ID	Risk Title	Risk Description	Risk Rating	Post Risk
2-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Confined space environment may lead to lower productivity.	9	6
2-40	Coating Quality Control	Poor quality control and assurance requires spot repairs or reapplication of coating system. Occurs after construction is complete.	9	6
2-46	Additional or Less Welds Require Repair	Assume ±20% of the welds will need repair. Original assumption is 50% of welds will require a repair.	9	No change
2-55	Preconstruction Risk	Design not complete, bid package not released on time and tendering delays lead to mobilization delays.	9	4
2-56	Regulator Project Approval	Delay in obtaining approval from regulators	9	4

ID	Risk Title	Risk Description	Risk Rating	Post Risk
2-58	Risk of Not Obtaining Preferred 2nd Coating Quality due to the Thickness of Penstock	Not having enough plate thickness available to surface prep penstock for an additional coating in 20 years.	12	4

Risk mitigation is identified for each of these items in Section 4 of the Risk Report in Appendix B that lowers the risk rating to 6 or lower except for Item 2-46, Additional or Less Welds Require Repair. This risk item reviews the possibility that more or less weld repairs are required than are currently planned for, which is about 50 percent. The team decided on 20 percent more or less welds as a point of discussion. The team found this risk item to be likely with costs exceeding $500,000 if 20 percent more welds are required. The team found it just as likely that 20 percent less welds will be needed saving over $500,000. The mitigation of this risk is a thorough and complete weld inspection and repair identification prior to repair scoping. A thorough weld testing program for all welds would mitigate this down to a risk rating of 6; however, the labor costs and downtime costs associated with this level of testing occurring pre-construction scoping would be extensive and could exceed $500,000 making it on par with the cost of the risk itself. The costs for this risk could be built into the construction budget to allow for the potential additional cost but keeping in mind there is the potential that less welds could be required. This risk item applies to Options 3 and 4 as well and warrants further review of welds tested and repairs to date. This should be completed during the next phase of studies and included in the detailed risk assessment for the chosen option.

Option 3 – Section Replacement and Weld Refurbishment

The third life extension refurbishment option includes replacement of the entire 17-foot section of Penstock 2 and 3 and refurbishment of the welds and coating in the remaining section of the penstock. The team developed 64 risks for Option 3 with various construction risks and post construction failure scenarios. Four high risk items were found with a maximum risk rating of 9. Two of the four high risk items were construction related and two were pre-construction related. The four high risk items were able to be mitigated to a lower rating as discussed below. A summary list of the risk items is contained in the

Risk Registry and further analysis and comparison of the data is provided in the Risk Report (Appendix B).

The four items for Option 3 that have a risk rating of 9 pre-mitigation are listed in Table 6.4.

Table 6-4 Option 3 - Construction High Risk Rating

ID	Risk Title	Risk Description	Risk Rating	Post Risk
3-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Confined space environment may lead to lower productivity.	9	6
3-40	Coating Quality Control	Poor quality control and assurance requires spot repairs or reapplication of coating system. Occurs after construction is complete.	9	6
3-55	Preconstruction Risk	Design not complete, bid package not released on time and tendering delays lead to mobilization delays.	9	4
3-56	Regulator Project Approval	Delay in obtaining approval from regulators	9	4

There is no change to the high-risk construction items identified when compared to Option 2 high-risk construction items, except for Item 2-46, the potential risk of requiring more or less weld repairs affecting the project schedule or budget. The number of weld refurbishments will significantly decrease if the 17-foot diameter section of penstock is replaced. The welds associated with the 17-foot section would be a known quantity very unlikely to change. The overall risk to the budget and schedule due to the uncertainty in the number of weld repairs will be reduced compared to Option 2.

Additional minor to medium construction risks were identified that are unique to Option 3 and are listed below. Further discussion is provided in the Risk Report (Appendix B). None of these items require significant mitigation beyond typical construction practices and quality control.

- *3-58* - Existing and new penstock sections do not fit as designed. *(Risk Rating 3*)
- *3-59* – Steel fabrication errors. *(Risk Rating 2*)
- *3-60* - Foundation; lack of uniformity. *(Risk Rating 3*)

- *3-61* - Compaction issues around the haunches and springline of the penstock caught during construction phase. *(Risk Rating 4*)
- *3-62* - Compaction issues around the haunches and springline of the penstock not caught during the construction phase; may lead to settlement issues. *(Risk Rating 3*)
- *3-63 and 3-64* - Minor and major design inaccuracies. *(Risk Rating 8 and 6, respectively*)

Option 4 – Weld Reinforcement

Option 4 includes refurbishment of deteriorated welds, coating of the entire interior of the penstock and reinforcement of the longitudinal and circumferential welds in the 17-foot diameter penstock section with reinforcing plates. The welded plates will cover the repaired welds and increase stiffness in the area to mitigate weld peaking. The reinforcement plates will be welded using fillet welds all around the edge of the plate.

The team developed 61 risks items for Option 4 with various construction risks and post construction failure scenarios. Seven high risk items were found with a maximum risk rating of 9. Four of the seven high risk items were construction related and two were pre-construction related and one is a new failure mode. The seven high risk items can be mitigated down to a lower rating as discussed below, except for the risk involving weld quantity as discussed previously for Option 2. A summary list of the risk items is contained in the Risk Registry and further analysis and comparison of the data is provided in Section 6 of the Risk Report.

The seven items for Option 4 that have a risk rating of 9 pre-mitigation are listed in Table 6.5.

Table 6-5 Option 4 - Construction High Risk Rating

ID	Risk Title	Risk Description	Risk Rating	Post Risk
4-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Confined space environment may lead to lower productivity.	9	6
4-40	Coating Quality Control	Poor quality control and assurance requires spot repairs or reapplication of coating system. Occurs after construction is complete.	9	6
4-46	Additional or Less Welds Require Repair	Assume ±20% of the welds will need repair. Original assumption is 50% of welds will require a repair.	9	9
4-54	Preconstruction Risk	Design not complete, bid package not released on time and tendering delays lead to mobilization delays.	9	4
4-55	Regulator Project Approval	Delay in obtaining approval from regulators	9	4

Table 6-6 Option 4 – Additional Construction Risks

ID	Risk Title	Risk Description	Risk Rating	Post Risk
4-58	Failure of Plates Cyclic Operations	Assuming full operability and removing restrictions. Plates are only installed on longitudinal welds.	9	6
4-60	Constructability Lifting Plates in Place	Constructability issues with regards to lifting the plates in place, handling of the plates inside of the penstock creating safety issues i.e., Dropping plates.	9	3

These high risk items have been discussed previously for Option 2 and remain unchanged for Option 4 except for two new items, Items 4-58 and 4-60, which are discussed here.

- *4-58* - Failure of the plates (cyclical operations).

  If the operational restrictions are lifted, cyclic pressure loadings will increase, and the risk of plate failure becomes likely over a 30-year period. The toe of the fillet welds used to attach the plates are susceptible to cyclic loading and the weld could fail. There is a high probability that failures of the weakened material or cracks will develop due to fatigue from the cyclical nature of the loads. It is assumed over a

30-year period that the welds will see an increased number of high stress cycles and that failure is probable. *(Risk Rating 9*)

- *4-60* - Constructability – lifting plates in place.

  There are constructability risks as the plates are heavy and need to be welded at different locations, sometimes high on the side of the penstock or overhead. Lifting the plates in place, securing or tack welding to the penstock and welding the plates pose difficulties and there may be the risk of dropping the plates and increasing the risk of injury. Good construction planning, proper work methods in place and redundancy in the lifting mechanisms will reduce the risk of workplace injury. *(Risk Rating 9*)

For Option 4, risks related to construction, scope creep, schedule delays, budget overages, will be the same as Option 2 excepted as noted below. The additional welding required for the steel plates adds a complexity to this refurbishment option and new risks identified for this option are as follows:

- *4-57* - Failure of the plates (static operations). *(Risk Rating 1*)
- *4-59* - Plate detaching and entering the powerhouse. *(Risk Rating 3*)
- *4-61* - Measurable head loss due to plating. *(Risk Rating 1*)

6.3 Risk Analysis

Data collected in the risk register was used to make quantitative comparisons of the options. The comparisons are accurate only to the degree to which the data is accurate in developing the 4 by 4 matrix risk assessment. Options 1 through 4 were compared to one another with a high-level analysis, utilizing simple statistical methods. These methods include analyzing the cumulative cost and cumulative schedule with respect to the cumulative probability, the normal cumulative distribution of the risk ratings, the normal distribution of the risk ratings, and analyzing the mean, median, and standard deviation. The mean, median, and standard deviation of the risk ratings of each option are summarized in Table 6.7.

Table 6-7 Sample Size, Mean, Median, and Standard Deviation

Option	No. of Risk Items	Mean Value	Median Value	Standard Deviation
1	21	5.71	4	3.35
2	55	4.89	4	2.29
3	62	4.52	4	1.99
4	59	4.88	4	2.37

From Table 6-7 it can be noted that Option 3 has the lowest mean value and the lowest standard deviation, while Option 1 has the highest mean value and highest standard deviation by a significant margin. These results are what the team would expect after discussing the options and ranking the risks.

6.3.1 Normal Distribution Model

One of the more visually descriptive plots was of the normal distribution of the risk ratings for each option, shown here as Figure 6.2. The normal distribution model plots the risk rating (x-axis) in contrast to the risk rating density (y-axis). The curve describes the density, or occurrence of the corresponding risk rating. The probability of obtaining a certain risk rating between two points of interest is measured by calculating the area under the curve between the points of interest.

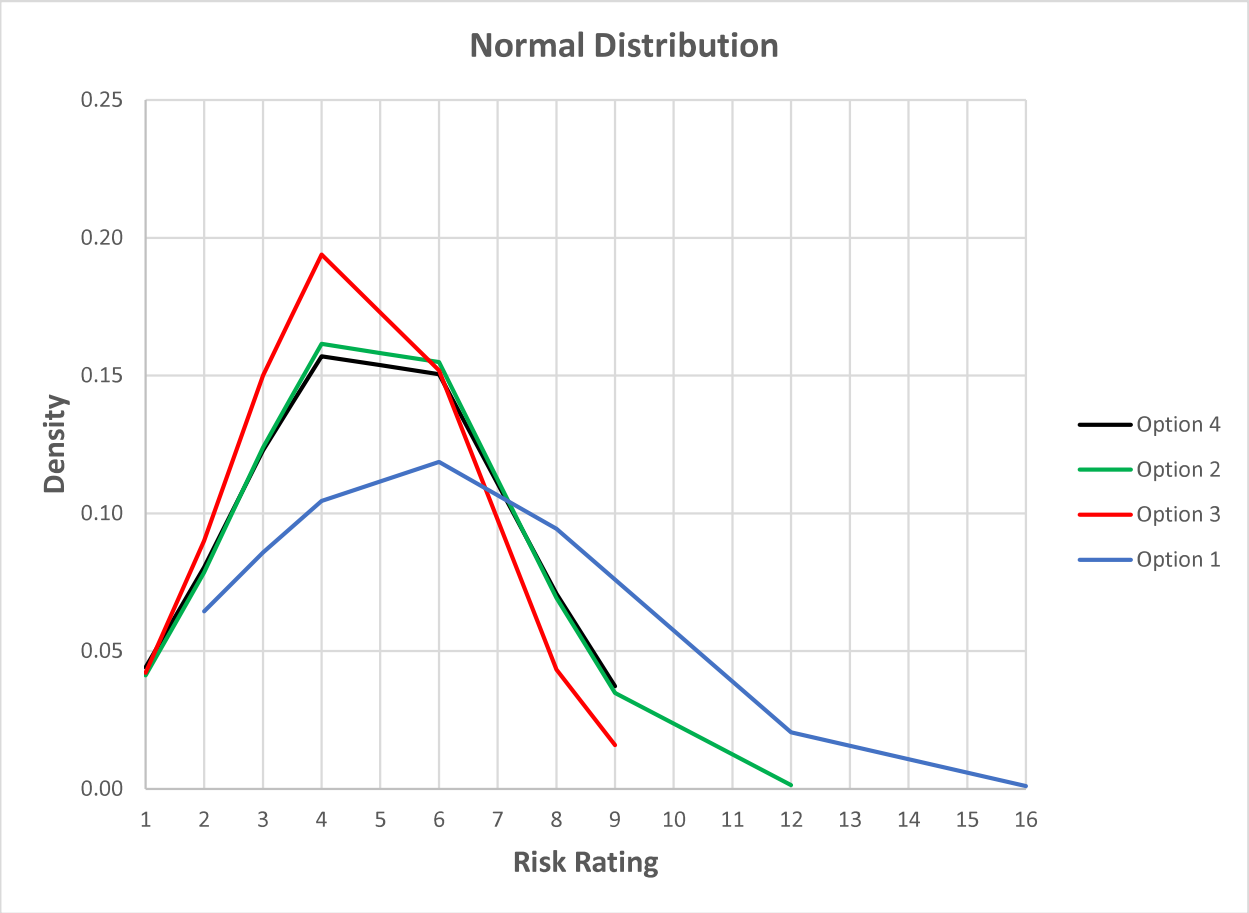


Figure 6.2 Normal Distribution Models

From the models it can be seen that Option 1 has the smallest probability of having a risk fall within both the low and moderate risk categories and the largest probability of having a risk rating fall within the high risk category. This option displays the greatest amount of skewness to the right, or positive skewness, compared to Options 2 through 4. This is also a result of option 1 being the only option with risk ratings above 9 which significantly skews the distribution. The mean is greater than the median by 1.71, in comparison to Option 3, where the mean is only greater than the median by 0.52. The smaller difference suggests the data set is less skewed, that there are fewer outliers impacting the distribution such as with the Option 1 distribution.

In comparison, Option 3 has the highest probability (0.374) of having a risk rating fall within the Low risk category and scored the least probability (0.03) of having a risk rating fall within the High risk category. Option 3 displays the least amount of skewness to the right, with the mean being greater than the median by 0.45. In comparison to the other options, Option 3 has the lowest mean and standard deviation of 4.52 and 1.99,

respectively. Having the lowest mean suggests Option 3 has the lowest average risk, and the lowest standard deviation indicates Option 3 has less variability in the risk distribution and more confidence in the mean.

Options 2 and 4 fall between Options 1 and 3 with Option 2 showing slightly more favorable values than Option 4.

6.3.2 Cumulative Probability vs Cumulative Cost

The cumulative cost was plotted in contrast to the cumulative probability as seen in Figure 6.3 and 6.4 to compare project costs and the probability of exceeding those costs. Note that this is a tool to draw a relationship between risks and cost, and does not represent a cost estimate or "risk of exceedance" costs. A detailed discussion on the development of the plots can be found in Section 7 of the Risk Report. It should be noted that the starting point for the cost for each option is based on an AACE Class 4 cost opinion developed for these studies and discussed in Section 3.0 of this report. The curve produced from plotting the cumulative cost in contrast with the cumulative probability represents the probability of multiple risk items occurring simultaneously. As more risks simultaneously occur, the probability becomes exponentially lower while the costs are cumulative.

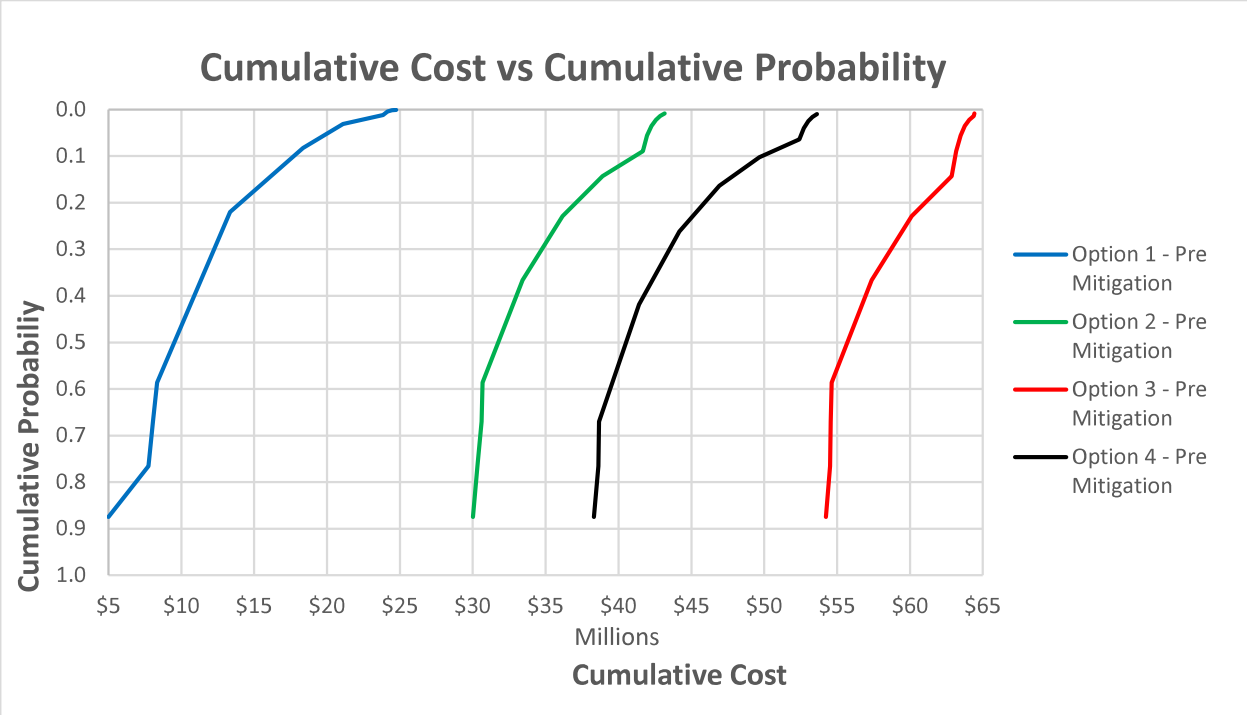


Figure 6.3 Cumulative Cost vs Cumulative Probability – Pre-Mitigation

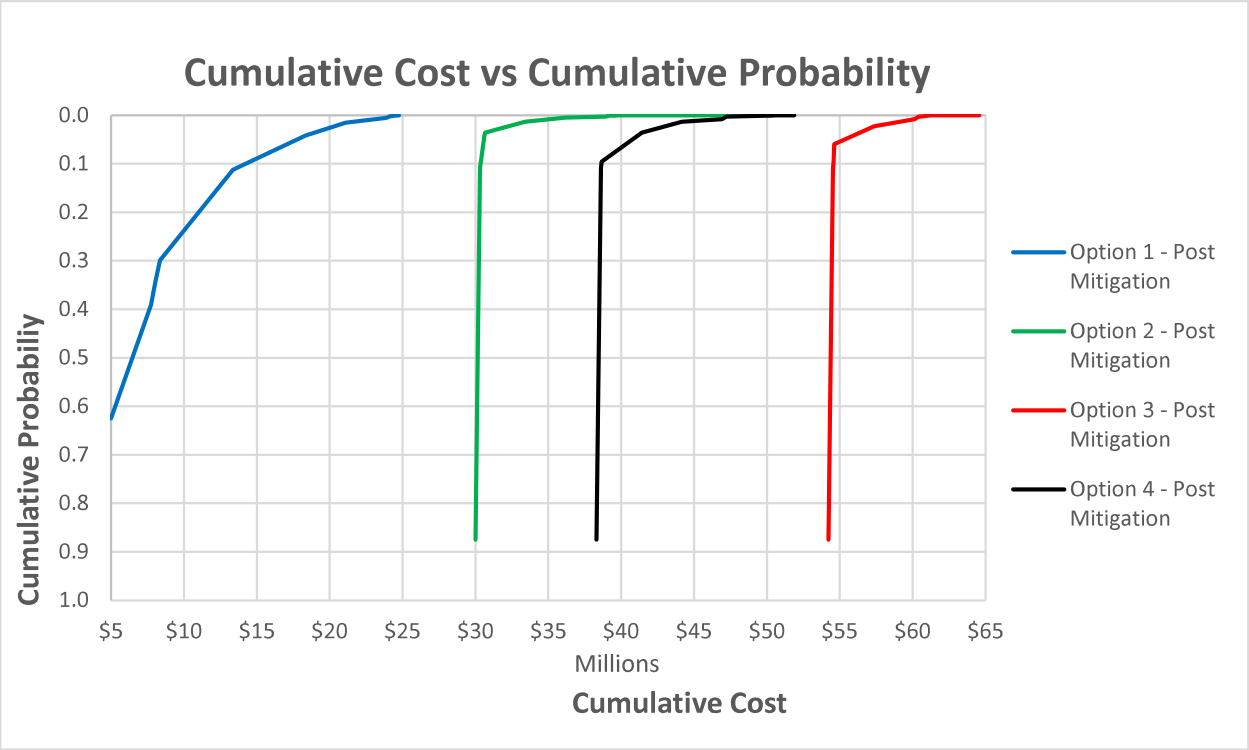


Figure 6.4 Cumulative Cost vs Cumulative Probability – Post-Mitigation

The results of Figure 6.4 show Option 3 has the steepest post-mitigation plot suggesting the risks can be well mitigated to control costs. The plot also shows no significant overlap between the options in terms of costs except at very low probability points high in the plot. This suggests that Option 1 is the lowest cost option even with multiple failure repairs included. Note that these costs do not include operational loses which would be significant for Option 1. Option 2 is the least costly refurbishment option and there is less than a 20 percent chance that its cost would exceed the starting cost of Option 4 and no chance, according to the plot, that it will exceed the cost of Option 3.

6.3.3 Risk Analysis Summary

As detailed in the Risk report various statistical methods were utilized to compare each of the options. The mean, median, and standard deviation of the risk ratings of each option were compared to one another. The normal cumulative distribution models of each option were analyzed to determine the density of risk ratings at, or below a risk rating of certain interest. The cumulative probability versus cumulative cost and schedule delay models were used to determine the probability, cost and schedule delay of multiple risk items occurring simultaneously in a worst-case scenario.

Using this analysis, Option 1 is found to be the riskiest option as a result of being the only option with a risk ratings above 9 that cannot be mitigated to an acceptable level. The risk rating of 16 heavily negatively influence the results across all models.

Option 3 has the smallest mean and standard deviation, indicating that the risk ratings in the option are overall less than the risk ratings in the other options. The normal distribution curve was also used to determine that Option 3 had the highest probability of having a risk rating fall within the low risk matrix category and had the least probability of having a risk rating fall into the high risk matrix category. Through the results of the described analysis, Option 3 is accepted as the lowest risk option.

6.4 Risk Summary

Option 1 was determined to be very risky due to the high probability of multiple failures and associated costs over the next 30 years. Operational constraints and negative public opinion of failures at the local and provincial level add to the negative impacts and negative opinion of this option. The level of risk associated with Option 1, with its elevated probability of failures and high consequence, coupled with the potential reliability issues leads us to recommend that Option 1 not be considered as a viable option. There are no mitigating measures for Option 1 that can adequately reduce the elevated risks without going to life extension Options 2, 3, or 4.

The evaluation of Option 2 identified five risk items having a pre-mitigation high-risk rating of 9 and one risk item with a pre-mitigation risk of 12. These six items are pre-construction or construction related and can be mitigated down to a moderate risk rating. The team concluded that Option 2 was viable though not ideal as issues related to peaking and fatigue are not addressed, and operational constraints will remain. A detailed penstock inspection was completed in May for Penstock 1 following the risk assessment workshop for Penstock 1 and discovered cracks at welds in 14 cans and all at previously refurbished welds including around five reinforcing plates. More than 60 feet of cracks were repaired. These previously refurbished welds were less than five years old. This coupled with the failure of a previously repaired weld in 2019 suggests that the current weld repairs lack long-term reliability, may have a short life expectancy, and there is likely an increased risk of failure following repair compared to what was assumed in the workshop. Following these recent discoveries following the workshop, Kleinschmidt is not convinced that Option 2 is a viable option and recommends against moving forward with this option.

Option 3 identified four risk items having a pre-mitigation high-risk rating of 9. These four items are pre-construction or construction related and can be mitigated down to a moderate risk rating. The team concluded that this Option was viable and adequately mitigated the peaking and fatigue issues allowing operational constraints to be lifted.

Option 4 identified seven risk items having a pre-mitigation high-risk rating of 9. Five of the items are pre-construction or construction related and can be mitigated down to a moderate risk rating. Two of the items are related to plates being used and are unique to Option 4. The team concluded that this Option was viable, however it did not adequately deal with the peaking and fatigue issues, meaning operational constraints would not be recommended to be lifted. The plates may not be worth the added expense. As noted for Option 2 cracks were discovered during the Penstock 1 inspection at welds in 14 cans and all at previously refurbished welds including around five reinforcing plates. The reinforcing plates were less than five years old. This suggests that repairing with reinforcing plates may lack long-term reliability. Following these recent discoveries following the workshop, Kleinschmidt is not convinced that Option 4 is a viable option and recommends against moving forward with this option.

7.0 SUMMARY

A comparison is provided in Table 7.1 and 7-2 for the four options for Penstock 2 and 3 based on the up-front budget estimate determined in Section 3.2, and the estimated risk as determined in the Risk Assessment Report (summarized in Section 6.0 with the full report in Appendix B).

Table 7-1 Comparison Summary for Penstock 2

Penstock 2	Option 1	Option 2	Option 3	Option 4
Capital Budget	$0	$29,715,700	$53,495,600	$38,016,200
Number of Identified Risks	23	58	64	61
Maximum Risk Value (post mitigation)	12	9	8	9
Mean Risk Value	5.71	4.89	4.52	4.88
Return to Normal Operations?	No	No	Yes	No

Table 7-2 Comparison Summary for Penstock 3

Penstock 3	Option 1	Option 2	Option 3	Option 4
Capital Budget	$0	$28,248,700	$53,204,600	$36,780,200
Number of Identified Risks	21	55	62	59
Maximum Risk Value (post mitigation)	12	9	8	9
Mean Risk Value	5.71	4.89	4.52	4.88
Return to Normal Operations?	No	No	Yes	No

7.1 Option 1 – No Rehabilitation

Option 1 is the no refurbishment option in this review. If the option of no refurbishment is selected, the existing operational and maintenance procedures would continue with no changes, and repairs would be completed as needed. Based on previously identified corrosion and weld cracking in Penstock 2 and 3, it is assumed that failures in the areas of the existing penstock welds will continue to occur at a pace of approximately one failure every two years during the 30-year evaluation period (total 15 failures) if no repairs are made and the interior of the penstock is not recoated. The impact of each failure could vary depending on the location and size of failure. Operational restrictions will remain for Option 1 due to pitting corrosion of the heat affected zone, weld peaking and the high diameter to thickness ratio.

Short term economic benefits due to no major capital investment for repairs or replacement of Penstock 2 and 3 will be offset by the cost of potential emergency repairs. The extent of the repairs is dependent upon the type of failure, number of failures, multiple failures involving more than one penstock, and location of the failure(s). Long lead times for repair materials, repair durations and associated generation losses should be considered in conjunction with the short-term savings.

Option 1 excludes the application of an interior coating, increasing the potential for internal surface corrosion and ultimately leading to plate steel thickness loss and corrosion of the weld material and heat affected zone. It was identified in the 2019 options report that the existing base material contains larger amounts of sulfur which can result in porosity of the welds causing future pitting corrosion. If the interior penstock surfaces are not coated, internal corrosion will progress, which increases the risk of failure in the long term.

If the condition of the welds and interior surface are not monitored frequently and repairs are not completed, there is an increased risk of catastrophic failure, potential prolonged outages to complete the repairs, other equipment damage, loss of generation revenue, and increased frequency of inspections of the interior penstock surface. The penstocks location is remote; however, public safety, environmental and social losses, damage to other local infrastructure are risks that were considered for this option.

Recommended long term maintenance and monitoring associated with Option 1 include:

- Live pressure monitoring of Penstock 2 and 3 tied to a warning system that will alarm when a significant pressure drop is detected.
- Daily exterior site inspection with weekly walking inspections along the penstock alignment to identify settlement and/or wet spots.
- Weekly monitoring of the drainage system as increased flow can be an early warning of a leak.
- Annually detailed inspections including magnetic particle weld testing, weld inspection, plate thickness readings, and visual inspection.
- Annual condition inspection of the drainage system by operations and cleaning as required based on inspection findings.
- Consideration of an emergency intake gate closure system tied to the pressure monitoring system to capture large ruptures.

Overall Option 1 carries a very high risk due to the elevated probability of multiple failures and associated costs over the next 30 years. Reliability of this option is very low and requires constant monitoring. Operational constraints limit the flexibility of the system under various power and flow conditions. Negative public opinion of failures at the local and provincial level further add to the negative perception of this option. The overall risk level for this option exceeds what Kleinschmidt recommends should be tolerated and the risks cannot be effectively mitigated to a lower risk rating without executing one of Options 2, 3, or 4. Kleinschmidt does not recommend this option as we consider it not viable based on risk and reliability concerns.

7.2 Option 2 – Weld Refurbishment

Option 2 includes repair of the deteriorated welds in Penstock 2 and 3 and cleaning and coating the entire interior of the penstock. A large percentage of the longitudinal weld seams of Penstock 2 and 3 were previously inspected and repaired. If the remaining circumferential and longitudinal welds are inspected and repaired and the penstock interior resurfaced and coated, the service life and reliability of the penstock will be significantly improved, but not ideal. This option does not address the design issues related to peaking and fatigue, and operational constraints will remain.

A risk of failure remains as it was assumed that only fifty percent of the welds would be repaired. A small risk remains that a non-refurbished weld may fail in the next 30 years. A failure of Penstock 1 in 2019 from a previously repaired weld and multiple cracks discovered in previously repaired welds in 14 cans of Penstock 1 in 2021, indicate that the refurbished welds do not have the reliability or life expectancy that would provide trouble free operation for the next 30 years. No failures of the welds occurred in Penstock 2 or 3; however, previous inspections identified weld cracking and corrosion throughout the penstocks. We expect yearly inspections and operational constraints would continue after Option 2 is implemented and weld repairs would be expected every 3 to 5 years based on what we have observed in the short time the existing repairs have been in place. There is a lower probability of multiple failures in Penstock 2 and 3 over a 30-year period because during past inspections the welds were found to be corroded and cracked but did not fail creating a breach during operation. Interior inspections will need to continue with both repaired and unrepaired welds being inspected every year using mag particle inspection (MPI) over the coating.

It is assumed that interior surface inspections will also need to continue to monitor the condition of the coating for cracks and delamination as moisture ingress under the surface of the coating may cause localized areas of corrosion and peeling. The penstock interior is expected to require recoating in approximately 15 to 20 years depending on the surface preparation and service life of the product. Resurfacing will reduce the steel thickness in areas where there is existing steel loss. It is estimated that the penstock can be thoroughly cleaned once but it may not be able to be heavily resurfaced a second time due to the risk of excessive thinning of the plate. This second coat may be a different material requiring less surface cleaning and will likely have a shorter life expectancy. This makes it imperative to select a quality coating system designed and tested for this application and installed by an experienced contractor following applicable quality control and assurance measures to prevent premature coating failure. Regular monitoring of the coating will be required, yearly for the first two years and then every 3 to 5 years if the coating shows no signs of deterioration. Any deterioration of the coating should be repaired as soon as practicable to limit further plate deterioration and need for excessive surface cleaning that may further thin the plating. It is believed that a second coating can be applied but the surface preparation and material may be different to allow for less than white metal application.

Option 2 will reduce the risk of a large up-front capital investment such as is the case with a penstock replacement, which requires longer outages, larger work force and replacement materials with a longer lead time.

The primary disadvantages of this option include:

- There will be no remediation to the existing deficiencies related to the design of Penstock 2 and 3, such as joint peaking issues that contribute to fatigue in the weld area, the existing out of roundness, and steel plate thickness issues of the upper 17-foot diameter section.
- Yearly inspections will need to continue to monitor welds, especially in the 17-foot diameter section where weld corrosion and cracking was identified.
- Operational constraints to limit operations in the rough zone will need to continue. This will reduce fatigue on the original welds and on the new welds in the 17-foot diameter section that will still have peaking issues.
- The penstock interior will need to be recoated in approximately 15-20 years depending on the surface preparation and service life of the product. There is some risk involved in applying the second coating as the thinning material may not allow

for a second deep clean resulting in selecting a product that can be applied over less than clean material.

Recommended long term maintenance and monitoring associated with Option 2 include:

- Live pressure monitoring tied to a warning system that will alarm when a pressure drop is detected.
- Weekly monitoring of the drainage system as increased flow can be an early warning of a leak.
- Bi-weekly walks along the penstock alignment to look for settlement and wet spots.
- Annual condition inspection of the drainage system by operations and cleaning as required based on inspection findings.
- Yearly inspections including magnetic particle weld testing over the coating, plate thickness readings, and visual inspection of the coating.
- Consideration of an emergency intake gate closure system tied to the pressure monitoring to detect large ruptures.

Overall Option 2 improves the reliability and reduces the risk of failure when compared to Option 1. Option 2 has the lowest construction costs at $28.2M for Penstock 3 and $29.7M for Penstock 2 compared to the other life extension options. This option was considered viable by the risk team but not ideal as issues related to peaking and fatigue are not addressed, operational constraints will remain, and yearly inspections will continue to monitor existing and repaired weld conditions. Long term maintenance and monitoring costs are expected to be the highest of the refurbishment options, and second highest only to Option 1 overall.

New cracks discovered in 14 cans of Penstock 1 in previously repaired welds in the 17-foot diameter section raise questions and concerns regarding the service life of these repairs as these repairs were less than 5-years old. The new cracks were discovered following the first risk assessment workshop but are referred to in this report as they add valuable insight into the potential longevity and serviceability of Option 2. It should be noted that the last failure of Penstock 1 during operation was in a previously repaired weld also in the 17-foot diameter section. Following these recent discoveries after the first risk assessment workshop, Kleinschmidt is not convinced that Option 2 is a viable option and recommends against moving forward with this option.

7.3 Option 3 – Section Replacement and Weld Refurbishment

The third life extension refurbishment option includes replacement of the entire 17-foot section of Penstock 2 and 3 and refurbishment of the welds and recoating in the remaining sections of the penstock. The entire replacement of both Penstock 2 and 3 was determined not to be a feasible option and recommendations were made to replace the 17-foot diameter section of penstock only as the design issues appear more pronounced in this section as well as corroded and cracked welds were identified on previous inspection. The remaining sections of the penstock would undergo weld refurbishment and resurfacing and recoating of the interior.

The main advantage to this option is the design issues of the existing 17-foot section of Penstock 2 and 3, including out of roundness, wall thickness, flexibility, weld peaking, and weld corrosion, would be mitigated. The new 17-foot section would be designed to current standards and would include remediation of the existing drainage and cover. This would result in operational constraints being lifted, allowing a return to normal operations and increased operational flexibility. Another advantage is that dewatered inspections could be reduced to occur every 3 to 5 years to assess the coating condition and welds, though yearly inspections should be planned for the first two years of normal operations to assess the coating system and welds.

The disadvantage to this option is the high cost for materials and installation. It is assumed that the steel plate for the penstock would have a long lead time and that transportation of materials would be costly if fabrication were completed outside the province of Newfoundland. The penstock interior will still need to be recoated in approximately 20 years depending on the surface preparation and service life of the product though it is expected that the coating in the new section of penstock should last longer as the coating will primarily be applied in the shop on new steel without pitting.

Recommended long term maintenance and monitoring associated with Option 3 include:

- Live pressure monitoring tied to a warning system that will alarm when a pressure drop is detected.
- Weekly monitoring of the drainage system as increased flow can be an early warning of a leak.
- Monthly walks along the penstock alignment to look for settlement and wet spots.

- Annual condition inspection of the drainage system by operations and cleaning as required based on inspection findings.
- Internal inspections every 3-5 years including magnetic particle weld testing over the coating, plate thickness readings, and visual inspection of the coating.
- Consideration of an emergency intake gate closure system tied to the pressure monitoring to detect large ruptures.

Option 3 is the most expensive option by a significant amount being $25M more than Option 2 for Penstock 2 and $15M more than Option 4 for Penstock 2, about 80% and 40% more respectively. However, Option 3 presented the lowest risk rating, is the only option to fully address the design issues for the 17-foot section, would return the units to normal operations, and would be the most reliable. Long term maintenance and monitoring costs are expected to be the lowest of the refurbishment options.

7.4 Option 4 – Weld Reinforcement

Option 4 includes the refurbishment of deteriorated welds, recoating of the entire interior surface of the penstock and reinforcement of the repaired welds. The welds in the 17-foot diameter penstock section would be reinforced with plates welded to the interior surface.

The advantages and disadvantages of Option 4 are similar to Option 2. The service life and reliability of Penstock 2 and 3 will be significantly improved, but not ideal. Like Option 2 this option does not fully address the design issues related to peaking and fatigue, and operational constraints will remain. The welds will be reinforced but the fillet welds required to attach the new plating are susceptible to fatigue failure. The joint peaking will remain and although the plating will reinforce the welds the stresses and fatigue loading will remain.

It is assumed that only fifty percent of the welds would be repaired so a small risk remains that a non-refurbished weld may fail in the next 30 years. A failure of Penstock 1 in 2019 from a previously repaired weld and multiple cracks discovered at previously repaired welds including five with reinforcing plates in 14 cans of Penstock 1 in 2021 suggest that the refurbished welds do not have the reliability or life expectancy that would provide trouble free operation for the next 30 years. During previous inspections of Penstock 2 and 3, weld corrosion and cracking were identified, but no failures. We expect yearly inspections of Penstock 2 and 3 would continue and operational constraints would remain for Option 4. Weld repairs would be expected every 3 to 5 years based on what we have

observed in Penstock 1 in the short time the existing repairs in have been in place. The impacts are reduced as the chances of multiple failures over 30 years is reduced. The probability of failure of Penstock 1 is higher than Penstock 2 and 3 because of recent failures. Interior inspections will need to continue with both repaired and unrepaired welds inspected every year using MPI over the coating.

It is assumed that interior surface inspections will also be needed to monitor the condition of the coating for cracks and delamination as moisture ingress under the surface of the coating may cause localized areas of corrosion and peeling. Inspections will need to include the new reinforcing plates and the potential coating failure around the corners and edges. The penstock interior will need to be recoated in approximately 15 to 20 years depending on the surface preparation and service life of the product. Resurfacing will reduce the steel thickness in areas where there is existing steel loss. It is estimated that the original penstock can be resurfaced once but it may not be able to be heavily resurfaced a second time due to the risk of excessive thinning of the plate. This makes it imperative to select a quality coating system designed and tested for this application and installed by an experienced contractor following applicable quality control and quality assurance measures to prevent premature coating failure. Regular monitoring of the coating will be required, yearly for the first two years and then every 3 years if the coating shows no signs of deterioration. Any deterioration of the coating should be repaired as soon as practicable to limit further penstock deterioration and need for excessive surface cleaning that may further thin the plating.

The primary disadvantages of this option include:

- The existing deficiencies related to the design of Penstock 2 and 3, such as joint peaking issues that contribute to fatigue in the weld area, the existing out of roundness, and steel plate thickness issues of the upper 17-foot diameter section will not be effectively mitigated.
- Yearly inspections will need to continue to monitor welds, especially in the 17-foot diameter section.
- Operational constraints to limit operations in the rough zone will need to continue. This will reduce fatigue on the original welds and on the new plate welds in the 17-foot diameter section that will still have peaking issues.
- The penstock interior will need to be recoated in approximately 15-20 years depending on the surface preparation and service life of the product.

Recommended long term maintenance and monitoring associated with Option 4 include:

- Live pressure monitoring tied to a warning system that will alarm when a pressure drop is detected.
- Weekly monitoring of the drainage system as increased flow can be an early warning of a leak.
- Bi-Weekly walks along the penstock alignment to look for settlement and wet spots.
- Annual condition inspection of the drainage system by operations and cleaning as required based on inspection findings.
- Yearly inspections including magnetic particle weld testing over the coating, plate thickness readings, and visual inspection of the coating.
- Consideration of an emergency intake gate closure system tied to the pressure monitoring to detect large ruptures.

Overall Option 4 improves the reliability and reduces the risk of failure when compared to Option 1 and is a slightly better than Option 2 but does not fully address the design issues. Option 4 has the second highest construction costs at $38.0M and $36.8M for Penstock 2 and 3 respectively, with only Option 3 being more expensive. This option was considered viable by the risk assessment Team but not ideal as issues related to peaking and fatigue are not fully addressed, operational constraints will remain, and yearly inspections will continue to monitor weld conditions. Long term maintenance and monitoring costs are expected to be high, similar to Option 2.

The risk team determined that this option was viable but that it did not adequately deal with the peaking and fatigue issues and operational constraints would not be recommended to be lifted. It is our opinion that the plates are not worth the added expense of approximately $8M over Option 2. New cracks discovered five reinforcing plate welds in the 17-foot diameter section of Penstock 1 raise questions and concerns regarding the service life of these repairs as these repairs were less than 5 years old. The new cracks were discovered following the first risk assessment workshop but are referred to here as the identified cracks add valuable insight into the potential longevity and serviceability of Option 4. Following these recent discoveries Kleinschmidt is not convinced that Option 4 is a viable option and recommends against moving forward with this option.

8.0 RECOMMENDATION

There are many considerations when reviewing the options and choosing one that provides asset integrity and reliability at best value to rate payers. Risk, reliability, construction costs, and long-term maintenance are the considerations highlighted here.

First, Kleinschmidt recommends Option 1 be ruled out as a viable option. This option is very risky due to the high probability of multiple failures and associated costs over the next 30 years. Operational constraints and negative public opinion of failures at the local and provincial level add to the negative opinion of this option. The overall risk level for this option exceeds what should be tolerated and it cannot be effectively mitigated to a lower risk rating without going to Options 2, 3, or 4, making this option not viable.

When considering risk and reliability Option 3 is preferred. Option 3 is the least risky option and the only option that adequately addresses the peaking and fatigue issues in the 17-foot diameter section, allowing it to be the only option that could lift the current operational constraints. This would result in a return to normal operations and increased operational flexibility. In addition, the reliability associated with a new penstock section to replace the existing 17-foot diameter section of Penstock 1 which had multiple failures over the past 5 years and Penstock 2 and 3 with corroded and cracked welds, is unmatched compared to the other options.

From a construction cost point of view Option 2 is the least cost solution by a significant margin. Option 2 is about 80% less than Option 3 and 40% less than Option 4. Option 2 however does not completely address design concerns in the existing 17-foot diameter section and we do not recommend returning to normal operations following the Option 2 refurbishment. The significant quantity of cracks discovered in previously repaired welds and in the new reinforcing plate welds in 2021 supports the continuation of operational constraints following Option 2 and Option 4 refurbishment. These new cracks raise considerable concerns regarding the service life of these repairs as these repairs were less than 5-years old.

For long term maintenance Option 3 is also the preferred option with its new penstock section and associated new bedding and drainage. The requirements for inspections, maintenance, and repairs are expected to be significantly reduced for Option 3 when compared to Options 2 and 4. There will still be inspection and maintenance requirements but they are expected to be half the effort when compared to the other two options.

Although penstocks 2 and 3 have not experienced a failure resulting in a breach during operation, they have both had multiple welds cracks identified that would have eventual resulted in a full breach had they not been repaired. From this perspective we find little difference between the failure related risks for Penstock 1 versus Penstocks 2 and 3 and this is evidenced in the Risk Assessments.

Option 3 is the recommended option to move forward. Although Option 3 is the most costly in terms of up front capital cost, it is expected to have the lowest long term maintenance costs, the lowest risk rating, the highest reliability, and is the only option that adequately addresses the design issues and removes operational constraints. Based on this it is our opinion that Option 3 will provide the required asset integrity and reliability at best value to rate payers.

Thinking forward to implementation it is expected that the Penstock 1 refurbishment would be the first to be completed as it shows the greatest level of deterioration and risk of failure. Penstocks 2 and 3 could be completed in the next 5 to 10 years as they have a better performance history with regards to weld failures. There are risks associated with delaying refurbishment of Penstocks 2 and 3 associated with the various failures discussed in the risk report. The greatest risk would be that of a small failure similar to what has been experienced at Penstock 1. Facts that support this risk are:

- Weld indications have been found previously in Penstocks 2 and 3,Failures at welds in Penstock 1, which is of the same construction and operation, have occurred.
- Failures at previously repaired welds in Penstock 1 have occurred.
- Seeps through the welds in Penstock 3 around the penstock to surge tank transition have been identified.

Items that make this risk less likely include:

- Penstocks 2 and 3 have not experienced a weld failure resulting in a breach previously,
- The penstocks have been inspected and indications repaired,

To mitigate the risk of failure prior to refurbishment it is recommended that yearly detailed penstock inspections with weld testing continue until the penstocks are refurbished in 5 to 10 years.

The other risk related to delaying refurbishment is the risk that the steel plating deteriorates to the point that it becomes too thin to maintain adequate levels of stress in the steel thus requiring a complete replacement. Based on current deterioration and stress levels in the pates it is recommended that refurbishment be completed prior to 2031. Plate thickness should continue to be monitored as part of the yearly penstock inspections.

9.0 REFERENCES

Hatch 2017. BDE Penstock #1 Condition Assessment, Final Report. H349209-00000-200-230-0001 Rev 1. January 29, 2016.

_____ 2017 Bay d'Espoir Penstock No. 1 Refurbishment, Root Cause Analysis Report. H352666-00000-220-066-0002 Rev 1. March 17, 2017.

_____ 2017. Bay d'Espoir Penstock No. 1 Stress Analysis, Final Report. H352666-00000-240-230-0002 Rev 0. March 29, 2017.

_____ 2018. Repair and Failure Investigation, Final Report. H356043-00000-240-230-0003 Rev 2. May 17, 2018.

_____ 2018. Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3, Final Report. H357395-00000-240-066-0001 Rev 0. December 13, 2018.

_____ 2019. Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2, and 3. H357395-00000-240-066-0002 Rev.0. March 28, 2019.

_____ 2020. Penstock No.'s 1, 2 and 3 Life Extension Options, Final Report. H357395-00000-240-066-0003 Rev. 1. March 13, 2020a.

_____ 2020. Bay d'Espoir Penstock No. 1 2019 Failure Investigation, Final Report. (By SNC Lavalin for Newfoundland and Labrador Hydro) 668998-0000-40ER-0001 Rev. 00. March 29, 2020b.

SNC Lavalin 2020. Bay d'Espoir Penstock No. 1 2019 Failure Investigation, Final Report. 668998-0000-40ER-0001 Rev. 00. March 29, 2020a.

REPORT SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Structural Engineer

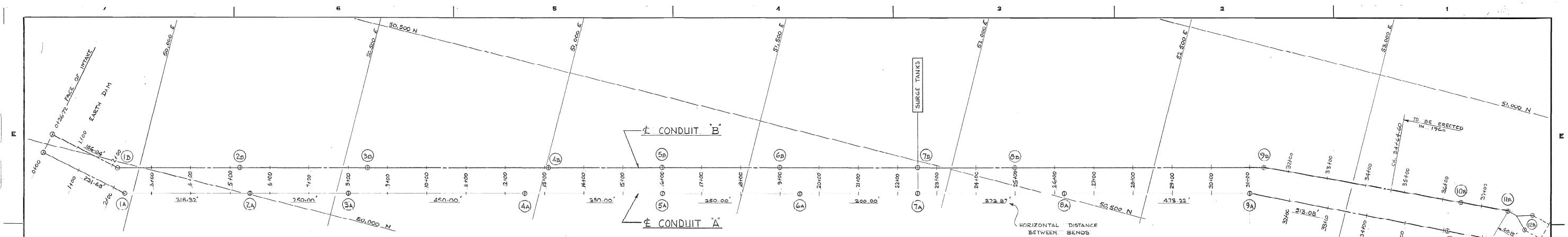
CMV:SCB

REGISTERED PROFESSIONAL ENGINEER
PEGL Newfoundland and Labrador
CHRISTOPHER M. VELLA
SIGNATURE
NOV 19, 2021
DATE
NEWFOUNDLAND & LABRADOR

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEGL Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
KLEINSCHMIDT ASSOCIATES CANADA INC.
To practice Professional Engineering in Newfoundland and Labrador. Permit No. as issued by PEGNL No 708 which is valid for the year 2021

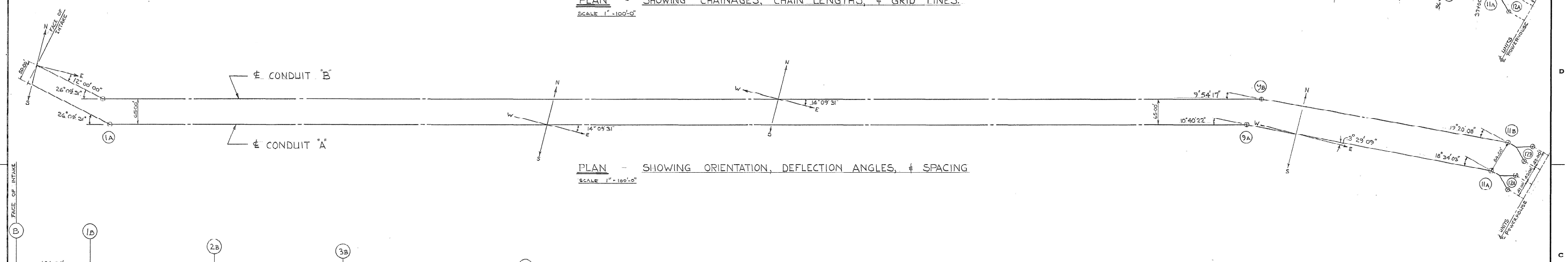
APPENDIX A

DRAWINGS



PLAN - SHOWING CHAINAGES, CHAIN LENGTHS, & GRID LINES.

SCALE 1" = 100'-0"



PLAN - SHOWING ORIENTATION, DEFLECTION ANGLES, & SPACING

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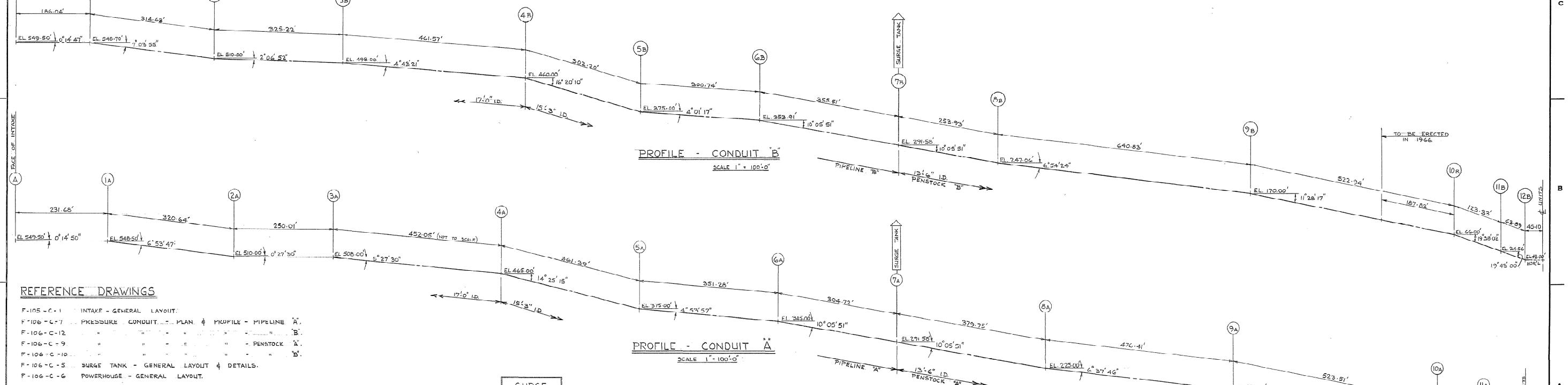

PROFILE - CONDUIT "B"

SCALE 1" = 100'-0"

PROFILE - CONDUIT "A"

SCALE 1" = 100'-0"

REFERENCE DRAWINGS

F-105-C-1 INTAKE - GENERAL LAYOUT.
F-106-C-7 PRESSURE CONDUIT - PLAN & PROFILE - PIPELINE "A".
F-106-C-12 " " " - " " " - " "B".
F-106-C-9 " " " - " " " - PENSTOCK "A".
F-106-C-10 " " " - " " " - " "B".
F-106-C-5 SURGE TANK - GENERAL LAYOUT & DETAILS.
F-106-C-6 POWERHOUSE - GENERAL LAYOUT.

PIPE	DATA	INTAKE	BEND 1	BEND 2	BEND 3	BEND 4	BEND 5	BEND 6	SURGE TANKS BEND 7	BEND 8	BEND 9	BEND 10	BEND 11	BEND 12	℄ OF UNITS
A	CHAINAGE	0+00.00	2+31.68	5+50.00	8+00.00	12+50.00	16+00.00	19+50.00	22+50.00	26+23.87	30+91.09	36+10.17	37+25.80	37+85.95	38+31.05
A	NORTHING	49,975.55	49,927.38						50,421.08		50,628.28		50,666.51		
A	EASTING	49,754.80	49,981.42						51,938.43		52,759.79		53,387.34		
B	CHAINAGE	0+26.72	2+12.76	5+25.00	8+50.00	13+10.00	16+00.00	19+00.00	22+50.00	25+00.00	31+36.18	36+48.67	37+64.83	38+24.98	38+70.08
B	NORTHING	50,024.46	49,985.78								50,700.98		50,747.62		
B	EASTING	49,765.20	49,947.17								52,782.26		53,409.20		

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

APPROVED FOR CONSTRUCTION
AUG 13 1965
APPROVED BY: W. Bonnell
MANAGER ENGINEERING

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
3	JAN. 25/66		I.D.'s INDICATED.	J.P.	J.H.M.
2	OCT. 18/65		STA. B-1D. VERTICAL ANGLE REVISED	J.P.	J.H.M.
1	SEPT. 27/65		PLANS & PROFILES REVISED	J.P.	J.H.M.

REVISIONS

	TRANS'N	ELECT'L	CIVIL
PASSED			J.H.M.

DESIGNED R. MacD.
DRAWN J.P.
CHECKED A.P. H.K.
RECOMMENDED J.H. Mason

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
LAYOUT & LOCATION DATA

CONTRACT	SCALE	FILE NO	DATE	DWG. NO.	REVISION
	1" = 100'-0"	PD - 11	SEPT. 27, 1965	F-106-C-11	3

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
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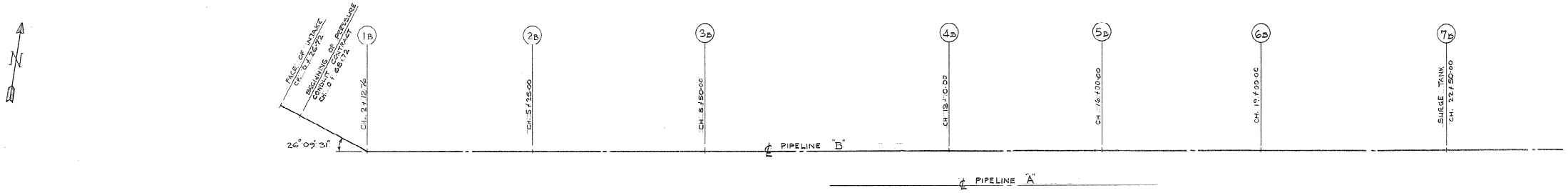
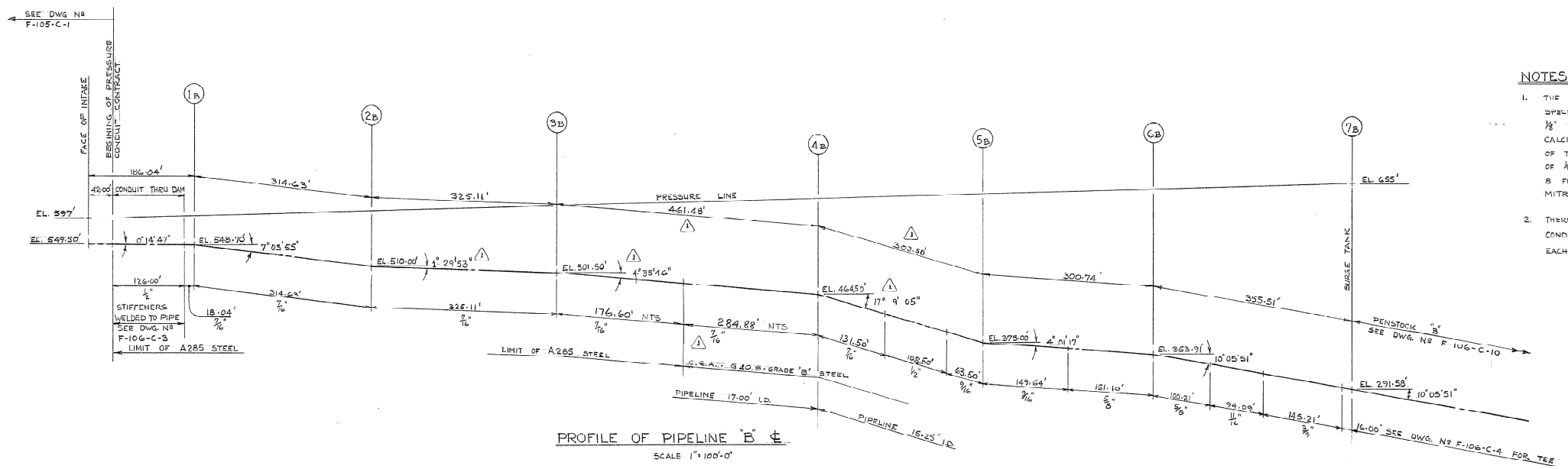


PLAN OF PIPELINE "B" ℄

SCALE 1" = 100'-0"

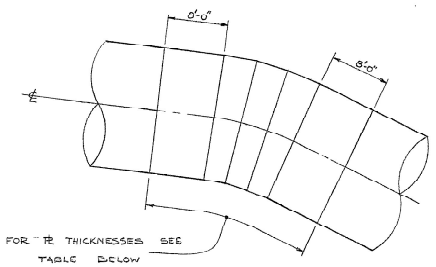


PROFILE OF PIPELINE "B" ℄

SCALE 1" = 100'-0"

NOTES

1. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE ⅛" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF ⅛" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THERE ARE TWO SEPARATE CONDUITS CALLED "A" AND "B". CONDUIT "A" IS SOUTH OF CONDUIT "B". EACH CONDUIT CONSISTS OF A PIPELINE AND A PENSTOCK.



TYPICAL BEND

SCALE 1" = 10'-0"

SEE SPEC. M-3116

ANGLES & ℔ THICKNESSES AT BENDS

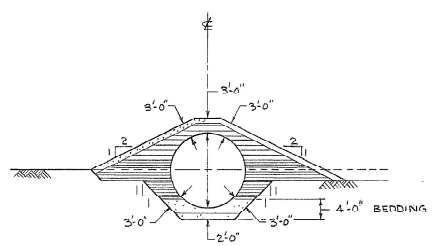
BEND	∠A	∠B	∠C	TRUE ANGLE	℔ THICKNESS
1B	26° 09' 31"	0° 14' 47"	7° 03' 55"	26° 57' 55"	7/16"
2B	——	7° 03' 55"	1° 29' 53"	5° 34' 2"	½"
3B	——	1° 29' 53"	4° 35' 46"	3° 05' 53"	5/16"
4B	——	4° 35' 46"	17° 9' 05"	12° 33' 18"	9/16"
5B	——	17° 9' 05"	4° 01' 17"	13° 07' 18"	¾"
6B	——	4° 01' 17"	10° 05' 51"	6° 04' 34"	13/16"
7B	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	



ANGLE IN PLAN



VERTICAL ANGLES



TYPICAL CROSS SECTION

(LOOKING DOWNSTREAM) SCALE 1" = 15'-0"

REFERENCE DRAWINGS

F-106-C-3	CONDUITS THROUGH DAM.
F-106-C-4	SURGE TANKS - DETAILS OF TEES.
F-106-C-5	SURGE TANKS - GENERAL LAYOUT & DETAILS.
F-106-C-6	PRESSURE CONDUITS - CLEARING.
F-105-C-1	INTAKE GENERAL LAYOUT.
F-106-C-11	PRESSURE CONDUITS - LAYOUT & LOCATION DATA.
F-106-C-7	" " - PLAN & PROFILE PIPELINE "A".
F-106-C-10	" " " " PENSTOCK "B".

OTHER REFERENCES

1. SPECIFICATION Nº M-3116.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPD'D
1	DEC/66		REV. ON PROFILE OF EL. AT 3B & 4B	C.C.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
OCT 21 1965
APPROVED BY: W. E. Bonnell
MANAGER ENGINEERING

	DRAWN	CHECKED	TRACED	CHECKED
				JHM

PASSED

DESIGNED R. Mac D.
DRAWN J.P.
CHECKED HK
RECOMMENDED J.H. Mann P.Eng.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

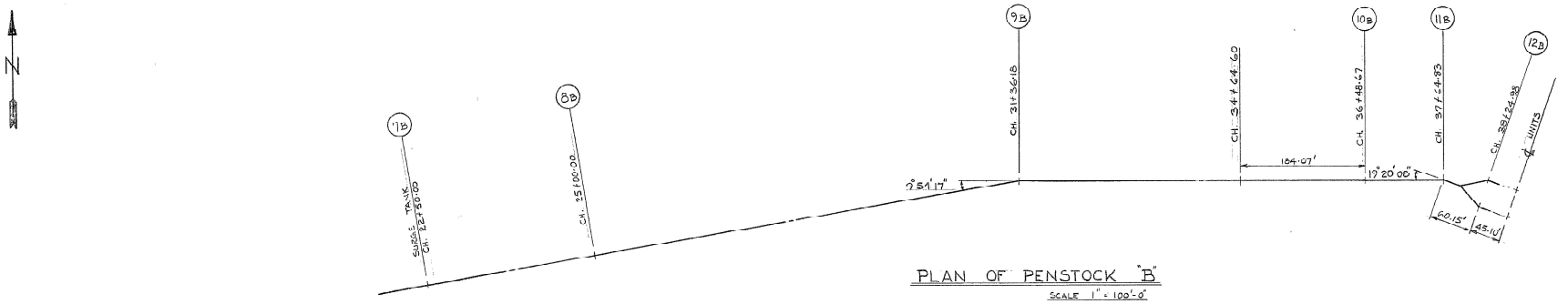
BAY D'ESPOIR DEVELOPMENT

ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PIPELINE "B"

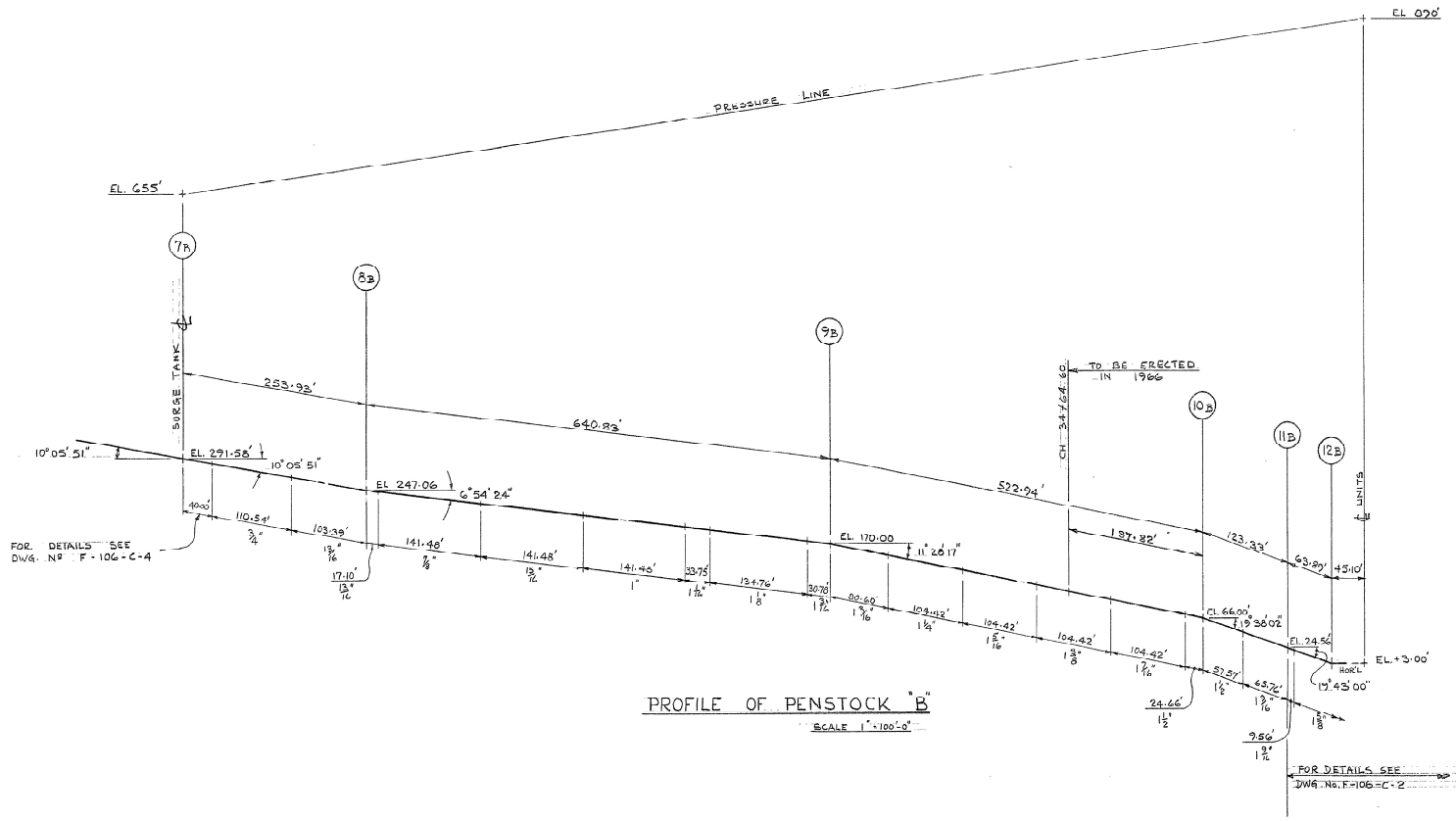
CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-A1	OCT. 18, 1965	F-106-C-12	1

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 68 of 212



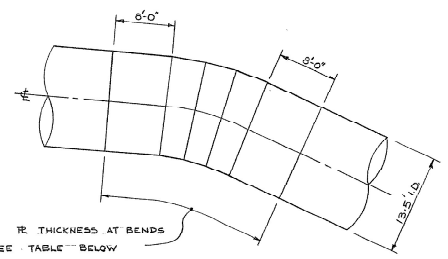
PLAN OF PENSTOCK "B"

SCALE 1" = 100'-0"



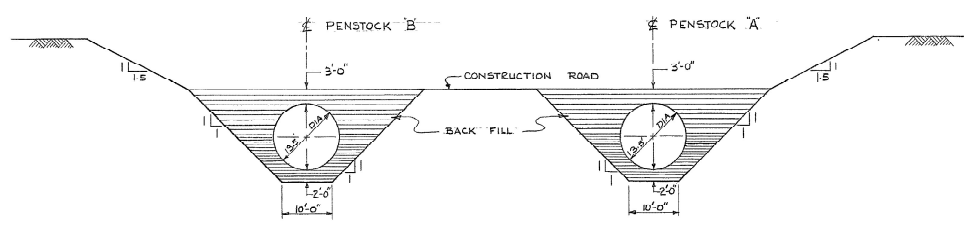
PROFILE OF PENSTOCK "B"

SCALE 1" = 100'-0"



TYPICAL BEND

SCALE 1" = 10'-0"

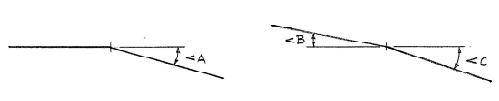


TYPICAL CROSS SECTION 9B TO 11B

SCALE 1" = 10'-0"

BEND	∠A	∠B	∠C	TRUE ANGLE	ℝ THICKNESS
7 B	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	
8 B	——	10° 05' 51"	6° 54' 24"	3° 11' 27"	1 1/2"
9 B	9° 54' 17"	6° 54' 24"	11° 26' 17"	10° 47' 16"	1 7/16"
10 B	——	11° 26' 17"	19° 38' 02"	8° 09' 45"	1 3/4"
11 B	19° 20' 08"	19° 38' 02"	17° 43' 00"	18° 11' 49"	1 7/8"

ANGLES AND ℝ THICKNESSES AT BENDS



ANGLE IN PLAN

VERTICAL ANGLES

NOTES

1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INSIDE DIAMETER OF THE PENSTOCK IS 13·50'
3. STEEL SHALL BE C.S.A. G40·8 GRADE "B".
4. FOR TYPICAL CROSS SECTION FROM 7B TO 9B SEE DWG Nº F-106-C-7.
5. A PORTION AT THE DOWNSTREAM END OF THIS PENSTOCK "B" SHALL BE ERECTED IN 1966, THE REMAINDER IN 1967. SEE PROFILE.

REFERENCE DRAWINGS

F-106-C-2	PRESSURE CONDUITS - LAYOUT & DETAILS OF BIFURCATION.
F-106-C-4	SURGE TANKS - DETAILS OF TEES,
F-106-C-5	SURGE TANKS - GENERAL LAYOUT & DETAILS.
F-106-C-6	PRESSURE CONDUITS - CLEARING.
F-106-C-11	PRESSURE CONDUITS - LAYOUT & LOCATION DATA.

OTHER REFERENCES

1. SPECIFICATION Nº M-3116

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPD
2	SEPT.		REVISED PLAN & PROFILE	JP	

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 20 1965
APPROVED BY: W. E. Bonnell
CANADIAN ENGINEERING

TRANSM'L | ELECT'L | CIVIL
PASSED

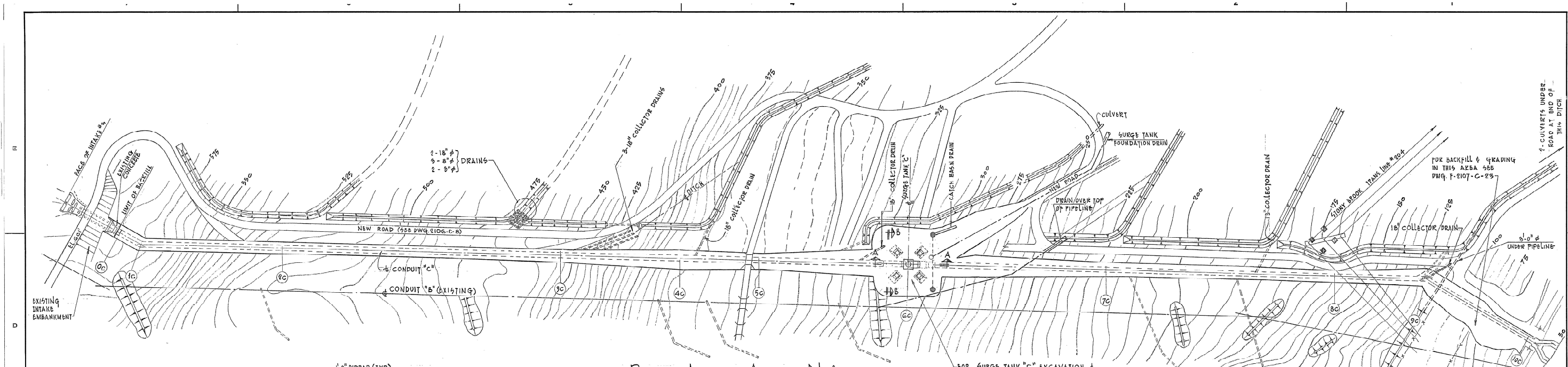
DESIGNED R. MacD.
DRAWN JP
CHECKED A.P.K.
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PENSTOCK "B"

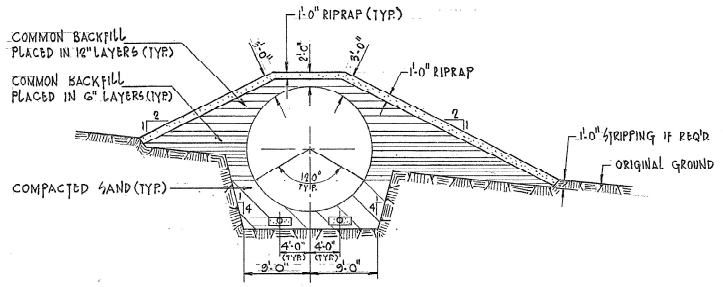
CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-11	SEPT. 1965	F-106-C-10	2

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 69 of 212



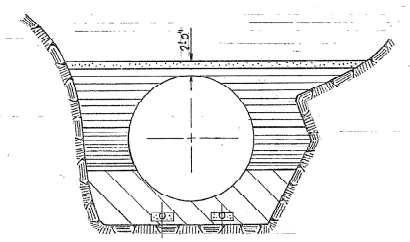
P L A N (2)

SCALE : 1" = 100'



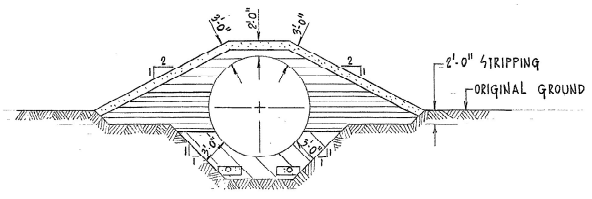
TYPICAL SECTION THROUGH ROCK CUT

SCALE : 1" = 10'-0"



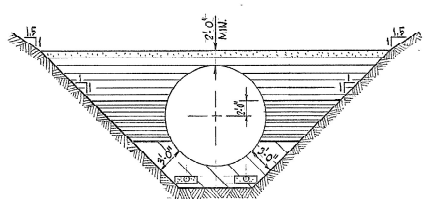
SECTION THROUGH EXISTING CUT ROCK

SCALE: 1" = 10'-0"



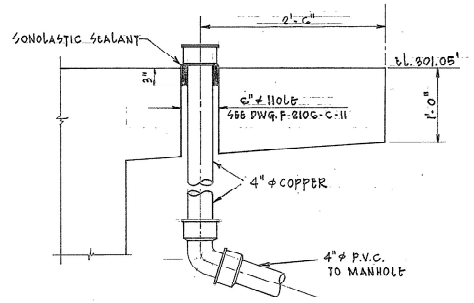
TYPICAL SECTION FOR SHALLOW EXCAVATION

SCALE: 1" = 10'-0"



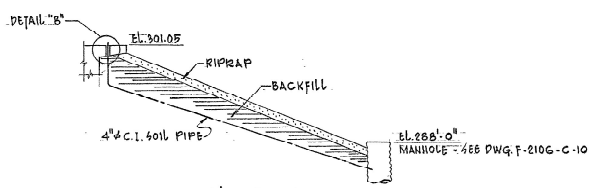
TYPICAL SECTION FOR DEEP EXCAVATION

SCALE: 1" = 10'-0"



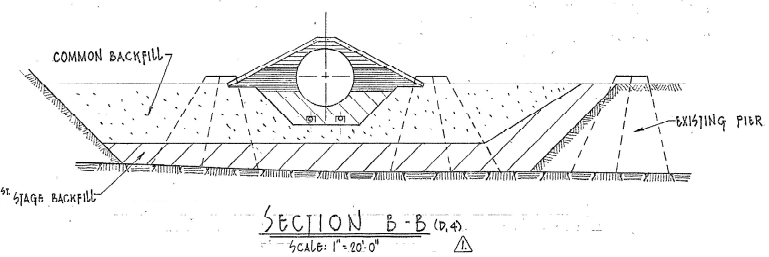
D E T A I L - B (C,3) ⚠⚠

SCALE: 1" = 1'-0"



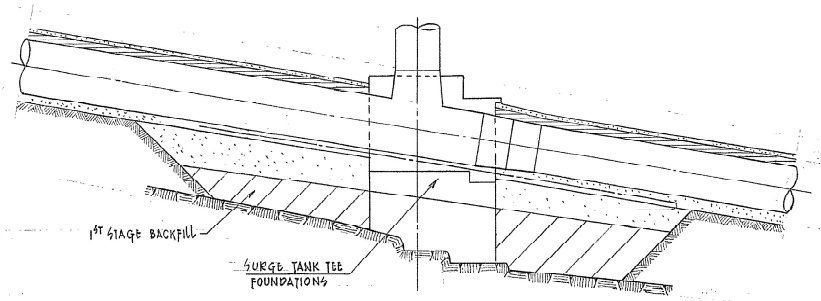
SECTION C-C (B,2) ⚠

SCALE : 1" = 10'-0"



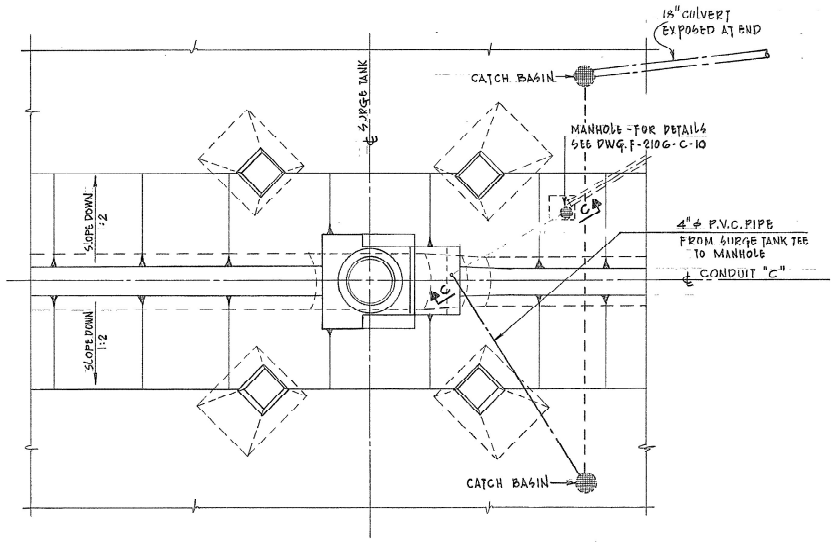
SECTION B-B (D,4) ⚠

SCALE: 1" = 20'-0"



SECTION A-A (D,4) ⚠

SCALE: 1" = 20'-0"



D E T A I L - A (D,3) ⚠⚠

SCALE : 1" = 20'-0"

NOTE:

⚠ 1. CONTRACTOR TO SUPPLY & INSTALL CAST IRON SOIL PIPE FROM SURGE TANK TEE TO MANHOLE UNDER SCHEDULE OF PRICE ITEM C 1003.

⚠ 2. CONDUIT & SURGE TANK FOUNDATION DRAINAGE OUTLETS SHALL BE INSPECTED TWICE YEARLY AND CLEANED AS REQUIRED TO INSURE PROPER DRAINAGE.

NEWFOUNDLAND PROFESSIONAL ENGINEER — R.A. Hutchinson — PROVINCE OF NEWFOUNDLAND

FINAL

DWG. No.	TITLE
	REFERENCE DRAWINGS
F-210G-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS
F-210G-C-2	SURGE TANK "C" - GENERAL LAYOUT & DETAILS
F-210G-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F-210G-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F-210G-C-5	" " " - FOUNDATIONS, CONCRETE DETAILS & ROCK DOWELS
F-210G-C-8	PRESSURE CONDUIT "C" - EXCAVATION & DRAINAGE
F-210G-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLES - CONCRETE & REINF. DETAILS
F-210G-C-11	SURGE TANK "C" - TEE STAGE II - CONCRETE DETAILS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
			REVISIONS		
⚠	12 NOV. '69		DWG. REVISED TO SHOW AS-BUILT	T.C.D.	
⚠	6 JUL '69	A-C, C-B.	DETAILS. NOTE 2 ADDED		
			SECTIONS A,B&C, DETAILS A & B NOTE ADDED	T.C.D.	A.B.

APPROVED FOR CONSTRUCTION
JUL 9 1969
APPROVED BY: CHIEF ENGINEER

TRANS'N	ELECT'L	CIVIL
PASSED		

DESIGNED A.B.
DRAWN T.C. DAVIS
CHECKED A.B.
RECOMMENDED

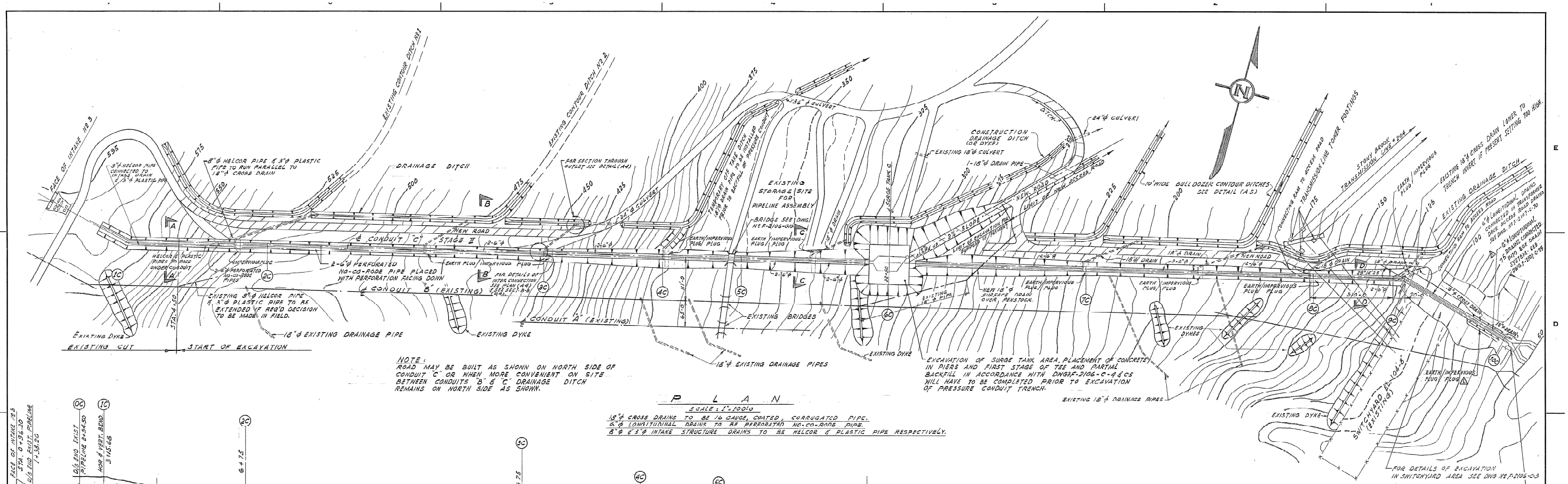
NEWFOUNDLAND AND LABRADOR POWER COMMISSION

BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY SHAWMONT NEWFOUNDLAND LIMITED ST JOHN'S NEWFOUNDLAND

PRESSURE CONDUIT "C" & SURGE TANK "C" BACKFILL DETAILS

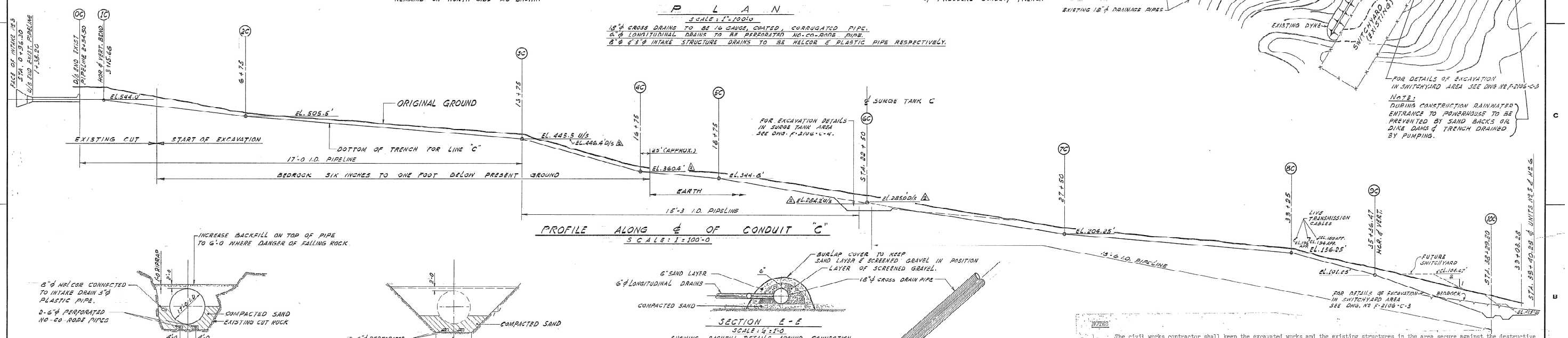
CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	AS SHOWN	2-15	5TH SEPT. 1968	F-210G-C-9	2.



PLAN

SCALE: 1"=100'-0

18"ϕ CROSS DRAINS TO BE 16 GAUGE, COATED, CORRUGATED PIPE.
6"ϕ LONGITUDINAL DRAINS TO BE PERFORATED NO-CO-RODE PIPE.
8"ϕ & 3"ϕ INTAKE STRUCTURE DRAINS TO BE HELCOR & PLASTIC PIPE RESPECTIVELY.



PROFILE ALONG ℄ OF CONDUIT "C"

SCALE: 1:100-0

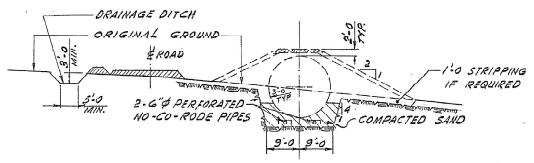
SECTION A-A

SCALE: 1"=20'-0

SECTION D-D

SCALE: 1"=20'-0

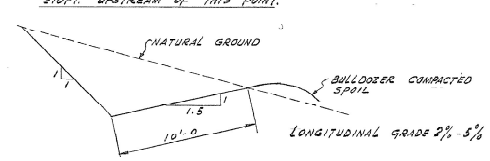
SECTION OF SPECIALLY EXCAVATED TRENCH FOR ERECTION OF PRESSURE CONDUIT UNDER TRANSMISSION LINE FROM A POINT 30 FT. U/S OF BEND 3C AND EXTENDING 20 FT. DOWNSTREAM OF THIS POINT.



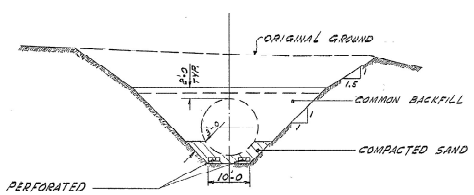
SECTION B-B

SCALE: 1"=20'-0

TYPICAL SECTION THROUGH ROCK CUT



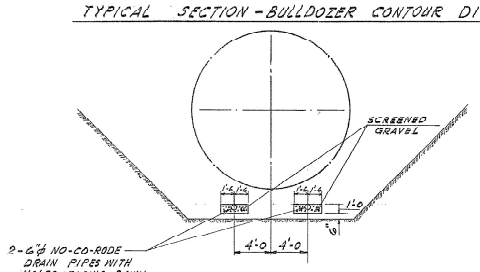
TYPICAL SECTION - BULLDOZER CONTOUR DITCH



SECTION C-C

SCALE: 1"=20'-0

TYPICAL SECTION THROUGH EARTH CUT



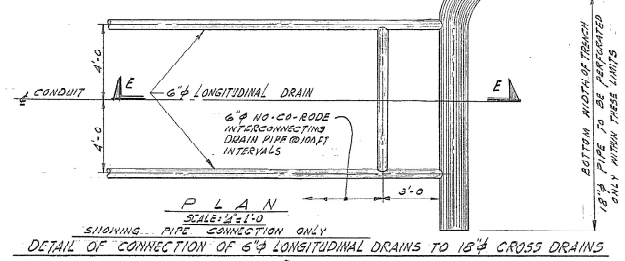
DETAIL OF DRAIN

SCALE: ½"=1'-0

SECTION E-E

SCALE: ¼"=1'-0

SHOWING BACKFILL DETAILS AROUND CONNECTION

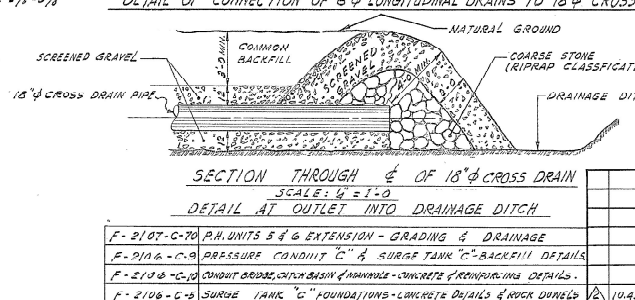


PLAN

SCALE: ¼"=1'-0

SHOWING PIPE CONNECTION ONLY

DETAIL OF CONNECTION OF 6"ϕ LONGITUDINAL DRAINS TO 18"ϕ CROSS DRAINS



SECTION THROUGH ℄ OF 18"ϕ CROSS DRAIN

SCALE: ¼"=1'-0

DETAIL AT OUTLET INTO DRAINAGE DITCH

NOTES

1. The civil works contractor shall keep the excavated works and the existing structures in the area secure against the destructive effects of the maximum expected storm water.
2. When a section of the pressure conduit trench to be left open for an appreciable length of time, the trench shall be closed with a 6'-0" high plug of compacted selected common backfill. This plug shall be placed immediately upstream of the end of conduit and shall have sufficient drains to insure adequate control of run-off at all times during construction. The Engineer's decision of the adequacy of the contractor's provisions for drainage shall be final and binding.
3. For sequence of erection of pressure conduit "C" see Drawing No. F-2106-C-1.
4. New roads are shown as cross hatched.
5. 18 in. dia. cross drains to be installed when the conduit trench is being excavated. The unexcavated earth plugs (Clause C2.6) shall be left immediately downstream of the 18 in. dia. cross drains. The connection of the cross drains to the longitudinal drains shall be done after the erection of the conduit and just prior to the back-filling.
6. The location of the cross drains and earth plugs are approximate and the actual positions are to be determined in the field to the approval of the Engineer.
7. Impervious plugs (Clause C3.3). After erection of the conduit, the trench shall be filled to 1 ft. above the top of the pipe or to original grade, where this is below the top of the pipe, with selected common fill for a length of 6 feet at a point immediately downstream of the 18 in. dia. cross drains, to form a permanent impervious plug across the trench.
8. All the work indicated on this drawing must be done in accordance with Spec. M2-3714. Reference should be made to the following clauses:-
   C1 - Unwatering
   C2 - Excavation
   C3 - Backfill & Grading
   C4 - Foundation Drains

REFERENCE DRAWINGS.	
F-2107-C-70	P.H. UNITS 5 & 6 EXTENSION - GRADING & DRAINAGE
F-2106-C-9	PRESSURE CONDUIT "C" & SURGE TANK "C" - BACKFILL DETAILS
F-2104-C-10	CONDUIT CROSS-DITCH BASIN & DRAINAGE - CONCRETE & RECONDITIONING DETAILS.
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS
F-2106-C-4	SURGE TANK "C" EXCAVATION & BACKFILL.
F-2106-C-3	PRESSURE CONDUIT "C" EXCAVATION DETAILS - LOCAL TO SWITCHYARD EMBANKMENT
F-2106-C-1	PRESSURE CONDUIT "C" PLAN, PROFILE AND DETAILS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
4	10.4.63	C.5	EL. 445.5' U/S AT BENT 3C ADDED; EL. 360.6' AT BEND 4C REVISED; WAS EL. 360.1'		
3	1.1.63	D.1.	EL. 284.0' U/S & EL. 285.0' U/S & D/S; & EL. 285.0' D/S REVISED; WAS EL. 286.0' U/S & EL. 287.0' D/S. DRAINAGE DETAILS BETWEEN BENDS 9C & 10C SHOWN	K.C.	D.B.
				T.C.D.	D.B.

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 26 1968
APPROVED BY: [signature] CHIEF ENGINEER
Per [signature]

PASSED: CONST. | TRANSM | ELECT'L | CIVIL

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

PRESSURE CONDUIT "C"
EXCAVATION AND DRAINAGE

DESIGNED	DRAWN	CHECKED	RECOMMENDED
D.B.	K.C.	D.B.	R.H.L.

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	As Noted	2-15	July 24, 1968	F-2106-C-8	2

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

BAY D'ESPOIR DEVELOPMENT

PENSTOCK NO. 3

ENGINEERING DESIGN BY

SHAWMONT NEWFOUNDLAND LIMITED

MONTREAL, QUEBEC

PRESSURE CONDUIT "C"

PLAN, PROFILE & DETAILS

DESIGNED	DRAWN	CHECKED	RECOMMENDED	APPROVED
	AR	AP	AP	

CONTRACT	SCALE	FILE NO	DATE	DWG NO	REVISION
	AS NOTED	2-15	APR18-68	F-2106-C-1	1

PASSED			
TRANS'N	ELECT'L	CIVIL	

FINAL

REVISIONS					
NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
1	APR18		EL. AT SURGE TANK TOP WAS 893.88	JLB	

REFERENCE DRAWINGS:	
DWG NO	TITLE
F-2106-C-5	SURGE TANK 'C' - FOUNDATION & CONCRETE DETAILS
F-2106-C-4	SURGE TANK 'C' - EXCAVATION & BACKFILL
F-2106-C-3	PRESSURE CONDUIT 'C' & SURGE TANK 'C' EXCAVATION & DRAINAGE
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS

FOR INFORMATION PURPOSES ONLY

NOTES
1) THIS DRAWING TO BE READ IN CONJUNCTION WITH SPECIFICATION M2-3714
2) WHEN A SECTION OF THE PRESSURE CONDUIT TENCH IS TO BE LEFT OPEN FOR AN APPRECIABLE LENGTH OF TIME, THE TRENCH SHALL BE CLOSED WITH A 4'-0" WIDE PLUG OF COMPACTED SELECTED COMMON MATERIAL. THIS PLUG SHALL BE PLACED IMMEDIATELY UPSTREAM OF THE END OF THE CONDUIT AND SHALL HAVE SUFFICIENT DRAINS TO INSURE ADEQUATE CONTROL OF RUNOFF AT ALL TIMES DURING CONSTRUCTION. THE ENGINEERS DECISION ON THE ADEQUACY OF THE CONTRACTOR'S PROVISIONS FOR DRAINAGE SHALL BE FINAL AND BINDING

NOTE
FOR DETAIL OF DRAINS SEE DRAWING No F-2020-C-109

TYP. SECTION THRU ROCK
SCALE 1"=10'

TYP. SECTION-SHALLOW EXCAVATION
SCALE 1"=10'

TYP. SECTION-DEEP EXCAVATION
SCALE 1"=10'

ELEVATION ALONG ℄ OF BIFURCATION
SCALE 1"=20'

PLAN OF BIFURCATION
SCALE 1"=20'

PROFILE ALONG ℄ OF CONDUIT "C"
SCALE 1"=100'

PROFILE AT ℄ OF TRANSMISSION LINES BETWEEN TOWER ℄ SWITCHYARD
SCALE 1"=100'

PLAN
SCALE 1"=200'

EXTENT OF PAGE CONDUIT ERECTION TO BE ERECTED UPHILL

FIRST HALF 1969 CONDUIT ERECTION TO BE ERECTED UPHILL

SECOND HALF 1969 CONDUIT ERECTION TO BE ERECTED DOWNHILL

HYDRAULIC GRADIENT

CONDUIT THROUGH DAM

POWER CANAL

INTAKE

SURGE TANK A EXISTING

SURGE TANK B EXISTING

SURGE TANK C STAGE II

CONDUIT A EXISTING

CONDUIT B EXISTING

CONDUIT C STAGE II

CONSTRUCTION TYPE ROAD

SWITCHYARD EXISTING

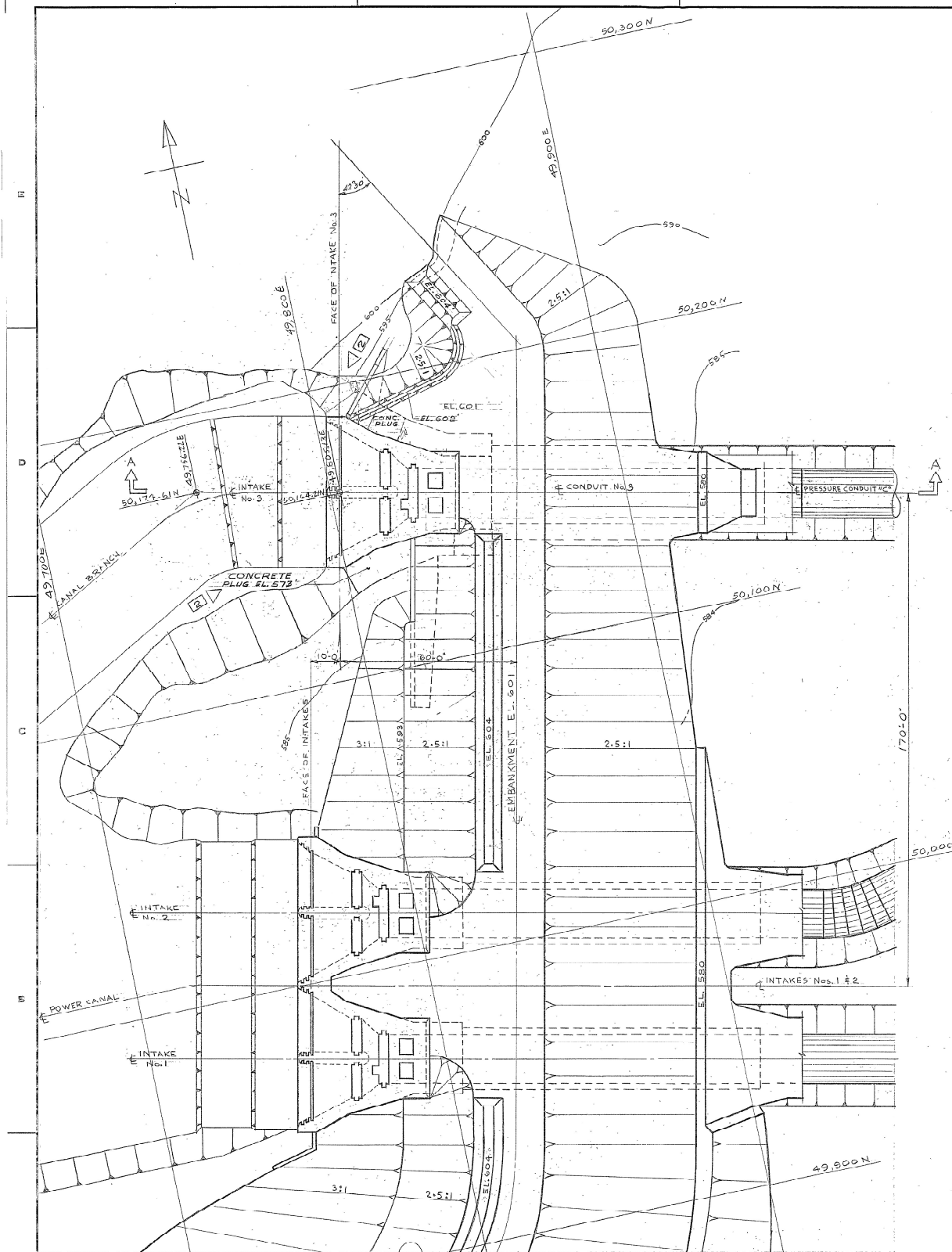
POWERHOUSE EXISTING

SWITCHYARD PROPOSED

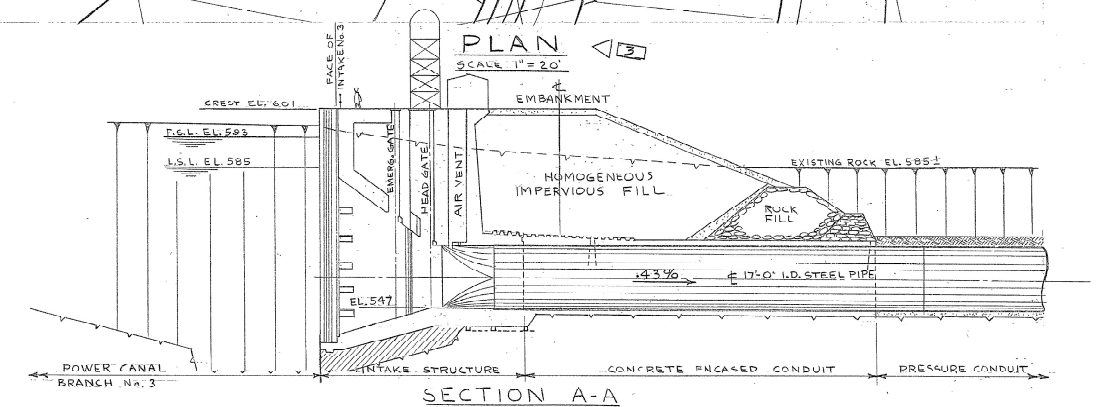
TAILRACE CHANNEL

ROAD TO STAGE NO 3

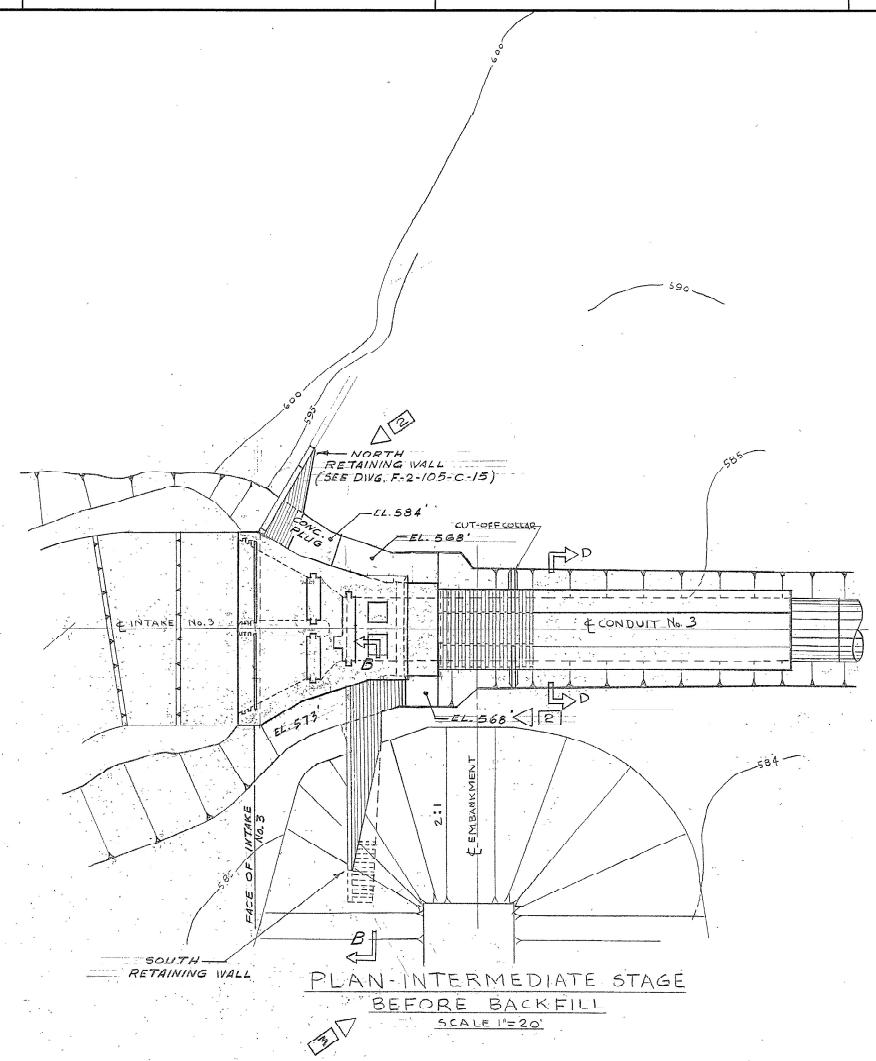
LOWER BROOK



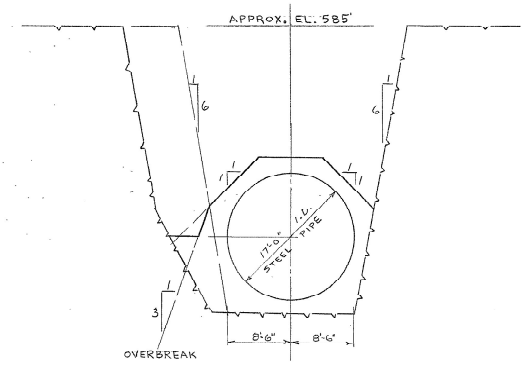
PLAN
SCALE 1"=20'



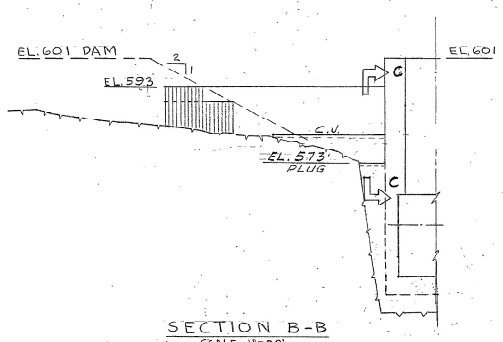
SECTION A-A
SCALE 1"=20'



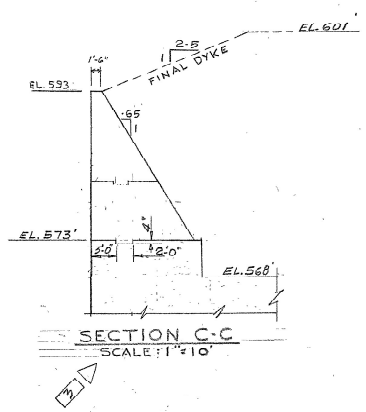
PLAN-INTERMEDIATE STAGE
BEFORE BACKFILL
SCALE 1"=20'



SECTION D-D
SHOWING CONDUIT THRU DAM
SCALE 1"=10'



SECTION B-B
SCALE 1"=20'



SECTION C-C
SCALE 1"=10'

NOTES

1. THIS IS A GENERAL LAYOUT DRAWING. KEY ELEVATIONS AND DIMENSIONS ONLY ARE SHOWN. FOR ALL DETAILS, REFER TO LARGER SCALE, PARTICULAR DRAWINGS OF THE SPECIFIC PART INVOLVED.
2. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH THE SPECIFICATIONS OF THE GENERAL CONTRACT DOCUMENTS.
3. DURING THE INTERMEDIATE STAGE, THE EARTH DAM WILL NOT BE PLACED IN THE AREA BEHIND THE INTAKE STRUCTURE

THE FOREBAY WATER WILL BE CONTAINED DURING THIS PERIOD BY THE SYSTEM OF CONCRETE PLUGS, RETAINING WALLS AND INTAKE STRUCTURE.
INTAKE STABILITY DURING THIS PERIOD DEPENDS ON THE CONCRETE PLUGS POURED TO SOUND ROCK AND CLOSURE IN THE INTAKE MADE WITH THE HEAD GATE.

4. DESIGN CRITERIA FOR INTAKE LISTED ON DWG. F-2-105-C-2.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

FINAL

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	11-5-67		AS BUILT, FROM FIELD INFORMATION	A.R.	JHM
2	1-12-66		NORTH RETAINING WALL MOVED FORWARD PLUGS CHANGED	A.R.	JHM
1	780-66	—	CONC. RETAINING WALLS & EMBANKMENT REVISED	A.R.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 12 1966
APPROVED: J.C. Bonnell
MANAGER ENGINEERING

PASSED: TRACED | BLUEPRINT | CHECKED JHM

DESIGNED: HC
DRAWN: A.R.
CHECKED:
RECOMMENDED: J H Morrice Ed

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

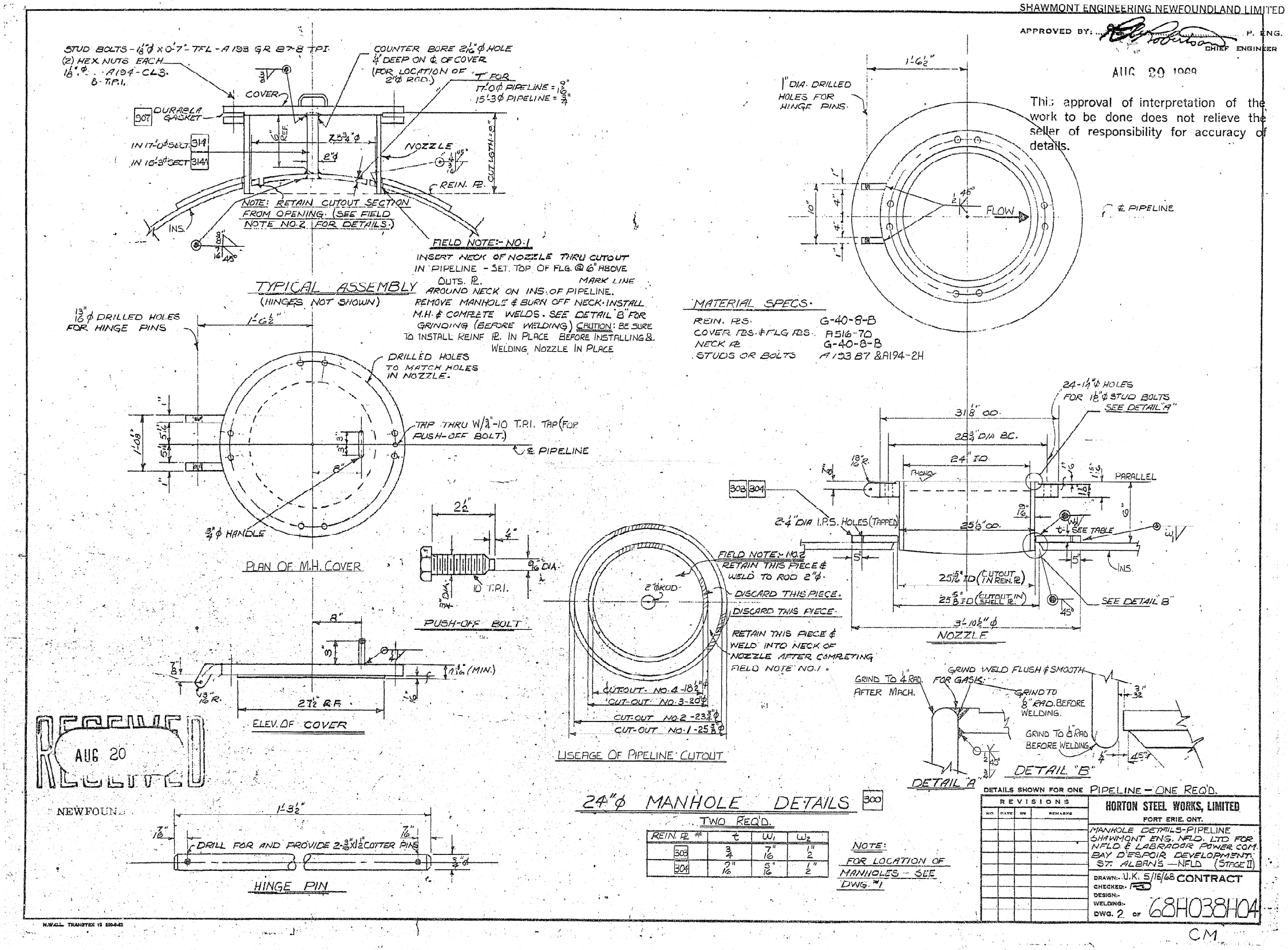
INTAKE No. 3
GENERAL LAYOUT

CONTRACT	SCALE	FILE NO	DATE	DWG NO	REVISION
	NOTED	PD-11	9 SEPT. 66	F-2-105-C-1	3

12 X

APPROVED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
APPROVED BY: ..... P. ENG.
CHIEF ENGINEER
AUG 20 1968

This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.



REIN. PL. #	t	W_1	W_2
303	3/4	7/16"	1/2"
304	7/16"	5/16"	1/2"

RECEIVED
AUG 20
NEWFOUN...
FILE COPY
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
LICENSE NO.
DWG. B.ESPOIR

APPROVED

SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED

APPROVED BY: ..... P. ENG. CHIEF ENGINEER

OCT 22 1968

This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.

RECEIVED OCT 24

SHAWMONT NEWFOUNDLAND LTD.

PLAN OF PIPELINE "C"

LENGTH ALONG ℄ OF 17'-0" I.D. PIPELINE = 1125'-1 19/32"

LENGTH ALONG ℄ OF 15'-3" I.D. PIPELINE = 876'-6 5/32"

A285 Fbx. STEEL — G40.8B STEEL — STIFFENERS MK 49 — STIFFENERS MK 46 — G40.8B STEEL — OX522-D STEEL — G40.8B STEEL STIFFENERS

SECT. #2 — SECT. #3 — SECT. #4 — SECT. #5 — SECT. #6

ELBOW #2C — ELBOW #3C — ELBOW #4C

START OF PIPELINE — FLOW

PIPE LINE 68H038H04 — SURGE TANK T.E.E. 68H038H02 — SURGE TANK 68H038H05 — FENSTOCK 68H038H03 — BIFURCATION 68H038H01

KEY ELEVATION

ELEVATION OF PIPELINE "C"

℄ M.H. MK 300 — ℄ OF TEE — 125'-0" — 312'-1" — 200'-7 3/32" — 363'-10 7/16" — 16'-0"

3 SP (7/16") @ 8'-8 1/16" = 26'-0" — 31 SP (11/16") @ 9'-10 3/8" = 306'-5 3/8" — 32 SP (7/16") @ 9'-10 3/8" = 316'-4" — 37 SP (7/16") @ 9'-10 3/8" = 365'-6 7/32" — 3 SP (7/16") @ 9'-1 1/4" = 27'-3 3/4" — 3 SP (7/16") @ 9'-0 1/8" = 27'-1 3/8" — 2 SP (7/16") @ 9'-0" = 18'-0" — 3 SP (7/16") @ 9'-0" = 27'-0" — 5 SP (5/8") @ 9'-0" = 36'-0" — 2 SP (5/8") @ 9'-0" = 18'-0" — 3 SP (5/8") @ 9'-0" = 27'-0" — 5 SP (5/8") @ 9'-10 3/8" = 49'-1 7/8" — 2 SP (5/8") @ 9'-10 3/8" = 19'-8 3/4" — 3 SP (5/8") @ 9'-10 3/8" = 29'-5 1/8" — 5 SP (5/8") @ 9'-10 3/8" = 49'-1 7/8" — 3A SP (5/8") @ 9'-10 3/8" = 29'-5 1/8" — 3 SP (5/8") @ 9'-10 3/8" = 29'-5 1/8" — 1 SP (5/8") @ 9'-10 3/8" = 9'-10 3/8" — 155'-5 3/32" (5/8") MATERIAL @ SITE 4 SP @ 35'-9" = 143'-0" — 52'-11 3/4" (5/8") MATERIAL @ SITE — 72'-8" (3/4") MATERIAL @ SITE

ELBOW #2C SEE DETAIL — ELBOW #3C SEE DETAIL — ELBOW #4C SEE DETAIL — ELBOW #5C SEE DETAIL

P. MK 4 INCL. 1'-0" EXTRA FOR TRIM. IN FIELD

MATERIAL AT SITE.				
NEW MARK	OLD MARK	P. THICK	Nº SECTS	MATERIAL TRIMMING
1	35	3/4"	1-4 RING	36'-5"
1	35	3/4"	1-4 RING	36'-5"
7	34	5/8"	1-4 RING	34'-4"
8	34	5/8"	1-3 RING	33'-9 1/16"
	33	5/8"	1-1 RING	
9	33	5/8"	1-4 RING	31'-10 3/4"
12	33	5/8"	CUT FROM ABOVE	
13	29	5/8"	1-4 RING	35'-10 1/4"
13	29	5/8"	1-4 RING	35'-10 1/4"
13	29	5/8"	1-4 RING	35'-10 1/4"
13	29	5/8"	1-4 RING	35'-10 1/4"
19	28	9/16"	1-4 RING	36'-3 3/8"
20	28	9/16"	1-4 RING	36'-3 3/8"
	27	5/8"	1/2-4 RING	35'-10 1/4"
21	23	9/16"	1-4 RING	33'-0 1/4"
45	12	1/2"	1/2-1 RING	18'-11 3/8"
44	107	1/16"	1/2-1 RING	9'-1 1/4"

FIELD LOCATION OF KEY NUTS (AT ENDS OF FIELD FAB'D. SECT'S)

17'-0" ϕ SECT.

FIELD LOCATION OF KEY NUTS (AT ENDS OF FIELD FAB'D. SECT'S.)

15'-3" ϕ SECT.

FIELD: TRANSFER PUNCH MKS. TO OUTS. IF REQ'D.

UPPER R.'S — LOWER R.'S — ALTERNATE LONGL. JTS. — PUNCH MKS. ON INS. AT BOTH ENDS OF R.'S

9 EQUAL SPC'S @ ABT. 2'-11 1/2" — 8 EQUAL SPC'S @ ABT. 2'-11 3/8"

VERT. ℄ — HORIZ. ℄

ORIENTATION OF R.'S LOOKING UPSTREAM EXCEPT AT ELBOWS — SEE ELEV. OR PLAN VIEW.

VERT. ℄ — 24" ϕ OPENING — ARC = 2'-6" APPROX.

FIELD NOTES: FOR ERECTION PURPOSES — LOCATE 24" ϕ OPENINGS APPROX. 2'-6" OFF BOTT. ℄ AS SHOWN & APPROX. 200'-0" APART, LOCATED TO SUIT, CUTOUTS TO BE RETAINED & REWELDED INTO OPENINGS AFTER COMPLETION OF ERECTION. (EDGE PREP TO SUIT R. THICKNESS.)

ANGLE IN PLAN — VERTICAL ANGLE

BEND	∠ "A"	∠ "B"	∠ "C"	TRUE ℒ	R. THICK	RAD.
1C	26°09'31"	0°15'10"	6°07'25"	26°45'26"	1/2"	45'-0"
2C	6°07'25"	4°53'57"	1°13'28"		1/2"	45'-0"
3C	4°53'57"	15°59'45"	11°05'48"		1/2"	45'-0"
4C	15°59'45"	4°26'35"	11°33'10"		3/4"	38'-6"
5C	4°26'35"	9°11'00"	4°44'25"		3/4"	38'-6"

46 46A 47 48 49 49A ∠ 5"X3"X3/8" — 2"X3/8" BILL BAR 59 TACK WELD TO STIFFENERS — OUTS. PIPELINE — 3/4"ϕ RND. HOLE — VIEW "A-A"

DETAIL OF STIFFENERS ON PIPELINE.

SPACING = 12'-3" APPROX. - ADJUST SPACING IF NECESSARY SUCH THAT STIFFS. DO NOT COME WITHIN 5' OF CIRCUM. JTS.

NOTE: ALL STIFFENERS MADE FROM A36 EXCEPT MK. 49A - (G40.12).

TRUE VIEW OF ELBOW # 1C.

TWIST = 1'-4 1/2" OUTS. R. — TOP ℄ PIPELINE — HORIZ. JT. — TAPER ELBOW — 17'-3 3/4" — 17'-9 3/16" — SPC'D @ 12'-3" TO INLET — 6'-1 1/2" — 3-SPC'S @ 12'-3" TO STIFFENER MK 49

DETAIL OF ELBOW # 2C (ELEVATION)

TWIST = 1'-6 1/16" ON OUTS. R. — TOP ℄ PIPELINE — VERT. JT. — W.P. — 9'-9 1/2" — SPC'D @ 12'-3" TO STIFFENER MK 49A — SPC'D @ 12'-3" TO ELBOW # 3C.

DETAIL OF ELBOW # 3C (ELEVATION)

SPC'D @ 12'-3" TO ELBW. # 2C. — 10'-10 7/16" — HORIZ. JT. — W.P. — 17'-0" I.D. — 6'-1 1/2" SPC'D @ 12'-3" TO ELBOW # 4C — 10'-10 7/16" — 15'-3" I.D. — SPC'D @ 12'-3" TO ELBOW # 2C.

DETAIL OF ELBOW # 4C (ELEVATION)

SPC'D @ 12'-3" TO ELBW. # 3C — 10'-4 7/8" — 6'-1 1/2" — SPC'D @ 12'-3" TO ELBOW # 5C.

DETAIL OF ELBOW # 5C (ELEVATION)

SPC'D @ 12'-3" TO ELBW. # 4C — 6'-1 1/2" — 7'-8 3/4" — SPC'D @ 12'-3" TO TEE — VERT. JT. — HORIZ. JT. — W.P.

GENERAL NOTES:-

PIPELINE R. - A285 Fbx., G40.8B. & OX522-D

R.'S FLUSH ON INS. OF PIPELINE

MAX. OFFSET OF INNER SURFACES 3/32"

PAINT - YES.

MATL. SPECS - M.2.-3664

CUST. P.O. -

SEE ALSO SPECIAL SHOP INSTRUCTIONS FOR TOLERANCES & FURTHER NOTES

⚠ -W.O's. "OM." TO "OM.3" INCLUSIVE

SEE ALSO SPECIAL FIELD INSTRUCTIONS FOR TOLERANCES & FURTHER NOTES

⚠ -W.O's. "ON." TO "ON.6" INCLUSIVE.

100% X-RAY ALL VERT. & LONGL. SEAMS

DETAILS SHOWN FOR ONE PIPELINE - ONE REQ'D.

REVISIONS				HORTON STEEL WORKS, LIMITED FORT ERIE, ONT.
NO.	DATE	BY	REMARKS	GENERAL PLAN 17'-0" & 15'-3" PIPELINE
1	7/68	J.K.	GEN. REVISIONS	SHAWMONT ENG. NFLD. LTD. - CONSULT. ENG.
⚠	8/68	J.K.	REV. SPC'S 9 & 8 EQUAL SPC'S	FOR NFLD. & LABRADOR POWER COMM.
⚠	9/68	J.K.	REV. TAPER ELBOW	BAY d'ESPOIR - HYDRO ELEC. DEVELOP.
⚠	10/68	J.K.	DIST. MARKED ON PIPE WERE WRONG	ST. ALBANS, NFLD. (STAGE III)
⚠	10/68	J.K.	ADD'L PIPE FABD.	DRAWN: J.K. 5/8/68 CONTRACT
				CHECKED:
				DESIGN:
				WELDING:
				DWG. 1 OF 68H038H04

C.M.

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 75 of 212

APPENDIX B

RISK ASSESSMENT REPORT PENSTOCK 2 AND 3

RISK ASSESSMENT: PENSTOCK 2/3

BAY D'ESPOIR HYDRO SITE

FRONT END ENGINEERING AND DESIGN

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
Kleinschmidt Associates

September 2021

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NL Hydro) is reviewing four options regarding the long-term life extension of Bay d'Espoir Penstocks 1, 2, and 3 to provide asset integrity and reliability at best value to rate payers. A decision support package is being developed to facilitate NL Hydro's decision-making process for each of the three penstocks regarding which option to advance. The decision support package will evaluate the costs, benefits, viability, life expectancy, and risks and reliability associated with each option for each penstock. Kleinschmidt Associates Canada Inc. (Kleinschmidt)'s Risk Assessment Report focuses on risks for each life extension option associated with Penstocks No. 2 and 3 and will be appended to and summarized in the Decision Support Package for Penstock 2 and 3.

The options evaluated to refurbish Penstocks 2/3 are as follows:

- ***Option 1*** (No Rehabilitation) - No refurbishment of the penstock with continued operational and maintenance procedures only. Repairs to be completed on an as needed basis.
- ***Option 2*** (Weld refurbishment) - Refurbishment of deteriorated circumferential and longitudinal weld seams including resurfacing and recoating of the penstock interior. Welds to be refurbished will be selected after inspection of all welds.
- ***Option 3*** (Section Replacement) - Replacement of the 17-foot diameter section of penstock plus weld refurbishment and recoating of the interior of the smaller diameter sections of the penstock. Welds to be refurbished will be selected after inspection of all welds.
- ***Option 4*** (Weld Reinforcement) - Refurbishment of deteriorated welds, recoating of the entire interior of the penstock and reinforcement of the longitudinal and circumferential welds in the 17-foot diameter penstock section with reinforcing plates. Welds to be refurbished will be selected after inspection of all welds.

A risk assessment workshop was conducted to evaluate risks associated with the various aspects of the life extension options for Penstock 2 and 3 and is documented in this report. Identified risks for the four life extension options were compiled in a risk registry (Appendix A). For each identified risk, the impact severity and probability of occurrence was determined. The risk assessment workshop was one of the most significant steps in the risk assessment process with a multi-disciplinary team including participants with

various relevant technical and operational backgrounds contributing to the assessment. The workshop team included engineering consultants with specialties in penstocks, welding, construction, and hydropower, and NL Hydro representatives from engineering, operations, and management. The risk workshop team worked together to identify and describe risks associated with each life extension option. The consequences and likelihood of each risk occurrence were used to develop a risk rating for each item.

Option 1 was determined by the Team to be high risk due to the elevated probability of multiple failures and significant costs over the next 30 years. Operational constraints over 30 years and negative public and government opinion of failures at the local and provincial level add to the negative impacts of this option. One risk item for Option 1 associated with overall general corrosion of the penstocks had a risk rating of 16, the highest possible risk rating. Risk of localized failure in the 17 ft diameter section was given a risk rating of 12, which is the second highest rating but lower than the rating developed for Penstock 2 and 3 for this same item. Kleinschmidt believes the level of risk associated with Option 1, with the increased probability of failures and high consequence, exceeds what should be tolerated making Option 1 not viable in our opinion. There are no mitigating measures for Option 1 that can adequately reduce the elevated risks without going to Options 2, 3, or 4.

The evaluation of Option 2 identified five risk items having a pre-mitigation high-risk rating of 9. These five items are pre-construction or construction related and can be mitigated down to a moderate risk rating. However, an additional high risk item associated with potential steel thickness loss due to required abrasive surface preparation for the application a coating was identified for Penstock 2 and 3 and was assigned a risk rating of 12. The Team identified that the number of times to recoat with abrasive surface preparation may be limited to one during the 30 year period. The Team concluded that Option 2 was viable though not ideal as issues related to peaking and fatigue are not addressed, and operational constraints will remain.

Option 3 identified four risk items having a pre-mitigation high-risk rating of 9. These four items are pre-construction or construction related and can be mitigated down to a moderate risk rating. The Team concluded that this Option was viable and adequately mitigated the peaking and fatigue issues in the larger diameter section of Penstock 2 and 3 allowing operational constraints to be lifted.

Option 4 identified seven risk items having a pre-mitigation high-risk rating of 9. Five of the items are pre-construction or construction related and can be mitigated down to a moderate risk rating. Two of the items are related to the installation of reinforcing plates and are unique to Option 4. The Team concluded that this Option was viable, however it did not adequately deal with the peaking and fatigue issues in the larger diameter sections of Penstock 2 and 3, meaning operational constraints would not be recommended to be lifted. The cost and installation of the plates may outweigh the benefits of this option.

Based on this assessment and risk profiles for each option, Option 3 is the lowest risk option and is the only option that could restore the units to normal operations. Option 3 also has the lowest risk in terms of post-mitigated cost increases or schedule days. Option 1 is the highest risk option and requires a continuation of operational limitations and yearly weld inspections.

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1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NL Hydro) is reviewing four options regarding the long-term life extension of Bay d'Espoir Penstocks 1, 2, and 3 to provide asset integrity and reliability at best value to rate payers. For NL Hydro to make prudent and justifiable investment decisions regarding the long-term life of these penstocks, studies are being conducted to develop a Decision Support Package. The decision support package will evaluate the costs, benefits, viability, life expectancy, risks and reliability associated with each option. This Risk Report focuses on risks for each life extension option and will be appended to and summarized in the Decision Support Package.

To complete a thorough risk assessment Kleinschmidt Associates Canada Inc. (Kleinschmidt) facilitated and documented a risk assessment workshop. The workshop evaluated risks associated with the various aspects of the life extension options for Penstock 2 and 3. A separate risk assessment and decision support package was developed for Penstock 1 because the multiple operational failures of Penstock 1, that did not happen with Penstocks 2 or 3, created the urgency and impression that Penstock 1 should be handled separately as it may have different risks, results, and recommendations.

This summary report documents the Penstock 2 and 3 workshop outcomes and analysis of the data. Current and expected risks are discussed in the report as well as methods of mitigation. The risks were identified for each option, compiled in a risk registry, and rated with impact severity and probability of occurrence documented. The penstock life extension options were evaluated for risks related to cost, schedule, reliability, safety, reputation, and life expectancy.

The options evaluated to refurbish, repair, or replace Penstock 2 and 3 are as follows:

- ***Option 1*** - No refurbishment of the penstocks with continued operational and maintenance procedures only. Repairs to be completed on an as needed basis.
- ***Option 2*** - Refurbishment of deteriorated circumferential and longitudinal weld seams including resurfacing and recoating of the penstock interior. Welds to be refurbished will be selected after inspection of all welds.
- ***Option 3*** - Replacement of the 17-foot diameter section of penstock plus weld refurbishment and recoating of the interior of the smaller diameter section of penstock. Welds to be refurbished will be selected after inspection of all welds.

- ***Option 4*** **-** Refurbishment of deteriorated welds, recoating of the entire interior of the penstock and reinforcement of the longitudinal and circumferential welds in the 17-foot diameter penstock section with reinforcing plates. Welds to be refurbished will be selected after inspection of all welds.

The risk assessment in this phase of the study is intended to highlight the consequential risks associated with each alternative and to compare the four options on the basis of risk. The risk comparison will feed into the Decision Support Package as a component of the overall discussion and comparison of the life extension options. These discussions and comparisons will support a recommendation for which option to proceed. Once a decision has been made to move forward with a specific option, a more detailed risk assessment thoroughly reviewing the execution of the chosen option, and detailing costs, schedule, and mitigating actions will be performed.

It is assumed that for all life extension options that there will be lessons learned if Penstock 1 refurbishment is completed first before Penstock 2 and 3. The assumption is that the chosen Option would proceed faster and more efficiently due to the experience gained from Penstock 1 repairs.

Penstock 2 is located between Penstock 1 and 3 which may pose challenges during construction and excavation for the different life extension options due to the location of Penstock 2 between Penstocks 1 and 3 and their proximity.

2.0 RISK ASSESSMENT METHODOLOGY

A risk assessment methodology was developed to identify risks associated with each option and to develop means to compare risks between each option.

The first step in any risk assessment process is to identify risks and then to determine their consequences and likelihood of occurrence to develop a risk rating. To accomplish this a semi-quantitative risk assessment workshop was completed virtually. A multidisciplinary team with specific technical and operational backgrounds was assembled to participate in the workshop. The workshop team included engineering consultants with specialties in penstocks, welding, construction, and hydropower, and NL Hydro representatives from engineering, operations, and management. The risk assessment workshop team (Team) included:

- Dylan Drake, Project Manager, NL Hydro
- Jeff Williams, Project Engineer, NL Hydro
- Julia Hiscock, Engineering Services, NL Hydro
- Matt Lambert, Long Term Asset Planning, NL Hydro
- Brent Peddle, Manager Long Term Asset Planning, NL Hydro
- Karl Inkpen, Work Execution Manager, NL Hydro
- Chris Vella, Facilitator, Project Engineer, Kleinschmidt
- Tim Saville, Project manager, Kleinschmidt
- Stig Skarborn, Welding Engineer, Skarborn Engineering
- Ted Chant, Construction Management, Chant
- Nancy Sutherland, Structural Engineer, Kleinschmidt
- Nick Townsend, Civil/structural Engineer and Note taker, Kleinschmidt

The workshop focused on consequential risks with the goal of collecting reliable data from an experienced and diverse team, from which differences between the risk profiles of each option can be assessed. A Risk Register was developed to record the risks and ratings during the workshop and can be found in Appendix A. Risks were identified in a round table discussion and once a specific risk was identified the risk description was developed to focus our understanding of the risk. Risks for each option were developed with the consideration of extending operations for thirty years. Risk likelihood, cost impacts,

schedule impacts, and other potential impacts were discussed and rated based on available data and experience. The risk items in the registry are listed in the order in which they were developed while Sections 3 to 6 of this report groups the items for discussion purposes.

A 4 by 4 matrix was utilized to develop a rating for each risk item. The matrix operates by assigning each risk item a likelihood and an impact score to obtain a risk rating. The risk rating is the product of the risk likelihood multiplied by the most significant risk impact. The risk matrix is illustrated in Figure 2.1. The numerical interpretation of the likelihood and impact values are provided in Table 2-1. Different size matrices were considered for this project; however, a 3 by 3 matrix was determined not to be detailed enough and would hinder comparison of the options by not showing enough differentiation between risks. A 5 by 5 matrix was strongly considered but was found to be more detailed than was warranted by the available data and ability to estimate likelihood of occurrence. The 4 by 4 matrix was found to be detailed enough to properly compare the options, sized appropriately for the level of detail available, within 25% accuracy, but not so detailed as to be impractical for use during a large workshop.

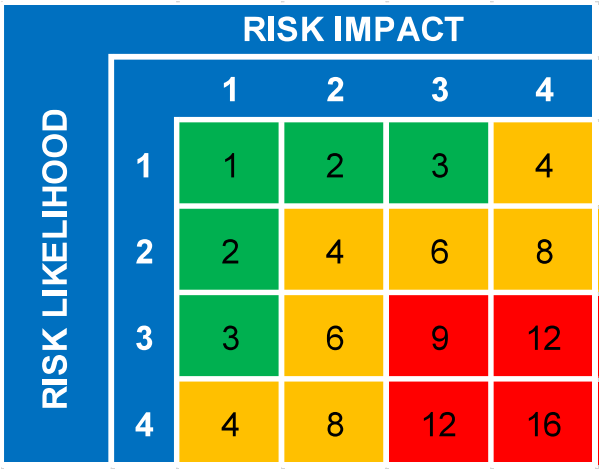

Figure 2.1 Risk Assessment Matrix

Kleinschmidt reviewed and considered NL Hydro's Enterprise Risk Management Framework and Procedures for use in this analysis, but it was determined to be less appropriate for this exercise in comparing the risk profiles for the four options.

Table 2-1 Matrix Value Interpretation

Matrix Value	Likelihood	Cost Impact	Schedule Impact	Other Impact
1	Very Unlikely	$0 to $100K	0 Weeks to 2 weeks	Little
2	Somewhat Unlikely	$100K to $500K	2 Weeks to 1 Month	Some
3	Somewhat Likely	$500K to $5M	1 Month to 4 Months	Significant
4	Highly Likely	$5M +	4+ Months	Ruinous

The risk rating values obtained from the risk matrix are grouped into three categories, Low (green), Moderate (yellow), High (red). If the risk rating is between the values of 1 and 3, the risks are assessed as low, and no action is needed. Risk rating values between 4 and 8 are assessed as moderate risks that will be managed using appropriate risk response and mitigating actions. Risk rating values between 9 and 16 are assessed as high risks that may result in option re-evaluation if appropriate risk mitigation cannot reduce the rating to an acceptable risk rating of 8 or lower. It is imperative that high risk items are mitigated down to an acceptable risk rating.

This risk assessment is considered semi-quantitative as costing data for each option prepared prior to the workshop along with historic repair costs and repair schedules were used to estimate and rate consequences. The risk assessment is not considered to be fully quantitative as an accurate determination of specific costs, such as in an opinion of cost estimate, was not developed for each risk item. The assessment rises above a qualitative analysis as it does more than identify the risks and assign a general risk description. For purposes of comparing the options in terms of risk a semi-quantitative analysis was determined to have the appropriate level of detail to facilitate a thorough comparison from which justifiable decisions can be made.

Risk mitigation was discussed and recorded for each risk item and a post-mitigation risk value was assessed and recorded as appropriate. A more detailed mitigation evaluation for project execution will be performed for the selected option following Decision Gate 1. A significant amount of discussion was had for some risk items and the highlights of these discussions were summarized in the notes section of the risk register. A qualitative discussion of identified risks is provided in Sections 3 to 6. The data from the Risk Register is also used to develop comparisons, such as normal distributions of the risk ratings for comparing relative risk of the options, and cumulative cost versus probability plots for comparing the likelihood of exceeding estimated budgets. Section 7.0 describes how the data was interpreted and used for analysis.

3.0 OPTION 1

Option 1 is the no refurbishment option in this risk assessment to be evaluated and compared to the three refurbishment options (Options 2 through 4). If the option of no refurbishment is selected, the existing operational and maintenance procedures would continue with no changes, and repairs would be completed as needed. Because of recent weld failures in the upper section of Penstock 1, it is important to identify the risks associated with not executing life extension measures in Penstock 2 and 3.

The Team developed a total of 21 risks for Option 1 primarily related to various failure scenarios. The number of risks developed for Option 1 are less than half the quantity developed for each of the three refurbishment options because the life extension options include many risks associated with construction related activities. Construction risks were compared for each refurbishment option including feasibility, work force management, and safety. Option 1 is the only option to develop risk items with a risk rating of 16, the highest rating, stemming from the high probability and consequences of failures over 30 years for this option. Further analysis and comparison of the data is provided in Section 7 of this report.

The general risk types associated with Option 1, no refurbishment of Penstock 2 and 3, include:

- Penstock failure (multiple failure modes are possible and are discussed)
- Operational risks
- Societal or environmental risks
- Safety risks
- Financial risks

3.1 Risk of Penstock Failure

Without the implementation of life extension measures there remains an inherent risk of failure of Penstock 2 and/or 3, especially for the upper 17-foot diameter section. Because of previously identified weld cracks and completion of weld repairs of Penstock 2 and 3 the potential risk of a minor failure is increased over a 30 year period. The risk rating is reduced, however, when compared to Penstock 1. In the first risk assessment, Penstock 1 was found to be at high risk for minor failures if no life extension measures were

implemented in the next 30 years. The high risk was attributed to recent failures at welds that occurred from 2016 to 2019. No weld ruptures have occurred to date at Penstock 2 and 3; however, previously identified weld cracks have been inspected and repaired. Penstocks 2 and 3 are of similar design and material to Penstock 1 with three different penstock diameters, the largest being the 17 ft diameter section upstream of the surge tank. Penstock 2 and 3 also have weld peaking issues in the 17 ft diameter section, pitting corrosion in the heat affected zone, high penstock diameter to thickness ratio, brittle failure (steel not meeting Charpy requirements), and overall general corrosion.

The previously identified risks for Penstock 1 were re-evaluated for Penstock 2 and 3 and the risk scores adjusted according to risk likelihood, cost impact, schedule impact or other. An overall risk rating was assigned to each risk and mitigating actions were proposed if any.

In the risk workshop, risk of a failure upstream of the surge tank, which includes the 17-foot diameter section, were categorized as minor, medium, and major failures and were further assessed for impacts and likelihood of different failure modes.

A minor failure was defined as a localized failure at a weld in the 17-foot diameter section of the penstock causing a temporary outage, but no damage to the surrounding infrastructure. For the risk assessment it was assumed that one penstock "can" length is affected with a small leak or breach. A "can" in this report is defined as a section of penstock from one circumferential weld to the next circumferential weld and averages approximately 9 feet long. Based on recent performance it was assumed that over a 30-year period more than one minor failure could occur. For impact estimation it was estimated that a failure could occur once every two years. The potential for multiple failures over the next 30 years drove the cost and operational impacts higher as well as societal risks such as negative public perception at the local and provincial level.

A medium failure was defined as failure in the 17-foot diameter section of penstock that impacts more than one can or creates a breach large enough to impact access roads and surrounding infrastructure. It was assumed that a medium failure would be less likely to occur than a minor failure.

A major failure was assumed to involve a complete blowout or a failure of multiple cans with a release of water that would affect the surrounding infrastructure, wash out roads and penstock bedding materials. It was assumed that a major failure would have a low probability of occurring.

If no life extension refurbishments are carried out, corrosion of the steel plate and pitting of the heat affected zone will increase over the next 30 years increasing the likelihood of failure. The existing design issues such as weld peaking, brittle failure and plate thickness will remain and pose risks. It was assumed that regular inspections of the interior of the penstock will continue annually and welds will be repaired as needed.

In addition to regular dewatered inspections of the penstock, operational restrictions of the units are in place to reduce cyclic loading in the rough zone. The operational restrictions are believed to mitigate the risk of failure; however, this comes at an operational and economic cost that the workshop team was unable to quantify but did discuss.

The cost of future repairs (time value of money was excluded from this analysis), scheduling impacts due to temporary shutdown of the units and public perception impacted the overall risk rating. Risk ratings related to failures in the penstock upstream of the surge tank are noted in Table 3-1. Refer to the risk registry in Appendix A for a breakdown of how the risk rating was developed based on likelihood and consequences.

Table 3-1 Option 1 Risk Rating - Weld Failure Upstream of Surge Tank

ID	Risk Title	Risk Description	Risk Rating
1-01	***Minor Failure*** Rupture at weld upstream of Surge Tank	Localized weld failure in 17 ft diameter section of penstock. No damage to surroundings or other infrastructure. One can affected. Assumed one failure every two years.	12
1-02	***Medium Failure*** Rupture at weld upstream of the Surge Tank	Weld failure in the 17 ft section of penstock. Weld failure causes rupture in adjacent can. Possible impact to access roads, surrounding area, and other infrastructure. Failure causes a medium leak.	6
1-03	***Major Failure*** Rupture at weld upstream of the Surge Tank	Complete catastrophic failure of one can or failure of 3+ cans including a significant release of water and wash out of roads, bedding materials.	6

Notes: 1. Assumed no damage to switch yard or surge tank.
2. Schedule impacts considered as time to repair.

The risk of a minor failure upstream of the surge tank is high for Penstock 2 and 3; however, is reduced from the risk rating determined for a minor failure of Penstock 1 because of the lack of previous weld failures/ruptures. The Team determined that the high risk of a minor failure of Penstock 2 and 3 could be mitigated reducing the risk rating to 9 by regular inspections, having work crews and materials available and making changes to the watering up procedures and unit operations. The repairs are also assumed to be completed quickly without lengthy unit shut-downs required.

A similar exercise was conducted for minor, medium, and major failures downstream of the surge tank. The steel plate varies in thickness and the plate thickness increases progressively downstream due to the increase in internal pressures in the penstock. Past inspections revealed steel plate thickness loss downstream of the surge tank due to corrosion; however, no weld failures have occurred in the downstream sections.

The increased plate thickness and smaller diameter to thickness ratio in the lower half of the penstock decreases the risk of failure downstream of the surge tank while the increase in pressure increases the potential impacts should a failure occur. Risk ratings for minor, medium, and major failures downstream of the surge tank are listed in Table 3-2.

Table 3-2 Option 1 Risk Rating – Weld Failure Downstream of Surge Tank

ID	Risk Title	Risk Description	Risk Rating
1-04	***Minor Failure*** Rupture at weld downstream of Surge Tank	Localized area of failure (1 can). Failure causes temporary outage. No damage to surrounding infrastructure.	4
1-05	***Medium Failure*** Rupture at weld downstream of the Surge Tank	Weld failure propagates in next can(s). Failure involves multiple cans. Possible impact to access road and surrounding infrastructure.	4
1-06	***Major Failure*** Rupture at weld downstream of the Surge Tank	Weld failure propagates in adjacent can(s). Failure involves multiple cans. Release of water impacts access road, switchyard, and surrounding infrastructure.	4

Note: 1. Schedule impacts considered as time to repair.

There was no change in the Penstock 2 and 3 risk ratings for failures downstream of the surge tank compared to Penstock 1. The smaller diameter penstocks and thicker steel plate do not have weld peaking issues as identified by previous studies. Therefore, regular inspections, availability of work crews and materials, and low penstock diameter to thickness ratio, mitigates the probability of penstock failure downstream of the surge tank.

3.2 Corrosion Related Risks

Corrosion and pitting will progress without a coating of the interior of the penstock and there is a high likelihood that the corrosion will continue over the next 30 years. A coating system is required to prevent unacceptable material loss, or corrosion to the point of failure in the base metal or heat affected zone. Corrosion induced risks are noted in Table 3-3.

General corrosion is an issue for Penstock 1, 2 and 3 and the risk rating did not change for Penstock 2 and 3 from the initial risk assessment of Penstock 1.

Table 3-3 Option 1 Risk Rating - Corrosion

ID	Risk Title	Risk Description	Risk Rating
1-09	General Corrosion	Base metal corrosion (Not in heat affected zone). Penstock interior corrodes to the point that a coating system is required to prevent unacceptable material loss.	16
1-08	Heat Affected Zone - Corrosion	Failure due to corrosion in the heat affected zone. High frequency cyclic loading can cause cracks in the heat affected zones. Coarse-grained section of the weld will corrode at a faster rate than the surrounding material.	8
1-20	Base metal corrosion and fatigue.	The base metal corrosion compounded with fatigue leads to failure of a section of the penstock. The affected section would need to be replaced.	3

3.3 Other Risks with Low to Medium Risk Ratings

Other low to medium risk penstock failure modes (Table 3-4) were considered for this study and were determined to be a lower probability of occurrence than a weld failure or general corrosion. The lower probability risks of a penstock failure were found to be dependent upon a major event such as a can rupture causing a significant release of water

(major failure) or an extreme weather event. Lower probability risks identified in the risk assessment include:

- *1-07*- Failure of the penstock drainage system causing instability of the penstock. In this scenario the drainage system becomes plugged or overwhelmed leading to increased ground water pressure. This may lead to floating the penstock or creating voids under the penstock from washout, causing the penstock to move and fail. Failure of the drainage system is considered somewhat unlikely, but the Team considered it very unlikely that a drainage system failure would cause a failure of the penstock and this drove the risk ranking. *(Risk Rating 3)*
- *1-10* - A rupture of Penstock 2 or 3 causing a failure of an adjacent penstock would be dependent upon a major failure of either penstock. The resulting consequence would be washing out the supporting soil of an adjacent penstock causing movement leading to a failure. This failure mode was considered very unlikely to occur based on previous failures and runoff area. The risk description is different than for Penstock 1 because a rupture of Penstock 2 could ultimately damage or wash out Penstock 1 and 3, although deemed highly unlikely. *(Risk Rating 4)*
- *1-11* – The Team assumed current operational constraints would remain over a 30-year time span to prevent operation in the rough zone causing weld fatigue from cyclical loading. This decreases operability of the units and system over the long term. There is also a lost revenue component that the Team recognized but lacked the detail to discuss or quantify. Without mitigation of the deteriorated welds and/or corrosion it is very likely that the operational constraints will remain. Rough zone restrictions are in place for Penstock 2 and 3. The Team noted that there is fluctuation in the use of Units 3 to 6. *(Risk Rating 8)*
- *1-12* -There is a risk that maintenance work at other sites may be impacted due frequency of the penstock weld failures and constant work stoppages at Bay d'Espoir. Over a 30-year period, it is very likely that there will be multiple weld failures if no life extension measures of the penstock are completed. Impacts to the planned maintenance work and budget allocation was considered unlikely to occur; however, extending maintenance schedules may impact required critical projects. *(Risk Rating 4)*
- *1-13* -Failure of the steel transition section of the penstock to surge tank. The steel thickness is greater in this section of the penstock and it is encased in concrete; therefore, it is unlikely for a failure to occur in this section. A leak in the transition section would be difficult to detect and over time can lead to further deterioration of the steel and wear of the concrete leading to a failure. The concrete section may contain and prevent a larger failure if a small crack develops in a weld. *(Risk Rating 4)*

- *1-14* - Surge tower footing failure due to rupture of the penstock upstream of the surge tank. Flow from a penstock failure washes out a surge tank footing causing failure of the surge tank support structure. This was considered to be highly unlikely to occur; however, the cost, schedule and economic impacts would be great due to damage caused, and design, fabrication, and installation of a new surge tower with two units offline for an extended period of time. *(Risk Rating 4)*
- *1-15* - Penstock collapse due to vacuum pressures is not directly dependent on a weld failure or failure due to corrosion. The vent could become iced over causing increased vacuum pressures in the penstock during dewatering. This was considered very unlikely to occur due to existing conditions and operations. The repairs would be dependent upon how many cans were affected and fabrication time for replacement sections. The increased vacuum pressures will most likely affect more than one can and the cost to replace multiple sections of the penstock would be greater than five million dollars. The schedule impacts could be greater than four months depending upon material lead times. The risk of a penstock failure due to vacuum pressures can be mitigated with regular inspections. *(Risk Rating 4)*
- *1-16* - Load rejection causing failure downstream of the surge tank is thought to be very unlikely to occur. This mechanism of failure is considered much less likely than a failure due to the cyclical nature of the loading causing metal fatigue that could be exacerbated by a load rejection that would increase pressures. *(Risk Rating 2)*
- *1-17* - Erosion of the penstock foundation due to a small leak causing a penstock failure. The penstock exterior is inspected regularly, and depressions or wet areas along the penstock are likely to be identified before a catastrophic failure occurs; however, the condition of the drainage system is largely unknown. The time to repair may be in the range of two weeks to a month and between $100,000 to $500,000 to complete the repairs depending upon the extent of the leak and damage to the bedding material. *(Risk Rating 4)*
- *1-18 and 1-19* – Minor and major penstock ruptures underneath the switchyard. A minor rupture or a pinhole leak in the penstock underneath the switchyard would cause erosion that could go undetected until the erosion becomes large enough over time to cause a collapse of the ground above damaging the switchyard. The Team recorded this as unlikely to occur; however, the cost, scheduling and economic impacts would be the same as a major failure resulting in several months of downtime and extensive damages. A major rupture under the switchyard would cause rapid and significant damage to the switchyard and potentially the powerstation. A major rupture was deemed very unlikely to occur; however, the

cost, schedule and economic impacts would be severe if the switchyard would become inoperable for longer than four months. *(Risk Rating 8 and 4 respectively)*

- *1-21* - Failure of the penstock during peak load (January and February). The penstock failure is dependent upon a minor, medium, or major failure occurring during this time frame. The Team believed it would be unlikely that the penstock would fail during the winter based on past failures; however, the economic impacts if a failure occurred during this time are greater than during the summertime. *(Risk Rating 8)*

Table 3-4 Option 1 - Low to Medium Risk Failure Modes

ID	Risk Title	Risk Description	Risk Rating
1-11	Reduction of Reservoir Operability	Operational restrictions implemented to reduce rough zone operations which may lead to penstock failure.	8
1-18	Minor rupture under switchyard	Minor leak in penstock underneath the switchyard goes undetected. Soil erosion occurs around the penstock causing a failure of switchyard foundation and equipment.	8
1-21	Winter penstock failure during peak load	Penstock failure occurs in the winter. Increased power demand due to seasonal impacts.	8
1-10	Rupture of a Penstock Damages Adjacent Penstock(s)	Rupture of a penstock damages adjacent penstocks, i.e., washes out earth supporting penstock leading to failure	4
1-12	Scheduled maintenance affected by multiple failures over a 30 year period.	Maintenance budgets and schedules of other facilities are at risk of multiple failures of Penstock 2 and 3 occur. Utilization of resources already allocated for maintenance plans.	4
1-13	Steel transition section fails – penstock to surge tower	Leak is undetected in the transition section (pinhole leaks contained within the concrete). Leak is minor.	4
1-14	Toppling of surge tower due to an upstream penstock rupture.	Rupture of penstock upstream of the surge tower causes soil erosion around the surge tank footings.	4
1-15	Penstock collapse due to vacuum pressures	Vent freezes over and penstock collapses due to vacuum pressures. Multiple cans are affected.	4

ID	Risk Title	Risk Description	Risk Rating
1-17	Erosion of penstock foundation	Minor can rupture causes pinhole leak which is undetected. Erosion of penstock bedding material.	4
1-19	Major rupture of penstock underneath switchyard	Penstock ruptures underneath switchyard causing extensive damage to electrical equipment.	4
1-07	Drainage failure	Failure of the drainage system to handle runoff and causes erosion of bedding materials. Penstock at risk for sagging or bending.	3
1-16	Load rejection downstream of surge tank	Load rejection occurs within 10 years and causes a penstock failure.	2

A failure from an earthquake event and penstock failure due to the surge tank freezing over and load rejections causing a penstock rupture were identified as failure modes but were not evaluated further in this risk assessment as the Team felt these failure modes to be too remote a possibility to warrant further consideration.

The evaluation of low to medium risks for Penstock 2 and 3 did not change from the Penstock 1 risk assessment. It is important to also note that none of the medium to low risks identified had mitigating actions to improve the risk rating score. The existing operational and maintenance procedures and routine inspections that are already in place reduce the overall risk of failure of the penstocks.

3.4 Mitigating Measures

Mitigating measures for Option 1 include continuing inspection, monitoring, and operating practices already in place and will continue into the foreseeable future with this Option. Mitigating measures include:

1) Yearly dewatered interior inspections to measure plate thickness and test welds for about 10 percent of the plates and welds, and to visually assess the condition of the penstock. These inspections are a critical requirement to potentially identify weld deterioration and cracks prior to failure but defects can be missed when only testing 10 percent, and it is impractical from a cost and scheduling point of view to test 100 percent of the welds and plates every year.
2) Regular surface inspections looking for wet spots, slumps, settlement, or misalignment that can be indications of leakage.

3) Regular drainage monitoring. A properly functioning drainage system combined with regular monitoring can detect increased flow from pin holes or small cracks that have not fully breached the penstock.
4) Pressure monitoring of the penstock to assess cyclic fatigue loading.
5) Real time pressure monitoring and automated intake gate closure was discussed during the workshop as a risk mitigating measure not in place today. Currently if the penstock experiences a minor failure, as it has in the past, the breach is not discovered immediately. Previous failures were detected by a local resident driving by or an operator performing duties, which indicates there can be a significant time gap from when the failure occurs to when it is noticed, reported, and the intake gates can be closed to stop flow. A significant amount of damage and washout can occur in this time frame. An automatic alarm triggered by a set pressure drop would provide a quicker response time and is recommended for this option and for the others. Some hydro owners set their gates to close automatically in the event of a set pressure drop to limit as much practicable the time lag from failure to gate closure thus limiting damage and safety risks.

3.5 Summary of Option 1

The Team identified twenty-one risk items for Option 1, with one item associated with overall general corrosion of the penstocks (Item 1-09) at a high rating of 16, the highest possible rating. Risk of a minor, localized failure in the 17 ft diameter section (Item 1-01) was assigned a risk rating of 12, reduced from the Penstock 1 assessment due to lack of historical failures of Penstock 2 and 3. Kleinschmidt believes the level of risk associated with Option 1, with the increased probability of failure and high consequence, exceeds what we would recommend be tolerated making Option 1 not viable. Both the items identified with high risk ratings have a high probability of occurrence and high costs. The Team determined that Option 1 is very high risk due to the high probability of multiple failures and associated costs over the next 30 years. Failure of Penstock 1, 2 or 3 will lead to lost generation and impact system reliability. The duration, seasonality, frequency and magnitude of penstock failures over the lifetime of the penstock is unknown and impossible to predict; therefore, there is a large degree of uncertainty associated with this high risk Option, which may not be tolerable for NL Hydro. Operational constraints and negative public opinion of failures at the local and provincial level add to the negative impacts and negative opinion of this option. Kleinschmidt believes the overall risk level for this option exceeds what should be tolerated and it cannot be effectively mitigated to a lower risk rating without going to Options 2, 3, or 4, making this option not viable. Further analysis and comparison of the data is provided in Section 7.0 of this report.

4.0 OPTION 2

Option 2 includes repair of the deteriorated welds in Penstock 2 and 3 (for this risk assessment the number of repairs were assumed to be approximately fifty percent of the longitudinal welds and fifty percent of the circumferential welds for the entire penstock) and cleaning and coating the entire interior of the penstock. Risks identified in Section 3 with regards to the existing design issues in the 17-foot diameter section will remain if Option 2 is implemented as a life extension measure. These risks include larger diameter to thickness ratio and weld peaking issues which will not be mitigated with the implementation of Option 2 life extension measures. However, the risk of weld failure will be reduced by refurbishing the existing welds and cleaning and coating the interior of the penstock which will limit the progression of corrosion of the steel in the heat affected zone and the base metal.

The Team developed 55 risks for Option 2 including various construction risks and post construction failure scenarios. Three risk items were identified (earthquake, surge tank freezing over, dropped object from a crane) but were not developed due to improbability and insignificance. Five high risk items were developed with a maximum risk rating of 9 for Option 2. Three of the five high risk items are construction related and two are pre-construction related. The five high risk items were discussed, and mitigating measures were identified to reduce the risk and the risk rating. Further analysis and comparison of the data is provided in Section 7.0 of this report.

4.1 Risk of Penstock Failure after Refurbishment

The risk likelihood of a minor penstock failure in the 17-foot section after weld refurbishments and recoating of the interior surface of the penstock was rated as unlikely which is a significant change from Option 1, which was rated as highly likely. It was assumed that only fifty percent of the welds would require repair based on previous testing. As a result, a risk remains that a non-refurbished weld may fail in the next 30 years. The 2019 failure and 2021 crack repairs in Penstock 1 all occurred in previously repaired welds raising concerns regarding the reliability and life expectancy of the weld repairs. The cost, schedule and other impacts of a minor failure are also reduced with the implementation of Option 2 as the probability of multiple failures over 30 years is reduced. The medium and major weld failures were rated as very unlikely to occur after refurbishment, which is a change from unlikely for Option 1. The cost and schedule impacts for a medium to major failure remain unchanged compared to Option 1.

However, the impact of a medium to major failure after implementation of mitigating measures and the weld repairs and recoating is completed for the entire penstock is ruinous because of public perception and the utilities accountability for the high cost of repairs. However, overall, the risk rating for a major failure remained low due to the low probability of occurrence.

Table 4-1 Option 2 –Weld Failure Upstream of Surge Tank

ID	Risk Title	Risk Description	Risk Rating	Post Mitigation Risk
2-01	***Minor Failure*** Rupture at weld upstream of Surge Tank	Localized weld failure in 17 ft diameter section of penstock. No damage to surroundings or other infrastructure. One can affected.	4*	No Change
2-02	**Medium Failure** Rupture at weld upstream of the Surge Tank	Weld failure in the 17 ft section of penstock. Weld failure causes rupture in adjacent can. Possible impact to access roads, surrounding area, and other infrastructure. Failure causes a medium leak.	4*	No Change
2-03	**Major Failure** Rupture at weld upstream of the Surge Tank	Complete catastrophic failure of one can or failure of 3+ cans including a significant release of water and wash out of roads, bedding materials.	4*	No Change

*Overall risk ratings are reduced, when compared to Option1, if Option 2 life extension measures are implemented.

The probability of a minor, medium, or major weld failure downstream of the surge tower remains a low probability of occurrence. However, the overall impacts of a failure downstream of the surge tank are considered more severe compared to upstream failures due to higher pressures and increased probability of impacting the switchyard. NL Hydro is accountable for project spending and will need to justify project costs if failures occur despite remediation measures.

Table 4-2 Option 2 – Weld Failure Downstream of Surge Tank

ID	Risk Title	Risk Description	Risk Rating	Post Risk
2-04	**Minor Failure** Rupture at weld downstream of Surge Tank	Localized area of failure (1 can). Failure causes temporary outage. No damage to surrounding infrastructure.	6*	No change
2-05	**Medium Failure** Rupture at weld downstream of the Surge Tank	Weld failure propagates in next can(s). Failure involves multiple cans. Possible impact to access road and surrounding infrastructure.	4	No change
2-06	**Major Failure** Rupture at weld downstream of the Surge Tank	Weld failure propagates in adjacent can(s). Failure involves multiple cans. Release of water impacts access road, switchyard, and surrounding infrastructure.	4	No change

*Risk rating is increased, when compared to Option 1, due to the impact of accountability for potential failures occurring after repairs.

4.2 Corrosion and Coating Related Risks

Risk of failure due to the progression of corrosion throughout the penstock base metal and heat affected zone of the welds is mitigated with Option 2 by resurfacing and recoating the penstock. However, associated risks with resurfacing and recoating of the penstock can be attributed to quality of the surface preparation and of the type of paint selected for the project. A localized or significant coating failure may be the result of poor coating adhesion or not obtaining the specified design dry film thickness. Strict QA (quality assurance) and QC (quality control) practices can be implemented to mitigate these issues or coating tests can be undertaken before coating the entire penstock to test how each coating performs. Moisture cured urethanes can be applied in high humidity conditions or there are epoxy's that may be suitable. We assumed for the workshop the coating types will be researched and tested before recoating the interior of the penstock.

Due to the expected high humidity within the penstock, the large surface area to cover, and the current rough condition of the penstock the risk likelihood of a localized coating failure is thought to be likely to occur following construction, but the impact to the project will be minimal because of QA and QC processes and coating thickness and adhesion measurements during application that should limit the likelihood, quantity, and size of localized coating failures. Good QA and QC processes are assumed as part of the baseline

risk assessment. Small repairs will not significantly impact the overall schedule and budget of the project as repairs can be planned around scheduled outages and would not require an outage just for the spot repairs. However, if a significant coating failure occurs, such as if the coating does not adhere or is not suitable for the application, the cost impacts would be significant. The risk likelihood is rated as unlikely for a significant large scale coating failure as it is expected the coating product will be thoroughly researched and tested before the interior surface is recoated.

We assume that multiple types of coatings will be tested, strict QA and QC processes will be adhered to and by following industry standards for surface preparation and testing during the coating process, the corrosion risks for Penstock 2 and 3 will be reduced if Option 2 is implemented.

Table 4-3 Option 2 – Corrosion and Coating Risks

ID	Risk Title	Risk Description	Risk Rating	Post Risk
2-08	Heat Affected Zone - Corrosion	Failure due to corrosion in the heat affected zone. High frequency cyclic loading can cause cracks in the heat affected zones due to reduction in material thickness. If no coating is applied, coarse-grained section of the weld will corrode at a faster rate than the surrounding material.	4*	No change
2-09	Localized Coating Failure	A coating failure that can be repaired with little impact to cost and schedule.	6	No change
2-10	Significant Coating Failure	An unexpected coating failure within a 10 year time frame. A large area of the coating fails due to lack of adhesion or other.	6	No change
2-21	Base metal corrosion and fatigue	Rupture caused by hoop stresses due to reduction in wall thickness from corrosion.	3	No change

*Risk likelihood is reduced with the implementation of Option 2 when compared to Option 1.

However, coating the penstock interior requires abrasive surface preparation before coating. Steel plate thickness loss due to corrosion was identified during previous penstock inspections and confirmed by non-destructive testing. The steel section loss from abrasive surface preparation may be minimal, however, with the additional loss of

plate thickness due to corrosion, coating with extensive surface cleaning may only be able to be completed once over a 30 year period. The risk description states that there is not enough plate thickness available for surface preparation for recoating a second time in a 30 year period assuming that the coating will last between 15 to 20 years. The mitigating action reduces the risk from 12 to 4 as the Team felt that there is a coating that could be designed for 30+ year life span or that a second coating could be applied without the same level of surface preparation that would be needed the first time (Table 4-4).

Table 4-4 Penstock 2 and 3 Identified Risk Coating Application

ID	Risk Title	Risk Description	Risk Rating	Post Risk
2-58	Risk of not obtaining preferred second coat. Quality due to the remaining thickness of steel penstock.	Not having enough plate thickness available for surface preparation of the interior surface of the penstock for an additional coating in 20 years.	12	4

4.3 Other Risks with Low to Medium Risk Ratings

Implementation of Option 2 life extension measures for Penstock 2 and 3 was evaluated and found that the risk ratings remained unchanged for low to medium risks identified in Option 1.

- *2-07* - A drainage failure causing piping or erosion along the penstock due to typical flows such as run off and weather events is independent of the weld refurbishments and recoating of the interior. *(Risk Rating 3)*
- *2-11* - If a rupture occurs in Penstock 2 or 3 and bedding materials are damaged on an adjacent penstock, the event would be dependent upon a failure of Penstock 2 or 3. No change was made to the risk rating for the same risk identified in Option 1; however, since the risk of failure of Penstock 2 or 3 would be reduced due to the implementation of the weld repairs and coating application, so it may be that the overall risk rating would actually be less than 4. *(Risk Rating 4)*
- *2-13* - The risk rating remains the same for scheduled maintenance being interrupted due to failures of Penstock 2 and 3. The risk of Penstock 2 or 3 failure is reduced if the weld refurbishments are completed; however, for this analysis, it was assumed that only fifty percent of the welds would require repair. There is a risk that a weld that is not refurbished may fail in the next 30 years. In addition,

there are no historical weld failures due to rupture, which further decreases the probability of failure in the remaining welds. Work stoppages or rescheduling of maintenance work would ultimately be directly related to the failure. *(Risk Rating 4)*

- *2-16* - Penstock 2 or 3 collapse due to vacuum pressures is not dependent upon the condition of the welds or interior coating so the risk rating remains unchanged from Option 1. Inspections of the vent include ensuring the vent is clear of debris or ice. *(Risk Rating 4)*
- *2-17* - If a load rejection occurs after repairs to the welds and the interior is coated the probability of failure of the penstock is reduced due to the reinforcement of the welds; however, the risk rating did not change for this failure mode as it was already rated low in Option 1. The likelihood of a failure occurring from a load rejection before or after the implementation of life extension measures is considered very unlikely. The penstock is more likely to fail due to cyclical loading and fatigue than from a load rejection. The Team determined regular inspections and operational procedures developed to rewater the penstock would further decrease the risk of load rejection. *(Risk Rating 2)*
- *2-20* - A major rupture of Penstock 2 or 3 under the switchyard was considered very unlikely. *(Risk Rating 4)*
- *2-21* - The risk rating for base metal failure due to hoop stress and loss of steel material due to pitting and corrosion did not change. The likelihood of occurrence should be lower with consideration of a new coating but the likelihood was rated as very unlikely for Option 1 and could not be rated lower. *(Risk Rating 3)*
- *2-22* - The risk rating is unchanged for a penstock failure occurring in the winter months. The failure investigations revealed the steel material does not meet Charpy requirements and there is potential for a brittle steel failure. The risk likelihood does not change if the welds are repaired and the interior is recoated as not all the welds are repaired and Risk Item 2-01 has a likelihood of 2, which carries to this item. When combined with the higher consequences of this item is results in a Risk Rating of 8. *(Risk Rating 8)*

The Option 2 life extension measures mitigate and change the risk rating of the following low to medium risks identified in Option 1:

- *2-12* - Reduction in the reservoir operability - The operational constraints that are in place to restrict running the units in the rough zone reducing vibrations may not be fully lifted even with repairs made to the welds. The risk likelihood of continued operational constraints is reduced to likely to occur from highly likely to occur, however, the existing design issues in the 17-foot diameter section of penstock

remain such as weld peaking, brittle material, and high diameter to thickness ratio which cannot be mitigated with a weld repair. *(Risk Rating 6)*

- *2-14* - Failure of the steel transition piece from the penstock to surge tower. *(Risk Rating 2)*
- *2-18* - Erosion and piping around the penstock from a pinhole leak. *(Risk Rating 2)*
- *2-19* - A minor failure due to a pin hole leak in the penstock affecting the switchyard structures. *(Risk Rating 4)*

If Option 2 is implemented, the risk likelihood of the steel transition piece from the penstock to the surge tank failing, a minor leak causing erosion and piping of the bedding material surrounding the penstock, or a minor failure of the penstock under the switchyard due to a pinhole leak, were all reduced to very unlikely compared to Option 1. With the refurbished welds and coated interior eliminating the progression of pitting corrosion, it is less likely that a pinhole leak will occur, propagate and cause erosion or piping of the bedding material.

4.4 Construction Related Risks

In addition to risks associated with Option 1 and penstock failures listed above, construction related risks were identified for Option 2 that cannot be compared to Option 1. The construction phase is expected to run from May to November. Construction risks involving workforce, schedule, safety, environment, financial constraints, and other potential risks are listed below.

Construction

- Availability of skilled workforce
- Workforce productivity
- Supervision and inspection quality
- Equipment and material availability
- Coating application challenges and quality control
- Excavation causing movement of Penstock 2 and/or 3
- Excavation causing issues with general operations
- Unplanned work interruptions
- Hoisting material or equipment

- Scaffolding – moving and constructing scaffolding along the penstock interior
- Pre-construction risks

Construction Safety

- Minor or major lost time incidents

Environmental – Site Works

- Obtaining appropriate permits
- Environmental incidents or spills

Financial – Construction Costs

- Work not completed as planned/scheduled
- More welds repairs required than budgeted for
- Price escalation
- Financing during construction

Other Construction Impacts

- Pandemic
- Failure occurs before construction commences
- A flawed weld is not identified during repairs, and failure occurs after construction
- Limited local accommodations
- Weather events
- Forest fires
- Protests
- Regulator project approval
- Marine Atlantic Ferry delays

4.5 Construction Risks with High Risk Rating

There were five items for Option 2 that have a risk rating of 9 or greater pre-mitigation. These high-risk items are listed in Table 4-5.

Table 4-5 Option 2 - Construction High Risk Rating

ID	Risk Title	Risk Description	Risk Rating	Post Risk
2-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Confined space environment may lead to lower productivity.	9	6
2-40	Coating Quality Control	Poor quality control and assurance requires spot repairs or reapplication of coating system. Occurs after construction is complete.	9	6
2-46	Additional or Less Welds Require Repair	Assume ±20% of the welds will need repair. Original assumption is 50% of welds will require a repair.	9	9
2-55	Delays During Preconstruction Activities	Design not complete, bid package not released on time and tendering delays lead to mobilization delays.	9	4
2-56	Regulator Project Approval	Delay in obtaining approval from regulators	9	4

- *2-29* - Workforce productivity slowdown was identified as a high risk with project delays occurring due to confined space working conditions, potential poor ventilation, poor lighting, shift work, and potential difficulty in coating application. The scaffolding will need to be moved along the penstock to access welds high on the penstock, which may slow the process and create delays if not accounted for in planning.
    - Risk Mitigation: The Team determined that it was likely productivity decreases will occur but that it can be mitigated by careful planning, adapting work methods to the site conditions, using qualified and experienced contractors, implementing quality supervision, and providing realistic schedules to complete the project. Good planning and scheduling will also mitigate issues such as material and equipment delays, disruptions to the workflow and other operational issues that may delay the project. Early contractor involvement is also recommended to review project execution options including automation of welding and painting activities where possible.
- *2-40* - The coating application was categorized as high risk for future shutdowns to apply coating repairs over a 30-year period if adequate measures are not taken to select and test an appropriate product and to control the application. The current rough condition of the surface and challenges in applying a coating in the

field drive this to a risk likely to occur. Abrasive surface preparation will reduce the remaining steel plate thicknesses and it is likely that recoating once over a 30 year period will be feasible.

  - Risk Mitigation: It was identified that the coating application will need close monitoring and a well-defined heightened quality assurance and control processes in place to decrease the risk of delamination or coating thickness issues. Due to the nature of this type of application where moisture cured urethanes or other coating types may need to be tested in this type of humid environment, well-defined processes must be in place to decrease the risk of potential future coating repairs.

- *2-46* – This risk item identifies the possibility that more or less weld repairs are required than are currently included in the baseline estimate. The Team decided on 20 percent more or less welds as a point of discussion. The Team found this risk item to be likely with costs exceeding $500,000 if 20 percent more welds are required. The Team found it just as likely that 20 percent less welds will be needed saving over $500,000.

  - Risk Mitigation: Thorough and complete weld inspection and repair identification prior to repair scoping.

- *2-55* - Preconstruction risks such as design delay, or delays issuing tender package and issuing construction packages was discussed. The Team agreed that these types of delays are common and will likely occur delaying mobilization of the work and pushing out the overall schedule. With the amount of estimated welding required for this option construction start delays should be avoided as much as possible so that extra shifts are not required to avoid working into December.

  - Risk Mitigation: The risk to the project schedule can be mitigated by completing the refurbishment design well in advance of the project start. Adequate time for design review, comments from the owner as well as the contractor and other design changes should be allotted so as not to affect the overall schedule. The overall management of the project is critical and design delays can be mitigated with realistic design schedules in place. Early development and release of the tender package will give contractors time to dive into the details and develop a thorough and well thought out execution plan thus limiting mobilization and other delays.

- *2-56* – The Team discussed the possibility and impacts of a delay in receiving project approval from the regulator. A delay in receiving approval was believed to be likely based on experience, considering the size of the project. It was estimated that the delay in receiving approval could be one to four months and could delay the project by the same amount.

- Risk Mitigation: Hire a consultant to conduct a detailed review, risk assessment, and develop a decision support package. Perform an internal review and keep the regulator apprised of the project status and direction as appropriate. Submit required paperwork to the regulator early to allow time for review and discussion of this large project.

4.6 Construction Safety

The risk likelihood of a major lost time incident is deemed to be very unlikely and a minor lost time incident unlikely, Items 2-44 and 2-25 respectively. A major lost time incident is defined as an incident that would shut down the work site for an extended period to allow investigation into incidents such as a fatality. A minor lost time incident is defined as an incident that shuts down the work site for shorter period to allow investigation and a subsequent work stoppage may not be required for the entire site. There will be strict safety measures in place such as frequent job hazard assessments, proper personal protective equipment, trained and certified staff, proper procedures and methods implemented such as lock out tag out, proper site orientation and supervision for the project duration. A major shut down due to a safety incident would affect the morale of the workers and generate a negative public perception. A fatality would be devastating to not only the family and workforce, but the company and community as a whole. It is typical to conduct safety audits to ensure the contractor complies with all NL Hydro and provincial safety policies and procedures.

4.7 Environmental – Site Works

The team discussed potential environmental impacts with Item 2-50. It was determined that it is unlikely that an environmental event or spill will occur on site during construction. Contamination of the watershed could include a coating material spill into the watershed (1 drum/55 gallons), release of corroded steel debris, release of sandblasting material, or various fuels. The Province of Newfoundland has strict legislation and environmental guidelines for which all contractors must be trained and comply with. Cost and schedule can be affected dependent upon the extent of the spill or harmful event and required clean up. To mitigate adverse environmental events, good planning, supervision, and training should be conducted for workers on the site in proper handling of materials. Mitigation measures include spill kits on site, double walled drums for fuels and implementation of work practices during sanding and surface preparation that will be designed to catch debris.

Item 2-57 identified that delays in obtaining environmental permits can impede mobilization of site works. Depending on when applications are submitted, delays of up to four months may occur. The risk of project delays due to approval of environmental permits can be mitigated with identification of the timeline for approvals by the Department of Environment in the construction planning phase and applying early to alleviate potential mobilization delays.

4.8 Financial – Construction Costs

As with all projects, there are project risks involving the project cost estimates and failing to include a large enough contingency to cover unforeseen events.

Item 2-33 reviewed financing rates. There is a risk of increased interest rates occurring over the construction period, but the Team viewed this as unlikely. If the project is completed within the scheduled timeframe and within the next couple of years, financial investigations and models can be adjusted to assess financial risks and the appropriate contingency applied to the budget.

Item 2-52 reviewed cost escalation. The price of materials and labor may escalate over the project timeframe. Purchasing contracts should be reviewed and terms and conditions amended as required for the overall project to mitigate the risk of increased costs.

Item 2-47 discusses the potential that work is not completed as planned and the construction schedule is exceeded by one month. The risk likelihood was categorized as somewhat unlikely to occur; however, costs and planned schedules would likely be impacted.

4.9 Other Construction Risks with Low to Medium Risk Rating

The following items have low to medium risk ratings and did not fit in the discussions above.

Items 2-25 and 2-26 discussed a potential pandemic, other than and including Covid 19 variants developing. It was assumed that the COVID-19 pandemic will impact construction methodologies, schedules, and budgets for the next few years. The risks on site will be mitigated by a frequent cleansing, social distancing and wearing masks. There is a risk that the construction schedule would be interrupted multiple times over the course of the project depending upon the number of cases identified and the possibility of community outbreaks. The risk likelihood was categorized as somewhat unlikely to occur; however,

change in processes due to the virus will probably remain and will not change in the near future. The risk likelihood of a new virus causing an unplanned work stoppage is very unlikely but would impact schedules and budgets if construction delays exceed more than one month. We assume that welding will be sequenced and that a plan and processes will be implemented to ensure the work can continue through potential outbreaks.

Item 2-27 discussed the potential of a failure in the 17-foot diameter section prior to the commencement of the construction phase. The Team felt it highly likely that a weld failure will occur before the repairs commence; however, the project budget and schedule will not be significantly impacted as it has been shown from previous weld repairs completed on Penstock 1 that a stoppage to operations will be short and the costs small resulting in a low impact in terms of this risk assessment.

Risks associated with weather events were discussed in Items 2-35 and 2-36. Extreme weather events (2-35) in the area are somewhat unlikely to occur during the construction timeframe. Extreme precipitation events such as a 1 in 100-year rain event can wash out roads, wash out existing bedding or excavated slopes, and cause power related delays. Such an event can be estimated to be a 1 in 100-year probability and any delays are not expected to last more than two weeks. Typical weather events (2-36) such as spring and falls storms or high temperatures in the summer are likely to occur but are not likely to affect the project schedule for more than one week.

Item 2-38 considered the risk of protests causing work stoppages. The Team identified this risk as somewhat unlikely; however, there should be efforts to notify the public and provide information as necessary to project stakeholders. The public scrutiny into utility spending can be resolved by sharing the justification for the project and the increased reliability of the assets by completing the life extension measures.

Items 2-42 and 2-43 reviewed risks involving damage to infrastructure due to excavation activities. The Team determined damage to be very unlikely to occur even though there can be significant adverse outcomes if structures are impacted by earthworks. Good supervision and properly planned excavations with strict protocols and processes in place will mitigate the occurrence of an adverse event affecting adjacent infrastructure. If required, methods can be developed to build temporary supports or barriers. Driving over sections of the penstock causing damage was also identified as very unlikely to occur with proper mitigation plans and processes in place such as site orientation and properly marked designated areas to cross over the penstock.

Item 2-48 addressed the risk of a forest fires, or threat of a forest fire delaying the project. Forest fire threats stopping work has occurred, but it was determined to be somewhat unlikely to occur at this location and the impact to the project schedule and budget is considered low.

Item 2-49 noted that unplanned work interruptions may occur due to a strike or other adverse events affecting the work site. Short term work stoppages are thought to be very unlikely to occur; however, good construction planning will mitigate these issues if work interruptions arise. Work interruptions should be considered during the project execution risk process for Penstock 1.

Item 2-54 discussed the fact that the Bay d'Espoir area has limited accommodations which are typically filled by multiple contractors providing services to the local area. It is very likely that a camp will need to be constructed for the duration of the project because the workers will need provision of adequate food and shelter over the course of the project. The workforce morale will be low and productivity reduced if suitable accommodations are not provided.

Item 2-51 discussed the risk related to Marine Atlantic Ferry delays at some point during construction. Although the delays are highly likely to occur, the risk of delays to workforce or materials can be mitigated by pre-planning and scheduling.

4.10 Summary of Option 2

The Team identified fifty-five risk items for Option 2 with five having a pre-mitigated high-risk rating of 9. These five items are pre- construction or construction related and can be mitigated down to a moderate risk rating. The Team determined that this Option was viable though not ideal as issues related to peaking and fatigue are not addressed, and operational constraints will remain.

During the risk assessment process for Penstocks 2 and 3 the same risks for Penstock 1 were re-evaluated and new risks were identified. An additional risk item 2-58 was identified during the Penstock 2 and 3 risk assessment and determined as highly likely to occur. This risk also applies to Penstock 1 though it was not identified during that workshop. The risk item 2-58 was defined as the loss of the material of the steel plating due to corrosion reducing the number of times that the interior surface can be prepared for re-coating with abrasive blasting. A typical coating life span is approximately 15 to 20 years; therefore, it is very likely that Penstock 2 and 3 will need to be recoated in a 30 year

period. The life span of the coating will affect cost and schedule over the 30 year period. If the penstock cannot be recoated again, there is significant impact to using Option 2 as a life extension measure. The Team determined item 2-58 could be mitigated with the design of a coating with a 30+ year life span. It is likely that the penstock could be recoated in 15 to 20 years using a coating system that does not require cleaning to clean white metal, especially if the surface is recoated before significant new corrosion develops.

In Penstock 2 and 3 risk assessment, item 2-32, the risk of a flawed weld not being discovered and causing a failure, was also re-evaluated. The risk likelihood was increased from a 1 (Penstock 1 risk assessment) to a 2. There is a risk that a flawed weld may not be identified, and that a repaired weld may fail. The Team assumes that 100% visual inspection and 100% magnetic particle inspection will significantly reduce the likelihood of this risk. Skilled welders and increased construction supervision will also mitigate the risk of not discovering a flawed weld or a repaired weld failing.

It was also noted that the existing weld procedure could be adjusted to mitigate potential cracking due to cyclical loading by grinding the welds flush with the substrate. It was determined if Option 2 were implemented, penstock inspections would still be required annually to assess the welds.

It was also discussed that even though the Penstock 2 and 3 welds did not rupture in the past during operation, a weld crack is still considered a failure and is indicative of cyclical loading and fatigue. Penstock 3 also has steeper sections than Penstock 1 and 2 with different weld locations that may be difficult to access requiring further assessment and potentially adjusted weld procedures.

Due to the location of Penstock 2 and 3, the impact to operations of an adjacent penstock (risk item 2-43) was increased from a 1 (Penstock 1 risk assessment) to a 2. It is unlikely that equipment will impact operations of adjacent penstocks if good site control, contractor supervision and designated locations for crossing adjacent penstocks is well laid out. However, the risk likelihood was increased because of the risk of generation loss if one penstock was affected or damaged during construction.

5.0 OPTION 3

The third life extension refurbishment option includes replacement of the entire 17-foot section of Penstocks 2 and 3 plus refurbishment of the welds and recoating in the remaining smaller diameter sections of the penstocks.

The Team developed 62 risks for Option 3 with various construction risks and post construction failure scenarios. Four high risk items were found with a maximum risk rating of 9. Two of the four high risk items were construction related and two were pre-construction related. The four high risk items were able to be mitigated down to a lower rating as discussed below. A summary list of the risk items is contained in the Risk Registry. Further analysis and comparison of the data is provided in Section 7 of this report.

5.1 Risk of Penstock Failure after Refurbishment

We assume with replacement of the 17-foot diameter section that the probability of failure of the penstock upstream of the surge tank would be greatly reduced. The new penstock sections would be designed to current standards, would meet the recommended diameter to thickness ratios and current weld peaking issues would be resolved.

The risk likelihood of a minor, medium, or major failure upstream of the surge tank was rated as very unlikely due to the new steel section of penstock. The risk rating improved for a minor failure when compared to Option 2 and the risk rating remains the same for medium and major failures (Table 5-1).

Table 5-1 Option 3 – Risk of Failure Upstream of the Surge Tank

ID	Risk Title	Risk Description	Risk Rating	Post Risk
3-01	***Minor Failure*** Rupture at weld upstream of Surge Tank	Localized failure in 17 ft diameter causing a temporary outage. Access roads, surrounding area, and other infrastructure are not impacted by the failure. One can is affected with a minor leak.	3*	No change

ID	Risk Title	Risk Description	Risk Rating	Post Risk
3-02	***Medium Failure*** Rupture at weld upstream of the Surge Tank	Failure in the 17 ft section of penstock. Failure propagates into adjacent can (multiple failures). Possible impact to access roads, surrounding area, and other infrastructure. Medium amount of leakage.	4	No change
3-03	***Major Failure*** Rupture at weld upstream of the Surge Tank	Complete catastrophic failure of one can or failure of 3+ cans including a significant release of water and wash out of roads, bedding materials.	4	No change

*Risk of a minor localized failure upstream of the surge tower is reduced from Option 2.

The risk of failure downstream of the surge tank remains the same as Option 2. There is no change to the weld repair design or recoating methods downstream of the surge tank for this option.

5.2 Failure Risks Changed Compared to Option 2

Other failure modes identified for Option 2 are unchanged for Option 3 except for the following risk items:

- *3-12* - Reduction of reservoir operability due to restrictions of operating in the rough zone.

  One of the most significant benefits of Option 3 is the ability to lift the operational restrictions in place to reduce vibrations since the 17-foot diameter section is replaced. The risk of needing to reduce the operability of the reservoir and units drops significantly as the existing design issues such as weld peaking and stresses in the heat affected zone due to cyclical loading in the 17-foot diameter section of penstock will no longer exist to cause operational constraints.

- *3-22* - Winter penstock failure during peak load (January/February).

  Since the overall probability of failure of Penstocks 2 and 3 is reduced because of the replacement of the 17-foot diameter section, the risk likelihood of a winter failure is also reduced to very unlikely.

- *3-10* - Significant coating failure after application.

  In Option 2 the risk of a coating failure after construction was identified as a medium risk with a risk rating of 6. The risk likelihood remains the same for option 3 and in relation to the remaining smaller diameter penstock. However, the cost and schedule are less impacted because the 17-foot diameter section of pipe is new and coated during the fabrication process removing this section from the volume of recoating required as it is highly unlikely that it will experience a premature coating failure in a 30 year period. The remaining smaller diameter penstock sections are considered likely to require repairs because of the current rough condition of the surface and challenges in applying a coating.

- *3-41* - Material availability such as welds, steel, paint.

  The potential for schedule delays due to material availability increases the overall construction risk of Option 3. The availability of steel plate, fabrication lead times and shipment to the site may cause an increased risk to the project schedule and budget. Steel plate availability, cost and shipment schedules should be planned and organized well in advance of the construction to reduce extended delays.

- *3-43* - Operational impacts at the site including operation of adjacent penstocks.

  Site works will be extensive as large sections of the penstock will need to be removed and a large crane will be required to lift the new 17-foot diameter sections into place. Earthworks and extensive excavations will be required to remove the buried penstock and repair bedding materials. Good site supervision and a proper site orientation for the contractor will help reduce the risk of damage to other infrastructure. Delineating areas of access and defining boundaries at the site will assist the contractor and reduce the risk likelihood of an incident. The risk rating was unchanged at 4, but the post mitigation risk changed from a 2 for Option 2 to a 4 for Option 3.

- *3-52* - Escalation of material pricing.

  The price of steel, other materials and labor should be well laid out in a contract and contingencies in place for potential increases. Standard terms and conditions should be agreed upon before construction commences. The cost impact increased to a 3 for Option 3.

- *3-54* - Hoisting materials, potential risk of dropped items.

  With the installation of the new penstock section lifting and hoisting for Option 3 is more significant than for Option 2. The Team believes the likelihood of occurrence is low but the cost impacts and consequence could be high. Work methods must be in place to reduce the risk of dropping materials or equipment.

5.3 Construction Risks with High Risk Rating

There were four items for Option 3 that have a risk rating of 9 pre-mitigation. These high-risk items are listed in Table 5-2.

Table 5-2 Option 3 - Construction High Risk Rating

ID	Risk Title	Risk Description	Risk Rating	Post Risk
3-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Confined space environment may lead to lower productivity.	9	6
3-40	Coating Quality Control	Poor quality control and assurance requires spot repairs or reapplication of coating system. Occurs after construction is complete.	9	6
3-55	Delays During Preconstruction Activities	Design not complete, bid package not released on time and tendering delays lead to mobilization delays.	9	4
3-56	Regulator Project Approval	Delay in obtaining approval from regulators	9	4

For Option 3, construction risks including safety, environmental, and financial were identified and four risk items were categorized as high risk. The four high risk items include workforce productivity, coating quality control, the potential for more or less weld repairs than budgeted for, preconstruction risks such as delays in tendering, and final regulator project approval.

There is no change to the high-risk construction practices identified for Option 3 when compared to Option 2 except for the potential risk of requiring more or less weld repairs than the assumed 50% affecting the project schedule or budget. The number of weld refurbishments will significantly decrease if the 17-foot diameter section of penstock is replaced. The overall risk to the budget and schedule due to the uncertainty in the number of weld repairs is reduced compared to Option 2.

5.4 Additional Construction Related Risks

Additional minor to medium construction risks were identified for Option 3 that are specific to Option 3:

- *3-58* - Existing and new penstock sections do not fit as designed.

  It is very likely that there will be challenges with field fit up and welding for the new section of penstock due to the large diameter and the out of roundness of the existing penstock sections. A steel thimble may be designed to connect the existing penstock to the new penstock sections. The out of roundness can be determined by a 3D survey and the steel thimble can be modified accordingly for field fit up. Interior spider bracing can be installed to keep the penstock shape during welding procedures. Contractor field welding procedures will need to be reviewed and third party weld inspections will be critical. For example, if backing bars are used to weld the sections together and there is an increase from a ¼ inch gap to a ½ inch gap the welding time will be doubled, which may increase the risk of cost overages and schedule delays. The risk rating is reduced to a 2 if well planned and executed construction practices are implemented during installation. *(Risk Rating 3*)

- *3-59* – Steel fabrication errors.

  There may be fabrication errors that are not picked up on field inspection. The field welding procedure may cause warping, distortion of the steel plating or weld peaking. It is important to balance the weld around the neutral axis. The contractor should have distortion control procedures in place during field fabrication and should be included in the contract. There is a risk that the material received in the field is defective and field modifications will be required for fit up. We assumed that the steel plating is interchangeable except for at bends in the penstock. If the penstock sections or cans are assembled at the shop, this may mitigate some of the risk of field fit up. *(Risk Rating 2*)

- *3-60* - Foundation; lack of uniformity.

  The bedding material of the existing 17-foot diameter section of penstock will be displaced and new bedding material will be required to level out and grade the area for installation of the new penstock. Proper installation methods and quality control is required to achieve needed compaction, elevation, and slope. *(Risk Rating 3*)

- *3-61* - Compaction issues around the haunches and springline of the penstock caught during construction phase.

  Compaction will be critical at the haunches and springline of the penstock. We assume hand compaction tools will be used and there is a risk that the standard compaction density may not be attained. Flowable fills or saddle supports may be alternatives that can be considered to further support the penstock. Field inspection procedures with frequent compaction testing will reduce the risk of compaction errors being missed. The Team assumes it is likely that compaction issues will be identified but that the overall impact, and the time and cost to correct, will be low. *(Risk Rating 4*)

- *3-62* - Compaction issues around the haunches and springline of the penstock not caught during the construction phase; may lead to settlement issues.

  Compaction will be critical at the haunches and springline of the penstock. We assume hand compaction tools will be used and there is a risk that the standard compaction density may not be attained and if compaction issues are not caught the Team contemplated the consequences. Ultimately poor compaction can lead to erosion and settlement over a long period which can lead to penstock damage due to excessive movement and overstress. It is likely that extensive poor compaction of the surrounding soil may be evident after the penstock is watered up. Survey rods can be welded to the penstock for future alignment and settlement survey checks. The Team found it very unlikely that lack of compaction, not caught during construction, would be extensive enough to cause settlement issues though the consequences were ranked higher than item 3-61 due to the potential for failure *(Risk Rating 3*)

- *3-63 and 3-64* - Minor and major design inaccuracies.

  Due to the variability in the existing site conditions, the out of roundness of the pipe and field welding procedures, there is a high likelihood of minor design errors impacting the schedule. There may be alignment and fit up issues, dimensional inaccuracies, specification discrepancies and problems with coating application and adhesion. The minor design errors can be mitigated by using an experienced design team and an engineering presence on site for the project duration to assist with minor design issues quickly and efficiently. A proper quality assurance and control procedure should be implemented with third party certified inspectors for

welds (CSA W178.2 – Certification of Welding Inspectors) and coatings (NACE certified).

For Penstock 2 and 3, the risk of a major design error is unlikely to occur, but the impacts to cost and schedule of the project may range up to an estimated $5 million and delay the project up to four months. There would be significant impacts as to the accountability and answerability to the public, the owner, and the utility review board if a major design error would occur. *(Risk Rating 8 and 6*)

5.5 Summary of Option 3

The Team identified sixty-two risk items for Option 3 with four having a pre-mitigated high-risk rating of 9. These four items are pre- construction or construction related and can be mitigated down to a moderate risk rating. The Team determined that this Option was viable and dealt with the peaking and fatigue issues allowing operational constraints to be lifted.

The overall comparison of life extension measures during the risk assessment for Penstock 2 and 3 was not significantly different to that of evaluating risks for Penstock 1.

However, the risk likelihood of a flawed weld not being discovered and failing was re-evaluated. The probability of a defective weld not being identified, and failing, was increased from a risk likelihood of very unlikely to unlikely. To mitigate the risk of weld failures, it was assumed that all welds will be 100% visually and 100% magnetic particle tested at the time of repair. The Team concluded that the increase in the risk likelihood was justified due to recent events where previously repaired welds completed on Penstock 1 were found to be cracked and required further repairs.

6.0 OPTION 4

Option 4 includes refurbishment of deteriorated welds, recoating of the entire interior of the penstock and reinforcement of the longitudinal and circumferential welds in the 17-foot diameter penstock section with reinforcing plates. The welded plates will cover the repaired welds and increase stiffness in the area to mitigate weld peaking. The reinforcement plates will be welded using fillet welds all around the edge of the plate and will be installed inside the penstock.

The Team developed 59 risks for Option 4 including various construction risks and post construction failure scenarios. Seven high risk items were found with a maximum risk rating of 9. Four of the seven high risk items were construction related and two were pre-construction related and one is a new failure mode. The seven high risk items can be mitigated down to a lower rating as discussed below, except for the risk involving weld quantity. A summary list of the risk items is contained in the Risk Registry. Further analysis and comparison of the data is provided in Section 7 of this report.

6.1 Construction Risks with High Risk Rating

There were seven items for Option 4 that have a risk rating of 9 pre-mitigation. These high-risk items are listed in Table 6-1.

Table 6-1 Option 4 - Construction High Risk Rating

ID	Risk Title	Risk Description	Risk Rating	Post Risk
4-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Confined space environment may lead to lower productivity.	9	6
4-40	Coating Quality Control	Poor quality control and assurance requires spot repairs or reapplication of coating system. Occurs after construction is complete.	9	6
4-46	Additional or Less Welds Require Repair	Assume ±20% of the welds will need repair. Original assumption is 50% of welds will require a repair.	9	9
4-54	Delays During Preconstruction activities	Design not complete, bid package not released on time and tendering delays lead to mobilization delays.	9	4

ID	Risk Title	Risk Description	Risk Rating	Post Risk
4-55	Regulator Project Approval	Delay in obtaining approval from regulators	9	4
4-58	Failure of Plates due to cyclic Operations	Assuming full operability, Removing restrictions.	9	6
4-60	Constructability Lifting Plates in Place	Constructability issues regarding lifting the plates in place, handling of the plates inside of the penstock creating safety problems i.e., Dropping plates.	9	3

The two new items with high risk ratings, Items 4-58 and 4-60, are discussed in the following section. The other high risk items have been discussed previously for Option 2 and remain unchanged for Option 4.

6.2 Additional Risks Over Option 2

For Option 4, risks related to construction, scope creep, schedule delays, budget overages, will be the same as Option 2 excepted as noted below. The additional welding required for the steel plates adds a complexity to this refurbishment option and new risks identified for this option are as follows:

- *4-57* - Failure of the plates (static operations).

  Failure of the plates under static conditions is very unlikely as operation restrictions are likely to remain unchanged if the 17-foot diameter section is not replaced. It is assumed that reinforcing plates are not required for the circumferential seams. *(Risk Rating 1*)

- *4-58* - Failure of the plates (cyclical operations).

  If the operational restrictions are lifted, cyclic pressure loadings will increase, and the risk of plate failure becomes likely over a 30-year period. The toe of the fillet welds used to attach the plates are susceptible to cyclic loading and the weld could fail. There is a high probability that failures of the weakened material or cracks will develop due to fatigue from the cyclical nature of the loads. It is assumed over a 30-year period that the welds will see an increased number of high stress cycles

and that failure is probable. The mitigating action would be to keep restrictions in place and not operate the units in the rough zone. *(Risk Rating 9*)

- *4-59* - Plate detaching and entering the powerhouse.

  The Team believes it is highly unlikely that the plates will detach and damage equipment in the powerhouse like the wicket gates or runner. The welds would need to fail completely to allow the plates to peel back and be carried into the powerhouse. There would be significant cost and schedule impacts if this were to occur. No mitigating action was identified for this risk. *(Risk Rating 3*)

- *4-60* - Constructability – lifting plates in place.

  There are constructability risks as the plates are heavy and need to be welded at different locations, sometimes high on the side of the penstock or overhead. Lifting the plates in place, securing or tack welding to the penstock and welding the plates pose difficulties and there may be the risk of dropping the plates and increasing the risk of injury. The mitigating actions are good construction planning, proper work methods in place and redundancy in the lifting mechanisms will reduce the risk of workplace injury and reduce the overall risk to a 3. *(Risk Rating 9*)

- *4-61* - Measurable head loss due to plating.

  There was a question as to whether the plates will affect head loss due to increased friction and area of flow. On a large diameter penstock, the percentage of the cross-sectional area of the penstock that the plates would take up is minimal and has little effect on the flows. *(Risk Rating 1*)

Table 6-2 Option 4 – Additional Design and Construction Risks

ID	Risk Title	Risk Description	Risk Rating	Post Risk
4-58	Failure of Plates Cyclic Operations	Assuming full operability and removing restrictions. Plates are only installed on longitudinal welds.	9	6
4-60	Constructability Lifting Plates in Place	Constructability issues with regards to lifting the plates in place, handling of the plates inside of the penstock creating safety issues i.e., Dropping plates.	9	3

ID	Risk Title	Risk Description	Risk Rating	Post Risk
4-59	A plate detaching and going through powerhouse	Assuming significant weld failure, plate peels back	3	3
4-57	Failure of Plates (Fillet Weld) - Static Operations	Keeping operating restrictions in place. Not operating in rough zone. Plates are installed on longitudinal welds only	1	1
4-61	Measurable Head-loss due to plating	Adding plates to the interior of penstock increases friction which decreases pressure leading to head-loss	1	1

- *4-09 and 4-10* - Localized and significant coating failures were re-evaluated for Penstock 2 and 3.

  A localized coating failure is described as a coating failure requiring spot repairs and a significant coating failure is described as an unexpected coating failure occurring within 10 years requiring more than spot repairs or patching. The post mitigation risk did not change; however, it was determined that rounding the edges of the reinforcing plates would improve paint durability, reducing the risk of delamination at the edges.

- *4-18* – The risk of erosion of the penstock foundation was re-evaluated for Penstock 2 and 3.

  It was noted that the seam location in Penstock 3 is lower than Penstock 1 and 2 which increases the probability of erosion of the penstock foundation. Since the risk likelihood was scored a 1 (very unlikely), the risk rating did not change in this evaluation.

6.3 Summary of Option 4

The Team identified sixty-two risk items for Option 4 with seven having a pre-mitigated high-risk rating of 9. Five of the items are construction related or pre-construction related and can be mitigated down to a moderate risk rating, except for the risk related to the quantity of welds, item 4-46. The Team determined that even with a thorough weld inspection preconstruction that the post mitigation risk could not be reduced. Two of the items are related to the plates being installed and are unique to Option 4. The Team

determined that this Option was viable but that it did not adequately deal with the peaking and fatigue issues and operational constraints would not be recommended to be lifted. The plates may not be worth the added expense.

The risks of implementing Option 4 were re-evaluated in relation to Penstock 2 and 3 and the findings remain unchanged from the first risk assessment for Penstock 1 except for the following.

1. Weld failures – *Item 4-01, 4-02, 4-03, 4-32*

   The risk likelihood for a minor, medium or major failure of Penstock 2 and 3 upstream of the surge tank was increased to a 3 (likely to occur) for minor failures and to a 2 (unlikely to occur) for medium or major failures.

   The risk likelihood of a flawed weld not being discovered, and failing, was re-evaluated for Penstock 2 and 3. The probability of a defective weld not being identified, and failing, was increased from a risk likelihood of very unlikely (1) to unlikely (2).

   To mitigate the risk of weld failures, it was assumed that all welds will be 100% visually and 100% magnetic particle tested at the time of repair. The Team concluded that the increase in the risk likelihood was justified due to recent events where previously repaired welds completed on Penstock 1 were found to be cracked and required further repairs.

   It was also noted that the existing weld procedure could be adjusted to mitigate potential cracking due to cyclical loading. The welds can be ground flush with the substrate and the toe of the fillet welds can be grinded to reduce metal fatigue. It was determined if Option 4 were implemented, penstock inspections would still be required annually for the first 3 years than every 5 to 6 years.

   It was also discussed that even though the Penstock 2 and 3 welds did not rupture in the past, a weld crack is still deemed a failure and is indicative of cyclical loading and fatigue. Penstock 3 also has steeper sections than Penstock 1 and 2 with different weld locations that may be difficult to access requiring further assessment and potentially adjusted weld procedures.

2. Accommodations – *Item 4-34*

   Lack of local accommodations during construction for all penstocks was given a risk rating of 8 due to lack of hotels in the area which may create schedule restraints, create worker morale issues, and reduce productivity. The post mitigation risk was re-evaluated for Penstock 2 and 3 and scored a 2. The Team felt that the contractor would secure accommodations before construction commences or build a site specific camp to mitigate the identified risk.

7.0 RISK ANALYSIS

The following section uses the data collected in the risk register from the risk assessment to make quantitative comparisons of the life extension options. The comparisons are accurate only to the degree to which the data is accurate in developing the 4 by 4 matrix risk assessment. The risk assessment methodology is discussed in Section 2. The risk matrix is illustrated again here in Figure 7.1 for quick reference. The matrix value is matched to the likelihood description and the numerical ranges for the impacts in Table 7-1.

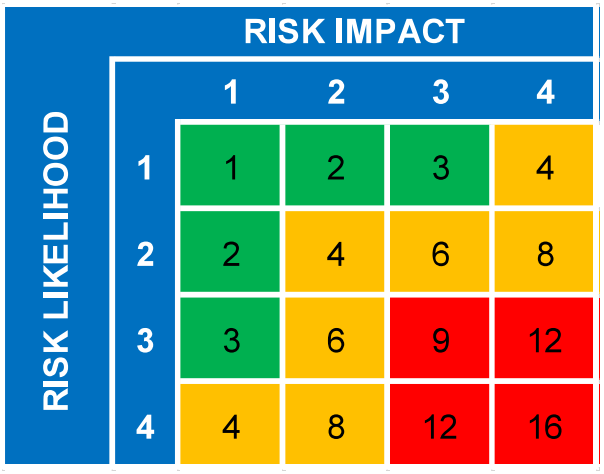

Figure 7.1 Risk Assessment Matrix

Table 7-1 Matrix Value Interpretation

Matrix Value	Likelihood	Cost Impact	Schedule Impact	Other Impact
1	Very Unlikely	$0 to $100K	0 Weeks to 2 weeks	Little
2	Somewhat unlikely	$100K to $500K	2 Weeks to 1 Month	Some
3	Somewhat likely	$500K to $5M	1 Month to 4 Months	Significant
4	Highly Likely	$5M +	4+ Months	Ruinous

Other impacts will include risks associated with the environment or public perception. The risk rating values obtained from the risk matrix by multiplying the risk likelihood and the risk impact are grouped into three categories. Low risks have a value between 1 and 3, moderate risks have values between 4 and 8, and high risks are values between 9 and 16. We assume that risks identified in the high risk category may result in project re-

evaluation if appropriate risk response and mitigation cannot reduce the rating to an acceptable risk rating of 8 or lower.

The likelihood and impacts of each risk item were reviewed and discussed amongst the risk assessment team to determine a post mitigation risk rating. The post mitigation risk rating was determined by scoring the likelihood and impacts to reflect the risk response and mitigating actions.

7.1 Comparing Options

Options 1 through 4 were compared to one another with a high-level analysis, utilizing simple statistical methods. These methods include analyzing the cumulative cost and cumulative schedule with respect to the cumulative probability, the normal cumulative distribution of the risk ratings, the normal distribution of the risk ratings, and analyzing the mean, median, and standard deviation. The mean, median, and standard deviation of the unmitigated risk ratings of each option are summarized in Table 7-2.

The density is the quantity of risk items at a specific rating and the density herein, refers to the probability density function (PDF), which is a function that provides a relative likelihood for a given risk rating. The PDF is also the derivative of the cumulative distribution function (CDF). The CDF provides the probability of a random risk rating being equal to, or less than, a given risk rating.

The mean is the sum of all the risk ratings within an option, divided by the total number of risk ratings within the option. The median is the middle risk rating of an option with an equal number of risk ratings found above and below the median.

Standard deviation is the measurement of the spread of a group relative to the mean risk rating. A high standard deviation represents a large spread of data from the mean risk rating while a small standard deviation represents a small spread of data from the mean risk rating.

Normalizing data refers to converting the entire distribution to a standard normal distribution. This process involves converting each sample value to a z score. The z score is the result of subtracting the risk rating from the mean and dividing by the standard deviation. The z score is the measurement that describes how far from the mean value a risk rating is.

Table 7-2 Sample Size, Mean, Median, and Standard Deviation

Option	No. of Risk Items	Mean Value	Median Value	Standard Deviation
1	21	5.71	4	3.35
2	55	4.89	4	2.29
3	62	4.52	4	1.99
4	59	4.88	4	2.37

In Table 7-2 it can be noted that Option 3 has the lowest mean value and the lowest standard deviation, while Option 1 has the highest mean value and highest standard deviation by a significant margin. These results are what the Team would expect after discussing the options and ranking the risks as there is less variability in the Option 3 risk ratings compared to Option 1. As previously identified, Option 1 no refurbishment risks were the highest identified in the study.

7.1.1 Normal Cumulative Distribution

The normal cumulative distribution model is a plot of the unmitigated risk rating (x-axis) in contrast to the cumulative risk rating density (y-axis). The curve describes the percentage, expressed as a decimal, of data that is expected at or below the corresponding risk rating value. The normal cumulative model of each option was derived from the actual cumulative density data. The actual cumulative density data and normal cumulative distribution models are displayed in Figure 7.2. The cumulative normal distribution models are compared in Figure 7.3. The cumulative densities depicted in Table 7-3 were compared at different risk ratings and larger values are indicative of a higher density of data falling below the specified risk rating.

Table 7-3 Normal Cumulative Density at Corresponding Risk Rating

Option	Risk Rating = 2	Risk Rating = 4	Risk Rating = 6	Risk Rating = 8	Risk Rating = 9	Risk Rating = 12	Risk Rating = 16
1	0.134	0.304	0.534	0.753	0.807	0.970	0.999
2	0.103	0.349	0.686	0.913	0.964	0.999	-
3	0.103	0.398	0.772	0.960	0.988	-	-
4	0.112	0.355	0.681	0.906	0.959	-	-

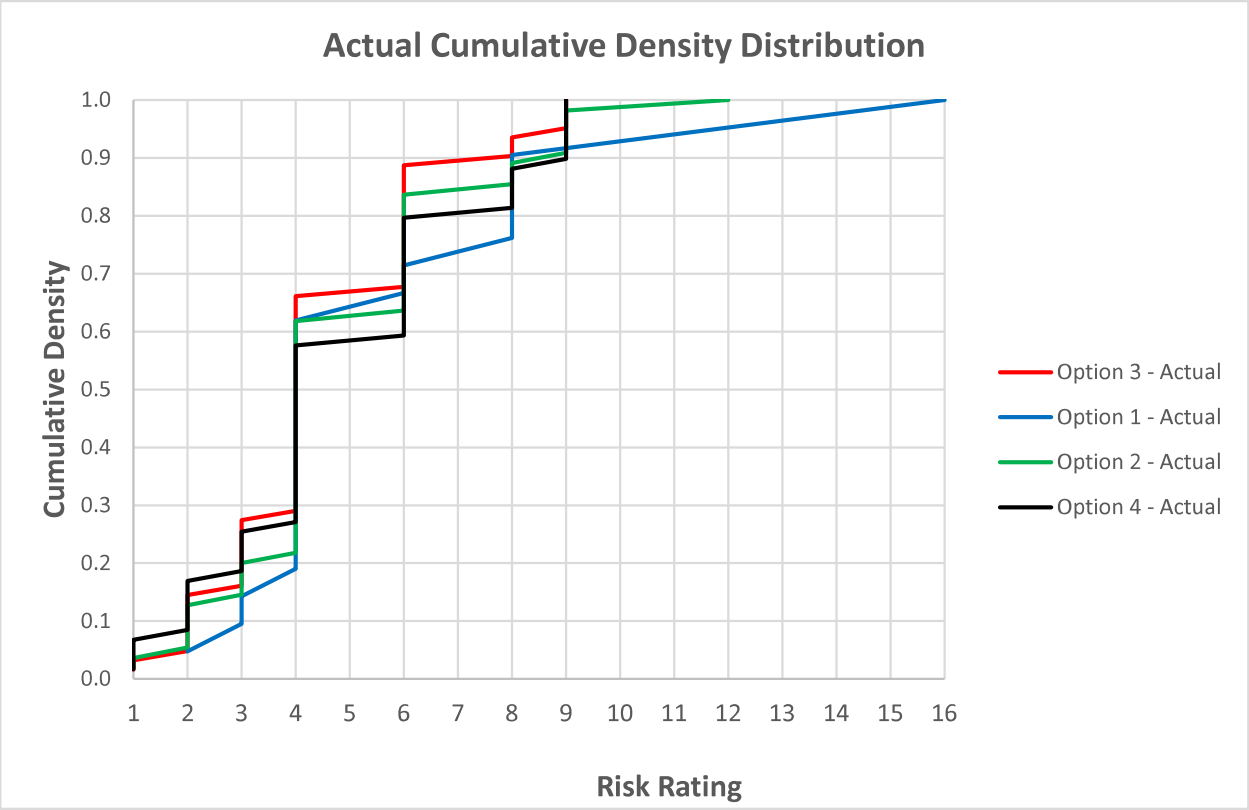

Figure 7.2 Actual Cumulative Density Distribution Models

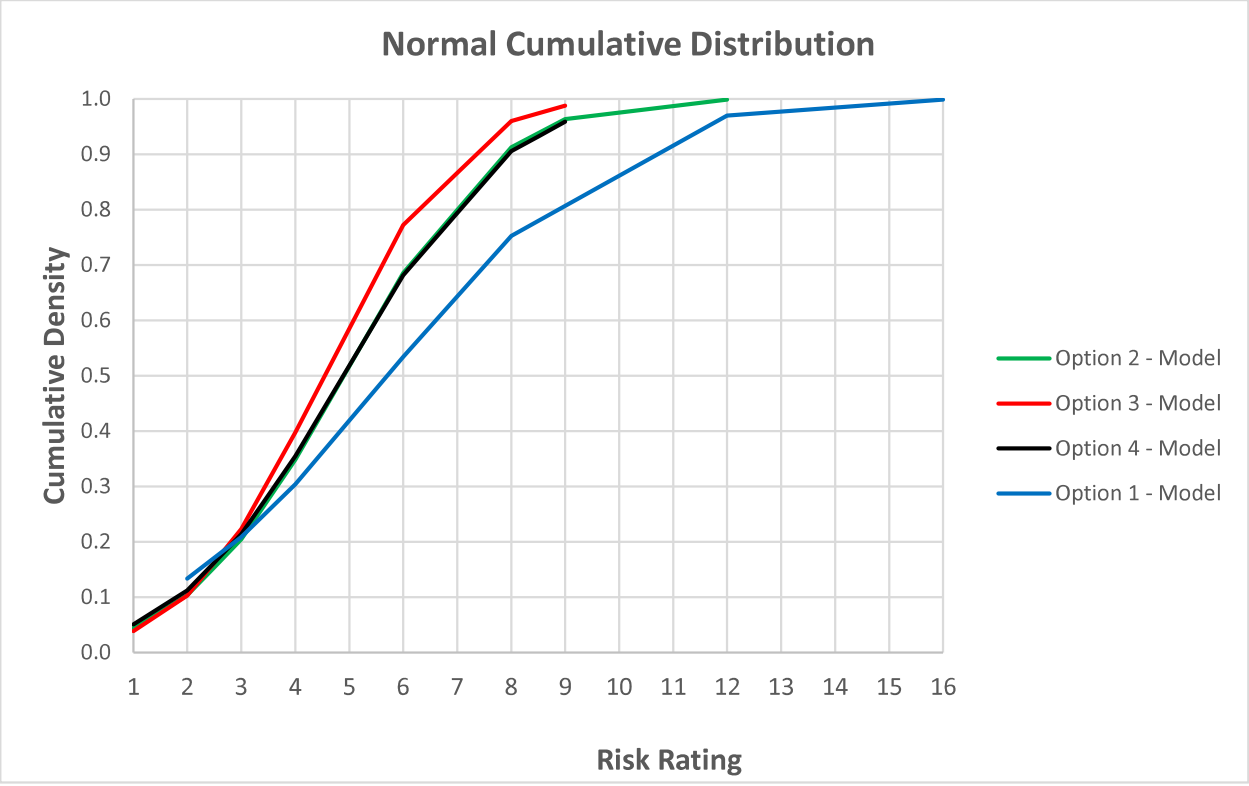

Figure 7.3 Normal Cumulative Distribution Models

7.1.2 Normal Cumulative Distribution Comparison

The plot for Option 1 displays a curve that extends from a risk rating of 2 to a risk rating of 16, corresponding to the minimum and maximum risk ratings, respectively. Comparably, the minimum and maximum ratings are:

- Option 1 min. 2 and max. 16
- Option 2: min. 1 and max. 9
- Option 3: min. 1 and max. 9
- Option 4: min. 1 and max. 9

The Option 1 curve is the furthest to the right compared to the other options, indicating that for any given cumulative density, Option 1 will have a higher risk rating.

Looking at Table 7-3, Option 1 displays a lower cumulative density compared to the other options, indicating that there is a lower amount of data at or below the corresponding risk rating. Option 1 displays this behavior as it is the only option that includes risk ratings above 9.

It is evident through interpretation of the normal cumulative distributions shown in Figure 7.3 that Option 1 displays a higher overall risk due to the option containing risk ratings of 16.

At a high-level analysis, the curve of Option 2 is slightly further to the left compared to Option 4, and therefore shows a lower risk overall. Compared to all options, Option 2 is the second least risky option.

Looking at Table 7-3 it is shown that Option 3 displays the highest expected cumulative density between a risk rating of 4 and 9, indicating that there are more lower risk ratings than higher risk ratings, when compared to the other options. Option 3 also displays a curve that is the farthest to the left in comparison to the other options making it the least risky option based on the available data.

Overall, Option 4 is slightly riskier than Option 2 making it the second riskiest option due to the location of its curve in comparison to the other options, and the normal cumulative densities for given risk ratings under 8 of 0.913 and 0.906 respectively, as compared in Table 7-3.

7.1.3 Normal Distribution Model

The normal distribution model plots the unmitigated risk rating (x-axis) in contrast to the risk rating density (y-axis). The curve describes the density, or occurrence of the corresponding risk rating. The probability of obtaining a certain risk rating between two points of interest is measured by calculating the area under the curve between the points of interest. The normal distribution model of each option is displayed in Figure 7.4.

The probability of obtaining a risk rating in each of the three risk matrix categories for Options 1 through 4 are summarized in Table 7-4. The three categories include:

- Low - a risk rating of 1 to 3
- Moderate - a risk rating of 4 to 8
- High - a risk rating of 9 to 16

Table 7-4 Probability of Risk Rating Category

Option	Probability of Low	Probability of Moderate	Probability of High
1	0.170	0.436	0.268
2	0.304	0.541	0.106
3	0.374	0.541	0.030
4	0.283	0.522	0.054

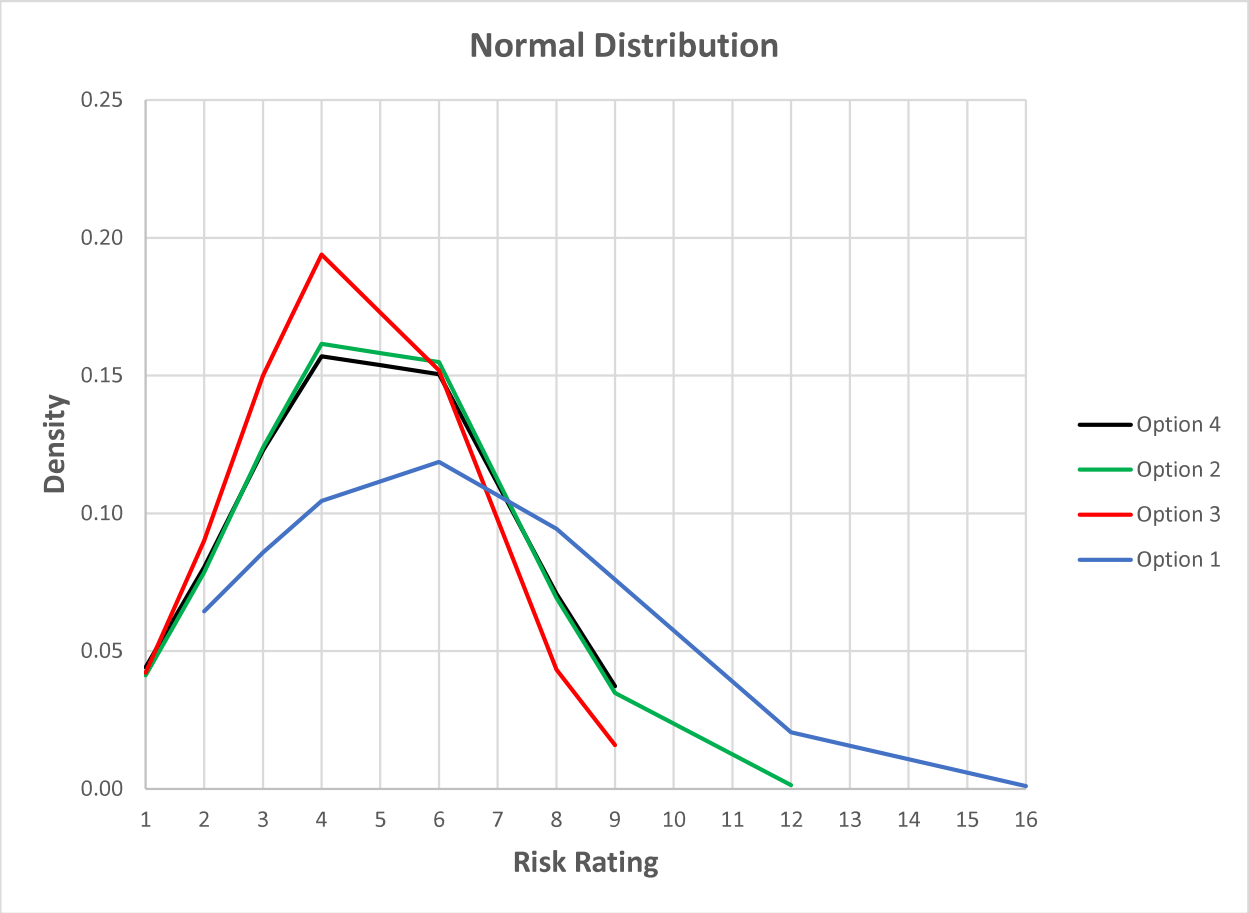

Figure 7.4 Normal Distribution Models

7.1.4 Normal Distribution Comparison

When normalizing the risk rating data to produce the models, a percentage of the predicted risk ratings by the model falls outside of the boundaries of each risk rating, ranging from 1 to 16 for Option 1, and a risk rating from 1 to 9 for Options 2 to 4. This is due to the risk rating data being semi-quantitative, and not naturally occurring data as well as there being boundaries placed on what the value of a risk rating can and cannot be. The normal distribution model predicts probabilities of a risk rating below 1 and above 16 because boundaries cannot be applied to a normal distribution model. Therefore, when summing the area under the curve from a risk rating of 1 to 16, the area does not sum to equal 1 because there is a small percentage of predicted data outside of the risk rating boundaries.

Option 1 has the lowest probability of having a risk rating falling within both the low and moderate risk categories and the highest probability of having a risk rating within the high-risk category. This option displays the greatest amount of skewness to the right, or positive skewness, compared to Options 2 through 4. The results are indicative of Option 1 being the sole option with risk ratings above 9 which significantly skews the distribution of data compared to the other options.

For Option 1 the mean is greater than the median by 1.71, in comparison to Option 3, where the mean is only greater than the median by 0.52. Positive skewness indicates that there are outliers within the data set. We consider the outlier for Option 1 a risk rating of 16. In comparison of Option 1 to Options 2 through 4, there is significant relative positive skewness of the Option 1 plot due to Options 2 through 4 not containing significant outliers. Skewness of the data can also be useful in determining the error within a normalized model as the greater skewness of a data set, the greater the error in the model will be.

In comparison, Option 3 has the highest probability of having a risk rating falling within the low-risk category, the same probability of a medium-risk rating as Option 2 (0.541) and scored the least probability (0.03) of having a risk rating fall within the high-risk category. Option 3 displays the least amount of skewness to the right (Figure 7.4), with the mean being greater than the median by 0.52. In comparison to the other options, Option 3 has the lowest mean and standard deviation of 4.52 and 1.99, respectively.

The calculated probabilities for Option 2 and 4 land between Options 1 and 3 with Option 2 showing slightly more favorable values than Option 4. In comparison, the probabilities calculated for Option 2 for occurrence of low to moderate risk ratings were larger for Option 2 compared to Option 4. The probability of low risk ratings was 0.304 for Option 2 and 0.283 for Option 4. Also, the probability of a moderate risk rating was 0.541 for Option 2 and 0.522 for Option 4. However, the probability of a high risk rating for Option 2 was calculated to be 0.106 and for Option 4 determined to be 0.054. The increase in the high risk rating for Option 2 may be due to the risk item 2-58 which identifies risk of coating quality and steel thickness loss during surface preparation. This item was not included in the identifiable risks for Option 4.

7.1.5 Cumulative Probability vs Cumulative Cost and Schedule Delay

The cumulative cost and schedule delays were plotted in contrast to the cumulative probability as seen in Figures 7.5 through 7.8 to compare project costs and schedule and probability of exceeding those costs and schedules. It should be noted that the starting point for the cost for each option is based on an AACE Class 4 cost opinion being developed by Kleinschmidt for these studies.

The probabilities, costs, and schedule delays that have been derived from the risk ratings, likelihood, cost impact, and schedule impacts do not represent the actual probability of cost or schedule delay. The values are intended to be used to compare each option at a high level relative to each other within the accuracy of the methods used. The overall goal is to determine the lowest risk option.

A probability value was obtained by assigning the matrix likelihood value to a numerical probability i.e., 0 = 0.0, 1 = 0.25, 2 = 0.5, 3 = 0.75, 4 = 1.0, and calculating the middle value between each ascending pair. A single cost and schedule numerical value was obtained by calculating the average of each range in Table 7-1, except for the greatest cost and schedule impacts, where the value was not averaged. The numerical values correlating to the matrix values are summarized in Table 7-5.

Table 7-5 Probability, Cost, and Schedule Values

Matrix Value	Probability	Cost Impact	Schedule Impact
1	0.125	$50,000.00	1 Week
2	0.375	$300,000.00	3 Weeks
3	0.625	$2,750,000.00	10 Weeks
4	0.875	$5,000,000.00	16 Weeks

Cumulative probability was calculated by arranging the risk items of each option in descending order, first by probability, and second by cost and schedule impact. The descending probabilities were then multiplied by each of the preceding probabilities. The cost and schedule values were accumulative in descending order.

The risk items were sorted in descending order with regards to probability, cost, and schedule impact to focus on risks with a higher probability of occurring, and secondly, the risks that had the most significant cost and schedule impacts. By arranging the risk items in this order, a worse case situation was constructed. A Monte Carlo simulation

(mathematical technique used to model the probability of different outcomes) was not run and is not believed to be necessary at this stage for comparing the options.

The curve produced from plotting the cumulative cost in contrast with the cumulative probability represents the probability of multiple risk items occurring simultaneously. As more risks simultaneously occur, the probability becomes exponentially lower while the cost and schedule are cumulative.

Two curves for each option were developed representing the pre-mitigation and post-mitigation cumulative probability versus cumulative cost and schedule. The pre-mitigation curve, Figures 7.5 and 7.7, display the cumulative probability, cost or schedule delay before any mitigating actions are implemented to lower the risk likelihood, cost, or schedule impact. The post-mitigation curve, Figure 7.6 and Figure 7.8, display the cumulative probability versus the cumulative cost or schedule after mitigating actions have been implemented to decrease the likelihood, cost, and schedule impact. Note that Option 1 is not included in the schedule plots as it has no construction to delay.

The base costs for each option in the analysis represent Penstock 2, and therefore, Figures 7.5, 7.6, and Table 7-6 correlate to Penstock 2 only. The cumulative cost vs cumulative probability curves for Penstock 2 and Penstock 3 are identical; however, different base costs were set for each penstock. Since, the analysis for Penstock 3 is identical to Penstock 2, separate graphs are not shown for Penstock 3.

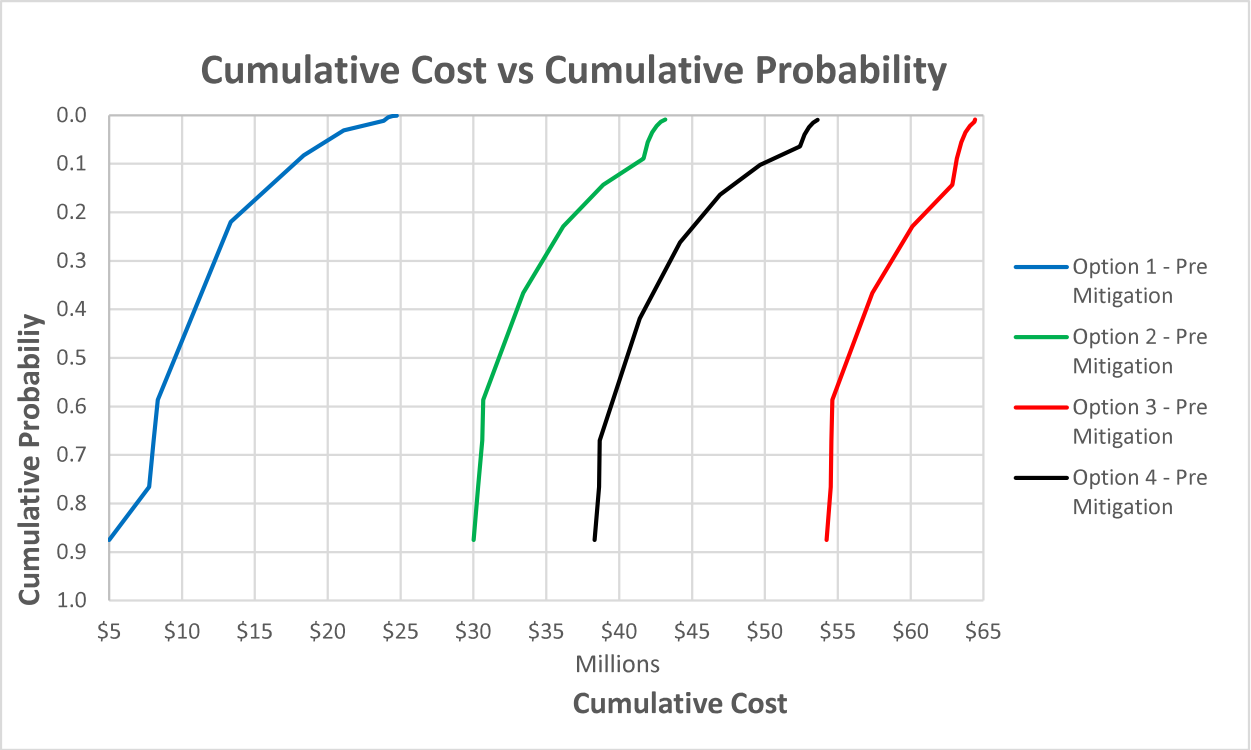

Figure 7.5 Cumulative Cost vs Cumulative Probability – Pre-Mitigation

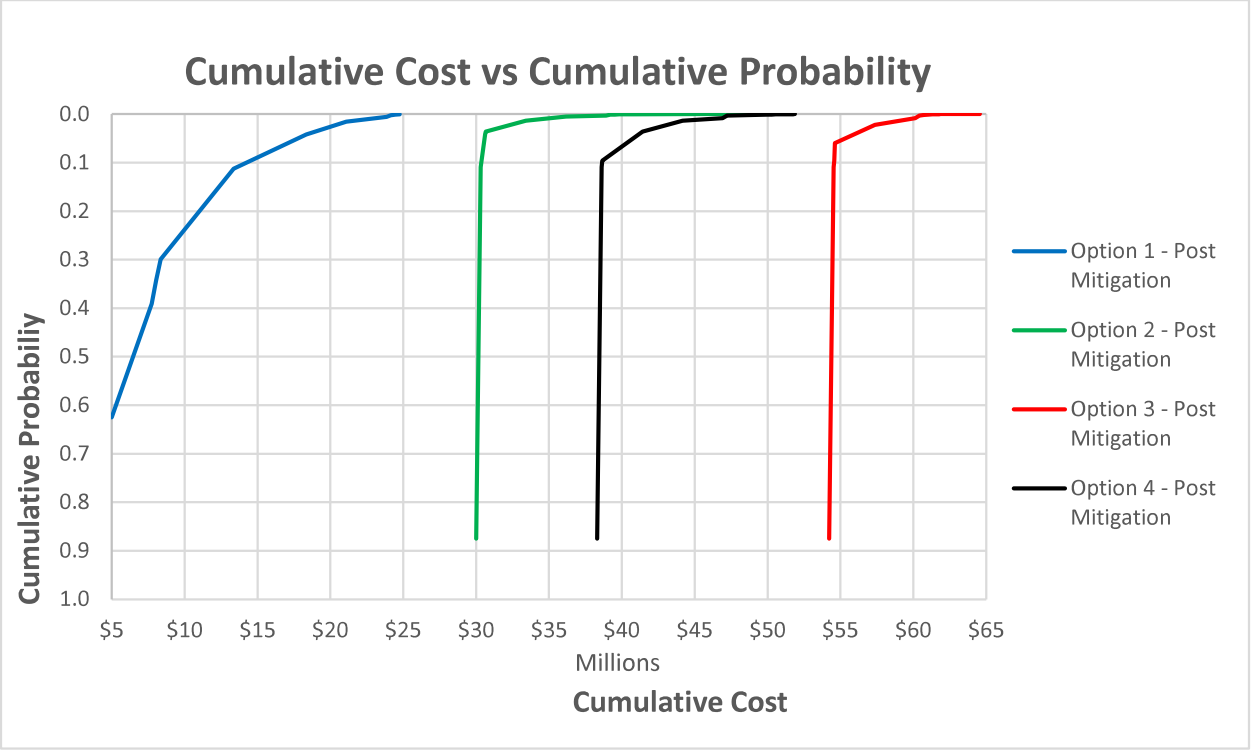

Figure 7.6 Cumulative Cost vs Cumulative Probability – Post-Mitigation

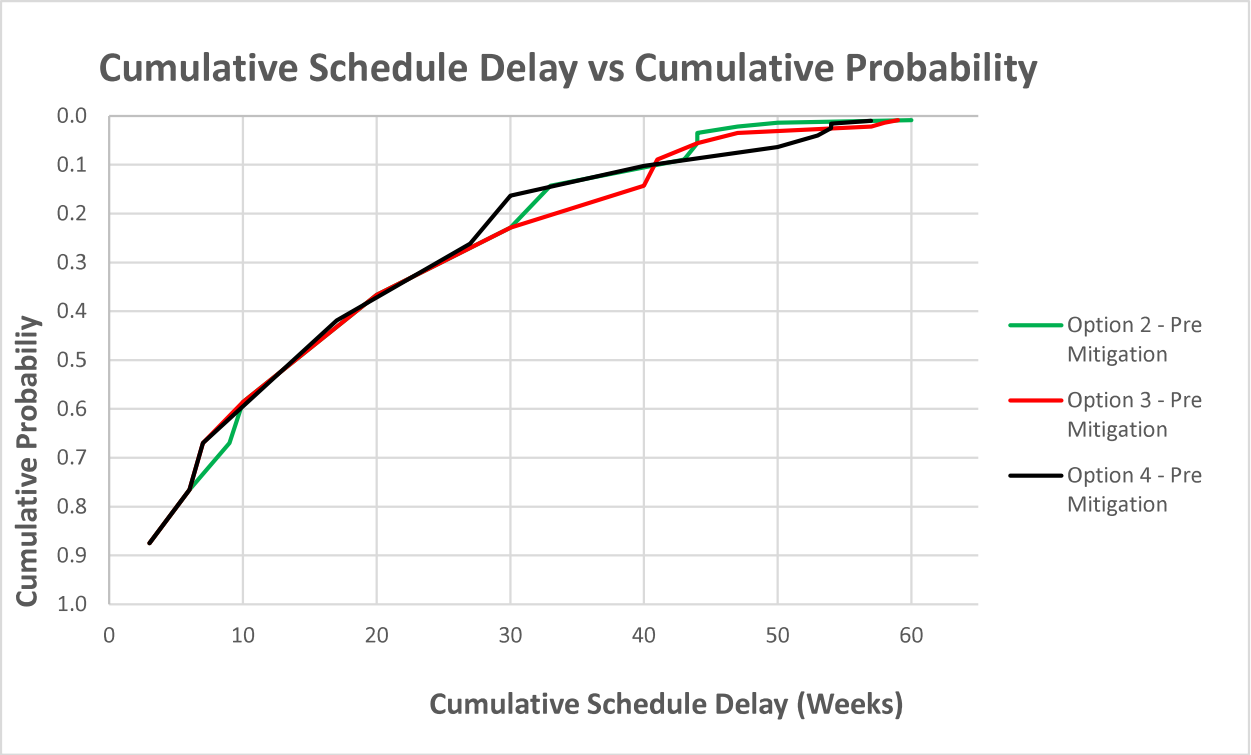

Figure 7.7 Cumulative Schedule Delay vs Cumulative Probability – Pre-Mitigation

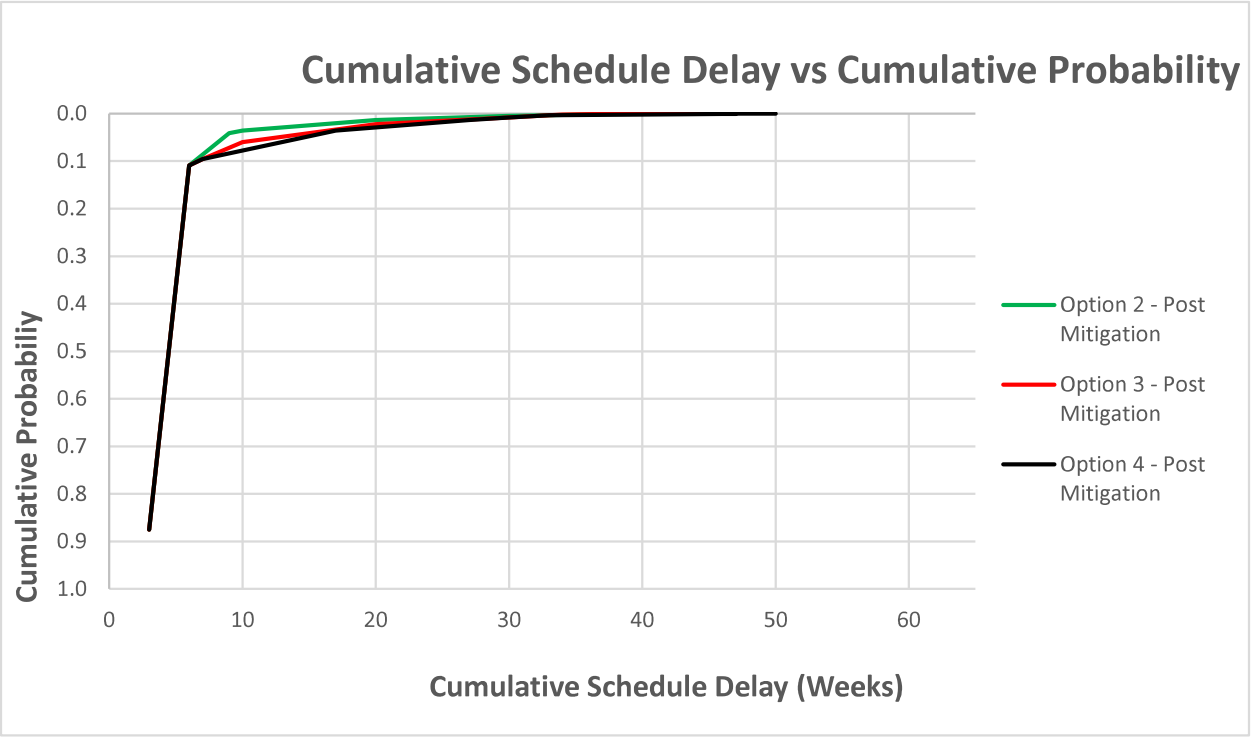

Figure 7.8 Cumulative Schedule Delay vs Cumulative Probability – Post-Mitigation

7.1.6 Cumulative Probability vs Cumulative Cost and Schedule Delay Comparison

The results listed in Table 7-6 provide a comparison of the pre mitigation and post mitigation curves displayed in Figures 7.5 and 7.6. The table summarizes the pre mitigation and post mitigation cost for each option at a cumulative probability of 0.1 and 0.2.

Table 7-6 Penstock #2 Cumulative Probability vs Cost

Cumulative Probability vs Cost					
Option #	**Base Cost**	**Cumulative Probability**	**Pre-Mitigation Cost**	**Post-Mitigation Cost**	**Difference in Cost**
1	$5,000,000	0.1	$17,710,600	$14,216,800	$3,493,800
		0.2	$14,071,300	$11,000,100	$3,071,200
2	$29,715,700	0.1	$41,124,800	$30,356,800	$10,768,000
		0.2	$37,093,700	$30,280,200	$6,813,500
3	$53,922,600	0.1	$63,113,600	$54,556,900	$8,556,700
		0.2	$61,050,600	$54,487,100	$6,563,500
4	$38,016,200	0.1	$49,825,600	$38,650,500	$11,175,100
		0.2	$45,894,900	$38,580,700	$7,314,200

Option 1:

The pre-mitigation and post-mitigation curves for Option 1 are the most alike compared to the curves of the other options, indicating that there is a lack of mitigating actions, or the mitigating actions are not effective. Out of 23 risk items, only two risk were mitigated to a lower risk rating by the Team.

Option 1 has the largest range of costs in comparison to the other life extension options, ranging from $5M to $26.5M. A base price of $5M was assumed for Option 1, representative of the cost to fix a minor leak every 2 years over the next 30 years. The large range of cumulative costs indicates that if multiple risks were to occur, Option 1 would be the most expensive relative to its base price. However, Option 1 is the lowest cost option even if multiple risk items were to occur and costs accumulate.

Option 2:

Option 2 has the second greatest difference between the pre-mitigation and post-mitigation cost vs probability curves. Out of 58 risk items, 12 of the identified risks could be potentially mitigated to effectively lower the risk rating.

The pre-mitigation cumulative cost of Option 2 ranges from the base price of $29.7M to $43.2M. The post-mitigation cumulative cost range reduces the upper end to $40.7M, and the cumulative probability is significantly reduced through much of the cumulative cost range, showing there is less than a 10 percent chance the cost would exceed $30M. The pre-mitigation cumulative schedule delay ranges from 3 to 60 weeks. The mitigating actions reduce the cumulative schedule delay, and the cumulative probability is significantly reduced.

Option 3:

Option 3 has the greatest difference between the pre-mitigation and post-mitigation cumulative probability versus cumulative cost and schedule delay curves. Out of 64 risk items identified by the Team, 16 risk items were determined to have potential mitigating actions that could be implemented to effectively mitigate and reduce the risk likelihood, cost, or schedule impact.

The pre-mitigation cumulative cost of Option 3 ranges from the base price of $54.2M to $64.4M. The post-mitigation cumulative cost range reduces at the upper end to $61.7M, and the post-mitigated cumulative probability is significantly reduced with a very steep curve showing there is less than a 10 percent chance costs would exceed $54.6M. The pre-mitigation cumulative schedule delay ranges from 3 to 59 weeks with mitigating actions reducing the cumulative schedule delay to 3 to 45 weeks. The cumulative probability has a very steep curve showing about a 10 percent chance that delays will exceed 6 weeks.

Option 4:

Option 4 has the third greatest difference between the pre-mitigation and post-mitigation cumulative probability versus cumulative cost and schedule delay. Out of 61 risk items, 15 risks were identified that could potentially be mitigated to reduce the risk likelihood, cost, or schedule impact.

The pre-mitigation cumulative cost of Option 4 ranges from the base price of $38.3M to $53.6M. The post-mitigation cumulative cost ranges from the base price of $38.3M to $51.2M. The pre-mitigation cumulative schedule delay ranges from 3 to 57 weeks with the cumulative schedule delay able to be mitigated to an estimated 50 weeks. The Option 4 post-mitigated cost and schedule curves are the least steep indicating mitigating actions were not as effective for this option.

7.1.7 Limitations and Assumptions

There are limitations to the interpretation of the methods used to compare between the individual options. The methods used are not intended to accurately predict probabilities, cost, and schedule delays, but to analyze each option at a high level relative to each other within the accuracy of the methods used to determine the lowest risk option. The following limitations and assumptions should be considered in the interpretation of the results:

- The numerical values representing the probability, cost, and schedule delay are derived from a mix of quantitative and qualitative data that is measured by using a relative scale such as likelihood, cost impact, and schedule impact. Much of the data analyzed in this analysis is qualitative data that has been assigned a quantity.
- Each option has a different quantity of risk items, with Option 1 having the least at 21, and Option 3 having the most, at 64. Due to the differences in the quantity of risk items between each option, some distribution models have a better fit than others, as displayed in Figure 7.2 and Figure 7.3. The normal cumulative distribution models of Options 2 through 4 have a better fit than Option 1. As a result, the Option 1 model overestimates the cumulative density with respect to the risk rating throughout most of the model.
- The probabilities, costs, and schedule delays that were derived from the risk rating, likelihood, cost impact, and schedule impacts depend on the accuracy of the measured data that was captured during the risk assessment workshop sessions.
- Individual risks and the interpretation, development, and assignment of risk was based on an experienced Team effort.

7.1.8 Summary

Various statistical methods were utilized to compare each of the options. The mean, median, and standard deviation of the risk ratings of each option were compared to one another. The normal distributions of the risk ratings of each option were also analyzed to determine the skew of each option, and to determine the probability of obtaining a risk rating in each of the three risk categories. The normal cumulative distribution models of each option were analyzed to determine the density of risk ratings at, or below a risk rating of certain interest. The cumulative probability versus cumulative cost and schedule delay models were used to determine the probability, cost and schedule delay of multiple risk items occurring simultaneously in a worst-case scenario. Finally, the frequency of the risk ratings in each option were analyzed through the use of histograms.

Option 1 was found to be the higher risk option and the only option with risk ratings above 9. Risk item1-09 general corrosion scored a risk rating of 16, the highest possible risk rating, and cannot be mitigated to an acceptable level without life extension measures. Therefore, the risk rating of 16 significantly impacts the results of the Option 1 models.

Option 3 has the smallest mean and standard deviation, indicating that the risk ratings in the option are less than the risk ratings in the other options. The normal distribution of Option 3 displays the least amount of skew. The normal distribution curve was also used to determine that Option 3 had the highest probability of having a risk rating fall within the low risk matrix category and had the lowest probability of having a risk rating fall into the high risk matrix category. The normal cumulative distribution models were analyzed and it was determined that Option 3 has a greater density of risk ratings at or below any of the specified risk ratings. Furthermore, through the analysis of the cumulative probability versus cumulative cost and schedule delay, Option 3 displayed the greatest difference between the overall pre-mitigation and post-mitigation curves, indicating that risk items identified in the risk assessment could be mitigated, reducing the risk, compared to the other options. From the risk assessment and analysis of the risk rating data, Option 3 is accepted as the lowest risk option.

8.0 SUMMARY

Based on the risk assessment detailed in this report Option 3 is clearly the least risky option. It is the only option that adequately addresses the peaking and fatigue issues in the 17-foot diameter section, allowing it to be the only option that could comfortably lift the current operational constraints limiting operation in the rough zone.

Option 3 identified four risk items having a pre-mitigated high-risk rating of 9. These four items are construction related or pre-construction related and can be mitigated down to a moderate risk rating. Not accounted for in the above recommendation is the fact that this Option has the highest estimated construction cost by a fair margin. This will be discussed in the Decision Support Package.

9.0 REFERENCES

Hatch. 2017. Final Report for Bay d'Espoir No. 1 Stress Analyses. Rev 0. March 2017.

_____ 2017. Root Cause Analysis Report for Bay d' Espoir Penstock No. 1 Refurbishment. Rev 1. March 2017.

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REPORT SIGNATURE PAGE

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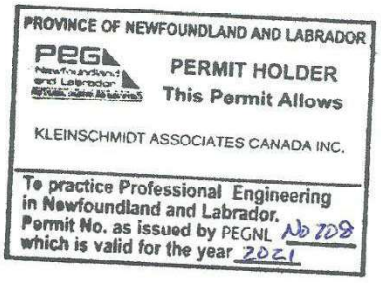


APPENDIX A

RISK REGISTER

Risk Register:

Bay d'Espoir Penstock Life Extension - Front End Engineering and Design (FEED)

Task 6: Risk Assessment of Life Extention Options for Penstocks 2 and 3

Risk Identification				Risk Impact						Mitigation		
Option	ID	Risk Title	Risk Description	Risk Likelihood	Cost Impact	Schedule Impact	Other Impacts	Overall Risk Impact	Risk Rating	Mitigating Actions	Post Mitigation Risk	Notes
Option # 1	1-01	Minor Failure - Rupture at Weld U/S of Surge Tank	Localized failure in 17ft dia. section creating a minor leak which causes a temporary outage. There is no damage to the surrounding infrastructure. Only one can is affected.	4	3	3	3	3	12	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	9	Assuming quick repair. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Assuming one failure once every two years over 30yr period.
	1-02	Medium Failure - Rupture at Weld U/S of Surge Tank	Failure in 17ft dia. section - Failure continues into the next can/ multiple failures causing a medium leak. Possible impact on access road and surrounding infrastructure.	2	3	2	2	3	6	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	6	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.
	1-03	Major Failure - Rupture at Weld U/S of Surge Tank	Failure of 3+ cans or major can failure causing a major leak. There is significant release of water and erosion of earth.	2	3	3	3	3	6	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	6	Assuming no damage to surge tank or switchyard. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.
	1-04	Minor Failure - Rupture at Weld D/S of Surge Tank	Localized failure in a section of one can which results in a temporary outage. The rupture does not damage surrounding infrastructure.	2	2	2	2	2	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	4	Assuming that any leaks would be noticed, does not include damage to switchyard, drainage system can handle runoff. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.
	1-05	Medium Failure - Rupture at Weld D/S of Surge Tank	Failure continues into the next can/ multiple failures causing a medium leak. Possible impact on access road and surrounding infrastructure.	2	2	2	2	2	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Assuming drainage system can handle runoff.
	1-06	Major failure - Rupture at Weld D/S of Surge Tank	Failure continues into next can/ multiple failures causing a major leak. Rupture impacts access road, switchyard, and surrounding infrastructure.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.. Assuming there is damage to the switchyard, drainage system cannot handle runoff, water spray, significant erosion
	1-07	Drainage Failure	Drainage system cannot handle run-off. Increased ground water pressure may lead to floating the penstock or create voids under the penstock, causing the penstock to collapse or bend.	1	3	3	2	3	3	Regular inspections and monitoring of drainage system. Internal ROV inspection	3	Drainage system is old and outlet blockages have been noted. Obtaining passive drainage upgrades - repairing known issues. i.e.. Removing blockages
	1-08	Heat Affected Zone - Corrosion	Low stress and high cyclic loading can lead to cracking. If left alone or untreated, the coarse grained section of the weld corrodes at a faster rate compared to the surrounding material.	4	2	2	1	2	8	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	8	Dependent on how many inches of weld need to be repaired. This risk assumes no coating system is applied or will be applied. Before coating system is applied, reinforcement should be ground flush.

Option # 1	1-09	General Corrosion	The base metal (away from weld area) corrodes. No prior preventative actions such as applying a coating is taken. However, action such as applying a coating is taken before the section needs to be replaced.	4	4	3	2	4	16	Regular inspections, Availability of work crews, Availability of materials, Apply coating system.	12	This risk assumes no coating system is applied but that corrosion reaches a point that coating needs to be applied to prevent further loss before 30 yrs. Inspections have displayed similar pitting depths between penstocks 1 to 3.
	1-10	Rupture of a Penstock Damages Adjacent Penstock(s)	Rupture of a penstock damages adjacent penstocks, i.e. washes out earth supporting penstock leading to failure.	1	4	3	3	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	1-11	Reservoir Operability	Without mitigation the operational constraints will remain to reduce rough zone operations	4	2		2	2	8	Reduction of reservoir operability is a mitigating action	8	Currently reducing reservoir operations to reduce rough zone operation. No schedule impact. Reduction leads to impact on other projects operations.
	1-12	Maintenance of Facilities Are Impacted if Rupture Occurs	The maintenance of other facilities is impacted if a rupture or failure occurs. Resources are moved away from maintenance activities to fixing the failure.	2	2	2		2	4	Contingency in maintenance plans	4	
	1-13	Transition Piece to Surge Tank Failure	Minor leak, such as pinholes goes undetected. The leak would be contained within the concrete.	2	2	2	1	2	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	A leak in the transition section would be difficult to detect and over time can lead to further deterioration of the steel and wear of the concrete. The concrete would likely prevent or contain a significant failure
	1-14	Toppling of Surge Tower U/S Rupture	Rupture of penstock U/S of surge tank. Leak is undetected which causes soil erosion around tower footing and leads to the surge tank toppling.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	1-15	Penstock Collapse - Vacuum	The penstock vent freezes which leads to vacuum pressure in penstock causing multiple cans to collapse.	1	4	3	2	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Not a differentiator between options.
	1-16	Load Rejection - D/S of Surge Tank	Load rejection occurs within the next 30 years which leads to penstock failure due to weakened welds or plating.	1	2	2	2	2	2		2	Is this more likely to fail from a load rejection increased pressure or from cyclic loading ot combination?
	1-17	Erosion of Penstock Foundation	A minor leak or rupture such as a pinhole leak goes undetected, which leads to erosion under the penstock causing settlment and damage to the penstock.	2	2	2	2	2	4	Regular inspections, drainage maintenance and monitoring to detect increased flows	4	
	1-18	Minor Rupture Under Switchyard	Minor leak in the penstock under the switchyard goes undetected. The leak erodes soil around the penstock under the switchyard creating a void, leading to failure of the penstock or collapse of the switchyard.	2	4	4	4	4	8	Regular inspections of penstock section under switchyard.	8	Pipe is thick, however, there is corrosion as seen on previous inspections. A small pressurized hole can cause significant erosion.

Option # 1	1-19	Major Rupture Under Switchyard	A major leak or rupture under the switchyard occurs causing significant damage to the surrounding infrastructure	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	
	1-20	Hoop Stress Rupture - Base metal failure	The base metal corrosion compounded with fatigue leads to failure of a section of the penstock. The affected section would need to be replaced.	1	3	2	2	3	3	Apply coating system to stop or slow corrosion, regular inspections,UT gauge inspection.	3	
	1-21	Winter Penstock Failure During Peak Load (Jan/Feb)	Penstock failure occurs in winter (Jan/ Feb) during peak loading.	2	4	2	4	4	8		8	This risk focusses on the economic impact due to compounding factors such as power availability and seasonal impacts. Charpy toughness is less during winter (colder).
	1-22	Failure of Penstock Due to Earthquake	An earthquake causes penstock failure.					0	0	Analyze existing infrastructure to determine earthquake resistance.		Not a differentiator. Was discussed but not quantified
	1-23	Surge Tank freezes - Load Rejection - Penstock failure U/S	A load rejection occurs during a period when the surge tank is frozen resulting in a penstock rupture.					0	0	Regular inspections during cold temperatures.		Not a differentiator. Was discussed but not quantified
Option # 2	2-01	Minor Failure - Rupture at Weld U/S of Surge Tank	Localized failure in 17ft dia. section creating a minor leak which causes a temporary outage. There is no damage to the surrounding infrastructure. Only one can is affected.	2	2	2	2	2	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	4	Assuming quick repair. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Assuming one failure once every two years over 30yr period. Other impacts include public perception
	2-02	Medium Failure - Rupture at Weld U/S of Surge Tank	Failure in 17ft dia. section - Failure continues into the next can/ multiple failures causing a medium leak. Possible impact on access road and surrounding infrastructure.	1	3	2	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts include public perception
	2-03	Major Failure - Rupture at Weld U/S of Surge Tank	Failure of 3+ cans or major can failure causing a major leak. There is significant release of water and erosion of earth.	1	3	3	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	4	Assuming no damage to surge tank or switchyard. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts include public perception. There is volatility in cost
	2-04	Minor Failure - Rupture at Weld D/S of Surge Tank	Localized failure in a section of one can which results in a temporary outage. The rupture does not damage surrounding infrastructure.	2	2	2	3	3	6	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	6	Assuming that any leaks would be noticed, does not include damage to switchyard, drainage system can handle runoff. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts
	2-05	Medium Failure - Rupture at Weld D/S of Surge Tank	Failure continues into the next can/ multiple failures causing a medium leak. Possible impact on access road and surrounding infrastructure.	1	2	2	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Assuming drainage system can handle runoff. Other impacts include public perception
	2-06	Major failure - Rupture at Weld D/S of Surge Tank	Failure continues into next can/ multiple failures causing a major leak. Rupture impacts access road, switchyard, and surrounding infrastructure.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.. Assuming there is damage to the switchyard, drainage system cannot handle runoff, water spray, significant erosion. Other

Option # 2	2-07	Drainage Failure	Drainage system cannot handle run-off. Run-off may lead to floating the penstock or create voids under the penstock, causing the penstock to collapse or bend.	1	3	3	2	3	3	Regular inspections and monitoring of drainage system. Internal ROV inspection	3	Obtaining passive drainage upgrades - repairing known issues. i.e.. Removing blockages
	2-08	Heat Affected Zone - Corrosion	Low stress and high cyclic loading can lead to cracking. If left alone or untreated, the coarse grained section of the weld corrodes at a faster rate compared to the surrounding material.	2	2	2	1	2	4	Regular inspections, Apply and maintain coating system.	4	Before coating system is applied, reinforcement should be ground flush.
	2-09	Localized Coating Failure	Localized coating failure requiring a spot repair.	3	2	1	1	2	6	QA/QC during all phases of coating application, NACE inspector	6	Coating will likely need replacement in 20 yrs. - dependent on assumptions. Sandblasting may decrease thickness of penstock. Inspection and maintenance of the coating system would become part of maintenance plan. Cost sensitivity of the level of effort during surface preperation?
	2-10	Significant Coating Failure	Unexpected coating failure within a 10 year period after the coating has been applied requires repair (more than spot patching). The contractor would be required to complete repair.	2	3	3	1	3	6	QA/QC during all phases of coating application, NACE inspector	6	Coating to be replaced after 20 yrs. - dependent on assumptions. Sandblasting may decrease thickness of penstock. Pitting will increase the chances of coating system failure. Welds need to be ground flush to reduce lieklihood of coating failure.
	2-11	Rupture of a Penstock damages Adjacent Penstock(s)	Rupture of a penstock damages adjacent penstocks, i.e. washes out earth supporting penstock leading to failure.	1	4	3	3	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation and water up procedures.	4	
	2-12	Reduction of Reservoir Operability	The instruction that has been implemented to reduce rough zone operations causes other penstock failure.	3	2		2	2	6	Reduction of reservoir operability is a mitigating action	6	Would there still be restrictions on operability post penstock refurbishment? The longitudinal seams are the most susceptible to cyclic loading. Peaking effect would be significantly reduced but remain. Cost and other impacts not well defined
	2-13	Maintenance of Facilities Are Impacted if Rupture Occurs	The maintenance of other facilities is impacted if a rupture/ failure occurs. Resources are moved away from maintenance activities to fixing the failure.	2	2	2		2	4	Contingency in maintenance plans	4	
	2-14	Transition Piece to Surge Tank	Leak is undetected. Pinholes would be contained within concrete. Minor leak.	1	2	2	1	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	A leak in the transition section would be difficult to detect and over time can lead to further deterioration of the steel and wear of the concrete. The concrete would likely prevent or contain a significant failure
	2-15	Toppling of Surge Tower U/S Rupture	Rupture of penstock U/S of surge tank. Leak is undetected which causes soil erosion around tower footing and leads to the surge tank toppling.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	2-16	Penstock Collapse - Vacuum	Vent freezes which leads to vacuum pressure in penstock. Multiple cans collapse.	1	4	3	2	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Not a differentiator between options.

Option # 2	2-17	Failure due to Load Rejection D/S of Surge Tank	Load rejection occurs which leads to penstock failure.	1	2	2	2	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	Preference for load rejection testing before visual inspection
	2-18	Erosion of Penstock Foundation	A minor leak or rupture such as a pinhole leak goes undetected, which leads to erosion around the penstock causing damage to the penstock.	1	2	2	2	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	
	2-19	Minor Rupture Under Switchyard	Minor leak in the penstock under the switchyard goes undetected. The leak erodes soil around the penstock under the switchyard creating a void, leading to failure of the penstock or colapse of the switchyard.	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	Pipe is thick, however, there is corrosion as seen on previous inspections. A small pressurized hole can cause significant erosion.
	2-20	Major Rupture Under Switchyard	A major leak or rupture under the switchyard occurs which would cause significant damage to the surrounding infrastructure	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	
	2-21	Hoop Stress Rupture - Base Metal Failure	The base metal corrosion compounded with fatigue leads to failure of a section of the penstock. The affected section would need to be replaced.	1	3	2	3	3	3	Apply coating system to stop or slow corrosion, regular inspections.	3	
	2-22	Winter Penstock Failure during Peak load (Jan/Feb)	Penstock failure occurs in winter (Jan/ Feb) during peak loading. This risk focusses on the economic impact due to compounding factors such as power availability and seasonal impacts.	2	4	2	4	4	8		8	Charpy toughness is less during winter (colder).
	2-23	Failure of Penstock Due to Earthquake	An earthquake causes penstock failure.					0	0			Not a differentiator. Was discussed but not quantified
	2-24	Surge Tank Freezes - Load Rejection - Penstock failure U/S	A load rejection occurs during a period when the surge tank is frozen resulting in a penstock rupture.					0	0			Not a differentiator. Was discussed but not quantifiec
	2-25	Pandemic	Pandemic slows construction work.	2	3	3	3	3	6	Project continuity plan, scheduled/sequenced construction approach, separating contracts (1 for weld repair, 1 for coating)	6	Current impacts on productivity range from %18 to 20% due to social distancing and other procedures impacted by COVID.
	2-26	Pandemic	Pandemic leads to stopping construction activities/work. Assuming work stops for the entire construction season (May to Nov).	1	3	4	3	4	4	Project continuity plan, scheduled/sequenced construction approach, separating contracts (1 for weld repair, 1 for coating)	4	Other impacts may include additional cracks that will need repairing due to pandemic delaying refurbishment. Stopping work for a year or a month? Demobilization costs?

Option # 2	2-27	Failures Before Construction Begins	Failure at a weld in the 17ft dia section U/S of surge tower occurs prior to the construction phase.	4	2	2	2	2	8	Regular inspections, Availability of work crews, Availability of materials, Changes to unit operation, and water up procedures.	8	This risk item is not a product of Option 2 repairs. Failure refers to a crack that requires repair, not a leak.
	2-28	Skilled Workforce Availability	i.e.. Welders that have experience with the condition of steel	1	1	1	1	1	1		1	Welding refurbishment should be separated from coating application. Contractor should be certified in W47.1 DIV1 & 2
	2-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Construction/ confined space environment may lead to lower productivity.	3	3	3	2	3	9	Good supervision, pre-planning, adequate access, good working conditions, qualified contractors, realistic baseline schedule, provide	6	Welding refurbishment should be separated from coating application. Contractor should be certified in W47.1 DIV1 & 2. Post mitigating risk is 4-6. Assuming there is no mitigation action taken.
	2-30	Supervision Quality	Lack of quality supervision highly impacts the productivity of the workforce, quality controls, safety.	2	3	3	2	3	6	Insert language in bid documents, require: resume, level of experience, references, and interview during pre-award meeting,	3	Assuming poor supervisioin quality.
	2-31	Inspection Quality		2	2	2	2	2	4	3rd party weld inspector, well integrated QMS.	2	Rework impacts morale which can decrease productivity. Assuming magnetic particle and visual inspections.
	2-32	Flawed Weld Not Discovered and Fails	A flawed weld is not discovered during the inspection phase and fails in the future.	2	2	2	2	2	4		4	Assuming 100% visual inspection and 100% magnetic particle testing. Skilled welders & inspectors assumed.Risk likelihood different compared to penstock #1. Risk Likelihood is different compared to the penstock #1 workshop
	2-33	Financing During Construction	Interest rates increase significantly by the time as the project starts which impact costs.	2	3		1	3	6	Complete project ASAP.	6	
	2-34	Local Accommodations	Lack of local accommodations in the surrounding Bay d'Espoir area creating schedule restraints, morale issues, reduced productivity	4	2	2		2	8	Building and operating a camp, contractor provide proof of local accommodations, seperating contract work to lessen accommodation need.	2	Other jobs may be occuring at the same time of penstock refurbishment i.e. Intake refurbishment.
	2-35	Serious Weather Event	Weather event that shuts down job/ site. i.e.. Access road is washed out. No power. Possible damage to excavation around penstock. 1 in 100 year event.	2	1	1	1	1	2	Taking weather delays into account when creating project schedule	2	Does not include cost to repair access road. Considering rain, snow, and heat wave event.
	2-36	Typical Weather Event	typical weather event including spring/winter storms/heat wave causing construction delays.	3	1	1	1	1	3	Taking weather delays into account when creating project schedule	3	Rain/snow/heat wave

Option # 2	2-37	Construction Equipment availability	Inability to mobilize equipment to site on time.	1	1	1	1	1	1	Pre-planning	1	
	2-38	Protests	Protest significant enough to stop work. Not including strikes.	2	1	1	2	2	4	Public outreach	4	Including public relations
	2-39	Coating application conditions/ environment	i.e.. humidity control, ventilation of noxious fumes/ VOC's	3	2	2	1	2	6	selection of appropriate coating system for application environment. Proper ventilation, proper staging/ bulkheads.	4	Assuming coating system that does not require a strict environment control. Procurement time can impact schedule. Cost impact is directly related to schedule impact.
	2-40	Coating QC	Poor QA/QC requires reapplication of coating system. Failure occurs post construction.	3	3	3	2	3	9	NACE/qualified inspector, representative from coating manufacturer, ITP's, QA looking over QC	6	What will the warranty be on the coating system?
	2-41	Material Availability	Weld material, coating system,	2	2	2	1	2	4	Pre-planning, pre-order coating system,	2	Hard spec a certain coating system or pre qualifying a few optoins?
	2-42	Excavation Causes Movement in Penstock	Excavation of penstock to daylight exterior welds causes local (1 - 2 cans) shift in penstock. Minor damage	1	2	3	3	3	3	Maintaining support of penstock during excavation	3	
	2-43	Impacts to Operation of Adjacent Penstocks	Equipment working on penstock impacts adjacent penstock i.e.. Excavator runs over penstock - penstock dewatered to inspect interior damage.	2	2	1	2	2	4	Site control, contractor knowing boundaries, designated locations for crossing penstock.	2	Other and cost impacts based on lost generation of power. Assuming no damage found.
	2-44	Major Lost Time Incident	A safety incident that shuts down work for any period of time. i.e.. Significant lost time - Fatality	1	1	3	4	4	4	Safety control measures, training, awareness, PPE	4	This risk item assumes a significant injury upto and including a fatality.
	2-45	Minor Lost Time Incident	A safety incident that shuts down work for a short period of time. Minor lost time. I.e.. broken finger	2	1	1	2	2	4	Safety control measures, training, awareness, PPE	4	
	2-46	Additional or Less Welds Need to be Repaired	Additional or less welds need to be repaired than what was planned for. Assuming +/-20% ?	3	3	2	1	3	9	Thorough weld inspection before contract is awarded.	9	Assuming 50% of welds need to be repaired.

Option # 2	2-47	Work Not Completed as Planned	Work not completed as planned and work extends beyond planned schedule. Assuming up to 1 month extension	2	3	2	3	3	6	Realistic scheduling	6	
	2-48	Threat of Forest Fire/ Forest Fire	Threat of, or occurrence of a forest fire stops work for 2 weeks or less.	2	2	1	1	2	4	Hot work permit,	4	Assuming no direct damage to the Site.
	2-49	Unplanned work interruption	Unplanned work interruption, such as a strike, lasts 2 weeks or less	1	2	1	1	2	2		2	
	2-50	Environmental spill into watershed	i.e.. Coating product leaks into watershed via penstock. Assuming 1 drum or less is released - 55 gallon drum. Release of corroded steel, Sandblasted material, fuels.	2	3	1	3	3	6	Environmental controls, monitoring drainage systems, material handling procedures, containment systems i.e.. Fuel pans	3	
	2-51	Marine Atlantic Ferry Delays	Weather event or ice congestion causes ferry to be delayed, impacting material, equipment, or man power.	4	1	1	1	1	4	Pre-planning.	4	
	2-52	Escalation	Price of materials and labour increases. Time from proposal phase to when construction occurs. Escalation prediction is outside of bounds.	2	2	1	1	2	4	Contractor to purchase coating system, contingency to prevent escalation	4	
	2-53	Challenges in Scaffolding	Difficulty in erecting scaffolding impacts productivity and costs.	3	2	2	1	2	6	Pre-planning a well designed scaffold that can be used for slopes and site conditions, Site visit during RFP Phase,	6	Does the contractor absorb the costs of problems in erecting scaffold? Seam locations are different for penstock #3 compared to penstock #1 & #2.
	2-54	Hoisting	Dropped object/ material									Was discussed but not quantified as no significant crane work is expected for this option
	2-55	Pre Construction Risks	Constraints in developing bid package/ getting bid out on time limits tendering and pre-mobilization time.	3	3	3	2	3	9	Develop realistic design and tender schedule along with realistic cost estimates (pre tender).	4	Not a differentiator between options.
	2-56	Regulator Approval	Delay in obtaining regulator approval	3	2	3	2	3	9	Hire consultant to conduct review, internal review, early submittal to regulator, keeping regulator up to date.	4	

Option # 2	2-57	Environmental Permits	Delay in obtaining environmental permits.	2	1	3	1	3	6	Seek environmental approval early/ engage environmental department early.	4	Working near water, sediment control
	2-58	Risk of Not Obtaining Preferred 2nd Coating Quality due to theThickness of Penstock	Not having enough plate thickness available to surface prep penstock for an additional coating in 20 years.	4	2	2	3	3	12	Design coating system to last 30yrs +	4	May be different for U/S vs D/S of surge tank. Cost impact is related to additional constraints around surface prep. Other impacts relates to the life expectancy of the less than preferred coating not lasting required time frame.
Option # 3	3-01	Minor Failure - Rupture at Weld U/S of Surge Tank	localized failure in 17ft dia. section which would include temporary outage. Does not damage surrounding infrastructure. Only one can is affected. Minor leak	1	2	2	3	3	3	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	3	Cost of inspection included. Life span of coating? Keeping Likelihood as 1 for consistency - overall probability is very low.
	3-02	Medium Failure - Rupture at Weld U/S of Surge Tank	Failure in 17ft dia. section - Failure continues into next can/ multiple failures. Possible impact on access road and surrounding infrastructure. Medium leak	1	3	2	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts include public perception
	3-03	Major Failure - Rupture at Weld U/S of Surge Tank	Failure of 3+ cans/ major can failure, Significant release of water and erosion of earth.	1	3	3	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Assuming no damage to surge tank or switchyard. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts include public perception
	3-04	Minor Failure - Rupture at Weld D/S of Surge Tank	Localized failure (one can) in section which results in a temporary outage. Does not damage surrounding infrastructure.	2	2	2	3	3	6	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	6	Assuming that any leaks would be noticed, does not include damage to switchyard, drainage system can handle runoff. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts
	3-05	Medium Failure - Rupture at Weld D/S of Surge Tank	Failure continues into next can/ multiple failures. Possible impact on access road and surrounding infrastructure.	1	2	2	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Assuming drainage system can handle runoff. Other impacts include public perception
	3-06	Major failure - Rupture at Weld D/S of Surge Tank	Failure continues into next can/ multiple failures. Impact on access road, switchyard, and surrounding infrastructure.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.. Assuming there is damage to the switchyard, drainage system cannot handle runoff, water spray, significant erosion. Other
	3-07	Drainage Failure	Drainage system cannot handle runoff. Run-off may lead to floating the penstock or create voids under the penstock, causing the penstock to collapse/bend.	1	3	3	2	3	3	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	3	Obtaining passive drainage upgrades - repairing known issues. I.e.. Blockage
	3-08	Heat Affected Zone - Corrosion	Low stress and high cyclic loading can lead to cracking. If left alone/ untreated, the coarse grained section of the weld corrodes at a faster rate than the surrounding material.	2	2	2	1	2	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Dependent on how many inches of weld need to be repaired. This risk assumes no coating system is applied or will be applied. Before coating system is applied, reinforcement should be ground flush.

Option # 3	3-09	Localized Coating Failure	Localized coating failure requiring spot repair.	3	2	1	1	2	6	QA/QC during all phases of coating application, NACE inspector	6	Coating to be replaced after 20 yrs. - dependent on assumptions. Sandblasting may decrease thickness of penstock. Inspection and maintenance of the coating system would become part of maintenance plan. Cost sensitivity of the level of
	3-10	Significant Coating Failure	Unexpected coating failure (within 10yrs) that would require more than spot patching. i.e.. Contractor would be required to complete repair.	2	2	2	1	2	4	QA/QC during all phases of coating application, NACE inspector	4	Coating to be replaced after 20 yrs. - dependent on assumptions. Sandblasting may decrease thickness of penstock. Pitting will increase the chances of coating system failure. Welds need to be ground flush to reduce lieklihood of coating failure.
	3-11	Rupture of Penstock damages adjacent Penstock(s)	Rupture of a penstock damages adjacent penstocks, i.e. washes out earth supporting penstock leading to failure.	1	4	3	3	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	3-12	Reduction of Reservoir Operability	Instruction that has been implemented to reduce rough zone operations which may lead to penstock failure.	1	2		2	2	2	Reduction of reservoir operability is a mitigating action	2	Would there still be restrictions on operability post penstock refurbishment? Replacement of the 17-foot diameter section effectively mitigates the issue
	3-13	Maintenance of Facilities Are Impacted if Rupture Occurs	The maintenance of other facilities is impacted if a rupture/ failure occurs. Resources are moved away from maintenance activities to fixing the failure.	2	2	2		2	4	Contingency in maintenance plans	2	A winter failure will have a greater cost impact compared to ther seasons. Risk level changes over the period of time.
	3-14	Transition Piece to Surge Tank	Leak is undetected. Pinholes would be contained within concrete. Minor leak.	1	2	2	1	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	
	3-15	Toppling of Surge Tower U/S Rupture	Rupture of penstock U/S of surge tank. Leak is undetected which causes soil erosion around tower footing and leads to the surge tank toppling.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	3-16	Penstock Collapse - Vacuum	Vent freezes which leads to vacuum pressure in penstock. Multiple cans collapse.	1	4	3	2	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	3-17	Failure due to Load Rejection - D/S of Surge Tank	Load rejection occurs (within 10 years) which leads to penstock failure.	1	2	2	2	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	
	3-18	Erosion of Penstock Foundation	Pinhole leak goes undetected which leads to erosion around penstock leading to shift in penstock leading to failure. Minor rupture	1	2	2	2	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	

Option # 3												
	3-19	Minor Rupture Under Switchyard	Minor leak (dime size but large head pressure) in penstock under the switchyard goes undetected. Leak erodes soil around penstock creating a void under penstock leading to failure.	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	
	3-20	Major Rupture Under Switchyard	Major rupture under switchyard.	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	
	3-21	Hoop Stress Rupture - Base Metal Failure	Base metal corrosion (away from heat affected zone)/ fatigue leading to failure. Section would need to be replaced.	1	3	2	3	3	3	Apply coating system to stop or slow corrosion, regular inspections.	3	
	3-22	Winter Penstock Failure During Peak Load (Jan/Feb)	Penstock failure occurs in winter (Jan/ Feb) during peak loading. This risk focusses on the economic impact due to compounding factors such as power availability and seasonal impacts.	1	4	2	4	4	4		4	Charpy toughness is less during winter (colder).
	3-23	Failure of Penstock Due to Earthquake						0	0			Not a differentiator. Was discussed but not quantified
	3-24	Surge Tank Freezes - Load Rejection - Penstock failure U/S	A load rejection occurs during a period when the surge tank is frozen resulting in a penstock rupture.					0	0			Not a differentiator. Was discussed but not quantified
	3-25	Pandemic - Decreased Productivity	Pandemic slows construction work.	2	3	3	3	3	6	Project continuity plan, scheduled/sequenced construction approach, separating contracts (1 for weld repair, 1 for coating)	6	
	3-26	Pandemic - Work Stops	Pandemic leads to stopping construction activities/work. Assuming work stops for the entire construction season (May to Nov).	1	3	4	3	4	4	Project continuity plan, scheduled/sequenced construction approach, separating contracts (1 for weld repair, 1 for coating)	4	Other impacts may include additional cracks that will need repairing due to pandemic delaying refurbishment. Stopping work for a year or a month? Demobilization costs?
	3-27	Failures Before Construction Begins	Failure at a weld in the 17ft dia section U/S of surge tower occurs prior to the construction phase.	4	2	2	2	2	8	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	8	This risk item is not a product of Option 2 repairs. Failure refers to a crack that requires repair, not a leak.
	3-28	Skilled Workforce Availability	i.e.. Welders that have experience with the condition of steel	1	1	1	1	1	1		1	

Option # 3												
	3-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Construction/ confined space environment may lead to lower productivity.	3	3	3	2	3	9	Good supervision, pre-planning, adequate access, good working conditions, qualified contractors, realistic baseline schedule, provide	6	Welding refurbishment should be separated from coating application. Contractor should be certified in W47.1 DIV1 & 2. Post mitigating risk is 4-6.
	3-30	Supervision Quality	Lack of quality supervision highly impacts the productivity of the workforce, quality controls, safety.	2	3	3	2	3	6	Insert language in bid documents, require: resume, level of experience, references, and interview during pre-award meeting,	3	Assuming poor supervisioin quality.
	3-31	Inspection Quality		2	2	2	2	2	4	3rd party weld inspector, well integrated QMS.	2	
	3-32	Flawed Weld Not Discovered and Fails	A flawed weld is not discovered during the inspection phase and fails in the future.	2	2	2	2	2	4		2	Assuming 100% visual inspection and 100% magnetic particle testing. Skilled welders & inspectors assumed.Risk likelihood different compared to penstock #1. Risk Likelihood is different compared to the penstock #1 workshop
	3-33	Financing During Construction	Interest rates increase significantly by the time as the project starts which impact costs.	2	3		1	3	6	Complete project ASAP.	6	
	3-34	Local Accommodations	Lack of local accommodations in the surrounding Bay d'Espoir area creating schedule restraints, morale issues, reduced productivity	4	2	2		2	8	Building and operating a camp, contractor provide proof of local accommodations	2	
	3-35	Serious Weather Event	Weather event that shuts down job/ site. i.e.. Access road is washed out. No power. Possible damage to excavation around penstock. 1 in 100 year event.	2	1	1	1	1	2	Taking weather delays into account when creating project schedule	2	Does not include cost to repair access road. Considering rain, snow, and heat wave event.
	3-36	Typical Weather Event	typical weather event including spring/winter storms/heat wave	3	1	1	1	1	3	Taking weather delays into account when creating project schedule	3	Rain/snow/heat wave
	3-37	Construction Equipment Availability	Inability to mobilize equipment to site on time.	1	1	1	1	1	1	Pre-planning	1	
	3-38	Protests	Protest significant enough to stop work. Not including strikes.	2	1	1	2	2	4	Public outreach	4	Including public relations

Option # 3	3-39	Coating application conditions/ environment	i.e.. humidity control, ventilation of noxious fumes/ VOC's	3	2	2	1	2	6	selection of appropriate coating system for application environment. Proper ventilation, proper staging/ bulkheads.	4	Assuming coating system that does not require a strict environment control. Cost and schedule impact may be reduced due to the 17ft section being shop coated.
	3-40	Coating QC	Poor QA/QC requires reapplication of coating system. Failure occurs post construction.	3	3	3	2	3	9	nace/qualified inspector, representative from coating manufacturer, ITP's, QA looking over QC	6	
	3-41	Material Availability	Weld material, coating system, steel plating	2	2	3	1	3	6	Pre-planning, pre-order coating system, pre-order steel	2	
	3-42	Excavation Causes Movement in Penstock	Excavation of penstock to daylight exterior welds causes local (1 - 2 cans) shift in penstock. Minor damage	1	2	3	3	3	3	Maintaining support of penstock during excavation	3	
	3-43	Impacts to Operation of Adjacent Penstocks	Equipment working on penstock impacts adjacent penstock i.e.. Excavator runs over penstock - penstock dewatered to inspect interior damage.	2	2	1	2	2	4	Site control, contractor knowing boundaries.	4	Other and cost impacts based on lost generation of power. Assuming no damage found.
	3-44	Major Lost Time Incident	A safety incident that shuts down work for any period of time. i.e.. Significant lost time - Fatality	1	1	3	4	4	4	Safety control measures, training, awareness, PPE	4	This risk item assumes a fatality. Duration of shut down?
	3-45	Minor Lost Time Incident	A safety incident that shuts down work for any period of time. Minor lost time. I.e.. broken finger	2	1	1	2	2	4	Safety control measures, training, awareness, PPE	4	Duration of shut down?
	3-46	Additional or less welds need to be Repaired	Additional or less welds need to be repaired than what was planned for. Assuming +/-20% ?	2	2	2	1	2	4	Thorough weld inspection pre-construction,	4	
	3-47	Work Not Completed as Planned	Work not completed as planned and work extends beyond planned schedule. Assuming up to 1 month extension	2	3	2	3	3	6		6	
	3-48	Threat of Forest Fire/ Forest Fire	Threat of, or occurrence of a forest fire stops work for 2 weeks or less.	2	2	1	1	2	4	Hot work permit,	4	Assuming no direct damage to the Site.

Option # 3	3-49	Unplanned Work Interruption	Unplanned work interruption, such as a strike, lasts 2 weeks or less	1	2	1	1	2	2		2	There would now be 2 work fronts as the penstock would be fabricated in shop.
	3-50	Environmental Spill Into Watershed	i.e.. Coating product leaks into watershed via penstock. Assuming 1 drum or less is released - 55 gallon drum. Release of corroded steel, Sandblasted material, fuels.	2	3	1	3	3	6	Environmental controls, monitoring drainage systems, material handling procedures, containment systems i.e.. Fuel pans	3	
	3-51	Marine Atlantic Ferry Delays	Weather event or ice congestion causes ferry to be delayed, impacting material, equipment, or man power.	4	1	1	1	1	4	Pre-planning.	4	
	3-52	Escalation	Price of materials and labour increases. Time from proposal phase to when construction occurs. Escalation prediction is outside of bounds.	2	3	1	1	3	6	Contractor to purchase coating system, contingency to prevent escalation, planning for steel volatility	6	There is a larger time horizon, therefore more volatility for penstocks 2 & 3 compared to penstock 1.
	3-53	Challenges in Scaffolding	Difficulty in erecting scaffolding impacts productivity and costs.	3	2	2	1	2	6	Pre-planning a well designed scaffold that can be used for slopes and site conditions,	6	
	3-54	Hoisting	Dropped object/ material	2	2	1	3	3	6		6	Other impacts include saftey concerns. i.e. injury due to dropped object. Cost impacts are related to damaged materials that may arise from a dropped object.
	3-55	Pre Construction Risks	Constraints in developing bid package/ getting bid out on time limits tendering and pre-mobilization time.	3	3	3	2	3	9	Develop realistic design and tender schedule along with realistic cost estimates (pre tender).	4	Not a differentiator between options.
	3-56	Regulator Approval	Delay in obtaining regulator approval	3	2	3	2	3	9	Hire consultant to conduct review, internal review, early submittal to regulator, keeping regulator up to date.	4	
	3-57	Environmental Permits	Delay in obtaining environmental permits.	2	1	3	1	3	6	Seek environmental approval early/ engage environmental dept. early.	4	
	3-58	Sections do Not Fit as Planned	New section to existing section fit, New section to new section, New section to intake, out of roundness issues, gap between sections.	3	1	1	1	1	3	utilize spider in new and existing sections, 3D Scan,	2	

Option # 3	3-59	Fabrication Errors	Error that is caught in the field. i.e.. Out of roundness, rolled in wrong direction, peaking due to welding, warping	2	1	1	1	1	2	distortion control plan,	2	Assuming only 1 or 2 pieces are affected - not a wide spread issue. Assuming there is a review of the shop drawings/ acceptance review
	3-60	Foundation - Lack of Uniformity	Bedding is not installed correctly. i.e. does not achieve compaction, wrong elevations, wrong slope	3	1	1	1	1	3		3	
	3-61	Backfill - Caught in Field	Not achieving proper compaction limits (below spring line) that is caught in the field during construction phase.	2	2	1	1	2	4	Field QA/QC (compaction testing), use of flowable-fill, Contractor having a compaction plan,	4	Integrity of the compaction should be riewed during the design phase.
	3-62	Backfill - Not Caught	Not achieving proper compaction limits that are not caught during the construction phase which may lead to future settlement issues. 30yr timeframe.	1	3	1	3	3	3	Surveying rods installed on top of penstock	3	
	3-63	Minor Design Inaccuracy	Design of weld and/or penstock leads to alignment, fitment, dimensional, specification, and coating problems which leads to minor rework/change.	4	1	2	1	2	8	Experienced design team, resume review, resident engineer, QA/QC	6	Risk likelihood could be lower due to repetitiveness.
	3-64	Major Design Error	Design of weld and/or penstock leads to alignment, fitment, dimensional, specification, and coating problems which leads to major rework/change.	3	2	1	1	2	6	Experienced design team, resume review, resident engineer, QA/QC	3	Cyclic loading shall be considered in design phase of penstock and supporting infastructure.

Option # 4	4-01	Minor Failure - Rupture at Weld U/S of Surge Tank	localized failure in 17ft dia. section which would include temporary outage. Does not damage surrounding infrastructure. Only one can is affected. Minor leak	3	2	2	2	2	6	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up,	6	Cost of inspection included. Life span of coating? Keeping Likelihood as 1 for consistency - overall probability is very low. What is the risk that welds that are not fixed are going to failure in the future?
	4-02	Medium Failure - Rupture at Weld U/S of Surge Tank	Failure in 17ft dia. section - Failure continues into next can/ multiple failures. Possible impact on access road and surrounding infrastructure. Medium leak	2	3	2	4	4	8	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up,	6	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts include public perception
	4-03	Major Failure - Rupture at Weld U/S of Surge Tank	Failure of 3+ cans/ major can failure, Significant release of water and erosion of earth.	2	3	3	4	4	8	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up,	6	Assuming no damage to surge tank or switchyard. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts include public perception
	4-04	Minor Failure - Rupture at Weld D/S of Surge Tank	Localized failure (one can) in section which results in a temporary outage. Does not damage surrounding infrastructure.	2	2	2	3	3	6	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	6	Assuming that any leaks would be noticed, does not include damage to switchyard, drainage system can handle runoff. Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Other impacts
	4-05	Medium Failure - Rupture at Weld D/S of Surge Tank	Failure continues into next can/ multiple failures. Possible impact on access road and surrounding infrastructure.	1	2	2	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact. Assuming drainage system can handle runoff. Other impacts include public perception
	4-06	Major failure - Rupture at Weld D/S of Surge Tank	Failure continues into next can/ multiple failures. Impact on access road, switchyard, and surrounding infrastructure.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Failure can cause impacts on overall maintenance plan. The time of year that failure occurs can influence level of impact.. Assuming there is damage to the switchyard, drainage system cannot handle runoff, water spray, significant erosion. Other
	4-07	Drainage Failure	Drainage system cannot handle runoff. Run-off may lead to floating the penstock or create voids under the penstock, causing the penstock to collapse/bend.	1	3	3	2	3	3	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	3	Obtaining passive drainage upgrades - repairing known issues. I.e.. Blockage
	4-08	Heat Affected Zone - Corrosion	Low stress and high cyclic loading can lead to cracking. If left alone/ untreated, the coarse grained section of the weld corrodes at a faster rate than the surrounding material.	2	2	2	1	2	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	Dependent on how many inches of weld need to be repaired. This risk assumes no coating system is applied or will be applied. Before coating system is applied, reinforcement should be ground flush.
	4-09	Localized Coating Failure	Localized coating failure requiring spot repair.	3	2	1	1	2	6	QA/QC during all phases of coating application, NACE inspector	6	Coating to be replaced after 20 yrs. - dependent on assumptions. Sandblasting may decrease thickness of penstock. Inspection and maintenance of the coating system would become part of maintenance plan. Cost sensitivity of the level of effort during surface, preperation? Corners of plates should be rounded.
	4-10	Significant Coating Failure	Unexpected coating failure (within 10yrs) that would require more than spot patching. i.e.. Contractor would be required to complete repair.	2	3	3	1	3	6	QA/QC during all phases of coating application, NACE inspector	6	Coating to be replaced after 20 yrs. - dependent on assumptions. Sandblasting may decrease thickness of penstock. Pitting will increase the chances of coating system failure. Welds need to be ground flush to reduce lieklihood of coating failure.

Option # 4	4-11	Rupture of Penstock damages adjacent Penstock(s)	Rupture of a penstock damages adjacent penstocks, i.e. washes out earth supporting penstock leading to failure.	1	4	3	3	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	4-12	Reduction of Reservoir Operability	Instruction that has been implemented to reduce rough zone operations which may lead to penstock failure.	3	2		2	2	6	Reduction of reservoir operability is a mitigating action	6	Plates may not help from the operability perspective due to the risk of the fillet weld failing caused by cyclic loading - would the restrictions on operability remain?
	4-13	Maintenance of Other Facilities is Impacted if Rupture Occurs	The maintenance of other facilities is impacted if a rupture/ failure occurs. Resources are moved away from maintenance activities to fixing the failure.	2	2	2		2	4	Contingency in maintenance plans	4	
	4-14	Transition Piece to Surge Tank	Leak is undetected. Pinholes would be contained within concrete. Minor leak.	1	2	2	1	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	
	4-15	Toppling of Surge Tower U/S Rupture	Rupture of penstock U/S of surge tank. Leak is undetected which causes soil erosion around tower footing and leads to the surge tank toppling.	1	4	4	4	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	4-16	Penstock Collapse - Vacuum	Vent freezes which leads to vacuum pressure in penstock. Multiple cans collapse.	1	4	3	2	4	4	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	4	
	4-17	Failure due to Load Rejection D/S of Surge Tank	Load rejection occurs (within 10 years) which leads to penstock failure.	1	2	2	2	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	
	4-18	Erosion of Penstock Foundation	Pinhole leak goes undetected which leads to erosion around penstock leading to shift in penstock leading to failure. Minor rupture	1	2	2	2	2	2	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	2	Seam location which is down low in penstock #3 increases probability of errosion if a leak occurs.
	4-19	Minor Rupture Under Switchyard	Minor leak (dime size but large head pressure) in penstock under the switchyard goes undetected. Leak erodes soil around penstock creating a void under penstock leading to failure.	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	
	4-20	Major Rupture Under Switchyard	Major rupture under switchyard	1	4	4	4	4	4	Regular inspections of penstock section under switchyard.	4	

Option # 4	4-21	Hoop Stress Rupture - Base Metal Failure	Base metal corrosion (away from heat affected zone)/ fatigue leading to failure. Section would need to be replaced.	1	3	2	3	3	3	Apply coating system to stop or slow corrosion, regular inspections.	3	
	4-22	Winter Penstock Failure During Peak Load (Jan/Feb)	Penstock failure occurs in winter (Jan/ Feb) during peak loading. This risk focusses on the economic impact due to compounding factors such as power availability and seasonal impacts.	2	4	2	4	4	8		8	Charpy toughness is less during winter (colder).
	4-23	Failure of Penstock due to Earthquake						0	0			Not a differentiator. Was discussed but not quantified
	4-24	Surge Tank Freezes - Load Rejection - Penstock failure U/S	A load rejection occurs during a period when the surge tank is frozen resulting in a penstock rupture.					0	0			Not a differentiator. Was discussed but not quantifiec
	4-25	Pandemic	Pandemic slows construction work.	2	3	3	3	3	6	Project continuity plan, scheduled/sequenced construction approach, separating contracts (1 for weld repair, 1 for coating)	6	
	4-26	Pandemic	Pandemic leads to stopping construction activities/work. Assuming work stops for the entire construction season (May to Nov).	1	3	4	3	4	4	Project continuity plan, scheduled/sequenced construction approach, separating contracts (1 for weld repair, 1 for coating)	4	Other impacts may include additional cracks that will need repairing due to pandemic delaying refurbishment. Stopping work for a year or a month? Demobilization costs?
	4-27	Failures Before Construction Begins	Failure at a weld in the 17ft dia section U/S of surge tower occurs prior to the construction phase.	4	2	2	2	2	8	Regular inspections, Availability of work crews, Availability of materials, Changes to the way units perform and are watered up.	8	Not a product of this option
	4-28	Skilled Workforce Availability	i.e.. Welders that have experience with the condition of steel	1	1	1	1	1	1		1	Welding refurbishment should be separated from coating application. Contractor should be certified in W47.1 DIV1 & 2
	4-29	Workforce Productivity	Low productivity leads to more costs, longer schedule. Construction/ confined space environment may lead to lower productivity.	3	3	3	2	3	9	Good supervision, pre-planning, adequate access, good working conditions, qualified contractors, realistic baseline schedule, provide	6	Welding refurbishment should be separated from coating application. Contractor should be certified in W47.1 DIV1 & 2. Post mitigating risk is 4-6.
	4-30	Supervision Quality	Lack of quality supervision highly impacts the productivity of the workforce, quality controls, safety.	2	3	3	2	3	6	Insert language in bid documents, require: resume, level of experience, references, and interview during pre-award meeting,	3	

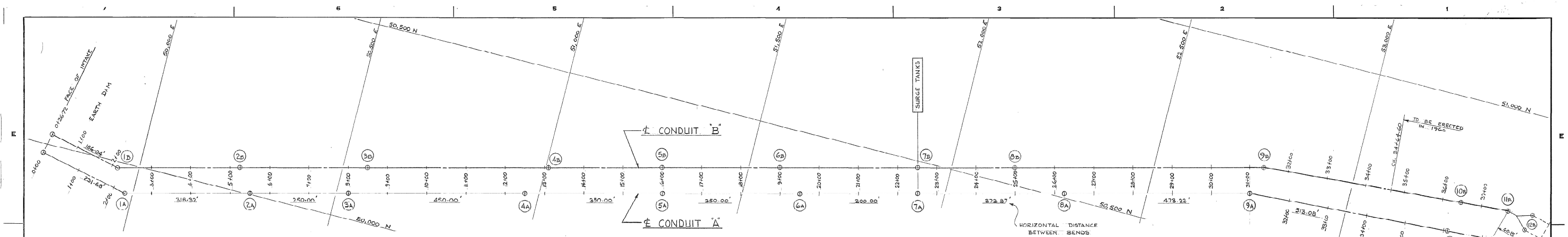
Option # 4												
	4-31	Inspection Quality		2	2	2	2	2	4	3rd party weld inspector, well integrated QMS.	2	
	4-32	Flawed Weld not Discovered and Fails	A flawed weld is not discovered during the inspection phase and fails in the future.	2	2	2	2	2	4		2	Assuming 100% visual inspection and 100% magnetic particle testing. Skilled welders & inspectors assumed.Risk likelihood different compared to penstock #1. Risk Likelihood is different compared to the penstock #1 workshop
	4-33	Financing During Construction	Interest rates increase significantly by the time as the project starts which impact costs.	2	3		1	3	6	Complete project ASAP.	6	
	4-34	Local Accommodations	Lack of local accommodations in the surrounding Bay d'Espoir area creating schedule restraints, morale issues, reduced productivity	4	2	2		2	8	Building and operating a camp, contractor provide proof of local accommodations	2	
	4-35	Serious Weather Event	Weather event that shuts down job/ site. i.e.. Access road is washed out. No power. Possible damage to excavation around penstock. 1 in 100 year event.	2	1	1	1	1	2	Taking weather delays into account when creating project schedule	2	Does not include cost to repair access road. Considering rain, snow, and heat wave event.
	4-36	Typical Weather Event	typical weather event including spring/winter storms/heat wave	3	1	1	1	1	3	Taking weather delays into account when creating project schedule	3	Rain/snow/heat wave
	4-37	Construction Equipment Availability	Inability to mobilize equipment to site on time.	1	1	1	1	1	1	Pre-planning	1	
	4-38	Protests	Protest significant enough to stop work. Not including strikes.	2	1	1	2	2	4	Public outreach	4	Including public relations
	4-39	Coating Application Conditions & Environment	i.e. humidity control, ventilation of noxious fumes/ VOC's	3	2	2	1	2	6	selection of appropriate coating system for application environment. Proper ventilation, proper staging/ bulkheads.	4	Assuming coating system that does not require a strict environment control.
	4-40	Coating QC	Poor QA/QC requires reapplication of coating system. Failure occurs post construction.	3	3	3	2	3	9	nace/qualified inspector, representative from coating manufacturer, ITP's, QA looking over QC	6	

Option # 4	4-41	Material Availability	Weld material, coating system, plate material	2	2	2	1	2	4	Pre-planning, pre-order coating system,	2	
	4-42	Excavation Causes Movement in Penstock	Excavation of penstock to daylight exterior welds causes local (1 - 2 cans) shift in penstock. Minor damage	1	2	3	3	3	3	Maintaining support of penstock during excavation	3	
	4-43	Impacts to Operation of Adjacent Penstocks	Equipment working on penstock impacts adjacent penstock i.e.. Excavator runs over penstock - penstock dewatered to inspect interior damage.	1	2	1	2	2	2	Site control, contractor knowing boundaries.	2	Other and cost impacts based on lost generation of power. Assuming no damage found.
	4-44	Major Lost Time Incident	A safety incident that shuts down work for any period of time. i.e.. Significant lost time - Fatality	1	1	3	4	4	4	Safety control measures, training, awareness, PPE	4	This risk item assumes a fatality. Duration of shut down? Dropping a plate has been covered in a separate risk item.
	4-45	Minor Lost Time Incident	A safety incident that shuts down work for any period of time. Minor lost time. I.e.. broken finger	2	1	1	2	2	4	Safety control measures, training, awareness, PPE	4	Duration of shut down?
	4-46	Additional or less welds need to be Repaired	Additional or less welds need to be repaired than what was planned for. Assuming +/-20%	3	3	2	1	3	9	Thorough weld inspection pre-construction,	9	
	4-47	Work not completed as planned	Work not completed as planned and work extends beyond planned schedule. Assuming up to 1 month extension	2	3	2	3	3	6		6	
	4-48	Threat of Forest Fire/ Forest Fire	Threat of, or occurrence of a forest fire stops work for 2 weeks or less.	2	2	1	1	2	4	Hot work permit,	4	Assuming no direct damage to the Site.
	4-49	Unplanned Work Interruption	Unplanned work interruption, such as a strike, lasts 2 weeks or less	1	2	1	1	2	2		2	
	4-50	Environmental Spill Into Watershed	i.e.. Coating product leaks into watershed via penstock. Assuming 1 drum or less is released - 55 gallon drum. Release of corroded steel, Sandblasted material, fuels.	2	3	1	3	3	6	Environmental controls, monitoring drainage systems, material handling procedures, containment systems i.e.. Fuel pans	3	
	4-51	Marine Atlantic Ferry Delays	Weather event or ice congestion causes ferry to be delayed, impacting material, equipment, or man power.	4	1	1	1	1	4	Pre-planning.	4	

Option # 4	4-52	Escalation	Price of materials and labour increases. Time from proposal phase to when construction occurs. Escalation prediction is outside of bounds.	2	2	1	1	2	4	Contractor to purchase coating system, contingency to prevent escalation	4	There is a larger time horizon, therefore more volatility for penstocks 2 & 3 compared to penstock 1.
	4-53	Challenges in Scaffolding	Difficulty in erecting scaffolding impacts productivity and costs.	3	2	2	1	2	6	Pre-planning a well designed scaffold that can be used for slopes and site conditions,	6	Scaffolding may be more difficult to errect in option 4 due to moving plates and holding plates in place.
	4-54	Pre Construction Risks	Constraints in developing bid package/ getting bid out on time limits tendering and pre-mobilization time.	3	3	3	2	3	9	Develop realistic design and tender schedule along with realistic cost estimates (pre tender).	4	Not a differentiator between options.
	4-55	Regulator Approval	Delay in obtaining regulator approval	3	2	3	2	3	9	Hire consultant to conduct review, internal review, early submittal to regulator, keeping regulator up to date.	4	
	4-56	Environmental Permits	Delay in obtaining environmental permits.	2	1	3	1	3	6	Seek environmental approval early/ engage environmental department early.	4	
	4-57	Failure of Plates (Fillet Weld) - Static Operations	Keeping operating restrictions in place. Not operating in rough zone. Plates are only installed on longitudinal welds	1	1	1	1	1	1		1	Assuming plates are not needed for the circumferential seams.
	4-58	Failure of Plates - Cyclic Operations	Assuming full operability, Removing restrictions. Plates are only installed on longitudinal welds.	3	3	3	3	3	9	Not operating in rough zone,	6	Assuming 30yr timeframe. Assumes significant stress range and number of cycles. Cost impact difference from 4-58 is due to multiple plate failures at toe of fillet welds. Benefits would include reducing stresses from peaking.
	4-59	Plate detaching and going through powerhouse	Assuming significant weld failure, plate peels back	1	3	3	3	3	3		3	
	4-60	Constructability - Lifting Plates in Place	Constructability issues regarding lifting the plates in place, handling of the plates inside of the penstock creating safety problems i.e.. Dropping plates.	3	1	1	3	3	9	Planning, redundancy of lifting mechanisms,	3	
	4-61	Measurable Head-loss due to plating	Adding plates to the interior of penstock increases friction which decreases pressure leading to head-loss	1	1	1	1	1	1		1	

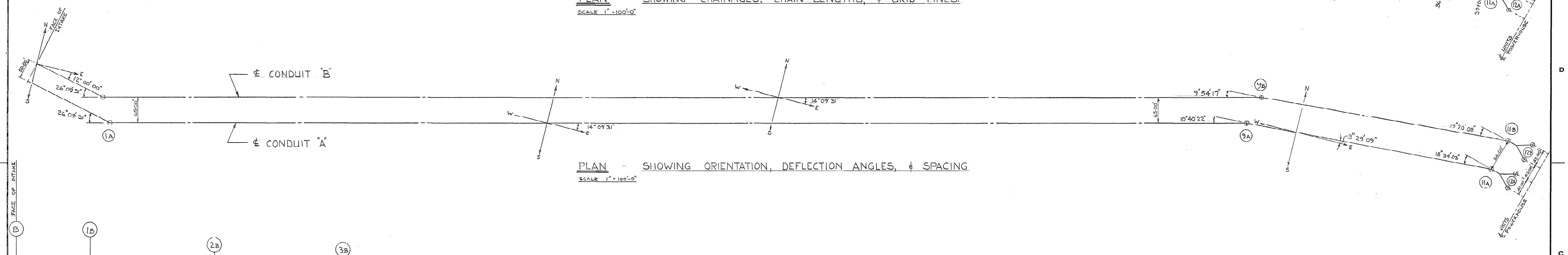
APPENDIX B

FIGURES



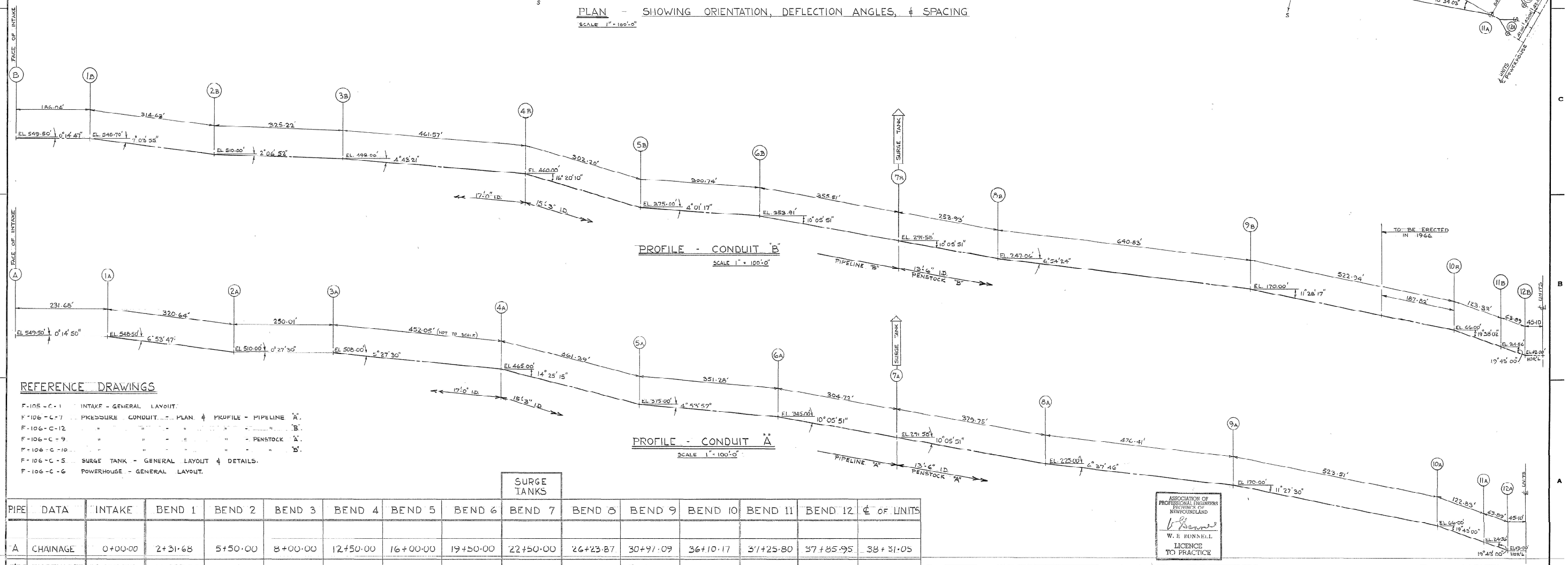
PLAN - SHOWING CHAINAGES, CHAIN LENGTHS, & GRID LINES.

SCALE 1" = 100'-0"



PLAN - SHOWING ORIENTATION, DEFLECTION ANGLES, & SPACING

SCALE 1" = 100'-0"



PROFILE - CONDUIT "B"

SCALE 1" = 100'-0"

PROFILE - CONDUIT "A"

SCALE 1" = 100'-0"

REFERENCE DRAWINGS

F-105-C-1 INTAKE - GENERAL LAYOUT.
F-106-C-7 PRESSURE CONDUIT - PLAN & PROFILE - PIPELINE "A".
F-106-C-12 " " " - " " " - " "B".
F-106-C-9 " " " - " " - PENSTOCK "A".
F-106-C-10 " " " - " " " - " "B".
F-106-C-5 SURGE TANK - GENERAL LAYOUT & DETAILS.
F-106-C-6 POWERHOUSE - GENERAL LAYOUT.

PIPE	DATA	INTAKE	BEND 1	BEND 2	BEND 3	BEND 4	BEND 5	BEND 6	SURGE TANKS BEND 7	BEND 8	BEND 9	BEND 10	BEND 11	BEND 12	℄ OF UNITS
A	CHAINAGE	0+00.00	2+31.68	5+50.00	8+00.00	12+50.00	16+00.00	19+50.00	22+50.00	26+23.87	30+97.09	36+10.17	37+25.80	37+85.95	38+31.05
A	NORTHING	49,975.55	49,927.38						50,421.08		50,628.28		50,666.51		
A	EASTING	49,754.80	49,781.42						51,938.43		52,759.79		53,387.34		
B	CHAINAGE	0+26.72	2+12.76	5+25.00	8+50.00	13+10.00	16+00.00	19+00.00	22+50.00	25+00.00	31+36.18	36+48.67	37+64.83	38+24.98	38+70.08
B	NORTHING	50,024.46	49,985.78								50,700.98		50,747.62		
B	EASTING	49,765.20	49,947.17								52,782.26		53,409.20		

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

APPROVED FOR CONSTRUCTION
AUG 13 1965
APPROVED BY: MANAGER ENGINEERING

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
3	JAN. 25/66		I.D.'s INDICATED.	J.P.	J.H.M.
2	OCT. 18/65		STA. B-1D. VERTICAL ANGLE REVISED	J.P.	J.H.M.
1	SEPT. 27/65		PLANS & PROFILES REVISED	J.P.	J.H.M.

REVISIONS

TRANS'N	ELECT'L	CIVIL
		J.H.M.

PASSED

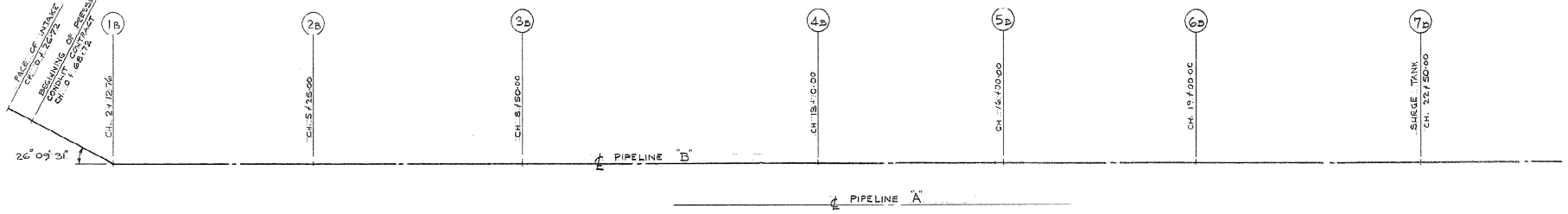
DESIGNED R. Mac D.
DRAWN J.P.
CHECKED A.P. H.K.
RECOMMENDED J.H. Mason

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
LAYOUT & LOCATION DATA

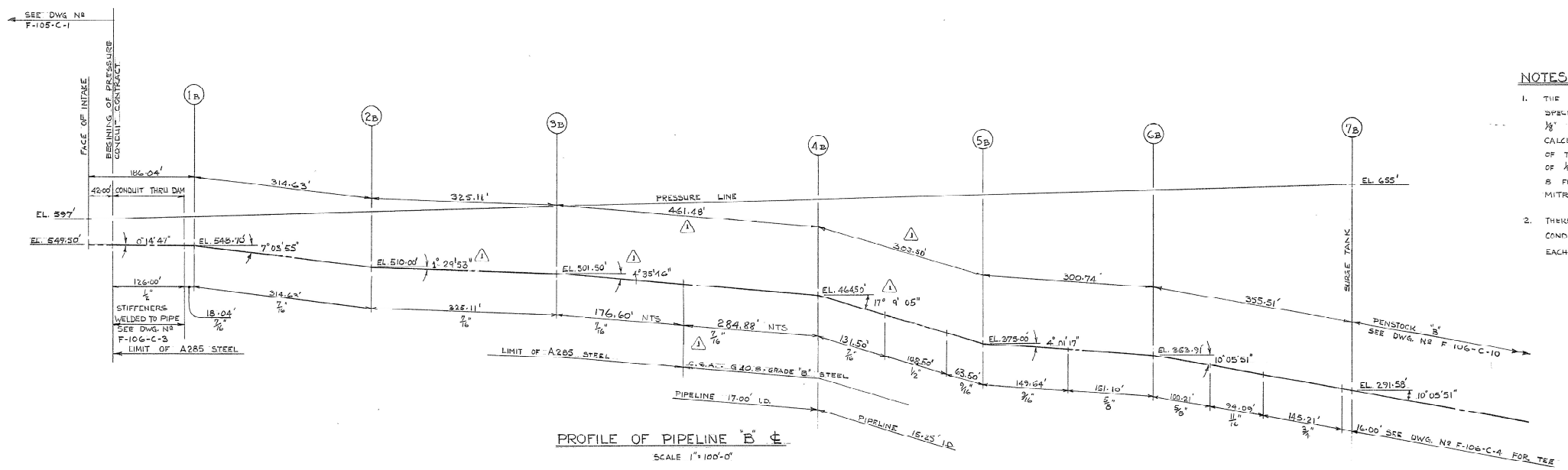
CONTRACT	SCALE	FILE NO	DATE	DWG. NO.	REVISION
	1" = 100'-0"	PD - 11	SEPT. 27, 1965	F-106-C-11	3

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 169 of 212



PLAN OF PIPELINE "B" ℄

SCALE 1" = 100'-0"

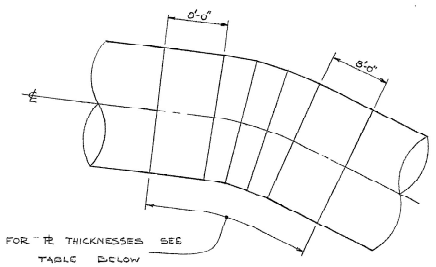


PROFILE OF PIPELINE "B" ℄

SCALE 1" = 100'-0"

NOTES

1. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE ⅛" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF ⅛" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THERE ARE TWO SEPARATE CONDUITS CALLED "A" AND "B". CONDUIT "A" IS SOUTH OF CONDUIT "B". EACH CONDUIT CONSISTS OF A PIPELINE AND A PENSTOCK.



TYPICAL BEND

SCALE 1" = 10'-0"

SEE SPEC. M-3116

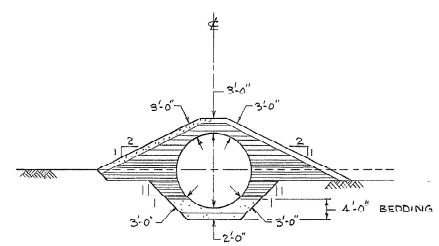
ANGLES & ℔ THICKNESSES AT BENDS

BEND	∠A	∠B	∠C	TRUE ANGLE	℔ THICKNESS
1B	26° 09' 31"	0° 14' 47"	7° 03' 55"	26° 57' 55"	7/16"
2B	——	7° 03' 55"	1° 29' 53"	5° 34' 2"	½"
3B	——	1° 29' 53"	4° 35' 46"	3° 05' 53"	9/16"
4B	——	4° 35' 46"	17° 9' 05"	12° 33' 18"	9/16"
5B	——	17° 9' 05"	4° 01' 17"	13° 07' 18"	¾"
6B	——	4° 01' 17"	10° 05' 51"	6° 04' 34"	13/16"
7B	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	



ANGLE IN PLAN

VERTICAL ANGLES



TYPICAL CROSS SECTION

(LOOKING DOWNSTREAM) SCALE 1" = 15'-0"

REFERENCE DRAWINGS

F-106-C-3	CONDUITS THROUGH DAM.
F-106-C-4	SURGE TANKS - DETAILS OF TEES.
F-106-C-5	SURGE TANKS - GENERAL LAYOUT & DETAILS.
F-106-C-6	PRESSURE CONDUITS - CLEARING.
F-105-C-1	INTAKE GENERAL LAYOUT.
F-106-C-11	PRESSURE CONDUITS - LAYOUT & LOCATION DATA.
F-106-C-7	" " - PLAN & PROFILE PIPELINE "A".
F-106-C-10	" " " " PENSTOCK "B".

OTHER REFERENCES

1. SPECIFICATION Nº M-3116.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
1	DEC/68		REV. ON PROFILE OF EL. AT 3B & 4B	C.C.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
OCT 21 1965
APPROVED BY: W. E. Bonnell
MANAGER ENGINEERING

	TRANS'N	ELECT'L	CIVIL
			JHM

PASSED

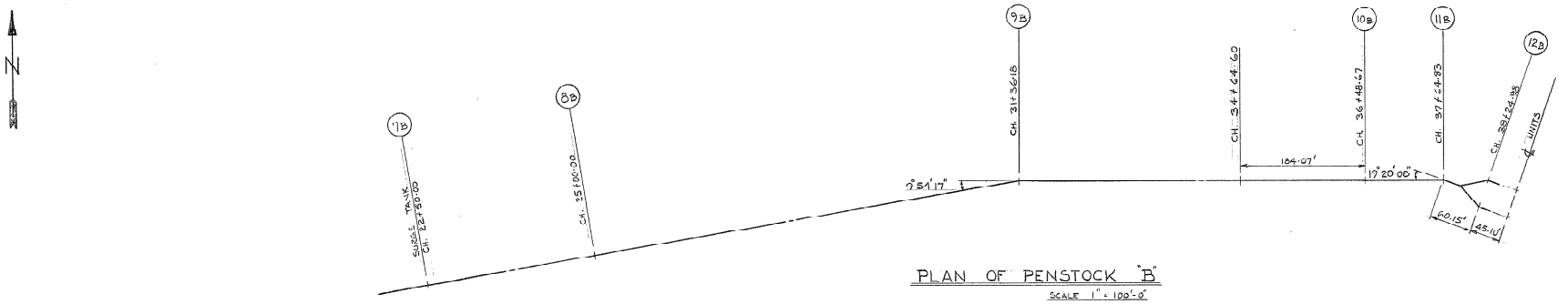
DESIGNED R. Mac D.
DRAWN J.P.
CHECKED HK
RECOMMENDED J.H. Mann P.Eng.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

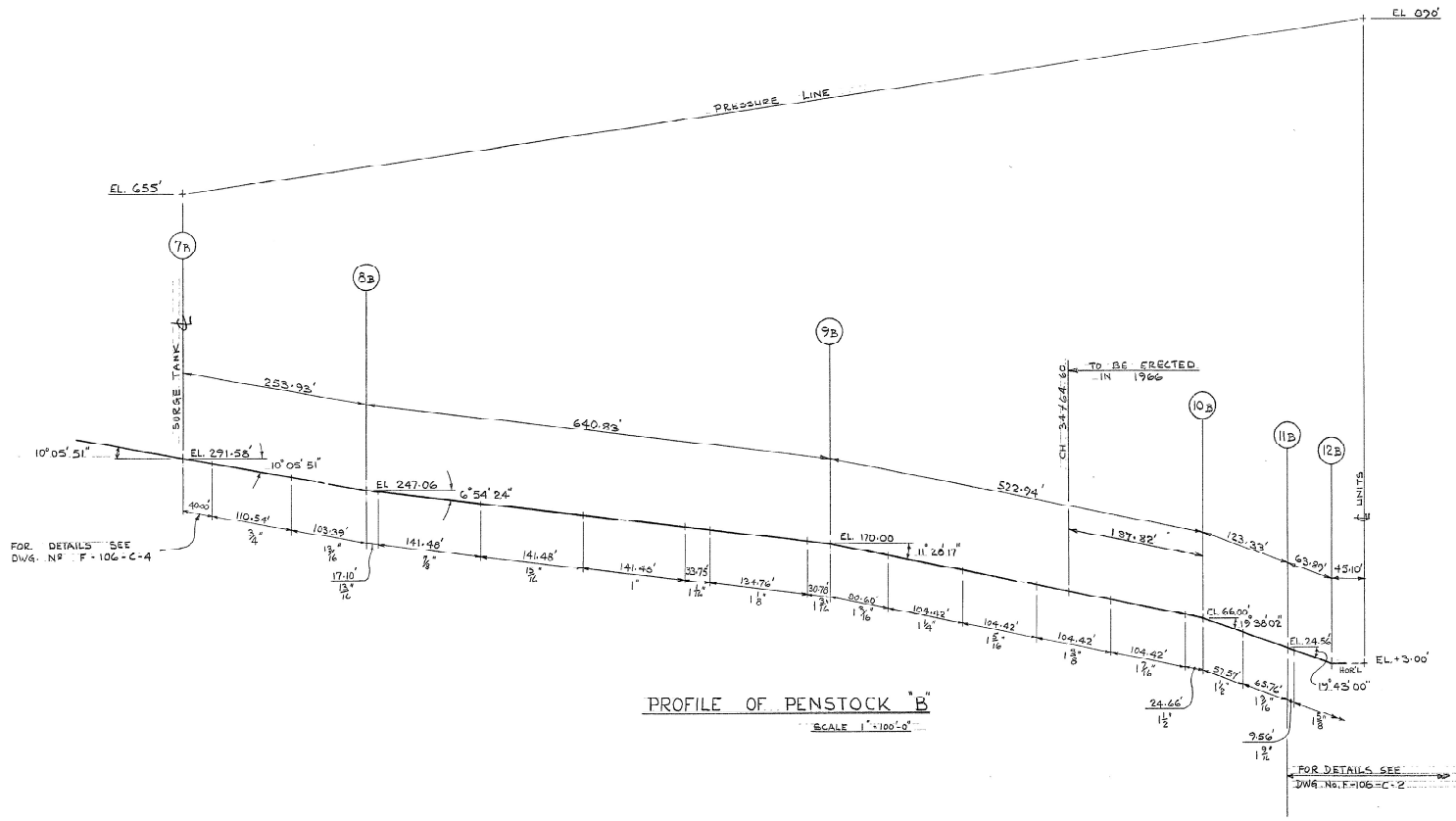
PRESSURE CONDUITS
PLAN & PROFILE PIPELINE "B"

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-A1	OCT. 18, 1965	F-106-C-12	1

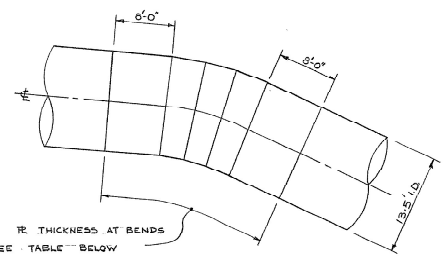
Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 170 of 212



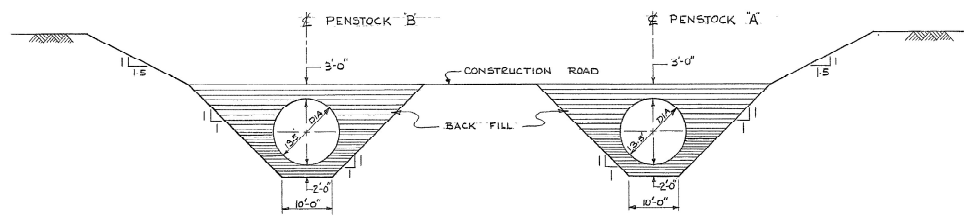
PLAN OF PENSTOCK "B"
SCALE 1" = 100'-0"



PROFILE OF PENSTOCK "B"
SCALE 1" = 100'-0"



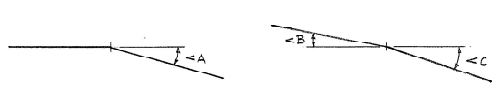
TYPICAL BEND
SCALE 1" = 10'-0"



TYPICAL CROSS SECTION 9B TO 11B
SCALE 1" = 10'-0"

BEND	∠A	∠B	∠C	TRUE ANGLE	R THICKNESS
7 B	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	
8 B	——	10° 05' 51"	6° 54' 24"	3° 11' 27"	1 1/2"
9 B	9° 54' 17"	6° 54' 24"	11° 26' 17"	10° 47' 16"	1 7/16"
10 B	——	11° 26' 17"	19° 36' 02"	8° 09' 45"	1 3/4"
11 B	19° 20' 08"	19° 36' 02"	19° 43' 00"	18° 11' 49"	1 7/8"

ANGLES AND R THICKNESSES AT BENDS



ANGLE IN PLAN

VERTICAL ANGLES

NOTES

1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INSIDE DIAMETER OF THE PENSTOCK IS 13·50'
3. STEEL SHALL BE C.S.A. G40·8 GRADE "B".
4. FOR TYPICAL CROSS SECTION FROM 7B TO 9B SEE DWG Nº F-106-C-7.
5. A PORTION AT THE DOWNSTREAM END OF THIS PENSTOCK "B" SHALL BE ERECTED IN 1966, THE REMAINDER IN 1967. SEE PROFILE.

REFERENCE DRAWINGS

F-106-C-2	PRESSURE CONDUITS – LAYOUT & DETAILS OF BIFURCATION.
F-106-C-4	SURGE TANKS – DETAILS OF TEES,
F-106-C-5	SURGE TANKS – GENERAL LAYOUT & DETAILS.
F-106-C-6	PRESSURE CONDUITS – CLEARING.
F-106-C-11	PRESSURE CONDUITS – LAYOUT & LOCATION DATA.

OTHER REFERENCES

1. SPECIFICATION Nº M-3116

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

APPROVED FOR CONSTRUCTION
SEP 20 1965
APPROVED BY: W. E. Bonnell
CANADIAN ENGINEERING

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
2	SEPT.		REVISED PLAN & PROFILE	J.P.	

REVISIONS

TRANSM'L | ELECT'L | CIVIL
PASSED

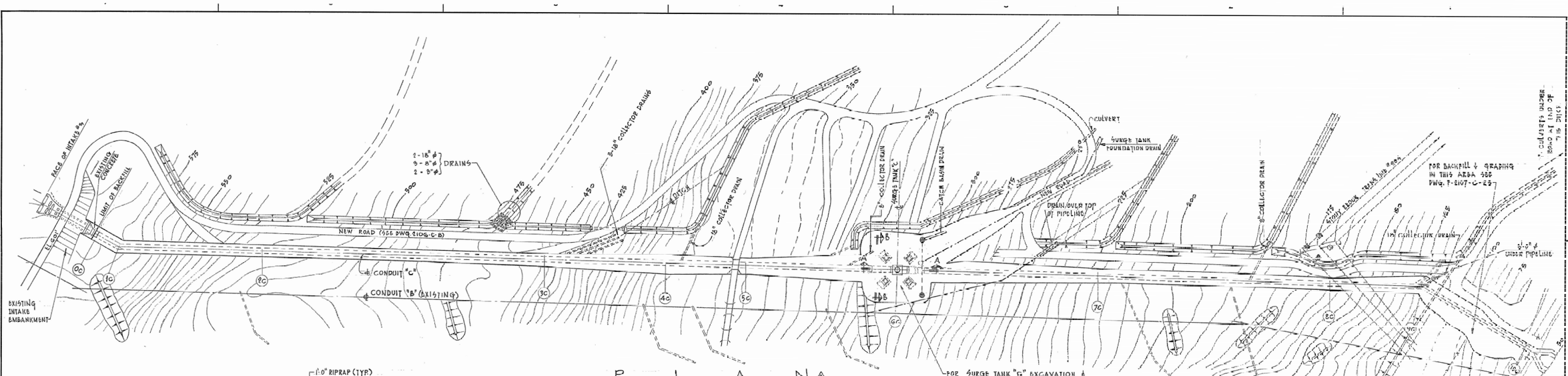
DESIGNED R. MacD.
DRAWN J.P.
CHECKED A.P.K.
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

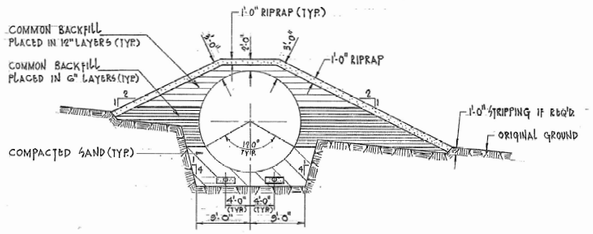
PRESSURE CONDUITS
PLAN & PROFILE PENSTOCK "B"

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	PD-11	SEPT. 1965	F-106-C-10	2

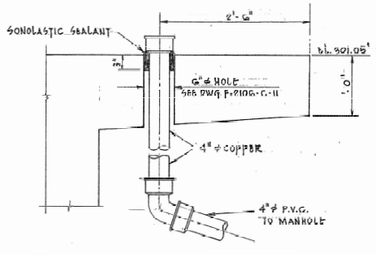
Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 171 of 212



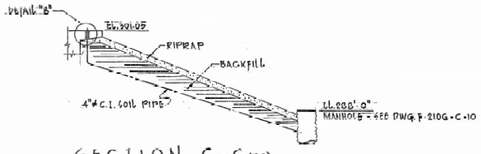
PLAN ⚠
SCALE: 1" = 100'



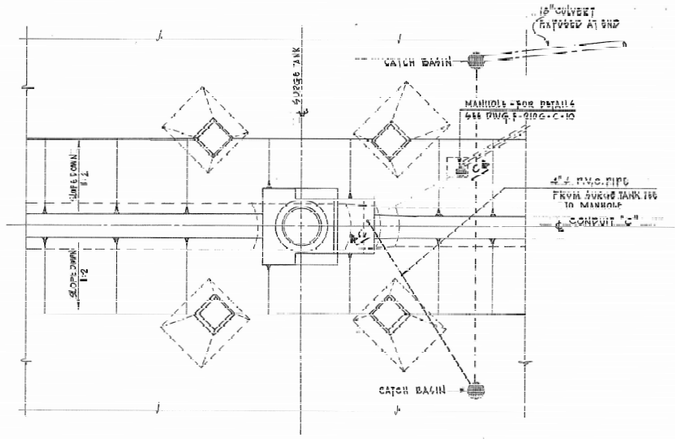
TYPICAL SECTION THROUGH ROCK CUT
SCALE: 1" = 10'-0"



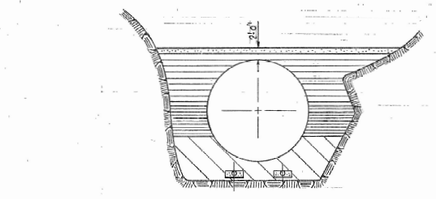
DETAIL - B (C,9) ⚠⚠
SCALE: 1" = 1'-0"



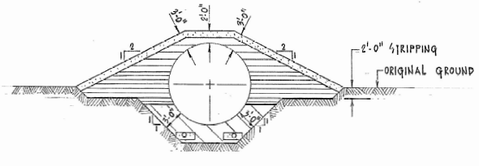
SECTION C-C (B,8) ⚠
SCALE: 1" = 10'-0"



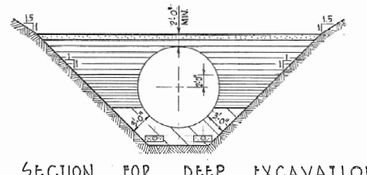
DETAIL - A (D,9)
SCALE: 1" = 20'-0" ⚠⚠



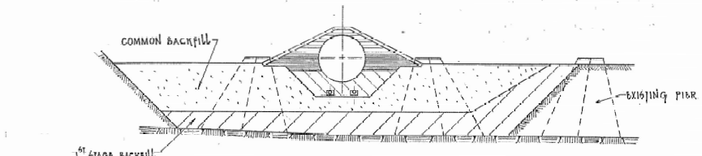
SECTION THROUGH EXISTING CUT ROCK
SCALE: 1" = 10'-0"



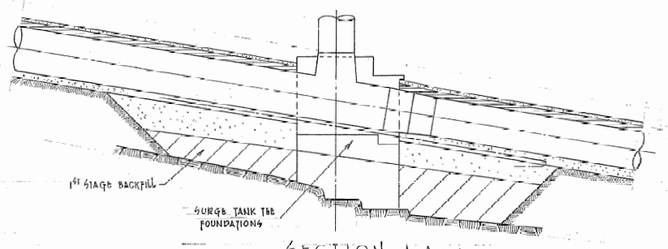
TYPICAL SECTION FOR SHALLOW EXCAVATION
SCALE: 1" = 10'-0"



TYPICAL SECTION FOR DEEP EXCAVATION
SCALE: 1" = 10'-0"



SECTION B-B (D,9) ⚠
SCALE: 1" = 20'-0"



SECTION A-A (D,9) ⚠
SCALE: 1" = 20'-0"

NOTE:
⚠ 1. CONTRACTOR TO SUPPLY & INSTALL CAST IRON SOIL PIPE FROM SURGE TANK TEE TO MANHOLE UNDER SUNDRY ITEMS OF PRICE ITEM C 1009.
⚠ 2. CONDUIT & SURGE TANK FOUNDATION DRAINAGE OUTLETS SHALL BE INSPECTED TWICE YEARLY AND CLEANED AS REQUIRED TO INSURE PROPER DRAINAGE.

FINAL

DWG. No.	TITLE
F-210G-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS
F-210G-C-2	SURGE TANK "C" - GENERAL LAYOUT & DETAILS
F-210G-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F-210G-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F-210G-C-5	" " " " - FOUNDATIONS, CONCRETE DETAILS & ROCK DOWELS
F-210G-C-8	PRESSURE CONDUIT "C" - EXCAVATION & DRAINAGE
F-210G-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLE - CONCRETE & REINF. DETAILS
F-210G-C-11	SURGE TANK "C" - TEE STAGE II - CONCRETE DETAILS

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPD.
⚠	12 NOV 69		DWG. REVISED TO SHOW AS-BUILT	T.C.D.	
⚠	6 JUL 69	A-C, B-C.	SECTIONS A, B & C, DETAILS A & B NOTE ADDED	T.C.D.	T.D.

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 9 1969
APPROVED BY: CHIEF ENGINEER

TRACED	ELECT'L	CIVIL

PASSED

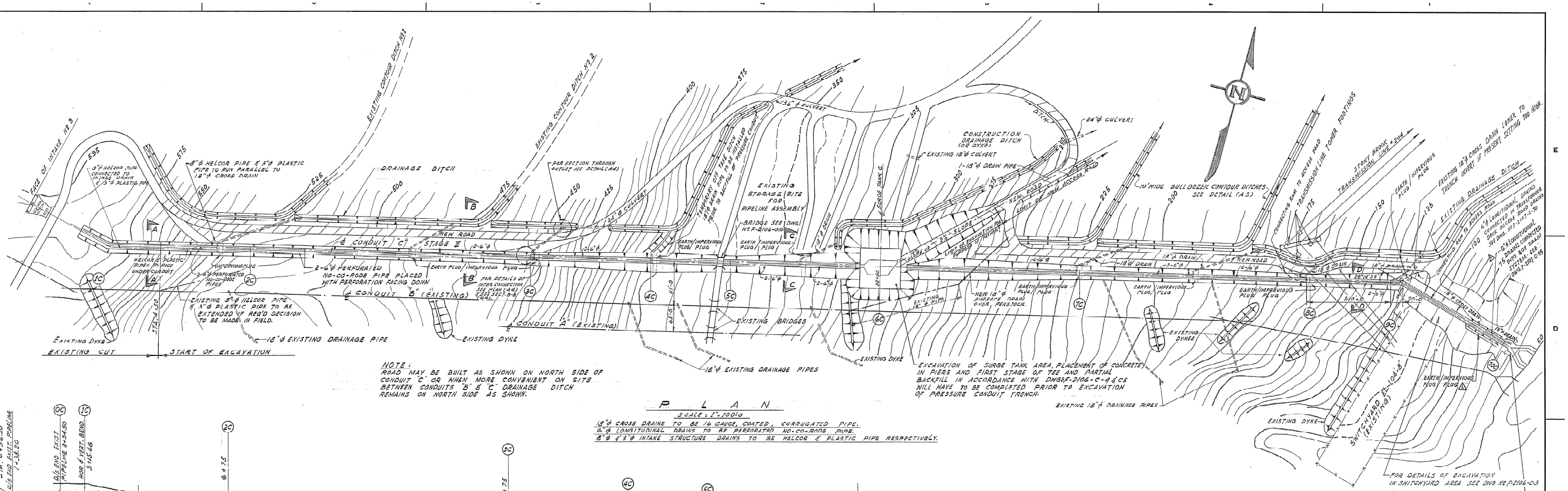
DESIGNED: J.B.
DRAWN: T.C. DAVIS
CHECKED: J.B.
RECOMMENDED

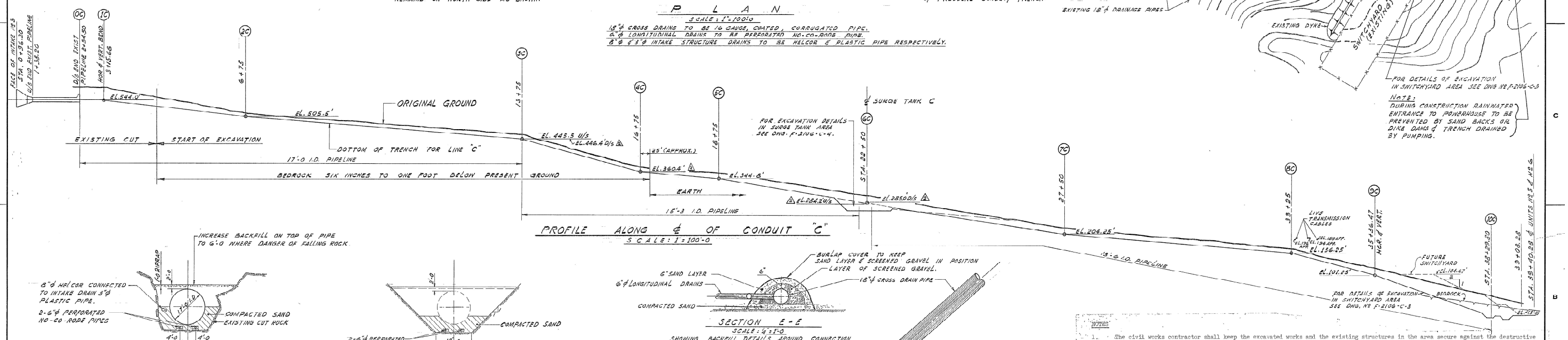
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

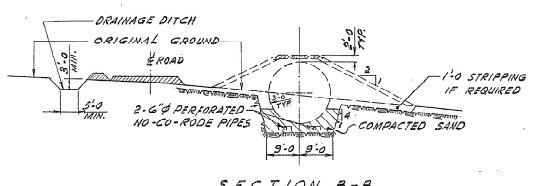
PRESSURE CONDUIT "C" & SURGE TANK "C"
BACKFILL DETAILS

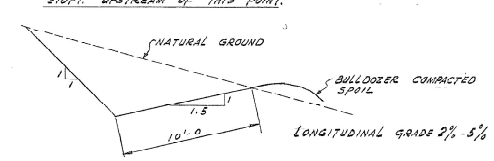
SCALE	DATE	DWG. No.	REV.
AS SHOWN	5TH SEPT. 1968	F-210G-C-9	2.

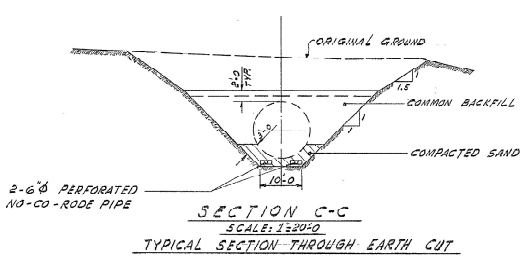
Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 172 of 212

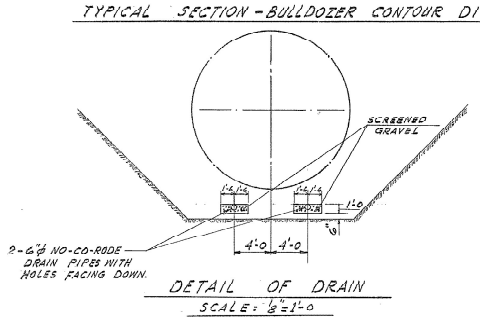


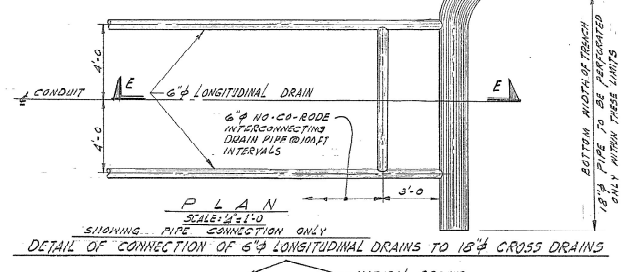


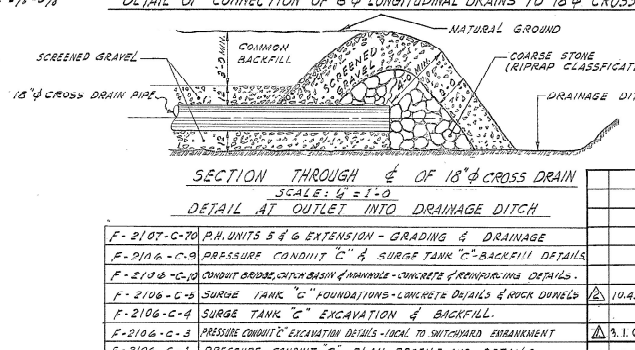












NOTES

1. The civil works contractor shall keep the excavated works and the existing structures in the area secure against the destructive effects of the maximum expected storm water.
2. When a section of the pressure conduit trench to be left open for an appreciable length of time, the trench shall be closed with a 6'-0" high plug of compacted selected common backfill. This plug shall be placed immediately upstream of the end of conduit and shall have sufficient drains to insure adequate control of run-off at all times during construction. The Engineer's decision of the adequacy of the contractor's provisions for drainage shall be final and binding.
3. For sequence of erection of pressure conduit "C" see Drawing No. F-2106-C-1.
4. New roads are shown as cross hatched.
5. 18 in. dia. cross drains to be installed when the conduit trench is being excavated. The unexcavated earth plugs (Clause C2.6) shall be left immediately downstream of the 18 in. dia. cross drains. The connection of the cross drains to the longitudinal drains shall be done after the erection of the conduit and just prior to the back-filling.
6. The location of the cross drains and earth plugs are approximate and the actual positions are to be determined in the field to the approval of the Engineer.
7. Impervious plugs (Clause C3.3). After erection of the conduit, the trench shall be filled to 1 ft. above the top of the pipe or to original grade, where this is below the top of the pipe, with selected common fill for a length of 6 feet at a point immediately downstream of the 18 in. dia. cross drains, to form a permanent impervious plug across the trench.
8. All the work indicated on this drawing must be done in accordance with Spec. M2-3714. Reference should be made to the following clauses:-
   C1 - Unwatering
   C2 - Excavation
   C3 - Backfill & Grading
   C4 - Foundation Drains

REFERENCE DRAWINGS.	
F-2107-C-70	P.H. UNITS 5 & 6 EXTENSION - GRADING & DRAINAGE
F-2106-C-9	PRESSURE CONDUIT "C" & SURGE TANK "C"-BACKFILL DETAILS
F-2106-C-10	CONDUIT CROSS-DITCH BASIN & DRAINAGE-CONCRETE & RECONDITIONING DETAILS.
F-2106-C-3	SURGE TANK "C" FOUNDATIONS-CONCRETE DETAILS & ROCK DOWELS
F-2106-C-4	SURGE TANK "C" EXCAVATION & BACKFILL.
F-2106-C-3	PRESSURE CONDUIT "C" EXCAVATION DETAILS-LOCAL TO SWITCHYARD EMBANKMENT
F-2106-C-1	PRESSURE CONDUIT "C" PLAN, PROFILE AND DETAILS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
			REVISIONS		
3	10.9.68	C.5	EL. 445.5' U/S AT BENT 3C ADDED; EL. 360.6' AT BEND 4C REVISED FROM EL. 360.1'		
2	3.1.68	D.1.	EL. 284.0 U/S & EL. 285.0 D/S ADDED; EL. 284.24 U/S & EL. 285.0 D/S REVISED FROM EL. 282.0 U/S & EL. 283.0 D/S. DRAINAGE DETAILS BETWEEN BENDS 9C & 10C SHOWN	R.G. T.C.D.	D.B. D.B.

APPROVED FOR CONSTRUCTION
JUL 26 1968
APPROVED BY: [signature] CHIEF ENGINEER
Per [signature]

CONST.	TRANSM	ELECT'L	CIVIL
PASSED			

DESIGNED D.B.
DRAWN K.C.
CHECKED D.B.
RECOMMENDED R.H.L.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

PRESSURE CONDUIT "C"
EXCAVATION AND DRAINAGE

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	As Noted	2-15	July 24, 1968	F-2106-C-8	2

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 173 of 212

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

BAY D'ESPOIR DEVELOPMENT

PRESSURE CONDUIT "C"
PLAN, PROFILE & DETAILS

SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

ENGINEERING AND DESIGN BY
STAGE 3E

DESIGNED	DRAWN	CHECKED	RECOMMENDED	APPROVED
	F.P.	A.R.	M.L. Alf	

CONTRACT	SCALE	FILE NO	DATE	DWG NO	REVISION
	AS NOTED	2-15	APR18-68	F-2100-C-1	1

FINAL

PASSED			
TRANS'N	ELECT'L	CIVIL	

REVISIONS					
NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
1	APR68		EL. AT SURGE TANK TOE W.A.S 893.88	M.L.	J.B.

DWG. No	TITLE
F-2100-C-5	SURGE TANK 'C' - FOUNDATION & CONCRETE DETAILS
F-2100-C-4	SURGE TANK 'C' - EXCAVATION & BACKFILL
F-2100-C-3	PRESSURE CONDUIT 'C' & SURGE TANK 'C' EXCAVATION & REMARKS
F-2100-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS.

REFERENCE DRAWINGS.

NOTES
1) THIS DRAWING TO BE READ IN CONJUNCTION WITH SPECIFICATION M2-3714
2) WHEN A SECTION OF THE PRESSURE CONDUIT TENCH IS TO BE LEFT OPEN FOR AN APPRECIABLE LENGTH OF TIME, THE TRENCH SHALL BE CLOSED WITH A 4'-0" WIDE PLUG OF COMPACTED SELECTED COMMON MATERIAL. THIS PLUG SHALL BE PLACED IMMEDIATELY UPSTREAM OF THE END OF THE CONDUIT AND SHALL HAVE SUFFICIENT DRAINS TO INSURE ADEQUATE CONTROL OF RUNOFF AT ALL TIMES DURING CONSTRUCTION. THE ENGINEERS DECISION ON THE ADEQUACY OF THE CONTRACTOR'S PROVISIONS FOR DRAINAGE SHALL BE FINAL AND BINDING

FOR INFORMATION PURPOSES ONLY

NOTE
FOR DETAIL OF DRAINS
SEE DRAWING No F-2020-C-109

TYP. SECTION THRU ROCK
SCALE 1"=10'

TYP. SECTION - SHALLOW EXCAVATION
SCALE 1"=10'

TYP. SECTION - DEEP EXCAVATION
SCALE 1"=10'

ELEVATION ALONG ℄ OF BIFURCATION
SCALE 1"=20'

PLAN OF BIFURCATION
SCALE 1"=20'

PROFILE ALONG ℄ OF CONDUIT "C"
SCALE 1"=100'

PROFILE AT ℄ OF TRANSMISSION LINES BETWEEN TOWER ℄ SWITCHYARD
SCALE 1"=100'

PLAN
SCALE 1"=200'

EXTENT OF PAGE CONDUIT ERECTION TO BE ERECTED UPHILL

FIRST HALF 1969 CONDUIT ERECTION TO BE ERECTED UPHILL

SECOND HALF 1969 CONDUIT ERECTION TO BE ERECTED DOWNHILL

HYDRAULIC GRADIENT

TAILRACE CHANNEL

POWER CANAL

INTAKE

SURGE TANK A EXISTING

SURGE TANK B EXISTING

SURGE TANK C STAGE II

CONDUIT 'A' EXISTING

CONDUIT 'B' EXISTING

CONDUIT 'C' STAGE II

CONSTRUCTION TYPE ROAD

SWITCHYARD EXISTING

POWERHOUSE EXISTING

SWITCHYARD PROPOSED

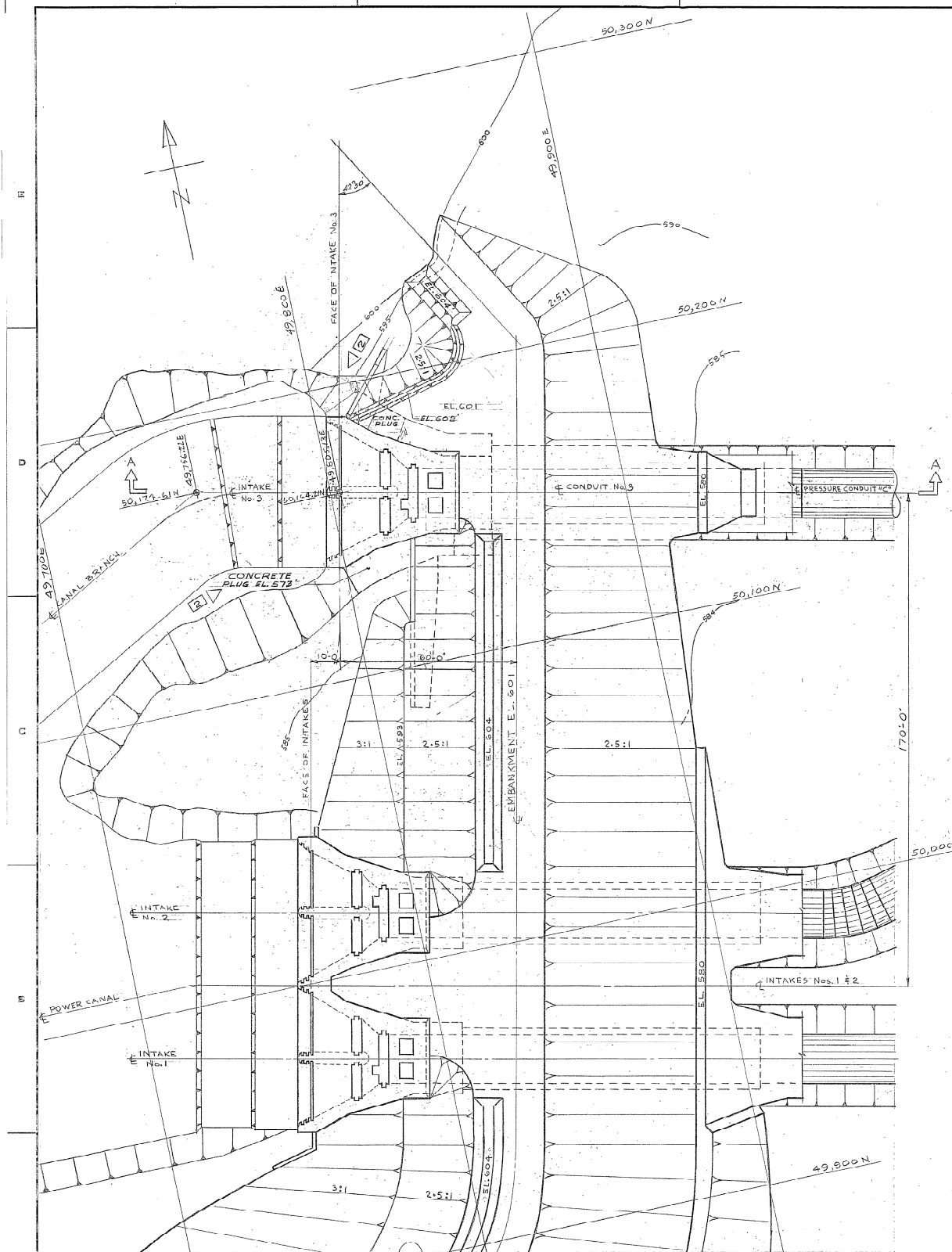
ROAD TO STEPHENVILLE

LOWER BROOK

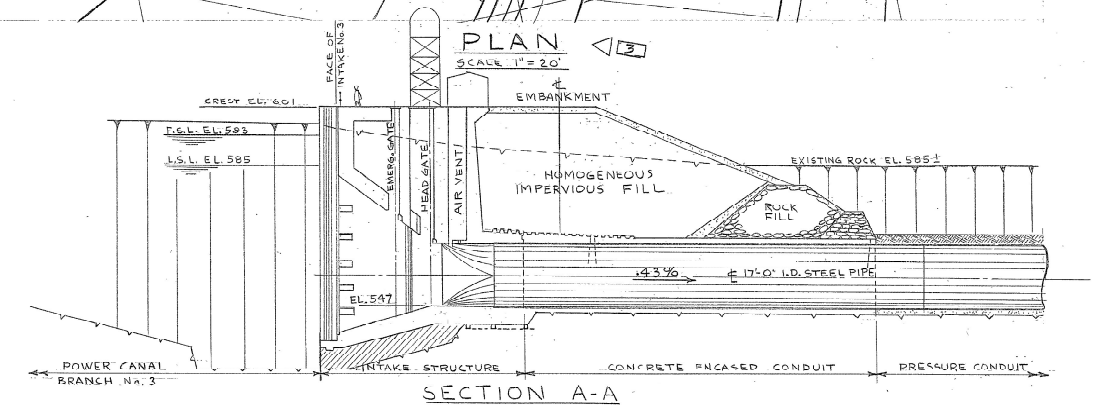
EXISTING SURGE TANK

ROCK FILL DAM

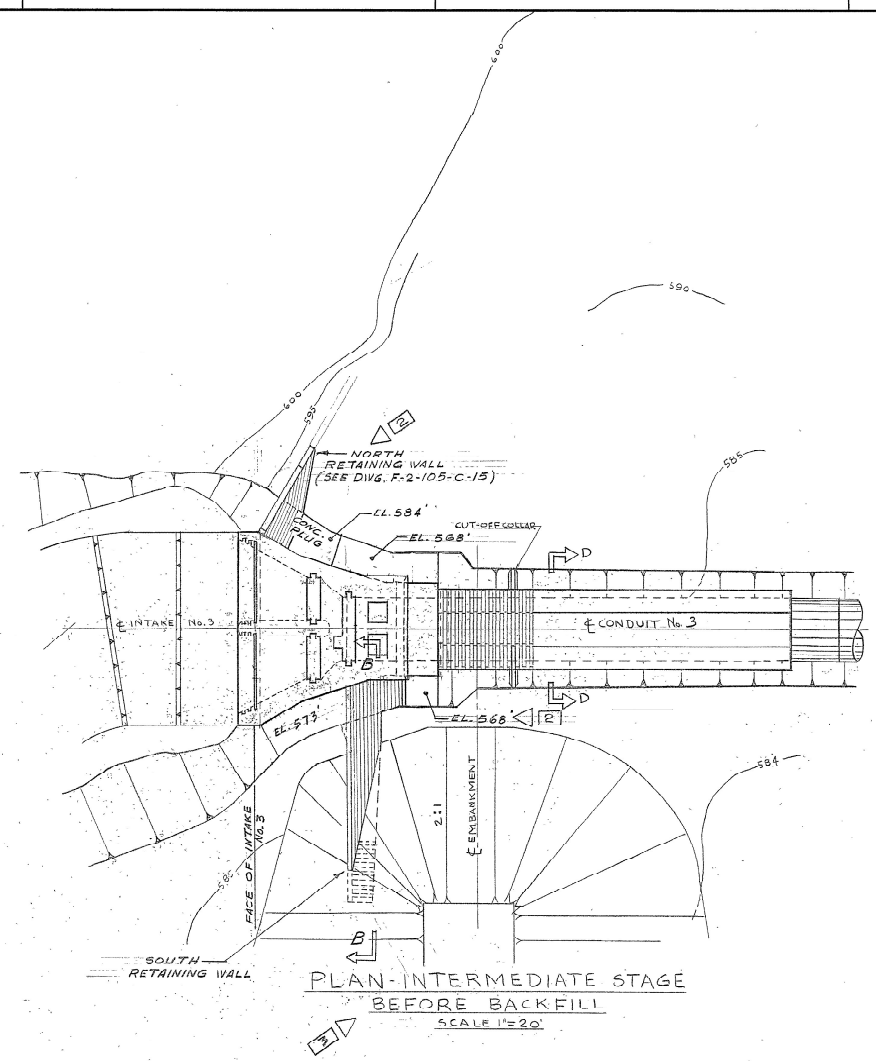
CONDUIT THROUGH DAM



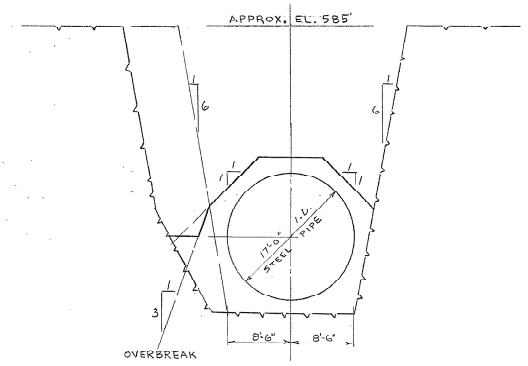
PLAN
SCALE 1"=20'



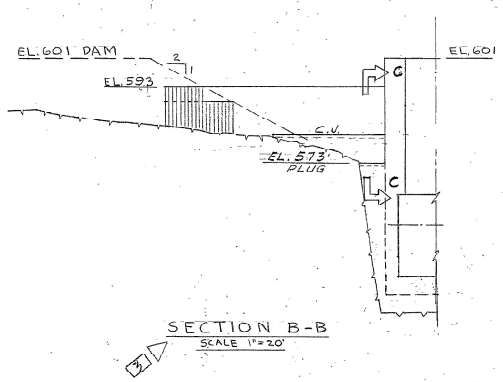
SECTION A-A
SCALE 1"=20'



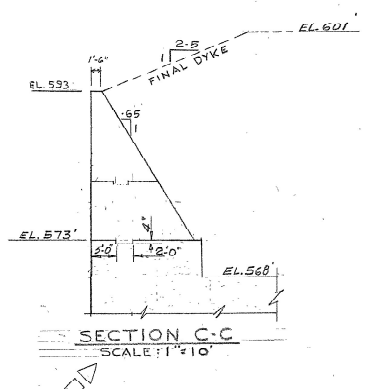
PLAN-INTERMEDIATE STAGE
BEFORE BACKFILL
SCALE 1"=20'



SECTION D-D
SHOWING CONDUIT THRU DAM
SCALE 1"=10'



SECTION B-B
SCALE 1"=20'



SECTION C-C
SCALE 1"=10'

NOTES

1. THIS IS A GENERAL LAYOUT DRAWING. KEY ELEVATIONS AND DIMENSIONS ONLY ARE SHOWN. FOR ALL DETAILS, REFER TO LARGER SCALE, PARTICULAR DRAWINGS OF THE SPECIFIC PART INVOLVED.
2. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH THE SPECIFICATIONS OF THE GENERAL CONTRACT DOCUMENTS.
3. DURING THE INTERMEDIATE STAGE, THE EARTH DAM WILL NOT BE PLACED IN THE AREA BEHIND THE INTAKE STRUCTURE

THE FOREBAY WATER WILL BE CONTAINED DURING THIS PERIOD BY THE SYSTEM OF CONCRETE PLUGS, RETAINING WALLS AND INTAKE STRUCTURE.
INTAKE STABILITY DURING THIS PERIOD DEPENDS ON THE CONCRETE PLUGS POURED TO SOUND ROCK AND CLOSURE IN THE INTAKE MADE WITH THE HEAD GATE.

4. DESIGN CRITERIA FOR INTAKE LISTED ON DWG. F-2-105-C-2.

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

FINAL

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	11-15-67		AS BUILT, FROM FIELD INFORMATION	A.R.	JHM
2	1-12-66		NORTH RETAINING WALL MOVED FORWARD PLUGS CHANGED	A.R.	JHM
1	7-20-66	—	CONC. RETAINING WALLS & EMBANKMENT REVISED	A.R.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
SEP 12 1966
APPROVED W. E. Bonnell
MANAGER ENGINEERING

PASSED — TRACED | BLUEPRINTED | CHECKED

DESIGNED HC
DRAWN A.R.
CHECKED
RECOMMENDED J H Maurice Ed

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

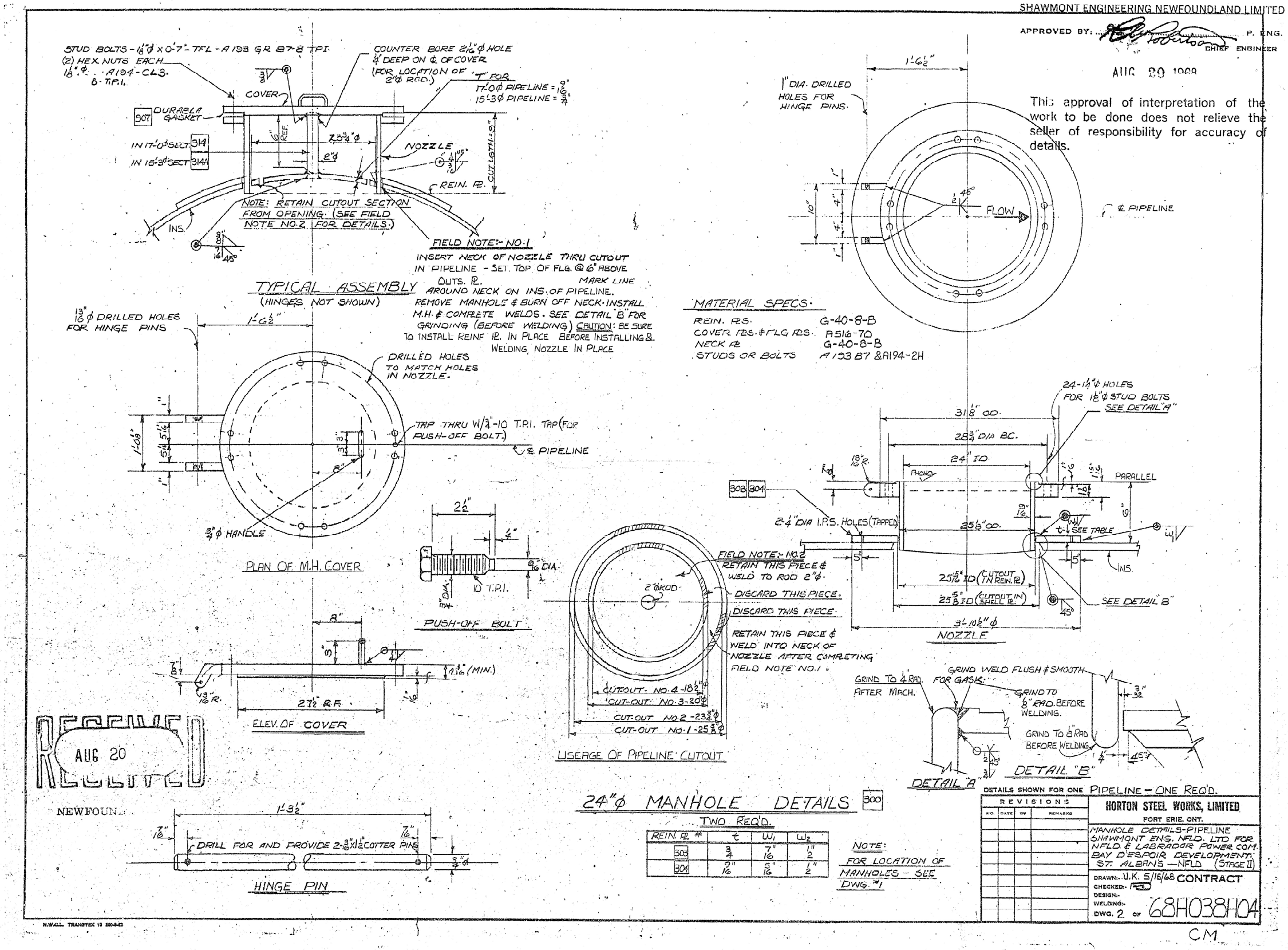
INTAKE No. 3
GENERAL LAYOUT

CONTRACT	SCALE	FILE NO	DATE	DWG NO	REVISION
	NOTED	PD-11	9 SEPT. 66	F-2-105-C-1	3

12 X

APPROVED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
APPROVED BY: ..... P. ENG.
CHIEF ENGINEER
AUG 20 1968

This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.



REIN. PL. #	t	W_1	W_2
303	3/4	7/16"	1/2"
304	7/16"	5/16"	1/2"

RECEIVED
AUG 20
NEWFOUN...
FILE COPY
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
LICENSE NO.
DWG. D.ESPOIR

APPROVED
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
APPROVED BY: ..... P. ENG. CHIEF ENGINEER
OCT 22 1988
This approval of interpretation of the work to be done does not relieve the seller of responsibility for accuracy of details.

RECEIVED
OCT
SHAWMONT
NEWFOUNDLAND LTD.

PLAN OF PIPELINE "C"

LENGTH ALONG ℄ OF 17'-0" I.D. PIPELINE = 1125'-1 19/32"
LENGTH ALONG ℄ OF 15'-3" I.D. PIPELINE = 876'-6 5/32"

ELEVATION OF PIPELINE "C"

KEY ELEVATION

TRUE VIEW OF ELBOW # 1C.

DETAIL OF ELBOW # 2C (ELEVATION)

DETAIL OF ELBOW # 3C (ELEVATION)

DETAIL OF ELBOW # 4C (ELEVATION)

DETAIL OF ELBOW # 5C (ELEVATION)

FIELD LOCATION OF KEY NUTS (AT ENDS OF FIELD FAB'D. SECT'S) 17'-0" ϕ SECT.

FIELD LOCATION OF KEY NUTS (AT ENDS OF FIELD FAB'D. SECT'S.) 15'-3" ϕ SECT.

ORIENTATION OF P's. LOOKING UPSTREAM EXCEPT AT ELBOWS — SEE ELEV. OR PLAN VIEW.

FIELD NOTES: FOR ERECTION PURPOSES — LOCATE 24" ϕ OPENINGS APPROX. 2'-6" OFF BOTT. ℄ AS SHOWN & APROX. 200'-0" APART, LOCATED TO SUIT, CUTOUTS TO BE RETAINED & REWELDED INTO OPENINGS AFTER COMPLETION OF ERECTION. (EDGE PREP TO SUIT P. THICKNESS.)

ANGLE IN PLAN / VERTICAL ANGLE

BEND	∠"A"	∠"B"	∠"C"	TRUE ℄	P. THICK	RAD.
1C	26°09'31	0°15'10	6°07'25	26°45'26	1/2"	45'-0"
2C	—	6°07'25	4°53'57	1°13'28	1/2"	45'-0"
3C	—	4°53'57	15°59'45	11°05'48	5/8"	45'-0"
4C	—	15°59'45	4°26'35	11°33'10	3/4"	38'-6"
5C	—	4°26'35	9°11'00	4°44'25	3/4"	38'-6"

MATERIAL AT SITE

NEW MARK	OLD MARK	P. THICK	Nº SECTS	CUTTING
1	35	3/4"	1-4 RING	36'-5"
1	35	3/4"	1-4 RING	34'-5"
7	34	1/2"	1-4 RING	34'-4"
8	34	1/2"	1-3 RING	33'-9 1/16"
	33	1/2"	1-1 RING	
9	33	5/8"	1-4 RING	31'-10 3/4"
12	33	5/8"	CUT FROM ABOVE	
13	29	5/8"	1-4 RING	35'-10 1/4"
13	29	5/8"	1-4 RING	35'-10 1/2"
13	29	5/8"	1-4 RING	35'-10 3/4"
13	29	5/8"	1-4 RING	35'-10 1/4"
19	28	1/2"	1-4 RING	36'-3 3/8"
20	28	1/2"	1-4 RING	34'-3 3/8"
	27	5/8"	1-4 RING	35'-10 1/4"
21	23	1/2"	1-4 RING	33'-0 1/4"
45	12	1/2"	1-1 RING	18'-11 3/8"
44	107	1/2"	1-1 RING	9'-1 7/8"

GENERAL NOTES:—

PIPELINE P. — A285 FBX., G40·8B. & 0X522-D
P.'S FLUSH ON INS. OF PIPELINE
MAX. OFFSET OF INNER SURFACES 3/32"
PAINT — YES.
CUST. SPECS — M. 2. -3664
CUST. P.O. —
SEE ALSO SPECIAL SHOP INSTRUCTIONS FOR TOLERANCES & FURTHER NOTES
△ -W.O.'S. 'OM.' TO 'OM. 3' INCLUSIVE
SEE ALSO SPECIAL FIELD INSTRUCTIONS FOR TOLERANCES & FURTHER NOTES
△ -W.O.'S. 'ON.' TO 'ON. 6' INCLUSIVE.
100% X-RAY ALL VERT. & LONG^L SEAMS

DETAILS SHOWN FOR ONE PIPELINE — ONE REQ'D.

REVISIONS				HORTON STEEL WORKS, LIMITED FORT ERIE, ONT.
NO.	DATE	BY	REMARKS	
1	7/88	JK	GEN'L REVISIONS	GENERAL PLAN 17'-0" ϕ 15'-3" ϕ PIPELINE
2	8/88	J.K.	REV. SECT'S 1 & 2	SHAWMONT ENG. NFLD. LTD. - CONSULT. ENG.
3	9/88	J.K.	REV. SECT'S 3 & 4	FOR NFLD. & LABRADOR POWER COMM.
4	10/88	J.K.	REV. SECT'S 5 & 6	BAY d'ESPOIR - HYDRO ELEC. DEVELOP.
5	10/88	J.K.	REV. MARKED AS PER FIELD	ST. ALBANS, NFLD. (STAGE III)
				DRAWN: J.K. 5/8/88 CONTRACT
				CHECKED:
				DESIGN:
				WELDING:
				DWG. 1 OF 68H038H04

C.M.

ACME CANADA 6 5 TENTHS 4 3 TENTHS 2 1 MM

12 X

APPENDIX C

BASIS OF ESTIMATE

Kleinschmidt

We provide practical **solutions** *for complex renewable energy, water, and environmental projects*

November 19, 2021

Newfoundland and Labrador Hydro
Hydro Place, 500 Columbus Drive
St. John's, NL A1B 47K

Document No.: 2670034_003LT

Basis of Estimate

1.0 PURPOSE

Kleinschmidt Associates Canada Inc. (Kleinschmidt) has been engaged by Newfoundland and Labrador Hydro (NL Hydro) to provide an Opinion of Probable Construction Cost (OPCC) for life extension options for Penstock 2 & 3 at the Bay d'Espoir Hydroelectric Generating Station on the south coast of Newfoundland near the community of Bay d'Espoir.

2.0 RECOMMENDATION

Kleinschmidt has compiled an OPC consistent with the requirements of an AACE Class 4 Cost Estimate and Basis of Estimate document. Included in the Basis of Estimate as appendices are the historical drawings provided by NL Hydro originally developed by Shawmont Engineering Newfoundland Ltd., which were used in the development of the OPC.

Table 1 details what Kleinschmidt recommends NL Hydro budget for each of the life extension options for Penstock 2 & 3 based on this early-stage review. These recommendations are based entirely on the information provided and reflect the expected accuracy of a Class 4 Cost Opinion as described in Section 4 of this document. The recommended budget is comprised of an Opinion of Supply and Construction Costs in addition to a Contractor's Profit and Contingency Costs. We recommend that NL Hydro carry the owner's contingencies as detailed in Table 1 for each of the options. The details of the estimate are presented in the Estimate Summary attached in Appendix 1.

TABLE 2.1 KLEINSCHMIDT COST ESTIMATE SUMMARY FOR OPTION 2, 3 AND 4

Penstock 2	Option 2	Option 3	Option 4
Total Contractor Direct & Indirect	$19,798,000	$36,195,000	$25,463,000
Contractor's Profit and Contingency (12% each)	$4,752,000	$8,686,000	$6,112,000
Opinion of Contractors Probable Price	$24,550,000	$44,881,000	$31,575,000
Owner's Cost (Engineering, Site Management, Project Management and Tendering)	$1,289,700	$1,636,600	$1,482,200
Owner Contingency (15% of direct + indirect)	$3,876,000	$6,978,000	$4,959,000
Total Recommended Budget	**$29,715,700**	**$53,495,600**	**$38,016,200**

TABLE 2.2 KLEINSCHMIDT COST ESTIMATE SUMMARY FOR OPTION 2, 3 AND 4

Penstock 3	Option 2	Option 3	Option 4
Total Contractor Direct & Indirect	$18,770,000	$35,990,000	$24,597,000
Contractor's Profit and Contingency (12% each)	$4,504,000	$8,638,000	$5,904,000
Opinion of Contractors Probable Price	$23,274,000	$44,628,000	$30,501,000
Owner's Cost (Engineering, Site Management, Project Management and Tendering)	$1,289,700	$1,636,600	$1,482,200
Owner Contingency (15% of direct + indirect)	$3,685,000	$6,940,000	$4,797,000
Total Recommended Budget	**$28,248,700**	**$53,204,600**	**$36,780,200**

3.0 PROJECT SCOPE DESCRIPTION

The proposed penstock life extension options are based upon the details provided by NL Hydro in the Request for Proposal (RFP) No. 2020 – 84124 JW.

3.1 Option 2

Option 2 consisted of refurbishment of the deteriorated weld seams, both longitudinally and circumferentially, and coating of the penstock interior. These tasks would be performed along the entire length of the penstock.

3.2 Option 3

Option 3 consisted of replacing the 17 ft diameter section of the penstock, as well as refurbishment of the deteriorated weld seams, both longitudinally and circumferentially in the remaining sections of the penstock. Option 3 also includes coating the interior for remaining sections.

3.3 Option 4

Option 4 consisted of refurbishment of the deteriorated weld seams, both longitudinally and circumferentially, and coating of the penstock interior for the entire penstock length. Additionally, reinforcing plates would be installed over the longitudinal and circumferential weld seams on the interior of the 17 ft diameter section of penstock.

4.0 ESTIMATING CLASSIFICATION AND ASSEMBLY METHODOLOGY

Based on AACE Recommended Practice (RP) 69R-12: Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Hydropower Industry, a Class 4 Cost Estimate is appropriate when:

- the maturity level of project definition deliverables (expressed as a percentage of complete definition) is in the 1% to 15% range; and
- the intended End Usage (purpose) of the Cost Estimate is for project study or feasibility.

The expected accuracy range of a Class 4 Cost opinion is:

- Low: -15% to -30%
- High: +20% to +50%

The state of technology, availability of applicable reference cost data, and other risks affect the expected accuracy range. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of P50 contingency for a given scope.

Class 4 Cost Opinions generally use stochastic estimating methods such as cost/capacity graphs or curves and factors, historical data and other parametric cost and modeling techniques in accordance with AACE RP 69R-12.

Kleinschmidt typically develops its Class 4 Cost Opinions using a combination of Unit Costs and quantity take-offs where information is available in the design documents and assumption-based scoping to fill in where design details are more limited. Regarding the Bay d'Espoir Penstock Life Extension Project, the quantities of work for penstock rehabilitation construction are generally discernable (within expected tolerances), from the available information. Where design details or scoping information are lacking, experience-based assumptions, and assumptions consistent with those presented in the Hatch Report (Final Report, Penstock No.'s 1, 2, and 3 Life Extension Options, March 13, 2020) are made that allow us to generate quantities of work and/or select appropriate Unit Costs/Lump Sums from our Reference Project data base.

5.0 CONSTRUCTION SEQUENCING

5.1 Option 2 Construction Sequencing

An access road would be constructed along the full length of the penstocks to allow for delivery, access, and rehabilitation of the new penstock. The welding crew would enter the penstocks to locate and repair any deteriorated welds on the inside. Welds that require full penetration would also require welds on the exterior of the penstocks. In areas that require full penetration welds and welder access on the exterior, the common fill on top and surrounding the penstock would be excavated as required to allow for welder access. It is assumed that there is space available on site to store the excavated material. Testing and inspections would be required on the welds after completion. After testing is complete, the excavated material would be reused as fill to cover the penstocks as shown in the original construction drawings. The contractor would then sand blast and apply the interior coating to the entire interior length of the penstock.

5.2 Option 3 Construction Sequencing

Construction of an access road the full length of the penstocks would be completed to allow for delivery, access, and installation of the new penstocks. The common fill on top of and surrounding the entire length of the 17 ft diameter penstock would be excavated and temporarily stored on site. As the excavation takes place, the 17 ft diameter penstocks would be demolished and removed from site for disposal. After the 17 ft diameter penstocks are removed the bedding material for that section would be excavated and disposed of on site. Rock cutting and excavation was assumed to not be required for the replacement of the 17 ft diameter section of pipe.

New bedding material is assumed to be supplied and installed in accordance with the original construction drawings and specifications for the 17 ft diameter penstock sections. The new 17 ft diameter penstocks are assumed to be delivered to site in 17′ diameter x 10′ long sections using a combination of railway and truck, utilizing an appropriately sized siding where/if available, located closest to the site. Final delivery to site will be by transport truck using a wide load permitted transport. The contractor is assumed to use the construction access road to deliver and install the new section of penstock. The new section of penstock will be connected to the existing thimble at the intake and the upstream end of the existing 15.25 ft diameter penstock using a new transition section of penstock to accommodate the expected ovality of the existing penstock. The new penstock is assumed to be manufactured off site and delivered to site in 10′ long sections where they will be field welded end to end. The new penstocks are assumed to be blasted and an interior and exterior coating applied in the shop prior to shipping.

The remaining 15′-3″ and 13′-6″ section of the penstock will be rehabilitated in the same manner as is described in Option 2 above.

5.3 Option 4 Construction Sequencing

Welding repairs to the penstocks will be executed as is done in Option 2.

Once the welds are tested and inspected, reinforcing plates will be supplied and welded over both the longitudinal and circumferential welds on the inside of the 17 ft diameter section of penstock. The entire length of the penstocks would then be sand blasted to meet the required surface preparation specification and coated from the inside.

5.4 Material and Commodity Pricing

Unit costs for the refurbishment of the welds is based upon the amount of weld material deposited over a period (expressed in lbs/hr). The development of the unit price is based on the width of opening and the depth of material to be welded. Information used to support the unit price calculation was provide by Skarborn Engineering (Skarborn). An operating factor of 20% was used as suggested by Skarborn welding experts. The method requires that assumptions be made regarding the percentage of shallow vs full depth repairs required to determine the required weight of weld material to repair the existing welds. For the purposes of this estimate, it was assumed that 50% of welds require refurbishment and 70% of weld refurbishments require full depth weld repairs and access to both the interior and exterior of the penstocks.

The opinion of cost utilizes the pricing for sandblasting and coating of penstocks from Kleinschmidt's information on the Dwight hydroelectric project penstock scaled to the ratio of the interior surface area per linear foot of penstock for this project. The scaled unit prices are escalated to 2021 dollars. Kleinschmidt utilized a $51.60 per square foot which includes surface preparation, coating, and cleanup of the existing penstock.

The opinion of cost for the demolition, supply, and installation of the 17 ft diameter penstock in option 3 was referenced from a demolition, supply and installation of a 6 ft diameter penstock done by Cahill in 2015. The historic value was scaled up on a per pound basis and included an additional 25% premium on demolition and supply as well as an additional factor of 2 on installation to account for the added complexity of handling and positioning a 17 ft diameter section.

Due to high volatility in material pricing within the current market conditions in the large-scale construction industry, contractor bids may be at a premium due to the high demand and low contractor availability. This premium and any additional markups that the bidding contractors may apply to their submittal has not been considered in the opinion of cost. The opinion of cost provided is assumed to be in a market with adequate contractor supply and standard profit margins as seen in historic large scale hydroelectric construction projects. Material and commodity pricing for items such as steel, concrete and timber are currently experiencing large price spikes due to supply and demand effects in the current market conditions. These large fluctuations are difficult to predict and for this reason, Kleinschmidt has applied pricing that is consistent with regular historic market conditions and trends.

The results of the Opinion of Probable Construction Cost (OPC) for Penstocks 2 & 3 reflect that of Penstock 1 with slight variations identified for each penstock's specific alignment and length. These variations result in minor differences in quantities and access between the three penstocks. The direct unit rates were kept consistent for all three penstocks. Penstock 2 is located between Penstock 1 and Penstock 3, resulting in slightly more difficult access and construction which was accounted for by utilizing a higher indirect/direct ratio (0.38 for Penstocks 1 & 3, 0.40 for Penstock 2). Another reason for the difference in OPC is due to the varying lengths of each penstock diameter. For example, Penstock 3 has a shorter 15'-3" diameter section but slightly longer 17' and 13.5' diameter sections. This results in different quantities between the three penstocks and in turn, different final OPC's.

6.0 PLANNING BASIS

Unit rates used in this cost opinion reflect tasks being undertaken in an open shop (non-union) environment with established and efficient craft and management personnel experienced in industrial construction. The construction timeline is expected to be 7 continuous months and is expected to utilize a predominantly 10-hour double shift operation.

7.0 COST BASIS

The Cost Estimate has been assembled in constant 2021 CAD dollars.

7.1 General and Administrative Expenses and Profit

The Contractor's mark-up (corporate overheads and profit, bonds, and insurance) is input at twelve percent (12%) of Total Cost (Direct and Site Indirect excluding Contingency) based on Kleinschmidt's experience for a job of this size considering regional market conditions and the expected capacity of competent regional contractors.

The selected mark-up reflects a construction contract being executed between the parties that reasonably assigns risk to the party best positioned to effectively manage the particular risk. This markup is consistent with a contract that does not contain liquidated or other punitive performance related damages. The required insurance regime to be provided by the contractor is expected to be typical for like work.

7.2 Reference Projects and Historical Database

The pricing for the coating of the penstock when required for the specific options was based upon pricing from Kleinschmidt's information on the Dwight hydroelectric project penstock scaled for inflation and the interior surface area per linear foot. Kleinschmidt utilized a $51.60 per square foot cost which includes surface preparation, coating (specifically with a MC-Zinc primer – one coat: MC-Tar moisture cure urethane -two coats), and cleanup of the existing penstock.

The pricing for the demolition, supply and installation of the 17 ft diameter penstock was referenced from a demolition, supply and installation of a 6 ft diameter penstock done by Cahill in 2015. The historic value was scaled up on a per pound basis for inflation and included a 25% premium on demolition and supply as well as an additional factor of 2

mark up on installation to account for the added complexity of handling and installing a 17 ft diameter section.

7.3 Project Site Indirect Costs

Indirect costs of construction are accounted for by applying a factor of 40% for penstock 2 and 38% for penstock 3 to the direct cost unit rates to establish a total cost unit rate for all construction activities that are not accounted for by either supplied quotes or the application of allowances. A factor between 37% and 45% is expected based on historical cost estimates for new and rehabilitative hydroelectric construction projects of similar size. These projects are of sufficiently large size and low complexity, that a percentage in the lower end of this range is warranted.

7.4 Project Direct Costs

Direct costs for the project are calculated for the following items per option:

7.4.1 Penstock 2

TABLE 2.3 PENSTOCK 2

Item	Section		Quantity		
			Option 2	Option 3	Option 4
Weld Material	17'-0"	Longitudinal	899 lbs	2,534 lbs	899 lbs
		Circumferential	1,600 lbs	4,511 lbs	1,600 lbs
	15'-3"	Longitudinal	934 lbs	934 lbs	934 lbs
		Circumferential	1,492 lbs	1,492 lbs	1,492 lbs
	13'-6"	Longitudinal	4,091 lbs	4,091 lbs	4,091 lbs
		Circumferential	5,783 lbs	5,783 lbs	5,783 lbs
Excavation and Backfill	17'-0"	Excavation	5,634 CY	16,096 CY	5,634 CY
		Backfill	5,634 CY	10,908 CY	5,634 CY
		New Fill Placement	- CY	5,189 CY	- CY
	15'-3"	Excavation	5,972 CY	5,972 CY	5,972 CY
		Backfill	5,972 CY	5,972 CY	5,972 CY
	13'-6"	Excavation	8,316 CY	8,316 CY	8,316 CY
		Backfill	8,316 CY	8,316 CY	8,316 CY
(2) Access Road	TOTAL		2,000 m	2,000 m	2,000 m
Demolition Existing Penstock	17'-0"		- ft	1,245 ft	- ft
Installation of New Penstock	17'-0"		- ft	1,245 ft	- ft
Manholes	17'-0"		-	3	- ft
Longitudinal Steel Plates	17'-0"	Steel Plates	- lbs	- lbs	33,782 lbs
		Weld Material	- lbs	- lbs	4,230 lbs
Circumferential Steel Plates	17'-0"	Steel Plates	- lbs	- lbs	60,141 lbs
		Weld Material	- lbs	- lbs	7,531 lbs

7.4.1.1 Option 2

1. Refurbishment of both the longitudinal and circumferential welds along the 17 ft, 15.25 ft, and 13.5 ft diameter sections of the penstock.
    i. 899 lbs of weld material longitudinally and 1,600 lbs circumferentially for the 17 ft diameter section;
    ii. 934 lbs of weld material longitudinally and 1,492 lbs circumferentially for the 15.25 ft diameter section; and
    iii. 4,091 lbs of weld material longitudinally and 5,783 lbs circumferentially for the 13.5 ft diameter section.
2. Excavation of the common fill and backfill as required when weld refurbishment occurs on both sides of the penstock can.
    i. 5,634 CY of excavation and 5,634 CY of backfill for the 17 ft diameter section;
    ii. 5,972 CY of excavation and 5,972 CY of backfill for the 15.25 ft diameter section; and
    iii. 8,316 CY of excavation and 8,316 CY of backfill for the 13.5 ft diameter section.
3. Sand blasting and coating the interior of the entire length of 17 ft, 15.25 ft, 13.5 ft, and bifurcation sections of the penstock.

7.4.1.2 Option 3

1. Refurbishment of both the longitudinal and circumferential welds along the 15.25 ft and 13.5 ft diameter sections of the penstock.
    i. 934 lbs of weld material longitudinally and 1492 lbs circumferentially for the 15.25 ft diameter section; and
    ii. 4,091 lbs of weld material longitudinally and 5783 lbs circumferentially for the 13.5 ft diameter section.
2. Excavation of the common fill and backfill as required when weld refurbishment occurs on both sides of the penstock can for the 15.25 ft and 13.5 ft diameter section.
    i. 5,972 CY of excavation and 5,972 CY of backfill for the 15.25 ft diameter section; and

ii. 8,316 CY of excavation and 8,316 CY of backfill for the 13.5 ft diameter section.

3. Excavation of the common fill and bedding material over the entire length of the 17 ft diameter section for a total of 16,096 CY. Backfill of 10,908 CY of the common fill and supply of 5,189 CY of new bedding material.
4. Construction of two 1000m access roads which is assumed to be left in place after construction.
5. Demolition of the existing 1,245 ft long 17 ft diameter section of penstock.
6. Supply and installation of a new 1,245 ft long 17 ft diameter penstock section including:
    i. 3 manholes; and
    ii. 2,534 lbs of weld material for longitudinal welds and 4,511 lbs of weld material for circumferential welds.
7. Coating the interior of the 17ft, 15.25 ft, 13.5 ft, and bifurcation sections of the penstock.

7.4.1.3 Option 4

1. Refurbishment of both the longitudinal and circumferential welds along the 17 ft, 15.25 ft, and 13.5 ft diameter sections of the penstock.
    i. 899 lbs of weld material longitudinally and 1,600 lbs circumferentially for the 17 ft diameter section;
    ii. 934 lbs of weld material longitudinally and 1492 lbs circumferentially for the 15.25 ft diameter section; and
    iii. 4,091 lbs of weld material longitudinally and 5783 lbs circumferentially for the 13.5 ft diameter section.
2. Excavation of the common fill and backfill as required when weld refurbishment occurs on both sides of the penstock can for the 15.25 ft and 13.5 ft diameter sections.
    i. 5,972 CY of excavation and 5,972 CY of backfill for the 15.25 ft diameter section; and
    ii. 8,316 CY of excavation and 8,316 CY of backfill for the 13.5 ft diameter section.

3. Excavation of the common fill and backfill on the 17' diameter penstock section, as required when weld refurbishment occurs on both sides of the penstock can is as described in Option 2.
4. Supply of 33,782 lbs of steel plate to cover the longitudinal welds on the 17 ft diameter section installed with 4,230 lbs of weld material.
5. Supply of 60,141 lbs of steep plate to cover the circumferential welds on the 17 ft diameter section installed with 7,531 lbs of weld material.
6. Coating the interior of the 17 ft, 15.25 ft, 13.5 ft, and bifurcation sections of the penstock.

7.4.2 Penstock 3

TABLE 2.4 PENSTOCK 3

Item	Section		Quantity		
			Option 2	Option 3	Option 4
Weld Material	17'-0"	Longitudinal	939 lbs	2,634 lbs	939 lbs
		Circumferential	1,672 lbs	4,689 lbs	1,672 lbs
	15'-3"	Longitudinal	917 lbs	917 lbs	917 lbs
		Circumferential	1,464 lbs	1,464 lbs	1,464 lbs
	13'-6"	Longitudinal	3,193 lbs	4,091 lbs	3,193 lbs
		Circumferential	4,513 lbs	5,783 lbs	4,513 lbs
Excavation and Backfill	17'-0"	Excavation	7,349 CY	20,998 CY	7,349 CY
		Backfill	7,349 CY	13,615 CY	7,349 CY
		New Fill	- CY	7,383 CY	- CY
	15'-3"	Excavation	5,609 CY	5,609 CY	5,609 CY
		Backfill	5,609 CY	5,609 CY	5,609 CY
	13'-6"	Excavation	7,810 CY	7,810 CY	7,810 CY
		Backfill	7,810 CY	7,810 CY	7,810 CY
(2) Access Road	TOTAL		2,000 m	2,000 m	2,000 m
Demolition Existing	17'-0"		- ft	1,294 ft	- ft
Installation of New	17'-0"		- ft	1,294 ft	- ft
Manholes	17'-0"		-	3	- ft
Longitudinal Steel Plates	17'-0"	Steel Plates	- lbs	- lbs	35,302 lbs
		Weld Material	- lbs	- lbs	4,421 lbs
Circumferential Steel Plates	17'-0"	Steel Plates	- lbs	- lbs	62,846 lbs
		Weld Material	- lbs	- lbs	7,870 lbs

7.4.2.1 Option 2

1. Refurbishment of both the longitudinal and circumferential welds along the 17 ft, 15.25 ft, and 13.5 ft diameter sections of the penstock.
    i. 939 lbs of weld material longitudinally and 1,672 lbs circumferentially for the 17 ft diameter section;

ii. 917 lbs of weld material longitudinally and 1464 lbs circumferentially for the 15.25 ft diameter section; and

iii. 3,193 lbs of weld material longitudinally and 4,513 lbs circumferentially for the 13.5 ft diameter section.

2. Excavation of the common fill and backfill as required when weld refurbishment occurs on both sides of the penstock can.

    i. 7,349 CY of excavation and 7,349 CY of backfill for the 17 ft diameter section;

    ii. 5,609 CY of excavation and 5,609 CY of backfill for the 15.25 ft diameter section; and

    iii. 7,810 CY of excavation and 7,810 CY of backfill for the 13.5 ft diameter section.

3. Sand blasting and coating the interior of the entire length of 17 ft, 15.25 ft, 13.5 ft, and bifurcation sections of the penstock.

7.4.2.2 Option 3

1. Refurbishment of both the longitudinal and circumferential welds along the 15.25 ft and 13.5 ft diameter sections of the penstock.

    i. 917 lbs of weld material longitudinally and 1464 lbs circumferentially for the 15.25 ft diameter section; and

    ii. 4,091 lbs of weld material longitudinally and 5,783 lbs circumferentially for the 13.5 ft diameter section.

2. Excavation of the common fill and backfill as required when weld refurbishment occurs on both sides of the penstock can for the 15.25 ft and 13.5 ft diameter section.

    i. 5,609 CY of excavation and 5,609 CY of backfill for the 15.25 ft diameter section; and

    ii. 7,810 CY of excavation and 7,810 CY of backfill for the 13.5 ft diameter section.

3. Excavation of the common fill and bedding material over the entire length of the 17 ft diameter section for a total of 20,998 CY. Backfill of 13,615 CY of the common fill and supply of 7,383 CY of new bedding material.

4. Construction of two 1000m access roads which is assumed to be left in place after construction.
5. Demolition of the existing 1,294 ft long 17 ft diameter section of penstock.
6. Supply and installation of a new 1,294 ft long 17 ft diameter penstock section including:
    i. 3 manholes; and
    ii. 2,634 lbs of weld material for longitudinal welds and 4,689 lbs of weld material for circumferential welds.
7. Coating the interior of the 17ft, 15.25 ft, 13.5 ft, and bifurcation sections of the penstock.

7.4.2.3 Option 4

1. Refurbishment of both the longitudinal and circumferential welds along the 17 ft, 15.25 ft, and 13.5 ft diameter sections of the penstock.
    i. 939 lbs of weld material longitudinally and 1,672 lbs circumferentially for the 17 ft diameter section;
    ii. 917 lbs of weld material longitudinally and 1464 lbs circumferentially for the 15.25 ft diameter section; and
    iii. 3,193 lbs of weld material longitudinally and 4,513 lbs circumferentially for the 13.5 ft diameter section.
2. Excavation of the common fill and backfill as required when weld refurbishment occurs on both sides of the penstock can for the 15.25 ft and 13.5 ft diameter sections.
    i. 5,609 CY of excavation and 5,609 CY of backfill for the 15.25 ft diameter section; and
    ii. 7,810 CY of excavation and 7,810 CY of backfill for the 13.5 ft diameter section.
3. Excavation of the common fill and backfill on the 17' diameter penstock section, as required when weld refurbishment occurs on both sides of the penstock can is as described in Option 2.
4. Supply of 35,302 lbs of steel plate to cover the longitudinal welds on the 17 ft diameter section installed with 4,421 lbs of weld material.

5. Supply of 62,846 lbs of steep plate to cover the circumferential welds on the 17 ft diameter section installed with 7,870 lbs of weld material.
6. Coating the interior of the 17 ft, 15.25 ft, 13.5 ft, and bifurcation sections of the penstock.

8.0 ASSUMPTIONS

The Cost Estimate reflects the following key assumptions:

1. Welds:
    a. Weld Quantities:
        i. Assumed 50% of welds need to be refurbished.
        ii. Assumed 70% of welds that are refurbished require full depth refurbishment.
        iii. Assumed 30% of welds that are refurbished require shallow depth refurbishment.
        iv. The 17 ft section was assumed to have 3 longitudinal welds.
    b. Weld Depth (Shallow vs. Full Depth):
        i. Shallow welds were assumed to have a depth equal to half the can thickness and do not require two-sided access.
        ii. Full depth welds were assumed to have a depth equal to the full can thickness and require excavation for two-sided access.
2. Structural pipe bedding to be replaced at locations where excavated.
3. The excavated common fill can be stored temporarily on site and the bedding material when excavated can be disposed of on site.
4. Penstock:
    a. Pricing:
        i. Scaled up a per pound price (demo, install and supply) of a 6 ft diameter penstock from Cahill from May 2015 (adjusted for inflation).
        ii. A 25% premium is added on demolition of existing, supply of new and a 100% premium on install costs to account for the complexity associated with a 17' diameter pipe (all on a per pound basis).

b. Delivery:
    i. Assumes that delivery uses rail as close to the site as possible and trucks the remaining distance. $5,000/load, 2 cans per load, 60% factor added for DOT escort.
c. Reinforcing Plates:
    i. Assume 6" wide plates over all seams.
    ii. Assume that the plate thickness was equal to the can thickness.
    iii. Assume that plate welding would require 2 fillet welds along each edge equal to the plate thickness.

This list is not exhaustive and is intended only to supplement the means, methods, and sequencing premise of the Cost Opinion as detailed elsewhere in this document.

9.0 EXCLUSIONS

In addition to exclusions mentioned elsewhere in the Basis of Estimate document, the following costs are expressly excluded from the Cost opinion:

1. A limited scope of Owner's Costs has been considered in the Cost Opinion including but not limited to Contractor Profit and Contingency, recommended Owners Contingency, contract development, project management, site management and design engineering. Owner Costs that are not provided in the Cost Opinion include but are not limited to owner's overhead – direct and indirect, finance and interest expense and other matters of like import.
2. The costs of permits are not included.
3. Taxes where applicable are not included.
4. Any escalation in labor, material, and equipment costs incurred beyond the year end 2021 is not included.

10.0 CLOSURE

We appreciate the opportunity to assist you with this project. If you have any questions regarding this letter report, please call or e-mail Tim Saville at 705-304-3053 or Tim.Saville@KleinschmidtGroup.com.

Sincerely,

KLEINSCHMIDT ASSOCIATES CANADA INC.



Tim M. Saville, P.Eng.
Project Manager

TMS:SCB
Attachments: Appendix 1: Summary of Estimate
Appendix 2: Base Drawing Information
Appendix 3: Skarborn Welding Estimating Information

https://kleinschmidtgroup.sharepoint.com/sites/projects/Bay_d'Espoir/Kleinschmidt Library/Items in Development/Decision Support Package - Penstock 2 & 3/AttC Letter_Penstock 2 & 3 - Basis of Estimate w-client comments.docx

APPENDIX 1

SUMMARY OF ESTIMATE

Kleinschmidt

Project:	2670-034
By:	RJC
Checked By:	TMS
Date:	2021-08-03

Project: **Bay d'Espoir Penstock Life Extension FEED**
Subject: **Cost Benefit Analysis - Penstock #2**

Item	Description	Quantity	Unit	Unit Price	Extension	Total
1.0	**Option 1**					**$0**
					Sum:	$0
	Status Quo – regular maintenance, inspections and leak repairs as failures occur.				Estimated Contractor Contingency 12%	$0
					Estimated Contractor Profit 12%	$0
					Opinion of Probable Contractor Price	**$0**
					Recommended Owner Contingency 15%	$0
					Recommended Owner Budget (Option 1)	**$0**
2.0	**Option 2**					
	2.1 Refurbish Deteriorated Weld Seams					
	2.1.1 17ft Diameter Penstock - 1245 ft					
	2.1.1.1 Longitudinal	899	lb	$ 350.00	$314,600	
	2.1.1.2 Circumference	1,600	lb	$ 450.00	$720,100	
	2.1.1.3 Excavation to Allow for Weld Repair	5,634	CY	$ 24.00	$135,200	
	2.1.1.4 Back Fill Excavation	5,634	CY	$ 67.00	$377,500	
						$1,547,400
	2.1.2 15.25ft Diameter Penstock - 960 ft					
	2.1.2.1 Longitudinal	934	lb	$ 350.00	$326,900	
	2.1.2.2 Circumference	1,492	lb	$ 450.00	$671,300	
	2.1.2.3 Excavation to Allow for Weld Repair	5,972	CY	$ 24.00	$143,300	
	2.1.2.4 Back Fill Excavation	5,972	CY	$ 67.00	$400,100	
						$1,541,600
	2.1.3 13.5ft Diameter Penstock - 1650 ft					
	2.1.3.1 Longitudinal	4,091	lb	$ 350.00	$1,431,700	
	2.1.3.2 Circumference	5,783	lb	$ 450.00	$2,602,300	
	2.1.3.3 Excavation to Allow for Weld Repair	8,316	CY	$ 24.00	$199,600	
	2.1.3.4 Back Fill Excavation	8,316	CY	$ 67.00	$557,200	
						$4,790,800
	2.1.4 Weld Inspection					
	2.1.4.1 Inspection of Welds on All Sections	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	2.1.5 Engineered Scaffold					
	2.1.5.1 Allowance for 10 sets of adjustable scaffold systems	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	2.2 Coating Penstock Interior					
	2.2.1 Recoating 17' diameter pipe	1,245	ft	$ 2,800.00	$3,486,700	
	2.2.2 Recoating 15'-3"' diameter pipe	960	ft	$ 2,500.00	$2,399,400	
	2.2.3 Recoating 13.5' diameter pipe	1,650	ft	$ 2,200.00	$3,630,000	
	2.2.4 Recoating after Bifurcation	99	ft	$ 1,600.00	$158,200	
						$9,674,300
	2.3 Access Roads					
	2.3.1 Access Roads	2,000	m	$ 158.00	$316,000	
						$316,000
	2.4 Mobilization and Demobilization (5%)	-	LS	$ -	$927,705	
						$927,705
	Refurbishment of deteriorated weld seams (both longitudinally and circumferentially), and coating the penstock interior.				*17'-0" Section*	*$5,367,433*
					15'-3" Section	*$4,274,333*
					13'-6" Section	*$8,754,133*
					After Bifurcation	*$158,200*
					Sum:	**$19,798,000**
					Estimated Contractor Contingency 12%	$2,376,000
					Estimated Contractor Profit 12%	$2,376,000
					Opinion of Probable Contractor Price	**$24,550,000**
					Owner's Costs	
					Design Engineering Allowance	$250,000
					Owner Site Management ($5700/ Day) 121 days	$689,700
					Owner Project Management Allowance	$100,000
					Preconstruc'n Allowance & Tender Develop't	$250,000
					Owner's Costs - Subtotal	**$1,289,700**
					Recommended Owner Contingency 15%	$3,876,000
					Recommended Owner Budget (Option 2)	**$29,715,700**

Kleinschmidt

Project:	2670-034
By:	RJC
Checked By:	TMS
Date:	2021-08-03

Project: **Bay d'Espoir Penstock Life Extension FEED**
Subject: **Cost Benefit Analysis - Penstock #2**

Item	Description	Quantity	Unit	Unit Price	Extension	Total
3.0	**Option 3**					
	3.1 Replacement of 17' Section					
	3.1.1 Demolish and Dispose of Existing Penstock	1,245	ft	$ 2,240.00	$2,789,400	
	3.1.2 Supply New Penstock (Including Coating)	1,245	ft	$ 7,400.00	$9,214,900	
	3.1.3 Delivery of New Penstock	1,245	ft	$ 560.00	$697,300	
	3.1.4 Install New Penstock	1,245	ft	$ 2,200.00	$2,739,600	
	3.1.5 Conection to Existing (Allowance)	2	Each	$ 75,000.00	$150,000	
	3.1.6 Longitudinal Welding of New Penstock	2,534	lb	$ 350.00	$886,900	
	3.1.7 Circumferencial Welding of New Penstock	4,511	lb	$ 450.00	$2,030,000	
	3.1.8 Excavate Existing Fill (Common and Pipe Bedding)	16,096	CY	$ 24.00	$386,300	
	3.1.9 Backfill Common Fill	10,908	CY	$ 67.00	$730,800	
	3.1.10 Provide & Place New Pipe Bedding	5,189	CY	$ 150.00	$778,300	
	3.1.11 Additional Can Costs for Mitered Joints	5	Each	$ 28,000.00	$140,000	
	3.1.12 Manholes	3	Each	$ 15,000.00	$45,000	
	3.1.13 Drainage	2,491	ft	$ 85.00	$211,700	
						$20,800,200
	3.2 Refurbish Deteriorated Weld Seams					
	3.2.1 15.25ft Diameter Penstock - 960 ft					
	3.2.1.1 Longitudinal	934	lb	$ 350.00	$326,900	
	3.2.1.2 Circumference	1,492	lb	$ 450.00	$671,300	
	3.2.1.3 Excavation to Allow for Weld Repair	5,972	CY	$ 24.00	$143,300	
	3.2.1.4 Back Fill Excavation	5,972	CY	$ 67.00	$400,100	
						$1,541,600
	3.2.2 13.5ft Diameter Penstock - 1650 ft					
	3.2.2.1 Longitudinal	4,091	lb	$ 350.00	$1,431,700	
	3.2.2.2 Circumference	5,783	lb	$ 450.00	$2,602,300	
	3.2.2.3 Excavation to Allow for Weld Repair	8,316	CY	$ 24.00	$199,600	
	3.2.2.4 Back Fill Excavation	8,316	CY	$ 67.00	$557,200	
						$4,790,800
	3.2.3 Weld Inspection					
	3.2.3.1 Inspection of Welds on 15.25' & 13.5' Sections	1	LS	$ 350,000.00	$ 350,000.00	
						$ 350,000.00
	3.2.4 Engineered Scaffold					
	3.2.4.1 Allowance for 10 sets of adjustable scaffold systems	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	3.3 Coating of Penstock Interior					
	3.3.1 Recoating 15'-3"' diameter pipe	960	ft	$ 2,500.00	$2,399,400	
	3.3.2 Recoating 13.5' diameter pipe	1,650	ft	$ 2,200.00	$3,630,000	
	3.3.3 Recoating after Bifurcation	99	ft	$ 1,600.00	$158,200	
						$6,187,600
	3.4 Access Roads					
	3.4.1 Access Roads	2,000	m	$ 158.00	$316,000	
						$316,000
	3.5 Mobilization and Demobilization (5%)	-	LS	$ -	$1,708,510	
						$1,708,510

Replacement of the penstock 17'-0" diameter section, weld refurbishment and coating of remaining penstock.

17'-0" Section		*$20,800,200*
15'-3" Section		*$4,366,000*
13'-6" Section		*$8,845,800*
After Bifurcation		*$158,200*
Sum:		**$36,195,000**
Estimated Contractor Contingency	12%	$4,343,000
Estimated Contractor Profit	12%	$4,343,000
Opinion of Probable Contractor Price		**$44,881,000**
Owner's Costs		
Design Engineering Allowance		$500,000
Owner Site Management ($5700/ Day)	138 days	$786,600
Owner Project Management Allowance		$100,000
Preconstruc'n Allowance & Tender Develop't		$250,000
Owner's Costs - Subtotal		**$1,636,600**
Recommended Owner Contingency	15%	$6,978,000
Recommended Owner Budget (Option 3)		**$53,495,600**

Kleinschmidt

Project:	2670-034
By:	RJC
Checked By:	TMS
Date:	2021-08-03

Project: **Bay d'Espoir Penstock Life Extension FEED**
Subject: **Cost Benefit Analysis - Penstock #2**

Item	Description	Quantity	Unit	Unit Price	Extension	Total
4.0	**Option 4**					
	4.1 Refurbish Deteriorated Weld Seams					
	4.1.1 17ft Diameter Penstock - 1245 ft					
	4.1.1.1 Longitudinal	899	lb	$ 350.00	$314,600	
	4.1.1.2 Circumference	1,600	lb	$ 450.00	$720,100	
	2.1.1.3 Excavation to Allow for Weld Repair	5,634	CY	$ 24.00	$135,200	
	2.1.1.4 Back Fill Excavation	5,634	CY	$ 67.00	$377,500	
						$1,547,400
	4.1.2 15.25ft Diameter Penstock - 960 ft					
	4.1.2.1 Longitudinal	934	lb	$ 350.00	$326,900	
	4.1.2.2 Circumference	1,492	lb	$ 450.00	$671,300	
	4.1.2.3 Excavation to Allow for Weld Repair	5,972	CY	$ 24.00	$143,300	
	4.1.2.4 Back Fill Excavation	5,972	CY	$ 67.00	$400,100	
						$1,541,600
	4.1.3 13.5ft Diameter Penstock - 1650 ft					
	4.1.3.1 Longitudinal	4,091	lb	$ 350.00	$1,431,700	
	4.1.3.2 Circumference	5,783	lb	$ 450.00	$2,602,300	
	4.1.3.3 Excavation to Allow for Weld Repair	8,316	CY	$ 24.00	$199,600	
	4.1.3.4 Back Fill Excavation	8,316	CY	$ 67.00	$557,200	
						$4,790,800
	4.1.4 Weld Inspection					
	4.1.4.1 Inspection of Welds on All Sections	1	LS	$ 500,000.00	$ 500,000.00	
						$500,000
	4.1.5 Engineered Scaffold					
	4.1.5.1 Allowance for 10 sets of adjustable scaffold systems	1	LS	$ 500,000.00	$ 500,000.00	
						$500,000
	4.2 Coating of Penstock Interior					
	4.2.1 Recoating 17' diameter pipe	1,245	ft	$ 2,800.00	$3,486,700	
	4.2.2 Recoating 15'-3"' diameter pipe	960	ft	$ 2,500.00	$2,399,400	
	4.2.3 Recoating 13.5' diameter pipe	1,650	ft	$ 2,200.00	$3,630,000	
	4.2.4 Recoating after Bifurcation	99	ft	$ 1,600.00	$158,200	
						$9,674,300
	4.3 Welds for Reinforcing Plates Over Welds of 17' Section					
	4.3.1 Longitudinal	4,230	lb	$ 350.00	$1,480,600	
	4.4.2 Circumference	7,531	lb	$ 450.00	$3,389,000	
						$4,869,600
	4.4 Reinforcing Plates Over Welds of 17' Section					
	4.4.1 Longitudinal Plates	33,782	lb	$ 5.60	$189,200	
	4.4.2 Circumference Plates	60,141	lb	$ 5.60	$336,800	
						$526,000
	4.5 Access Roads					
	4.5.1 Access Roads	2,000	m	$ 158.00	$316,000	
						$316,000
	4.6 Mobilization and Demobilization (5%)	-	LS	$ -	$1,197,485	
						$1,197,485

		17'-0" Section	*$10,763,033*
		15'-3" Section	*$4,274,333*
		13'-6" Section	*$8,754,133*
		After Bifurcation	*$158,200*
		Sum:	**$25,463,000**
	Estimated Contractor Contingency	12%	$3,056,000
	Estimated Contractor Profit	12%	$3,056,000
	Opinion of Probable Contractor Price		**$31,575,000**
	Owner's Costs		
	Design Engineering Allowance		$300,000
	Owner Site Management ($5700/ Day)	146 days	$832,200
	Owner Project Management Allowance		$100,000
	Preconstruc'n Allowance & Tender Develop't		$250,000
	Owner's Costs - Subtotal		**$1,482,200**
	Recommended Owner Contingency	15%	$4,959,000
	Recommended Owner Budget (Option 4)		**$38,016,200**

Refurbishment of deteriorated weld seams, recoating the entire penstock and installation of reinforcing plates over the longitudinal and circumferential weld seams of the 17'-0" diameter section.

Kleinschmidt

Project:	2670-034
By:	RJC
Checked By:	TMS
Date:	2021-08-03

Project: **Bay d'Espoir Penstock Life Extension FEED**
Subject: **Cost Benefit Analysis - Penstock #3**

Item	Description	Quantity	Unit	Unit Price	Extension	Total
1.0	**Option 1**					**$0**
					Sum:	$0
	Status Quo – regular maintenance, inspections and leak repairs as failures occur.			Estimated Contractor Contingency	12%	$0
				Estimated Contractor Profit	12%	$0
				Opinion of Probable Contractor Price		**$0**
				Recommended Owner Contingency	15%	$0
				Recommended Owner Budget (Option 1)		**$0**
2.0	**Option 2**					
	2.1 Refurbish Deteriorated Weld Seams					
	2.1.1 17ft Diameter Penstock - 1294 ft					
	2.1.1.1 Longitudinal	939	lb	$ 350.00	$328,800	
	2.1.1.2 Circumference	1,672	lb	$ 440.00	$735,800	
	2.1.1.3 Excavation to Allow for Weld Repair	7,349	CY	$ 23.00	$169,000	
	2.1.1.4 Back Fill Excavation	7,349	CY	$ 66.00	$485,000	
						$1,718,600
	2.1.2 15.25ft Diameter Penstock - 917 ft					
	2.1.2.1 Longitudinal	917	lb	$ 350.00	$320,800	
	2.1.2.2 Circumference	1,464	lb	$ 440.00	$644,000	
	2.1.2.3 Excavation to Allow for Weld Repair	5,609	CY	$ 23.00	$129,000	
	2.1.2.4 Back Fill Excavation	5,609	CY	$ 66.00	$370,200	
						$1,464,000
	2.1.3 13.5ft Diameter Penstock - 1602 ft					
	2.1.3.1 Longitudinal	3,193	lb	$ 350.00	$1,117,400	
	2.1.3.2 Circumference	4,513	lb	$ 440.00	$1,985,900	
	2.1.3.3 Excavation to Allow for Weld Repair	7,810	CY	$ 23.00	$179,600	
	2.1.3.4 Back Fill Excavation	7,810	CY	$ 66.00	$515,500	
						$3,798,400
	2.1.4 Weld Inspection					
	2.1.4.1 Inspection of Welds on All Sections	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	2.1.5 Engineered Scaffold					
	2.1.5.1 Allowance for 10 sets of adjustable scaffold systems	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	2.2 Coating Penstock Interior					
	2.2.1 Recoating 17' diameter pipe	1,294	ft	$ 2,800.00	$3,624,200	
	2.2.2 Recoating 15'-3"' diameter pipe	917	ft	$ 2,500.00	$2,291,900	
	2.2.3 Recoating 13.5' diameter pipe	1,602	ft	$ 2,200.00	$3,525,200	
	2.2.4 Recoating after Bifurcation	99	ft	$ 1,600.00	$158,200	
						$9,599,500
	2.3 Access Roads					
	2.3.1 Access Roads	2,000	m	$ 155.00	$310,000	
						$310,000
	2.4 Mobilization and Demobilization (5%)	-	LS	$ -	$879,025	
						$879,025
	Refurbishment of deteriorated weld seams (both longitudinally and circumferentially), and coating the penstock interior.				*17'-0" Section*	*$5,676,133*
					15'-3" Section	*$4,089,233*
					13'-6" Section	*$7,656,933*
					After Bifurcation	*$158,200*
					Sum:	**$18,770,000**
				Estimated Contractor Contingency	12%	$2,252,000
				Estimated Contractor Profit	12%	$2,252,000
				Opinion of Probable Contractor Price		**$23,274,000**
				Owner's Costs		
				Design Engineering Allowance		$250,000
				Owner Site Management ($5700/ Day)	121 days	$689,700
				Owner Project Management Allowance		$100,000
				Preconstruc'n Allowance & Tender Develop't		$250,000
				Owner's Costs - Subtotal		**$1,289,700**
				Recommended Owner Contingency	15%	$3,685,000
				Recommended Owner Budget (Option 2)		**$28,248,700**

Kleinschmidt

Project:	2670-034
By:	RJC
Checked By:	TMS
Date:	2021-08-03

Project: **Bay d'Espoir Penstock Life Extension FEED**
Subject: **Cost Benefit Analysis - Penstock #3**

Item	Description	Quantity	Unit	Unit Price	Extension	Total
3.0	**Option 3**					
	3.1 Replacement of 17' Section					
	3.1.1 Demolish and Dispose of Existing Penstock	1,294	ft	$ 2,210.00	$2,860,600	
	3.1.2 Supply New Penstock (Including Coating)	1,294	ft	$ 7,300.00	$9,448,900	
	3.1.3 Delivery of New Penstock	1,294	ft	$ 550.00	$711,900	
	3.1.4 Install New Penstock	1,294	ft	$ 2,200.00	$2,847,600	
	3.1.5 Conection to Existing (Allowance)	2	Each	$ 75,000.00	$150,000	
	3.1.6 Longitudinal Welding of New Penstock	2,634	lb	$ 350.00	$921,900	
	3.1.7 Circumferencial Welding of New Penstock	4,689	lb	$ 440.00	$2,063,200	
	3.1.8 Excavate Existing Fill (Common and Pipe Bedding)	20,998	CY	$ 23.00	$482,900	
	3.1.9 Backfill Common Fill	13,615	CY	$ 66.00	$898,600	
	3.1.10 Provide & Place New Pipe Bedding	7,383	CY	$ 150.00	$1,107,400	
	3.1.11 Additional Can Costs for Mitered Joints	5	Each	$ 27,600.00	$138,000	
	3.1.12 Manholes	3	Each	$ 15,000.00	$45,000	
	3.1.13 Drainage	2,589	ft	$ 84.00	$217,500	
						$21,893,500
	3.2 Refurbish Deteriorated Weld Seams					
	3.2.1 15.25ft Diameter Penstock - 917 ft					
	3.2.1.1 Longitudinal	917	lb	$ 350.00	$320,800	
	3.2.1.2 Circumference	1,464	lb	$ 440.00	$644,000	
	3.2.1.3 Excavation to Allow for Weld Repair	5,609	CY	$ 23.00	$129,000	
	3.2.1.4 Back Fill Excavation	5,609	CY	$ 66.00	$370,200	
						$1,464,000
	3.2.2 13.5ft Diameter Penstock - 1602 ft					
	3.2.2.1 Longitudinal	3,193	lb	$ 350.00	$1,117,400	
	3.2.2.2 Circumference	4,513	lb	$ 440.00	$1,985,900	
	3.2.2.3 Excavation to Allow for Weld Repair	7,810	CY	$ 23.00	$179,600	
	3.2.2.4 Back Fill Excavation	7,810	CY	$ 66.00	$515,500	
						$3,798,400
	3.2.3 Weld Inspection					
	3.2.3.1 Inspection of Welds on 15.25' & 13.5' Sections	1	LS	$ 350,000.00	$ 350,000.00	
						$ 350,000.00
	3.2.4 Engineered Scaffold					
	3.2.4.1 Allowance for 10 sets of adjustable scaffold systems	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	3.3 Coating of Penstock Interior					
	3.3.1 Recoating 15'-3"' diameter pipe	917	ft	$ 2,500.00	$2,291,900	
	3.3.2 Recoating 13.5' diameter pipe	1,602	ft	$ 2,200.00	$3,525,200	
	3.3.3 Recoating after Bifurcation	99	ft	$ 1,600.00	$158,200	
						$5,975,300
	3.4 Access Roads					
	3.4.1 Access Roads	2,000	m	$ 155.00	$310,000	
						$310,000
	3.5 Mobilization and Demobilization (5%)	-	LS	$ -	$1,699,060	
						$1,699,060

		17'-0" Section	*$21,893,500*
		15'-3" Section	*$4,180,900*
		13'-6" Section	*$7,748,600*
		After Bifurcation	*$158,200*
		Sum:	**$35,990,000**
	Estimated Contractor Contingency	12%	$4,319,000
	Estimated Contractor Profit	12%	$4,319,000
	Opinion of Probable Contractor Price		**$44,628,000**
Replacement of the penstock 17'-0" diameter section, weld refurbishment and coating of remaining penstock.	**Owner's Costs**		
	Design Engineering Allowance		$500,000
	Owner Site Management ($5700/ Day)	138 days	$786,600
	Owner Project Management Allowance		$100,000
	Preconstruc'n Allowance & Tender Develop't		$250,000
	Owner's Costs - Subtotal		**$1,636,600**
	Recommended Owner Contingency	15%	$6,940,000
	Recommended Owner Budget (Option 3)		**$53,204,600**

Kleinschmidt

Project:	2670-034
By:	RJC
Checked By:	TMS
Date:	2021-08-03

Project: **Bay d'Espoir Penstock Life Extension FEED**
Subject: **Cost Benefit Analysis - Penstock #3**

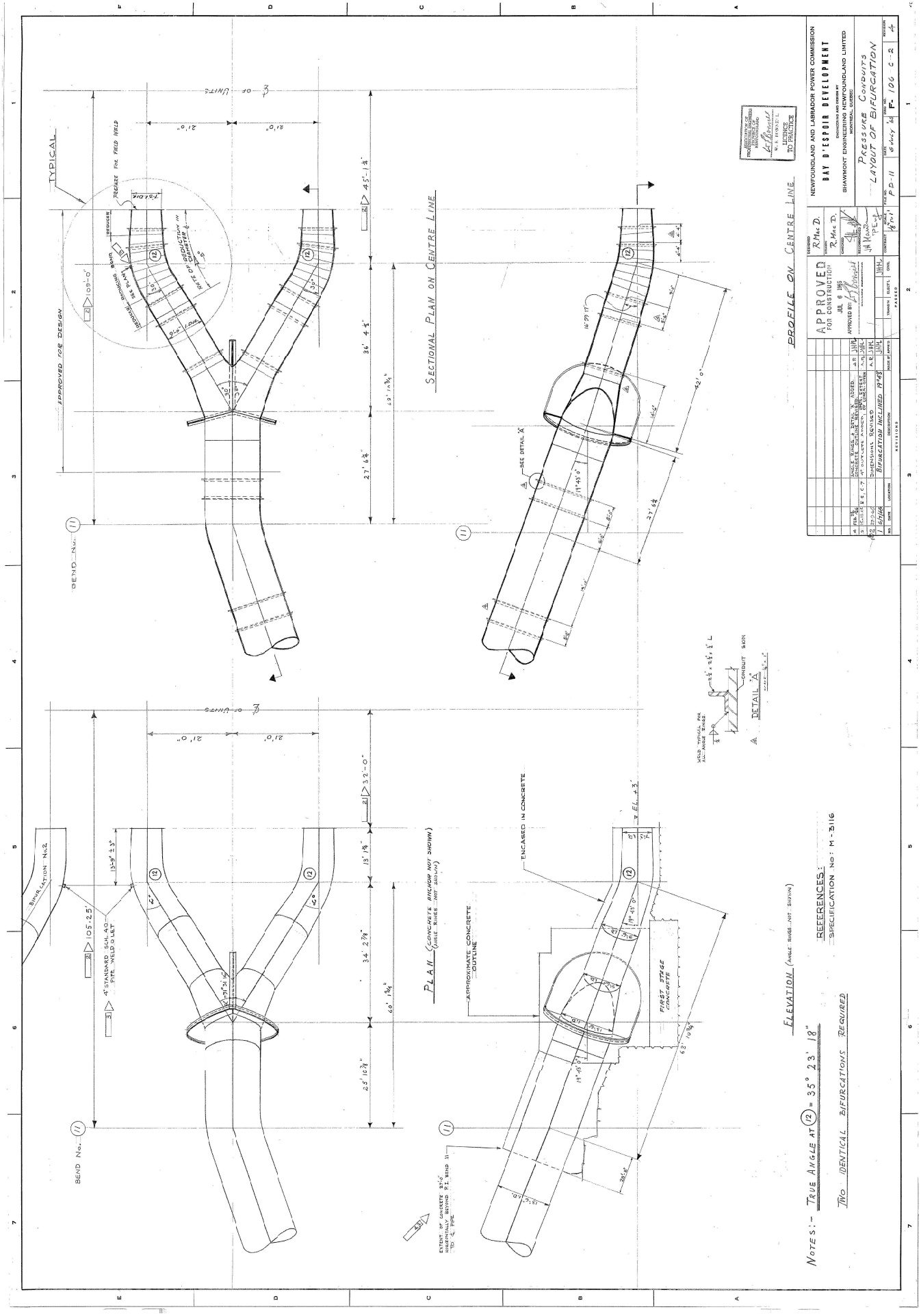
Item	Description	Quantity	Unit	Unit Price	Extension	Total
4.0	**Option 4**					
	4.1 Refurbish Deteriorated Weld Seams					
	4.1.1 17ft Diameter Penstock					
	4.1.1.1 Longitudinal	939	lb	$ 350.00	$328,800	
	4.1.1.2 Circumference	1,672	lb	$ 440.00	$735,800	
	2.1.1.3 Excavation to Allow for Weld Repair	7,349	CY	$ 23.00	$169,000	
	2.1.1.4 Back Fill Excavation	7,349	CY	$ 66.00	$485,000	
						$1,718,600
	4.1.2 15.25ft Diameter Penstock - 917 ft					
	4.1.2.1 Longitudinal	917	lb	$ 350.00	$320,800	
	4.1.2.2 Circumference	1,464	lb	$ 440.00	$644,000	
	4.1.2.3 Excavation to Allow for Weld Repair	5,609	CY	$ 23.00	$129,000	
	4.1.2.4 Back Fill Excavation	5,609	CY	$ 66.00	$370,200	
						$1,464,000
	4.1.3 13.5ft Diameter Penstock - 1602 ft					
	4.1.3.1 Longitudinal	3,193	lb	$ 350.00	$1,117,400	
	4.1.3.2 Circumference	4,513	lb	$ 440.00	$1,985,900	
	4.1.3.3 Excavation to Allow for Weld Repair	7,810	CY	$ 23.00	$179,600	
	4.1.3.4 Back Fill Excavation	7,810	CY	$ 66.00	$515,500	
						$3,798,400
	4.1.4 Weld Inspection					
	4.1.4.1 Inspection of Welds on All Sections	1	LS	$ 500,000.00	$ 500,000.00	
						$500,000
	4.1.5 Engineered Scaffold					
	4.1.5.1 Allowance for 10 sets of adjustable scaffold systems	1	LS	$ 500,000.00	$ 500,000.00	
						$ 500,000.00
	4.2 Coating of Penstock Interior					
	4.2.1 Recoating 17' diameter pipe	1,294	ft	$ 2,800.00	$3,624,200	
	4.2.2 Recoating 15'-3"' diameter pipe	917	ft	$ 2,500.00	$2,291,900	
	4.2.3 Recoating 13.5' diameter pipe	1,602	ft	$ 2,200.00	$3,525,200	
	4.2.4 Recoating after Bifurcation	99	ft	$ 1,600.00	$158,200	
						$9,599,500
	4.3 Welds for Reinforcing Plates Over Welds of 17' Section					
	4.3.1 Longitudinal	4,421	lb	$ 350.00	$1,547,300	
	4.4.2 Circumference	7,870	lb	$ 440.00	$3,462,900	
						$5,010,200
	4.4 Reinforcing Plates Over Welds of 17' Section					
	4.4.1 Longitudinal Plates	35,302	lb	$ 5.50	$194,200	
	4.4.2 Circumference Plates	62,846	lb	$ 5.50	$345,700	
						$539,900
	4.5 Access Roads					
	4.5.1 Access Roads	2,000	m	$ 155.00	$310,000	
						$310,000
	4.6 Mobilization and Demobilization (5%)	-	LS	$ -	$1,156,530	
						$1,156,530

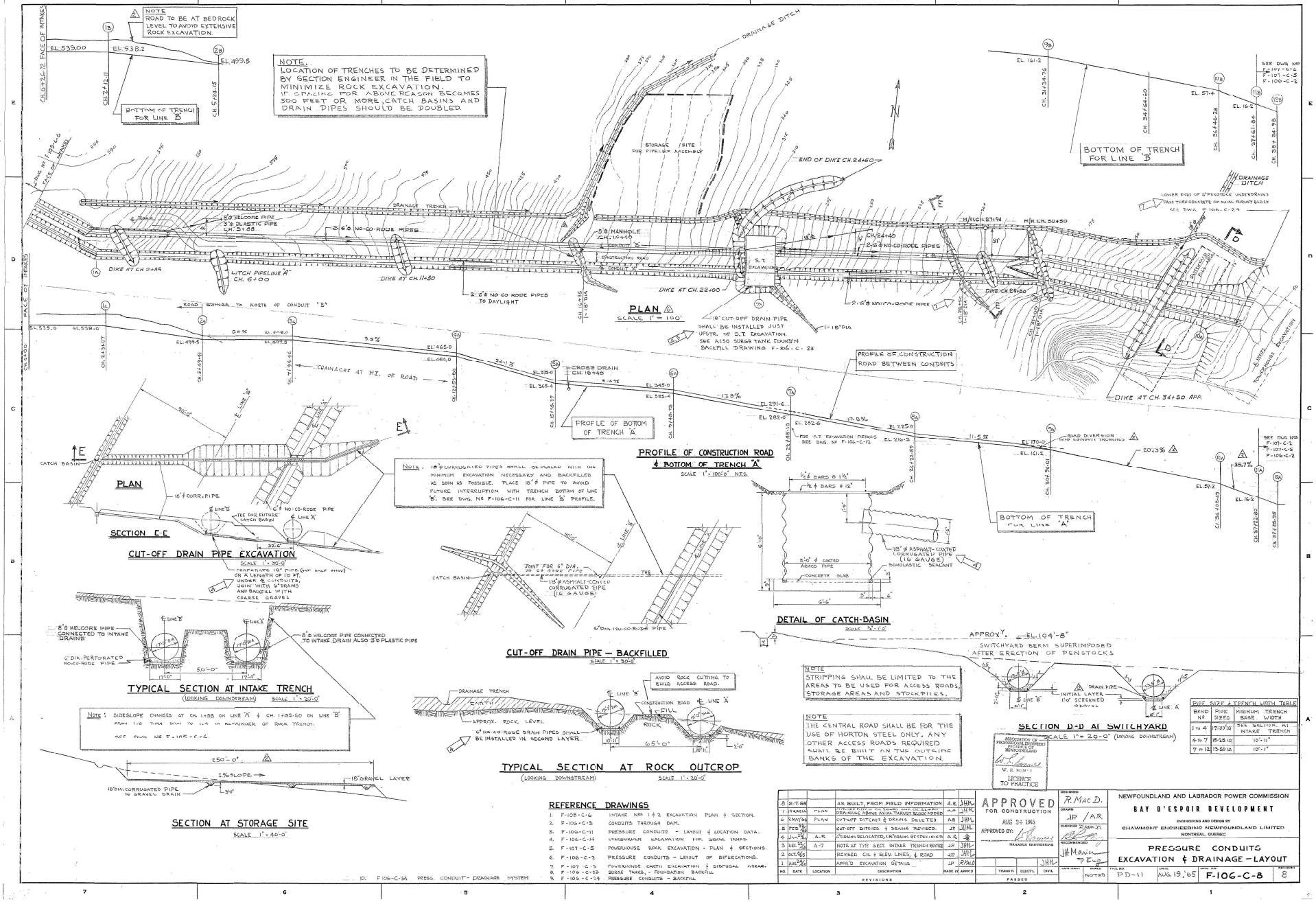
Refurbishment of deteriorated weld seams, recoating the entire penstock and installation of reinforcing plates over the longitudinal and circumferential weld seams of the 17'-0" diameter section.

17'-0" Section		*$11,226,233*
15'-3" Section		*$4,089,233*
13'-6" Section		*$7,656,933*
After Bifurcation		*$158,200*
Sum:		**$24,597,000**
Estimated Contractor Contingency	12%	$2,952,000
Estimated Contractor Profit	12%	$2,952,000
Opinion of Probable Contractor Price		**$30,501,000**
Owner's Costs		
Design Engineering Allowance		$300,000
Owner Site Management ($5700/ Day)	146 days	$832,200
Owner Project Management Allowance		$100,000
Preconstruc'n Allowance & Tender Develop't		$250,000
Owner's Costs - Subtotal		**$1,482,200**
Recommended Owner Contingency	15%	$4,797,000
Recommended Owner Budget (Option 4)		**$36,780,200**

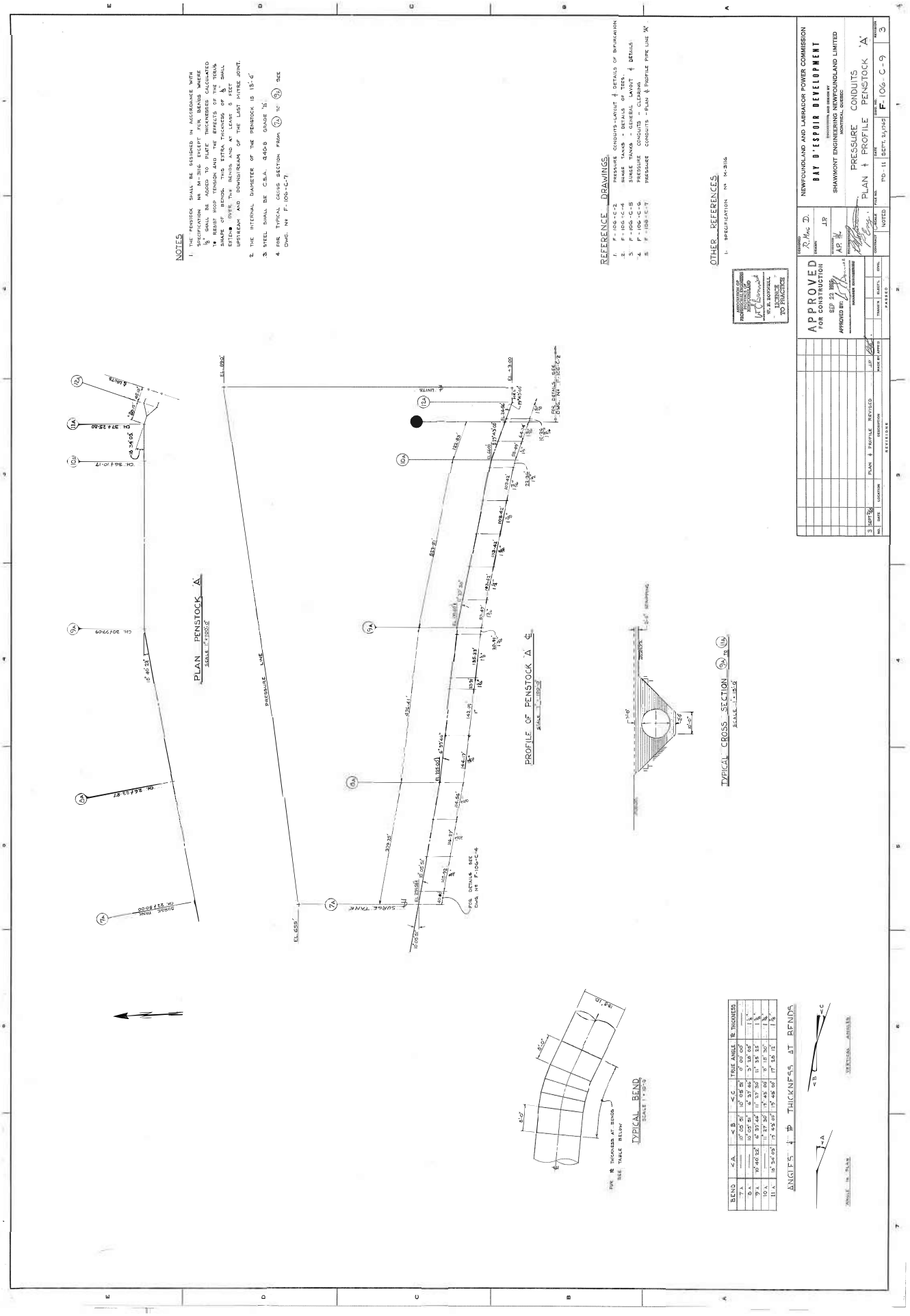
APPENDIX 2

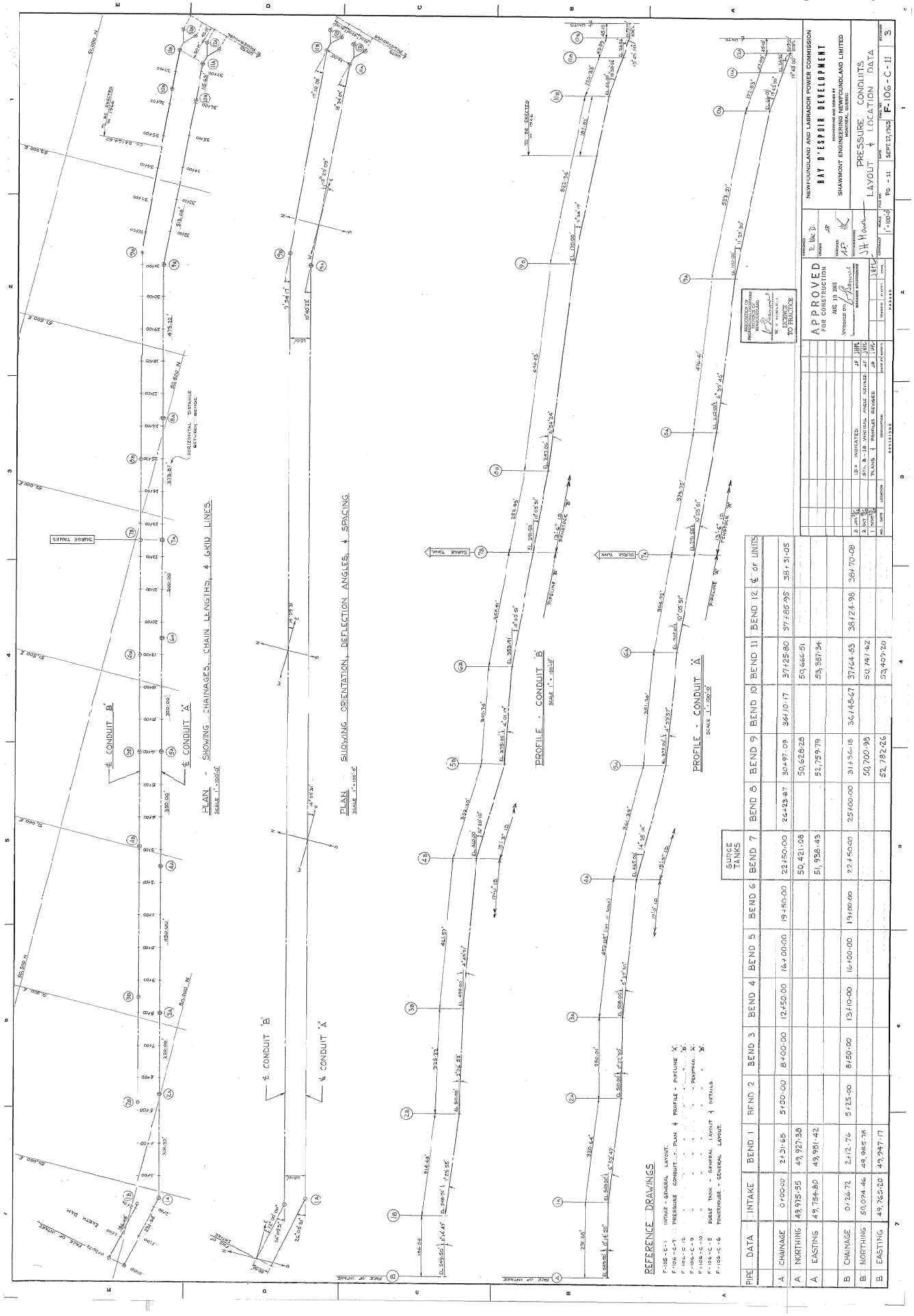
BASE DRAWING INFORMATION


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
PRESSURE CONDUITS
LAYOUT OF BIFURCATION
APPROVED FOR CONSTRUCTION
SECTIONAL PLAN ON CENTRE LINE
PROFILE ON CENTRE LINE
PLAN (CONCRETE ANCHOR NOT SHOWN)
ELEVATION (ANGLE RINGS NOT SHOWN)
DETAIL "A"
REFERENCES:
SPECIFICATION No: M-3116
NOTES:- TRUE ANGLE AT (12) = 35° 23' 18"
TWO IDENTICAL BIFURCATIONS REQUIRED
APPROVED FOR DESIGN
TYPICAL
BEND No. (11)
BIFURCATION No. 2
4" STANDARD SCH. 40 PIPE WELD OLET
APPROXIMATE CONCRETE OUTLINE
ENCASED IN CONCRETE
FIRST STAGE CONCRETE
CONDUIT SKIN
DIMENSIONS REVISED
BIFURCATION INCLINED 19°43'
PD-11
F-106 C-2



Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 1, Page 204 of 212


NOTES
1. THE PENSTOCK SHALL BE DESIGNED IN ACCORDANCE WITH SECTION 11 OF CSA STANDARD W59-1963 FOR WELDED STEEL CONSTRUCTION. A CORROSION ALLOWANCE OF 1/8" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION AND THE EFFECTS OF THE TEE/Y SHAPE OF BEND. THIS EXTRA THICKNESS OF 1/8" SHALL EXTEND OVER THE BENDS AND AT LEAST 5 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.
2. THE INTERNAL DIAMETER OF THE PENSTOCK IS 13'-6".
3. STEEL SHALL BE CSA. G40.8 GRADE 38.
4. FOR TYPICAL CROSS SECTION FROM (7A) TO (9A) SEE DWG. NO F-106-C-7.
REFERENCE DRAWINGS
1. F-106-C-2 PRESSURE CONDUITS-LAYOUT & DETAILS OF BIFURCATION
2. F-106-C-4 SURGE TANK - DETAILS OF TEE.
3. F-106-C-5 SURGE TANK - GENERAL LAYOUT & DETAILS
4. F-106-C-6 PENSTOCK CLEARANCE DIAGRAMS
5. F-106-C-7 PRESSURE CONDUITS - PLAN & PROFILE PIPE LINE 'A'
OTHER REFERENCES
1. SPECIFICATION NO. M-3116
PLAN PENSTOCK 'A'
SCALE 1"=100'-0"
PROFILE OF PENSTOCK 'A' ℄
SCALE 1"=100'-0"
TYPICAL CROSS SECTION
SCALE 1"=10'-0"
TYPICAL BEND
SCALE 1"=10'-0"
PIPE & THICKNESS AT BENDS SEE TABLE BELOW
ANGLES & THICKNESS AT BENDS
VERTICAL ANGLES
ANGLE IN PLAN
PRESSURE LINE
SURGE TANK
EL. 892'
EL. 839'
EL. 330.00
CH. 314+38.80
CH. 364+10.17
CH. 801+79.09
CH. 866+93.87
SURGE TANK CH. 871+80.00
R=325.00
R=325.00
R=325


PLAN - SHOWING CHAINAGES, CHAIN LENGTHS, & GRID LINES
PLAN - SHOWING ORIENTATION, DEFLECTION ANGLES, & SPACING
PROFILE - CONDUIT 'B'
PROFILE - CONDUIT 'A'
REFERENCE DRAWINGS
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
SHAWINIGAN ENGINEERING NEWFOUNDLAND LIMITED
PRESSURE CONDUITS
LAYOUT & LOCATION DATA
APPROVED FOR CONSTRUCTION
F-106-C-11

APPENDIX 3

SKARBORN WELDING ESTIMATING INFORMATION

SKARBORN ENGINEERING LTD
270 Douglas Avenue, Suite 402 | Bathurst, NB | E2A 1M9
skarborn@rogers.com | www.skarborneng.com | (506) 452-1804

February 16, 2021

Kleinschmidt Canada, Inc.
99 Wyse Road,
Dartmouth, Nova Scotia
B3A 4S5

Attention: Chris Vella, P.E., S.E., P. Eng

Re: Weld time estimating procedure for Bay d 'Espoir Penstock No. 1

As per our conversation last week this report itemizes how we recommend that estimating welding time and costs be carried out. A key item will be to determine the operating factor (see Step 4) for the work.

Should you require further input on this topic, please advise.

As with the last report, I'm assuming that you are distributing and filing this report as required.

Sincerely,



Stig Skarborn, P. Eng., IWE
CSA W178.2 Level 3 Weld inspector

CWB WELD SPECIALIST WSM100236

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Procedure for Estimating Weld Time

Step 1 – Determine Weld Metal Weight

The weld metal weight can either be calculated based on the cross section of the weld metal or taken from convenient tables. The one below is taken from The James F. Lincoln Arc Welding Foundation's "The Procedure Handbook of Arc Welding".

TABLE 12-1. Weight of Weld Metal (Pounds Per Foot of Joint)

d or r dimension	t 1/16	t 1/8	t 3/16	t 1/4	t 3/8	t 1/2	d 1/16	d 1/8	d 3/16	d 1/4	r	14°	20°	30°	45°	60°	70°	75°	80°	90°	30°	45°	60°	values below are for leg size 10% oversize, consistent with normal shop practices. flat	convex	concave	d or r dimension
1/16											.021																1/16
1/8	.027	.053	.080	.106	.159	.213					.083	.0065	.0094	.014	.022	.031	.037	.041	.045	.053	.015	.027	.046	.032	.041	.036	1/8
3/16	.040	.080	.120	.159	.239	.319	.027				.188	.015	.021	.032	.050	.069	.084	.092	.100	.120	.035	.060	.104	.072	.093	.081	3/16
1/4	.053	.106	.159	.213	.319	.425	.035				.334	.026	.037	.057	.088	.123	.149	.163	.178	.213	.061	.106	.184	.129	.165	.145	1/4
5/16	.066	.133	.199	.266	.398	.531	.044				.522	.041	.059	.089	.138	.192	.232	.255	.270	.332	.096	.166	.288	.201	.250	.226	5/16
3/8	.080	.159	.239	.319	.478	.638	.053	.106			.751	.059	.084	.128	.198	.276	.335	.367	.401	.478	.138	.239	.414	.289	.371	.325	3/8
7/16	.093	.186	.279	.372	.558	.744	.062	.124	.186		1.02	.080	.115	.174	.270	.376	.456	.499	.546	.651	.188	.325	.564	.394	.505	.443	7/16
1/2	.106	.213	.319	.425	.638	.850	.071	.142	.213		1.34	.104	.150	.228	.352	.491	.595	.652	.713	.850	.245	.425	.736	.514	.659	.578	1/2
9/16	.120	.239	.359	.478	.717	.956	.080	.159	.239			.132	.190	.288	.446	.621	.753	.825	.903	1.08	.311	.538	.932	.651	.834	.732	9/16
5/8	.133	.266	.398	.531	.797	1.06	.089	.177	.266	.394		.163	.234	.356	.550	.767	.930	1.02	1.11	1.33	.383	.664	1.15	.804	1.03	.904	5/8
11/16	.146	.292	.438	.584	.877	1.17	.097	.195	.292	.390		.197	.283	.431	.666	.928	1.13	1.23	1.35	1.61	.464	.804	1.39	.972	1.25	1.09	11/16
3/4	.159	.319	.478	.638	.956	1.28	.106	.213	.319	.425		.235	.337	.512	.792	1.10	1.34	1.47	1.60	1.91	.552	.956	1.66	1.16	1.48	1.30	3/4
13/16	.173	.345	.518	.691	1.04	1.38	.115	.230	.345	.460		.276	.396	.601	.930	1.30	1.57	1.72	1.88	2.24	.648	1.12	1.94				13/16
7/8	.186	.372	.558	.744	1.12	1.49	.124	.248	.372	.496		.320	.459	.698	1.08	1.50	1.82	2.00	2.18	2.60	.751	1.30	2.25	1.57	2.02	1.77	7/8
15/16	.199	.398	.598	.797	1.20	1.59	.133	.266	.398	.531		.367	.527	.801	1.24	1.73	2.09	2.29	2.51	2.99	.863	1.49	2.59				15/16
1	.213	.425	.638	.850	1.28	1.70	.142	.283	.425	.567		.417	.600	.911	1.41	1.96	2.38	2.61	2.85	3.40	.981	1.70	2.94	2.06	2.64	2.31	1
1-1/16	.226	.452	.677	.903	1.35	1.81	.151	.301	.452	.602		.471	.677	1.03	1.59	2.22					1.11	1.92	3.32				1-1/16
1-1/8	.239	.478	.717	.956	1.43	1.91	.159	.319	.478	.638		.528	.759	1.15	1.78	2.48					1.24	2.15	3.73	2.60	3.34	2.93	1-1/8
1-3/16	.252	.505	.757	1.01	1.51	2.02	.168	.336	.505	.673		.589	.845	1.28	1.99	2.77					1.38	2.40	4.15				1-3/16
1-1/4	.266	.531	.797	1.06	1.59	2.13	.177	.354	.531	.708		.652	.937	1.42	2.20	3.07					1.53	2.66	4.60	3.21	4.12	3.61	1-1/4
1-5/16	.279	.558	.837	1.12	1.67	2.23	.186	.372	.558	.744		.719	1.03	1.57	2.43	3.38					1.69	2.93	5.07				1-5/16
1-3/8	.292	.584	.877	1.17	1.75	2.34	.195	.390	.584	.779		.789	1.13	1.72	2.66	3.71					1.86	3.21	5.57	3.89	4.99	4.37	1-3/8
1-7/16	.305	.611	.916	1.22	1.83	2.44	.204	.407	.611	.815		.863	1.24	1.88	2.91	4.06					2.03	3.51	6.08				1-7/16
1-1/2	.319	.638	.956	1.28	1.91	2.55	.213	.425	.638	.850		.939	1.35	2.05	3.17	4.42					2.21	3.83	6.63	4.63	5.93	5.20	1-1/2
1-9/16	.332	.664	.996	1.33	1.99	2.66	.221	.443	.664	.885		1.02	1.46	2.22	3.44	4.79					2.40	4.15	7.19				1-9/16

Table 1 – Weight of Weld Metal

For repairs on Penstock No. 1, we envisage that there will be three types of repairs:

a) Repair of shallow cracks with a partial joint penetration weld.
b) Repair of crack extending through thickness of penstock wall (access required from both sides).
c) Fillet weld for doubler plate over penstock wall horizontal seams.

For alternative a) with an assumed thickness of 7/16" (11.1 mm) with a 3/16" (4.8 mm) deep crack we have calculated the required weld metal as 0.24 lb/ft assuming a prequalified U-joint with a radius of 3/16" and a reinforcement of 1/16" (1.6 mm).

Alternative b) will require approximately 0.57 lb/ft.

For alternative c) we have assumed that fillet welds will be required to transfer the full tensile resistance of the ASTM A285, Grade C, material, and that either a CSA G40.21, Grade 350W, or an ASTM A516, Grade 70, flat bar will be used as a doubler plate. Based on the mechanical properties of the penstock material and the flat bar, and assuming that a E49XX (E70XX) electrode is used we find that the required fillet weld size is approximately 12.7 mm (1/2") welded on 15.9 mm (5/8") flat bar with 3 mm (1/8") rounded corners for coating purposes.

From Table 1 it can be seen that 0.514 lb/ft is required if the surface is flat, 0.659 lb/ft for convex

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surface, and 0.578 lb/ft for a concave weld, all assuming 10% oversized legs. There is a 28% difference between a flat and convex weld which reinforces the fact that over-welding should be prevented. In addition to taking more time, it will also result in more residual stress which equals more distortion.

In our opinion, consideration should be given to repairing cracks and grinding off existing weld reinforcement before installing doubler plates.

Step 2 – Determine Welding Process

Two processes should be considered for field welding; Shielded Metal Arc Welding (SMAW) and Flux Cored Arc Welding (FCAW). These two processes have substantially different weld metal deposition and operating factors. The weld metal deposition rates are directly related to the current used.

The main advantages for SMAW are that power sources are fairly simple and that they can be located a considerable distance from the welding location. Disadvantages include low currents [160-190 Amperes for flat, horizontal and overhead welds, and 110-160 Amperes for vertical up welds assuming 4.0 mm (5/32") electrodes] which is associated with low deposition rates and substantial stub loss. Welders are often used to welding with even smaller electrodes which leads to even worse productivity. Proper storage and handling of electrodes are also issues.

FCAW has a continuous tubular electrode with flux in its void, is fed from a spool on a wire feeder located in the immediate vicinity of the welder. From the wire feeder cables extend to the power source. The weld is protected by a shielding gas which is usually located in the vicinity of the wire feeder. Typical current ranges for FCAW are 230-280 Amperes for flat, horizontal and overhead and 150-220 for vertical up. For shop work this is an obvious advantage, but for field work inside a sloping penstock, possibly with ventilation issues, the process's advantages are not obvious. There are self-shielded FCAW wires which negate the need for shielding gas, but they produce much more fume than gas shielded types and are not considered suitable for welding inside a penstock.

To give an example of the deposition rates an E4918 (E7018) operated at 170 Amperes has a deposition rate of approximately 1.9 kg/hr (4.1 lbs/hr). A 1.1 mm (0.045") diameter FCAW electrode operated at 250 Amperes results in a deposition rate of approximately 3.8 lbs/hr (8.3 lb/hr), double the deposition rate of SMAW. Clearly the welding process should be considered by a competitive contractor and in cost estimates.

Step 3 – Calculate travel speed and number of passes

Knowing the weld metal volume and the deposition rate the arc travel speed and the number of passes required can be calculated. We have given one example of this for a 12.7 (1/2") fillet weld in Table 2.

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Weld Size	Electrode type	Electrode diameter	Weld metal	Amperes	Deposition rate	Passes	Travel speed	Arc time for 12" (305 mm)	Operating factor	Time for 12" (305 mm)
mm		mm	lb/ft		lb/hr		mm/min	min	%	min
12.7	E4918	4.0	0.47	170	4.1	1	44	7	20	34
12.7	E4918	4.0	0.47	170	4.1	3	133	7	20	34
12.7	E4918	4.0	0.47	170	4.1	5	222	7	20	34
12.7	E4918	4.0	0.47	170	4.1	6	266	7	20	34
12.7	E4918	4.0	0.47	170	4.1	7	310	7	20	34

Table 2 – Arc Time and number of passes for 12.7 mm (1/2") fillet weld

In Table 2 we have demonstrated the welders travel speed for one through to seven passes. For flat, horizontal and overhead welding these are realistic. For all practical purposes the arc time, the time the arc is ignited, does not vary but the travel speed does. Typically, we expect travel speed for SMAW be in the 200 to 300 mm/min (8-12 in/min) for SMAW in these positions, and slower for the vertical up position. Practically, we estimate that the welder will require 6 to 7 passes to complete the fillet weld. The operating factor will be discussed in the next section.

Step 4 – Estimate Operating Factor

The ratio between the hours spent welding to the total hours worked is known as the operating factor. This factor must be estimated accurately in order to make realistic evaluations of cost. The operating factor allows for items such as:

- Preparing surface for welding
- Positioning
- Tacking
- Preheating
- Changing electrodes
- Chipping slag
- Moving from one location to another
- Unionized labour force
- Supervision quality
- Breaks

In planning a project, it is often desirable to plan the work in such a way that the welders time is not spent doing tasks which can be performed by less qualified, lower paid, individuals. Doing so will contribute to a higher welder operating factor. However, it is still very important that fit-up be accurate without gaps for fillet welds, since if this exceeds 2 mm (1/16") most welding codes requires

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that the fillet weld size be increased by the amount of the gap. From Table 1 it can be seen that increasing the weld size from ½" to 5/8" increases the weight of weld metal from 0.514 to 0.804 lb/ft, a 56% increase in arc and total time.

It can be seen that estimating the operating factor is extremely important, and is very much a function of how a project is planned and the productivity of the labour force. ESAB Welding and Cutting Products gives the following recommendation:

> "If the customer's operating factor is not known, assume a 30% operating factor for SMAW, and a 45% operating factor for semi-automatic GMAW and FCAW."

In our experience these factors appear high, and believe that for field work they will be the approximately 20% for SMAW, which is what we used in Table 2, and 30% if the contactor was to set up for FCAW.

Conclusion

To make an accurate estimate of costs, the length and weld sizes (PJP, CJP and fillet welds), and the operating factor(s) need to be determined. Based on these quantities it will be possible to estimate the total arc and welder times required for the welding. To these costs it will be necessary to add the other components, such as materials, consumables, staging, ventilation, and other direct and indirect costs.

Schedule 1, Attachment 2

Final Report for Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3

Hatch Ltd.

December 13, 2018



Newfoundland and Labrador Hydro

Final Report

For

Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3

H357395-00000-240-066-0001
Rev. 0
December 13, 2018

Newfoundland and Labrador Hydro

Final Report

For

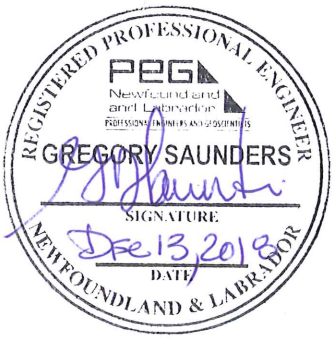
Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3

H357395-00000-240-066-0001
Rev. 0
December 13, 2018

HATCH

Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2, and 3

H357395-00000-240-066-0001





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Executive Summary

Newfoundland and Labrador Hydro (NL Hydro) engaged Hatch to conduct a condition assessment of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. Due to the nature of the 2018 outage schedule and NL Hydro's reporting requirements for items such as winter readiness and capital budget applications, the Condition Assessment report will be developed in three phases, as shown below.

- Report 1 – Bay d'Espoir Level II Condition Assessment of Penstocks No 1, 2 and 3
- Report 2 – Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3
- Report 3 – Penstocks No. 1, 2 and 3 Life Extension Options

All three Penstocks were inspected as part of a Level II Condition Assessment. Inspections and data collection included: detailed weld inspection, material testing, 3D scanning and water pressure monitoring.

The weld inspections consisted of, at a minimum, pressure washing, buffing, visually inspecting and magnetic particle inspecting the longitudinal welds at a frequency of 1 in every 10 cans for the total penstock length. The overview of the inspections consists of the following:

- Penstock No. 1 was inspected from August 13 to 24, 2018. Previous recent refurbishments inspected show no sign of degradation. Existing welds, that were not previously inspected, showed some signs of deterioration, in the form of cracking, pitting and general weld corrosion. One 2.74 m (9 feet) weld was refurbished where a crack indication was identified. The repair rate for existing untouched welds for this penstock was 1 seam out of 46.
- Penstock No. 2 was inspected from September 17 to 28, 2018. Previous repairs inspected show no sign of degradation. Existing welds, that were not previously inspected, showed some signs of deterioration. Two 2.74 m (9 feet) welds were refurbished where crack indications were identified. The repair rate for existing untouched welds for this penstock was 2 seams out of 102.
- Penstock No. 3 was inspected from May 14 to June 21, 2018. This was the first detailed inspection carried out and extensive weld metal corrosion and cracking was discovered, similar to what was found during the first inspections in penstocks 1 and 2 in 2016 and 2017. Approximately 1027 m (3369 feet) of weld refurbishment was completed.

A plate sample, containing base metal and weld metal, from Penstock No. 3 was examined and tested in the same manner as the material test plates from Penstock No. 1 and No. 2. The results indicated the mechanical properties met the requirements of the design specification.

To assess any internal pressure transients, pressure transducers were installed at key locations on all three penstocks and connected to a data logging device. Data for all three penstocks is being collected between September 2018 and January 2019 for analysis. These results will be analyzed and compared to those obtained in 2017 on Penstock No. 1 in the Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3 to be issued late in the first quarter of 2019.

In conjunction with the pressure data being obtained, laser scans were completed to create a more accurate 3D model of the penstock geometry this information will be used for additional stress analysis that will be included in Report 2 "Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3". Report 2 will be used to short list refurbishment options that will be analyzed in detail in Report 3 "Penstocks No. 1, 2 and 3 Life Extension" to be issued late in the second quarter of 2019. This geometric data is also valuable for future use should NL Hydro wish to review the penstocks for geometric changes, such as settlement.

The Penstocks have been in service for approximately 50 years. These are aging assets and as such require regular inspection and maintenance. To ensure the long-term performance of these assets, Hatch will be making refurbishment recommendations in the second quarter of 2019, following the completion of ongoing testing and analysis.

Based on the current operational history, since the penstocks latest refurbishments and current operating procedures, it is Hatch's belief the Penstock's current condition will provide uninterrupted service through the 2019 winter season. Hatch recommends annual inspection of the penstocks should continue until a life extension strategy is implemented within the next 3-5 years.

1. Introduction

NL Hydro engaged Hatch to conduct a Level II Condition Assessment of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. The findings from the condition assessment will ensure the penstocks are in reliable operating condition and will assist in verifying potential penstock life extension refurbishments.

The contents of this report provide an initial assessment of the inspections, testing and refurbishments completed to date. Due to the time intensive nature of inspection, data collection, analysis and refurbishment option evaluations this work will be completed in three phases each of which will have a report issued upon its completion. This report completes the first phase of the work and provides an initial assessment of each penstock's condition. The following are the three report titles.

- Report 1 – Bay d'Espoir Level II Condition Assessment of Penstocks No 1, 2 and 3
- Report 2 – Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3
- Report 3 – Penstocks No. 1, 2 and 3 Life Extension Options

The Bay d'Espoir Hydroelectric Generating Facility is comprised of four buried penstocks, three of which are connected to the main powerhouse containing six generating units. Each penstock bifurcates near the powerhouse to feed each unit through separate spherical valves. Units No.1 and No. 2 along with Penstock No. 1 were built in 1967. Units No. 3 and No. 4 along with Penstock No. 2 were built shortly after in 1968. The final addition to Powerhouse No.1 was completed in 1969 and consisted of units No. 5 and No. 6 and the construction of Penstock No. 3. The penstocks run approximately 1,200 m (3,900 feet) in length and are constructed from a series of carbon steel cans[1] that vary in length and diameter.

Penstock No 1 experienced multiple ruptures in longitudinal seams in an area upstream of the surge tank. A detailed description of these ruptures can be found in Hatch's "Repair and Failure Investigation" report dated May 17, 2017. These ruptures resulted in multiple inspections in 2016 and 2017 that discovered approximately 950 m (3116 feet) of longitudinal weld seams that had deteriorated primarily due to corrosion and required refurbishment. As Penstock No. 1 and No. 2 are very similar and of the same age Hatch recommended that Penstock No. 2 undergo similar inspections where similar deterioration was discovered resulting in 500 m (1640 feet) of seam refurbishment. As a result, NL Hydro engaged Hatch to complete a failure investigation.

[1] Lengths of penstock that are approximately 2.74 m (9 feet) long and constructed of two hemispheres of rolled plates longitudinally welded together to form a circumference.

Recommendations from the final "Repair and Failure Investigation" report May 17, 2017 for the November 2017 rupture of Penstock No. 1 included further assessment of Penstock No. 1 during the summer of 2018, along with further assessment of Penstock No. 2 and 3 during the next available outage. NL Hydro initiated the 2018 assessments of all three penstocks based upon these recommendations. The purpose of this report is to provide a thorough assessment of the current condition of all three penstocks and to collect data to assist in recommendations for Report 3 "Penstocks No. 1, 2 and 3 Life Extension" to be issued late in the second quarter of 2019.

All three penstocks were inspected as part of a Level II Condition Assessment during the summer of 2018. Penstock No. 1 was inspected from August 13 to 24, 2018, and showed no sign of degradation of previously refurbished weld seams or reinforcing plate fillet welds. However, weld refurbishment was required on a single seam that was not previously inspected. Penstock No. 2 was inspected from September 17 to 28, 2018, and showed no sign of degradation of previously refurbished weld seams. However, there were two weld refurbishments required on seams that were not previously inspected. Penstock No. 3 had not undergone the same inspection regime as Penstock No. 1 and Penstock No. 2. The first detailed inspection of Penstock No. 3 took place from May 14 to June 21, 2018, and similar problems with the longitudinal weld seams, as encountered in Penstock No. 1 and Penstock No. 2, were also found in this penstock. As a result, Penstock No. 3 underwent significant refurbishment prior to return to service in late June 2018.

2. Condition Assessment Methodology

Previous inspections of the penstocks utilized a can numbering based on manhole locations which varied by penstock. As this numbering system was not consistent for all three penstocks, it was not utilized for the Level II condition assessments carried out in 2018. The new numbering system refers to the first can at the intake as Can No. 1 for all penstocks and progresses numerically from the intake structure towards the surge tanks (approximately Can No. 250 to No. 260 depending on penstock) and finally to the powerhouse (Can No. 400).

Due to the length of the penstocks, the number of weld seams and the time available during shutdowns, an inspection methodology was employed that would quickly identify problem areas and provide a comprehensive overview of the overall condition of all three penstocks. All three Penstocks were inspected as part of a Level II Condition Assessment. Inspections included: detailed weld inspection, material testing and water pressure monitoring.

The general scope of the inspection was to pressure wash, buff, visually inspect and magnetic particle inspect the longitudinal welds at a frequency of 1 can in every 10 cans for the total length of the penstock. If welds that warranted refurbishment were discovered during inspection, a further 5 cans upstream and 5 cans downstream of this area would be subject to the same level of inspection. This method allows for an overview of the total penstock condition and an increased inspection frequency in areas that showed signs of damage. The weld inspection and subsequent refurbishments, completed on each penstock, were evaluated following inspection by NDE techniques. The inspection techniques used for the longitudinal and circumferential weld seams of Penstock No's. 1, 2, and 3 were visual inspection (VT) and MT examination carried out by Canadian Government Standards Board (CGSB) certified NDE Technicians.

All three of the penstocks have sections that are prone to general deformation/sagging and peaking of weld seams. This is particularly true in sections where the penstock diameter (D) is more than 400 times larger than the penstock wall thickness (t) ($D/t > 400$). Due to previous out of round concerns, the high D/t ratio, and high residual stresses observed in previously tested welds, it was decided that further review of the overall shape of the penstock was required. To assess these concerns and obtain information pertaining to the shape of the penstock, a 3D laser scan was completed to measure the roundness and weld seam peaking for each penstock.

Also, in a similar matter to mechanical tests that were carried out on Penstock No. 1 and No. 2, a piece of plate from Penstock No. 3 was also sent to a testing laboratory. The penstock plate coupon test results were used to determine the metallurgical properties of the weld and base metal and to compare them to the steel specifications listed on the drawings. In addition to the mechanical testing, chemical analysis of the welds and parent metal were completed along with a macro and microscopic examination of the weld cross sections.

These tests were completed to determine if there were any anomalies that could have contributed to the accelerated corrosion and subsequent cracking of the seams.

During the major refurbishment of Penstock No. 2 in 2017, rolled angle rings were discovered on the exterior of the penstock. These rings were not found on Penstock No. 1 but excavations on Penstock No. 3 in 2018 indicated rings similar in cross section to the ones found on Penstock No. 2. These rings were not of sufficient depth/thickness and/or frequency to provide additional support to Penstocks No. 2 and No. 3 while under pressure. In our opinion, these rings were more likely used to assist in field erection and weld fit up of the half can sections and adjacent circumferential seams. During internal inspections of Penstock No. 1, there was frequent evidence of poor alignment which required localized mechanical deformation of the penstock shell to achieve a fit up that would allow welding of the seams during original construction more than 50 years ago. It is believed that the fabricator installed these rings on Penstock No. 2 and No. 3 to reduce the fit up and installation issues encountered on the previously constructed Penstock No.1.

Following the data collection of Penstock No. 1 in November 2017, which included collection of pressure and strain data, Hatch recommended similar data collection for Penstocks No. 2 and 3. As a result of this recommendation, NL Hydro installed pressure transducers on Penstocks No. 2 and 3 along with additional ones on Penstock No. 1 and connected them to a data logger.

3. Penstock Inspections and Refurbishments

3.1 Initial Inspections and Major Refurbishments

To compare the refurbishments and overall condition of the penstocks, it is important to compare the initial inspection findings.

The initial inspections and major refurbishments of all three penstocks did not occur within the same year. Penstock No. 1 (2016), Penstock No. 2 (2017) and Penstock No. 3 (2018) found cracking in the form of linear indications along the top and bottom edge of the weld seams. In addition to the linear weld cracking, the weld seams had noticeable deterioration of the weld cap in the form of general corrosion (weld metal loss), localized pitting corrosion of varying degrees throughout the sections of penstocks, and preferential corrosion of the heat affected zone (HAZ) resulting in areas of low material thickness, edges and therefore high stress concentrations or "notches" in the upper and bottom portion of the weld edge. Regarding the condition of the weld seams, cracking and linear indications were found in all three penstocks and predominantly located in the longitudinal seams.



Figure 3-1: Sample of Deteriorated Longitudinal Weld Seam

Penstock No. 1 required refurbishment from the Can No. 1 through Can No. 173, which resulted in a total refurbished weld seam length of approximately 950 m (3116 feet) (a total of 346 seams at 2.74 m (9 feet) per seam). Penstock No. 2 required refurbishment from Can No. 1 through Can No. 91, which resulted in a total refurbished length of approximately 500 m (1640 feet) (a total of 182 seams at 2.74 m (9 feet) per seam). Penstock No. 3 required refurbishment of all cans in the 5.18m (17 feet) diameter sections (Can No. 1 through Can No. 132), excluding a single seam at Can No. 65. After Can No.132 refurbishments were intermittent from Can No. 132 through Can No. 175, Can No. 205 through Can No. 225 and Can No. 302 through Can No. 342. The total length of this refurbishment was approximately 1030 m (3378 feet). An overview of the refurbishments can be seen in Figure 3-2. For a detailed breakdown of inspections, repairs and general locations per penstock refer to P1 CA Tracker, P2 CA Tracker and P3 CA Tracker provided in Appendix C.

Where refurbishment was required, the indications identified by MT inspection were removed by gouging the full profile of the weld seam and HAZ with care not to remove the full thickness of the weld metal. Following the completion of gouging and subsequent grinding for cleanup of the seam, the seams were inspected visually and by MT to ensure no cracks or indications remained and sound weld metal was present prior to the start of refurbishment. The seams were then welded and after a hold time of 48 hours they were inspected by VT and MT methods to verify weld quality.

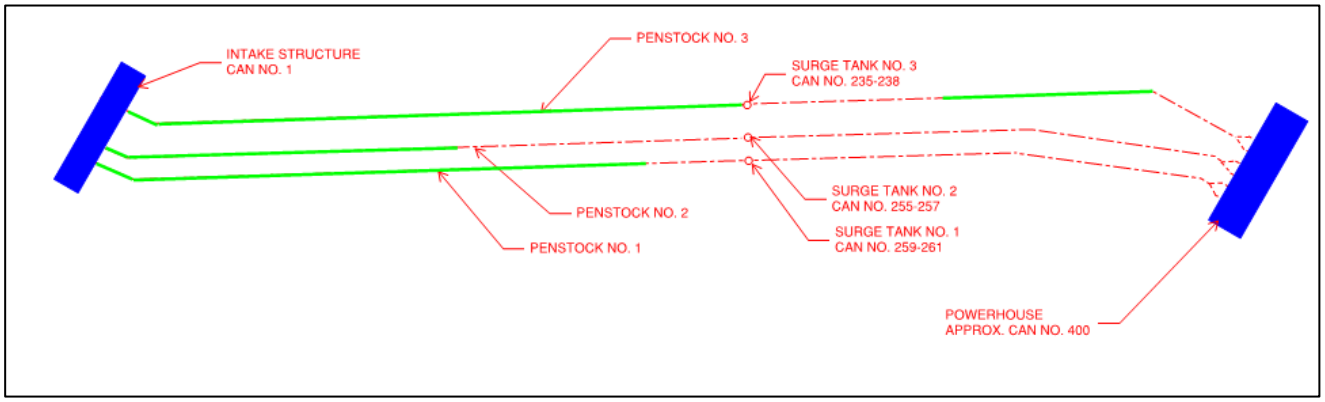

Figure 3-2: Concept Sketch of Penstock Refurbishment Overview

(Green Indicates Refurbished Areas)

3.2 Level II Condition Assessment 2018

The inspections and refurbishments of Penstocks No. 1, 2, and 3 were quantified during each penstock shutdown using inspection and refurbishment spreadsheets called trackers. These were used as progress aids as they identified can/seam locations. The data from these trackers was later used for statistical analysis welds, findings on weld quality, and refurbishment lengths.

3.2.1 Penstock No. 1

Penstock No. 1 was inspected from August 13 to 24, 2018. The inspection started adjacent to the intake and progressed through the penstock towards the powerhouse. The inspection followed a 1 can every 10 cans frequency. Additionally, all cans in the 2016 rupture area from Can No. 91 through Can No. 102 were inspected.

The inspection encompassed the full length penstock and included 102 weld seams. Of the 102 weld seams inspected, 56 were previously refurbished weld seams and/or reinforcing plate locations. The inspection verified that the welds remain intact and show no signs of degradation. Additionally, the inspection included 46 weld seams that were not repaired previously. Out of the 46 weld seams inspected, only the south seam on Can No. 215 had a defect requiring refurbishment, resulting in a total longitudinal weld seam refurbishment

length of approximately 2.74 m (9 feet)[2]. Since the first inspections conducted in 2016 approximately 61% of longitudinal weld seams have been inspected.

The surge tank transition in Penstock No.1 showed evidence of cracking as water was visible leaking through the weld seams. As this is not a structural connection and due to the schedule, the transition was not refurbished at that time. Hatch addressed this issue in "Project Completion Memorandum" H352666-00000-240-030-0002 for Penstock No. 1. While not a structural issue, there is no critical time line for this refurbishment, however, Hatch recommends these cracks be refurbished during the next planned refurbishment of this penstock.

3.2.2 Penstock No. 2

Penstock No. 2 was inspected from September 17 to 28, 2018. The inspection started at the intake and progressed downstream. The inspection followed a 1 can every 10 cans frequency.

The inspection encompassed the entire penstock and included 120 weld seams of which 18 were previously refurbished. The inspection verified that the welds remain intact and show no signs of degradation. Additionally, the inspection included 102 weld seams that were not repaired previously. Out of the 102 weld seams inspected, only the north seams on Can No. 230 and Can No. 270 required refurbishment resulting in a total longitudinal weld seam refurbishment length of approximately 5.49 m (18 feet)[2]. Since the first inspections conducted in 2017 approximately 40% of longitudinal weld seams have been inspected.

Penstock No. 2 surge tank transition cracked seams were re-welded in 2017 and visually appeared intact during the 2018 inspection. While there were no evident signs of leakage, detailed testing was not completed as this is not a structural concern. During the next shut down, it is recommended to perform spot MT to determine if the re-welded sections remain in good condition and are crack free.

Penstock No. 2 was noted to have "stiffener" rings present on the upstream sections; an excavated stiffener ring can be seen in Figure 3-3. The stiffener rings were fabricated by rolling a 5"x3"x3/8" angle spaced roughly every 3.66 m (12 feet). These rings are not of sufficient size or spacing to act as pressure retaining elements. As previously discussed, in Section 2 of this report, these rings were likely used to assist in field erection and weld fit up.

It should be noted that the quality of the penstock fit up was noted to be superior to that of Penstock No. 1, likely due to the use of external rings during assembly.

[2] Previous inspections conducted in 2017 were completed in areas re-inspected in 2018. Care was taken to inspected different seams during the latest inspection and the indications were discovered. To confirm that these indications were isolated instances additional cans upstream and downstream were inspected.



Figure 3-3: Excavated Stiffener Ring – Penstock 2

The Bay d'Espoir Operations group had scheduled the application of two coating samples to determine how they would respond over time to exposure to the penstock's interior environment. The two samples to be tested were originally intended to consist of a Galvatech 2000 Primer/MC Tar and a Mio Zinc Primer/MC Tar. The samples were to utilize two different primers as noted above and be applied on a tee section (capturing the intersection of a longitudinal and circumferential weld). During the assessment, the required curing time and application environmental conditions (humidity, dry bulb and wet bulb temperatures) for the Galvatech 2000 primer were not met, and this primer was not applied. Based on this issue, instead two locations were selected for application of the Mio Zinc primer coat and two top coats of MC Tar. The coating preparation and MC Tar finish coat can be seen in Figure 3-4.



Figure 3-4: Coating Prep (Left) Final MC Tar (Right) – Penstock 2

During the inspection, three new instrument trees were installed on Penstock No. 2. Each instrument tree consisted of a pressure transducer connection, a drain, and a high point vent. The pressure transducers were installed on Penstock No. 2. to determine if there are any pressure transients occurring within the penstock and to provide data to be used within the stress analysis to be provided in Report 2 "Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3". A typical pressure transducer tree is shown in Figure 3-5.



Figure 3-5: Pressure Transducer Instrument Tree – Penstock 2

3.2.3 Penstock No. 3

The Penstock No. 3 condition assessment and refurbishment took place from May 14 to June 21, 2018. During the shutdown, 561 longitudinal weld seams were inspected, and 390 longitudinal weld seams were refurbished, resulting in a total longitudinal weld seam refurbishment length of approximately 1030 m (3378 feet).

The inspection began with entry through a manhole at Can No. 118. Planned inspection frequency was 1 can every 10; however, initial findings showed the upstream section of Penstock No. 3 required major refurbishment similar to that of Penstock No. 1 and No. 2. Further inspection downstream indicated refurbishment in this section was also required. The 5.18 m (1717 feet) diameter section (excluding Can No. 65) was refurbished, Can No. 132 to Can No. 175; Can No. 205 to Can No. 225; and Can No. 302 to Can No. 342 sections were also refurbished intermittently. The areas between these sections had a minimum inspection frequency of 1 can every 10. The end of the refurbishment areas was determined when 5 cans passed inspection both upstream and downstream of the refurbished can. Since the inspection conducted in 2018 approximately 67% of longitudinal weld seams have been inspected.

The inspection identified seams in the downstream portion of the penstock, Can No. 240 to Can No. 295 and downstream of Can No. 345, that indicated the beginning stages of preferential corrosion of the heat affected zone. No refurbishment was performed in this area.

Refer to Hatch project memo H357358-00000-240-030-0001 "Minor Weld Indications in Penstock 3" for further discussion.

A coupon was removed from Can No. 222 and sent for mechanical testing and chemical analysis. The testing determined the plate was of similar composition and strength as the plates tested for the other two penstocks. Findings are discussed later in this report.

Similar to Penstock No. 1 and No. 2, the surge tank transition on Penstock No. 3 displayed cracking as well as visible water leakage through weld seams. As this is not a structural connection, and due to the schedule, the transition was not refurbished at this time. Hatch addressed this issue in "Project Completion Memorandum" H352666-00000-240-030-0002 for Penstock No. 1. Hatch recommends this be completed during the next planned refurbishment of Penstock No. 3.

Penstock No. 3 was discovered to have stiffener rings present on the upstream sections similar to those found on Penstock No. 2. These are believed to be fabrication aids similar to Penstock No. 2.

During the inspection, four new instrument trees were installed on Penstock No. 3 similar to those utilized on Penstock No. 2. The pressure transducers were installed on Penstock No. 3. to determine if there are any pressure transients occurring within the penstock and to provide data to be used within the stress analysis to be provided in Report 2 "Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3".

3.3 Testing

An extensive array of examination and mechanical testing was completed on coupons removed from various locations along the length of the penstocks. The coupon locations from Penstock No. 1 (2016) included one coupon from Section 8, one coupon from Section 16, and one coupon from Section 17. Penstock No. 3 (2018) had one coupon removed from Can No. 222. The coupons consisted of plate sections containing both base and weld metal. These samples underwent mechanical and chemical testing to determine if there were metallurgical abnormalities that could cause or contribute to failures of the penstock pressure boundary such as low tensile strength and high hardness. Test results indicated that there does not appear to be any metallurgical strength anomalies in the base metal or weld metal for any of the penstock material coupons tested. In all instances, the tested tensile strengths exceeded the minimum requirements of the specified steels from the design drawings.

The chemical analysis of the weld metal and base metals chemical measured levels of Sulphur, in all of the samples, that was higher than currently found in today's welding consumables and structural steels.

High amounts of sulphur can produce porosity in the weld metal and heat affected zones, primarily at the surface which can contribute to accelerated pitting corrosion. It is our opinion;

the higher Sulphur content could be a contributing factor in the accelerated corrosion and pitting of the welds and HAZ.

Refer to Appendix A.1 for a detailed summary of the mechanical testing completed on Penstock No. 1, 2 and 3.

The specifications and previous inspection reports indicate Penstock No. 1 and No. 2 had an interior coating of coal tar epoxy. There does not appear to be any information regarding the interior coating of Penstock No. 3 and based on communications with NL Hydro operations, regarding previous inspections it is our understanding no internal coating was utilized on Penstock No. 3. It is our opinion, this is the main reason for the extent of the pitting corrosion of this penstock.

In order to confirm this for the assessment of Penstock No. 3 in 2018, samples were taken from two areas to confirm if an internal coating is present. Internal samples were retrieved from a section near the surge tank and can section 345-350 of the penstock. The samples were sent to Cambridge Testing and Materials in Mississauga, Ontario, and are awaiting results for further analysis in the first quarter of 2019.

3.4 Data Collection

3.4.1 2017 Data Collection

In November 2017, during the shutdown for the third rupture of Penstock No. 1, strain gauges and pressure transducers were installed for data collection. The data collected was analyzed and results and conclusions based on the analysis were presented in Hatch's "Repair and Failure Investigation" report dated May 17, 2017.

The strain gauges provided stress magnitude data and displayed any transients for various operating zones and conditions (e.g., speed no load, unit ramp up and load rejection).

NL Hydro also provided data from their Supervisory Control and Data Acquisition System (SCADA) system which aided with interpretation of the collected strain and pressure data.

The data collected from 2017 will be used in conjunction with data collected from 2018 and 2019 for analysis in Report 2 "Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3" to be issued in the first quarter of 2019.

3.4.2 2018 Data Collection

During each of the shutdowns for Penstocks No. 1, 2, and 3, instrumentation trees were welded on the external (top) of each penstock for installation of pressure transducers.

With the data logger, the pressure transducers will measure and collect operational data. With this data, Hatch will analyze the pressure transients for anomalies and compare the results with the 2017 recorded pressure and stress/strain data.

Laser Scan and Inverts

In 2018, All North (an external survey company) completed 3D Laser Scan Inspections on Penstock No. 1, 2 and 3 during each of the three shutdowns. All three inspections utilized Leica C10 3D Laser Scanner – ACLLS-007 technology and the inspections for both Penstock No. 2 and 3 started at the intake gate and proceeded downstream to just upstream of the bifurcation. The laser inspection of most of Penstock No. 1 was completed by a different contractor, EPCO, thus only the areas not surveyed previously were completed by All North.

Refer to Appendix A for the tables showing the maximum, minimum, and average out of roundness for the laser scans completed on Penstocks No. 1, 2, and 3. This information can be compared with out of roundness tolerances used by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Sec. VIII division 1 which stated the difference between the maximum and minimum inside diameters at any cross-section shall not exceed 1% of the nominal diameter at the cross section under consideration.

This information will be used to generate a penstock stress analysis model which will run various load cases such as hydrostatic pressure, dynamic pressure, soil pressure, and water weight. This will allow the stress analysis to include the residual stresses induced by peaking and other geometric inconsistencies.

The penstock has three different diameters over its length. Based on the diameter, the following are the maximum acceptable out of round tolerances.

- 5.18 m (17 feet) I.D. section: 52 mm (2.04 in.)
- 4.57 m (15 feet) I.D. section: 46 mm (1.83 in.)
- 4.11 m (13.5 feet) I.D. section: 41 mm (1.62 in.)

For this analysis, the penstocks were put into 7 sections and compared (3 sections for the 17' I.D., 2 for the 15' I.D. and 2 for the 13.5' I.D.). To be conservative, the maximum and minimum values were compared across multiple scanned cross sections in each of the 7 sections. The below table summarizes the maximum out of roundness.

Table 3-1: Penstocks Out of Roundness

Penstock Diameter	Maximum Out of Roundness Measured by Laser Scan	Maximum Permissible Out of Roundness from ASME VIII
5.18 m (17' I.D.)	124 mm (4.88 in.)	51.8 mm (2.04 in.)
4.57 m (15' I.D.)	138 mm (5.43 in.)	45.7 mm (1.80 in.)
4.11 m (13.5' I.D.)	127 mm (5 in.)	41.1 mm (1.62 in.)

The scanned sections were also analyzed for the longitudinal weld seam peaking as shown below.

Table 3-2: Weld Seam Maximum Peaking

Penstock Diameter	Maximum Measured Peak	Maximum Permissible Out of Roundness from ASME VIII
5.18 m (17' I.D.)	60 mm (2.36 in.)	51.8 mm (2.04 in.)
4.57 m (15' I.D.)	28 mm (1.10 in.)	45.7 mm (1.80 in.)
4.11 m (13.5' I.D.)	35 mm (1.38 in.)	41.1 mm (1.62 in.)

The results show the penstock shell is very flexible and does not meet the generally accepted tolerances for out of roundness in the unpressured condition. Also, the peaking at the longitudinal joints does not meet the acceptable tolerance with respect to weld seam fit up for pressure vessels.

The out of roundness and the weld peaking results will need to be further explored through stress analysis". This condition has existed since installation, and in our opinion, does not present an immediate concern. The results of our analysis will determine if there are any long-term recommendations. The details of our analysis will be provided as part of the second report "Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3

4. Conclusions

Following the 2018 shutdowns of Penstocks No. 1, 2, and 3, each of the three penstocks have undergone a large-scale inspection and refurbishment of the sections upstream of the surge tank and for Penstock No. 3 the section downstream of the surge tank.

The three penstocks required refurbishment of the longitudinal seams due to significant weld metal loss from general corrosion, localized pitting corrosion, and preferential pitting corrosion of the HAZ. The weld metal loss has resulted in the formation of linear indications (i.e., cracking) along both edges of the weld. The 2018 inspection and refurbishment of Penstock No. 3 found the penstock in similar condition to that of Penstock No. 1 and No. 2 but with more refurbishment required downstream of the surge tank than the other two penstocks.

Previous analysis in 2016 and 2017 brought the operational zone described as the "rough zone", to the attention of Hatch. Data collected in 2017 concluded the rough zone was producing pressure pulsations of a frequency and magnitude that could be detrimental to the long-term operation of the penstocks. Hatch recommended that continued or extended operation (Penstock No. 1) in the rough zone be strictly limited.

Hatch will continue to assess the three Penstocks by reviewing the pressure data collection from Penstocks No. 1, 2 and 3 over the coming months

The 2018 inspection of Penstocks No. 1 and 2 indicates the refurbishments completed in 2016 and 2017 show no deterioration since the previous shutdown. Approximately 8.4% of the Penstock No. 1 refurbished welds showed deterioration when re-inspected in 2017 but since the reinforcement and additional refurbishment carried out in 2017, no new indications were found in these areas during the 2018 inspection.

Mechanical testing was completed on Penstock No.1, 2 and 3 and shows the materials used for fabrication meet or exceed the design specifications. Metallurgically the material does not appear to have any characteristics that would have caused a failure. There are high readings of sulphur within the base and weld metals tested. It is Hatch's belief this makes the penstock welds sensitized to corrosion when compared to typical steels when left unprotected.

The surveys completed indicate the penstocks are not within specified tolerances of the ASME BPVC. The excess peaking will cause higher stresses than typical code calculated stresses and will need to be evaluated in conjunction with the operational pressure data once available. However, it appears that weld repairs completed to date have sufficient ductility to allow for this deformation during water up. Stress analysis based on the collected survey and pressure data will be completed for the final report "Penstocks No. 1, 2 and 3 Life Extension" in the second quarter of 2019.

Penstocks No. 1 and No. 2 have reached 50 years in service. The internal coating of Penstocks No. 1 and No. 2 have failed in numerous locations and there is a possibility that Penstock No. 3 was never internally coated.

The unrefurbished sections of the three penstocks, including circumferential seams, are showing signs of weld metal loss and preferential pitting corrosion of the HAZ and in the future will need to be protected by application of a coating to avoid further deterioration.

Based on completed inspections, refurbishments and current operating procedures as recommended by Hatch in previous reports, there have been no ruptures or recurring indications in the longitudinal seams. As a result, Hatch believes the refurbishment methodology has been successful in stabilizing the penstocks and the penstock's current condition will provide uninterrupted service through the 2019 winter season. Hatch recommends annual inspection of the penstocks should continue until a life extension strategy is implemented within the next 3-5 years.

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Appendix A
Testing Results Summary

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A.1 Penstock No. 1 – 2016 Testing Summary

A.1.1 2016 Testing Results

Penstock No. 1 had three coupons removed and the following testing was completed on each sample:

- Radiographic Examination
- Macroetch Evaluation
- Microstructural Examination
- Vickers Hardness Traverse
- Transverse Weld Tensile Testing
- Weld Metal Chemical Analysis
- Base Metal Chemical Analysis

Penstock No. 1 had an analysis completed on internal samples that were coating the penstock (existing coating and organics) to determine the coating system used and for testing of organics. The following tests were performed for organics:

- Low Nutrient Bacteria (LNB)
- Iron-Related Bacteria (IRB)
- Anaerobic Bacteria (ANA)
- Acid-Producing Bacteria (APB)
- Sulfate-Reducing Bacteria (SRB)

A galvanic analysis was completed on the three coupons from Penstock No. 1.

A water analysis was completed in 2016 as part of the Penstock No. 1 testing.

A.1.2 ASTM A285 Gr. C Sample – Penstock No. 1 (Section 16)

As part of the root cause analysis performed in 2016-2017 for the assessment of Penstock No. 1, a 460 mm x 460 mm (18" x 18") coupon was removed from Penstock No. 1 and sent for analysis. The test results are as follows.

Radiographic Examination

The radiographic examination showed no rejectable defects. Porosity was detected but was in the range of acceptable limits.

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Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed a profile consistent with "Preferential Heat Affected Zone Corrosion".
- Both sections exhibited cracks propagating from the toes of the weld.
- One section exhibited porosity on the face of the weld.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line locations on either side of the weld, where cracks were observed in the macroexamination.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Viewing at a higher magnification, cavities can be seen at both weld toes. Both cavities were filled with corrosion product.
- Transgranular cracking was present within the corrosion cavities. Both cracks were propagating through the HAZ.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 169 to 198
- Hardness values for the HAZ ranged from 143 to 173
- Hardness values for the Base material ranged from 139 to 151

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Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of base metal = 69.5 ksi (480 MPa)

The tensile specimen fractured in the base metal indicating the UTS of the weld metal meets the requirements of being higher than the UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable, it is 2X the normal percentage.

Base Metal Chemical Analysis

The base metal chemistry is consistent with ASTM A285 Gr C material.

Coating System Asbestos and Quantitation Test

Coating system was identified as a Coal Tar Epoxy.

No presence of asbestos was detected in the coating system.

A.1.3 CSA G40.8 Gr. B Sample – Penstock No. 1 (Section 17)

A 460 mm x 460 mm (18" x 18") coupon of CSA G40.8B was removed from Penstock 1 (Section 17) for testing and incorporated a portion of one of the circumferential weld seams.

Radiographic Examination

The radiographic examination showed no rejectable defects. Porosity was detected but was in the range of acceptable limits.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed the weld had pitting along the inside diameter surface within the HAZ (at the weld toes).

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- No cracks or inclusions were exhibited in either of the sections.
- Both sections showed there was complete penetration and complete fusion was observed throughout the weld.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 170 to 214
- Hardness values for the HAZ ranged from 168 to 214
- Hardness values for the Base material ranged from 174 to 185

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line on either side of the weld and labeled "FL" and "FL+1mm" as instructed by the customer.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1 mm locations.
- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of weld metal = 84.5 ksi (582.6 MPa)

The tensile specimen fractured in the weld zone in a ductile manner. Even though this test failed in the weld metal, the UTS of the weld metal is significantly higher than the normal UTS of the base metal.

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Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable at 0.018%, it is still above normal levels.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within specifications.

Base Metal Chemical Analysis

The base metal chemistry is consistent with CSA 40.8 Gr B material.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within composition specifications for UNS grade G15240 (1524) steel.

A.1.4 ASTM A285 Gr. C – Penstock No. 1 (Section 8)

A second coupon of ASTM A285 Gr. C was removed from Penstock No. 1 (Section 8). This coupon incorporated a portion of one of the circumferential weld seams.

Radiographic Examination

The radiographic examination showed no rejectable defects.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed the weld had pitting along the inside diameter surface within the HAZ (at the weld toes).
- No cracks or inclusions were exhibited in either of the sections.
- Both sections showed there was complete penetration and complete fusion was observed throughout the weld.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to

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ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 153 to 181
- Hardness values for the HAZ ranged from 121 to 158
- Hardness values for the Base material ranged from 130 to 158

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line on either side of the weld, arbitrarily named "Side A" and "Side B" for CMTL identification purposes. These locations were labeled "FL" and "FL+1 mm" as instructed by the customer.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations; with "Side A" having more ferrite observed and "Side B" having more pearlite with a more distinct coarse grain HAZ.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of weld metal = 63.5 ksi (437.8 MPa)

The tensile specimen fractured in the weld zone in a ductile manner. Even though this test failed in the weld metal, the UTS of the weld metal is significantly higher than the normal UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with

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E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable at 0.023%, it is still above normal levels.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within specifications.

Base Metal Chemical Analysis

Chemical Analysis is similar to the chemical composition limits of ASTM A285 Grade C steel, with the exception of Sulphur.

A.1.5 Organic Samples – Penstock No. 1

For the assessment conducted on Penstock No. 1 in 2016-2017, organic samples were taken and tested. The following organic tests were performed by Acuren (Mississauga, Ontario).

- Low Nutrient Bacteria (LNB)
- Iron-Related Bacteria (IRB)
- Anaerobic Bacteria (ANA)
- Acid-Producing Bacteria (APB)
- Sulfate-Reducing Bacteria (SRB)

Final readings of testing indicate the following:

- Negative readings for IRB and SRB
- Weak positive reading for LNB, ANA, and APB

A.1.6 Galvanic Testing

Potential difference measurements were taken on the three coupons removed from Penstock No. 1. They generally indicate that a galvanic cell between the weld metal and base metal is present and the weld metal, in particular the heat affected zone, was more susceptible to pitting corrosion than the base metal.

A.1.7 Water Analysis – Penstock No. 1

Water testing data was collected from 1965, 1980, 1988, 1992, 1993, 1994, 1995, 1996 and 2016. Testing between 1965 and 2016 yielded similar Langelier saturation index (LSI) results. However, the most recent water test indicates a change in water chemistry. We recommend additional testing to confirm these results.

The available data from 1965-2016 was used to compute the LSI, which is used to quantify the corrosive behavior of a specific water source. This calculation takes the pH, alkalinity, Total Dissolved Solids (TDS), temperature and calcium all into account rather than strictly depending on the pH value.

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The LSI ranks water corrosion potential on a scale typically between -5 to 4, with -5 being highly corrosive and 4 having a high likely hood of scale buildup. When applying the LSI to the Bay d'Espoir water samples the following values were obtained:

Table A-1: LSI vs Water Sample Year

Year	LSI	Year	LSI
1965	-4.77	1994	-5.72
1980	-6.57	1995	-5.69
1988	-5.02	1996	-4.75
1992	-5.71	-	-
1993	-5.65	2016	-3.9

In several instances the LSI ratings calculated were outside of the typical range, indicating the water is more corrosive than typical water bodies. These values would indicate that the water flowing through the penstock would be considered highly corrosive.

A.2 2018 Testing Summary

A.2.1 Mechanical Testing - Penstock No. 3

Macro Examination

The photomacrograph in Figure A-1 below shows the appearance. The macro shows a clean weld exhibiting columnar weld grains with good fusion, no cracking or weld defects.

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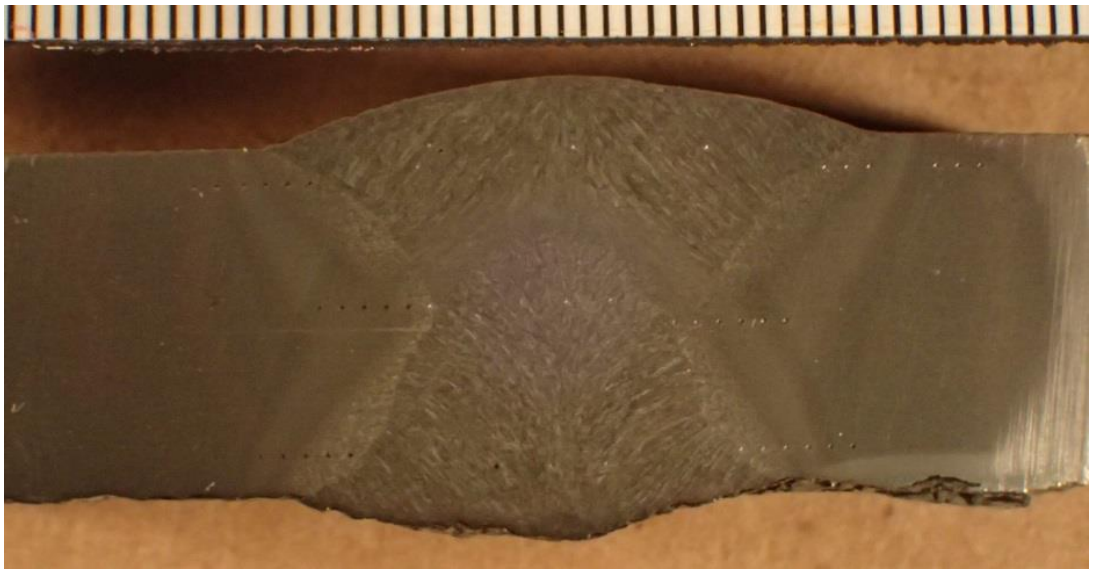

Figure A-1: Weld Macro Examination – Penstock 3

Microstructural Evaluation

A cross section of the weld was cut and prepared for a micro examination, polishing the cut to a 1µm finish and etched with a 5% Nital solution according to ASTM E3-11 standards. The micro examination revealed a fine grain, low carbon steel with few inclusions, typical of a structural quality steel.

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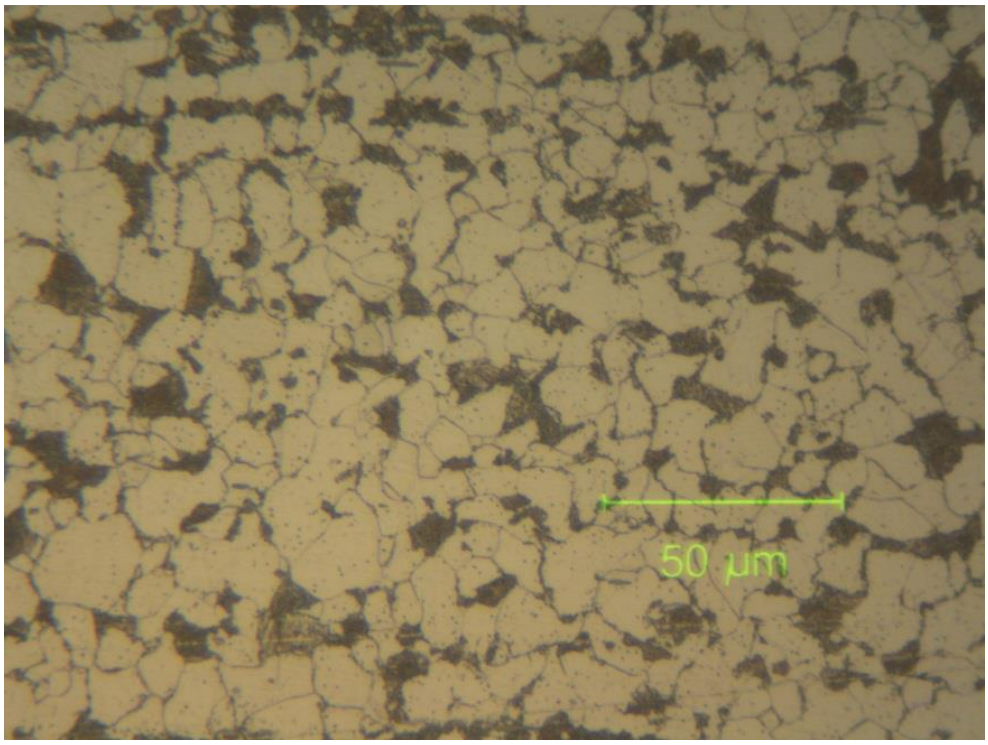

Figure A-2: Weld Micro Examination - Penstock 3

Vickers Hardness

Vickers hardness testing (HV10) using a 10-kg test load according to ASTM E3-11, was completed on the specimen. Three rows were tested according to ASTM E92-16 standards. Hardness values in these regions are stated below:

- Base Metal: 160 to 182 HV10
- HAZ: 183 to 223 HV10
- Weld: 183 to 201 HV10

Weld Tensile Results

Two specimens were sectioned and removed transverse to the weld in the sample using ASTM A370 specifications. The specimens were tested on a calibrated instron 8800 tensile machine with both resulting in a ductile fracture in the parent material. The numerical results are noted in the table below.

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Table A-2: Tensile Tests Results - Penstock 3 Coupon

Sample	Area (in^2)	Load (lbs)	UTS (ksi)	Type of Fracture	Location
T1	0.429	31 880	74.3	Ductile	Parent
T2	0.422	34 510	81.8	Ductile	Parent

Weld / Base Metal Chemical Analysis

A sample from both the plate and weld metal were analyzed using a conventional ICP instrument following ASTM D1976 Standard to determine the metal's chemistry. The material was found to be plain carbon steel with no significant amounts of nickel, chromium or molybdenum. The table summarizes both plate and weld metal chemistry in comparison with ASTM A612 and A285 standards.

Table A-3: Penstock No. 3 Coupon Chemical Analysis

Elements	Chemical Composition (%wt.)			
	Plate Metal	Weld Metal	ASTM A612	ASTM A285
Carbon	0.15	0.1	0.25 Max	0.28 Max
Nickel	0.02	0.02	Trace	-
Sulphur	0.023	0.021	0.05 Max	0.035 Max
Chromium	0.02	0.02	Trace	-
Aluminum	Trace	Trace	Trace	-
Copper	0.03	0.06	0.35 Max	-
Manganese	1.41	1.49	1.00-1.50	0.98 Max
Molybdenum	Trace	0.01	Trace	-

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Elements	Chemical Composition (%wt.)			
Silicon	0.44	0.40	0.15-0.50	-
Phosphorus	0.021	0.024	0.04 Max	0.035 Max

The plate sample is not consistent with the chemical requirements of ASTM A285. The manganese content found exceeds the max %wt, and the levels of silicon exceed that of A285 as well. Based on the report, the chemical composition indicates it is more suited towards the ASTM A612 standard.

Charpy Impact Testing

Twelve charpy specimens were machined from the welded plate to meet dimensional requirements of ASTM A370. The specimens were cut transversely to the weld with notch for testing perpendicular to the top and bottom surfaces of the plate. The specimens were chilled in a bath for at least 10 minutes to obtain a test temperature of -20°C. The bath was monitored and calibrated with a digital thermometer along with the charpy impact machine verified as per ASTM E23. The testing was completed on full size charpy impact specimens (10mm x 10mm), which can be seen in the table below.

Table A-4: Penstock No. 3 Coupon – Charpy Impact Testing Results

RPC ID	Notch Location	Test Temperature (°C)	Energy Absorbed		Average Energy Absorbed Ft-lbs (Joules)
			Ft - lbs	Joules	
2315	WC	-20	12	16.2	11.6 ft-lbs (15.8 J)
2316	WC	-20	11	14.9	
2317	WC	-20	12	16.2	
2318	FL	-20	13	17.6	12.1 ft-lbs (16.5 J)
2319	FL	-20	10	13.6	
2320	FL	-20	13.5	18.3	
2321	FL +2	-20	75	101.7	60.5 ft-lbs

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RPC ID	Notch Location	Test Temperature (°C)	Energy Absorbed		Average Energy Absorbed
2322	FL +2	-20	71	96.2	(82 J)
2323	FL +2	-20	35.5	48.1	
2324	FL +5	-20	71.5	96.9	68.8 ft-lbs
2325	FL +5	-20	67	90.8	(93.4 J)
2326	FL +5	-20	68	92.2	

Where:

- WC = Weld Center
- FL = Fusion Line of Weld
- FL+2 = Fusion Line +2 mm FL+5 = Fusion Line +5 mm

A standard consumable used for welding of steels for Penstocks No. 1, 2, and 3 during the timeframe of construction would be that of the SMAW E6010/6011 or E7018. A typical impact energy value of ASTM A285 Grade C and a E6010/6011 or E7018 would produce a minimum average impact energy of 27 J at -20°C. Given that the base metal sample is suspected to be of a higher grade of steel, the impact energies for the FL+2 and FL+5 appear to be reasonable. However, the weld metal and HAZ samples produced below average impact energies.

A.2.2 Penstock No. 1 and No. 3 Mechanical Testing Comparison

RPC indicates the coupon analyzed from Penstock No. 3 to be most consistent with ASTM A612. Of the three coupons taken from Penstock No. 1, the CSA G40.8B coupon is most mechanically similar to the ASTM A612. The report conducted by RPC compared the Penstock No. 3 sample to the ASTM A285 standard whereas the results and drawings align with the CSA G40.8 Gr. B standard. The mechanical testing for 2016 was conducted by Cambridge Materials (Mississauga, Ontario). For more accurate and comparable results, it would be beneficial to conduct all mechanical testing at the same facility (reduce lab error), have the same format of testing completed on all samples.

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Microstructural

Samples were prepared for microstructural examination and the Penstock No. 1 coupon was etched using a 2% Nital solution whereas Penstock No. 3 used a 5% Nital solution. The micrograph of the Penstock No. 3 coupon was completed on the base metal and shows a fine grain low carbon steel with few inclusions. The Penstock No. 1 coupon micrograph was completed on the fusion line (FL) and FL+1mm locations noting some sulphide inclusions present dispersed throughout the material and a HAZ with a refined and relatively coarse grain structure.

Vickers Hardness

The table below compares the hardness values obtained from the two separate samples in Penstock No. 1 along with the recent RPC test results for Penstock No. 3.

Table A-5: Vickers Hardness Results

Vickers Number	Penstock 1 Sample – ASTM A285			Penstock 3 Sample			Penstock 1 Sample – CSA G40.8 Gr B		
	Base Metal	HAZ	Weld Metal	Base Metal	HAZ	Weld Metal	Base Metal	HAZ	Weld Metal
Low	130	121	153	160	183	183	174	168	170
High	158	158	181	182	223	201	185	214	214

It can be noted that the Penstock No. 3 hardness test results correlate best with the Penstock No. 1 CSA G40.8B hardness numbers (right section of table).

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Weld Tensile

The tensile test results below show a comparative summary between the 2016 samples for penstock 1 and 2018 samples for penstock 3.

Table A-6: Tensile Test Results

Sample	UTS (ksi)	Type of Fracture	Location	Standard Range (ksi)
Penstock 3 T1 (A612)	74.3	Ductile	Parent	81-101
Penstock 3 T2 (A612)	81.8	Ductile	Parent	81-101
Penstock 1 CSA G40.8 Gr B	84.5	Ductile	Parent	65-85
Penstock 1 ASTM A285	63.5	Ductile	Parent	55-75

RPC indicated the chemical analysis for the Penstock No. 3 coupon is most consistent with ASTM A612. Comparing the tensile test results with the A612 standard, the tensiles are on the low side.

A.2.3 Laser Scan and Inverts

The laser surveys of the interior of the penstocks was used to determine the interior shape of the penstock and confirm the level of peaking present. The results for each of the penstocks, was used to compare the level of deviation in ovality as shown in Table A-7. Table A-8 compares the level of peaking found at the welds as an average for all three Penstocks. Through analysis of the data, the location of the maximum and minimum weld deviation around the penstock for each section was noted and can be seen in Tables A-9 to A-11. Zero degrees was taken at the top of the penstock and continued clockwise around the penstock. Since the laser scan inspection completed by All North was only taken from the surge tank downward, Penstock 1 was only compared using this section.

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Table A-7: Deviation in Penstock Ovality Comparison

	Location (m)	Length of Section (m)	# of Chainages in Section	Overall Average Deviations (mm)	Average Min. Deviation (mm)	Average Max. Deviation (mm)
Section 1	0.00-101.4 0.00-119.47	101.4 119.47	6 10	-3.96	-29.83	23.03
Section 2	101.4-200.49 119.47-244.53	99.09 125.06	3 8	-2.67	-25	35.04
Section 3	200.49-341.15 244.53-382.31	140.66 137.78	5 7	-2.18	-48.2	36.09
Section 4	341.15-433.65 382.31-492.46	92.5 110.15	3 5	-3.49	-60.33	30.68
Section 5	433.65-629.8 492.46-692.41	196.15 200.01	8 7	-4.43	-41.63	16.57
Section 6	692.41-953.37 628.8-889.64 692.41-953.37	260.96 260.84 260.96	12 9 9	-1.37	-16.79	17.11
Section 7	953.37-1163.48 889.64-1128.00 953.37-1163.48	210.11 238.36 210.11	11 10 6	-1.09	-35.32	20.40

Penstock 1
Penstock 2
Penstock 3

Table A-8: Peaking at Welds Comparison Across Penstocks No. 1, 2, and 3

	North Welds			South Welds		
	Average Peaking(mm)	Max. peak (mm)	Min. peak (mm)	Average Peaking (mm)	Max. peak (mm)	Min. peak (mm)
Section 1	5.1	60	-17	5.4	41	-23
Section 2	13.0	36	-6	16.8	56	-19
Section 3	6.8	29	-23	3.2	31	-30
Section 4	-2.4	28	-67	-4.8	17	-46
Section 5	1.7	24	-31	-2.1	18	-28
Section 6	3.7	35	-15	5.2	20	-12
Section 7	9.3	35	-21	7.6	27	-7

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Table A-9: Penstock 1: Location of Max. and Min. Weld Deviation

	Penstock 1					
	Approximate Location of Max. Deviation (deg.)	Chainage that had Max. Deviation	Max. Deviation (mm)	Approximate Location of Min. Deviation (deg.)	Chainage that had Min. Deviation	Min. Deviation (mm)
Section 1						
Section 2						
Section 3						
Section 4						
Section 5						
Section 6	99	HZ Chainage 54.96	27.07	186.75	HZ Chainage 54.96	-30
Section 7	274.5	HZ Chainage 264.18	34.94		HZ Chainage 416.74	-86.78

Table A-10: Penstock 2: Location of Max. and Min. Weld Deviation

	Penstock 2					
	Approximate Location of Max. Deviation (deg.)	Chainage that had Max. Deviation	Max. Deviation (mm)	Approximate Location of Min. Deviation (deg.)	Chainage that had Min. Deviation	Min. Deviation (mm)
Section 1	261	HZ Chainage 43.17	60	165.5	HZ Chainage 73.46	-33
Section 2	60	HZ Chainage 180.70	26	201	HZ Chainage 180.70	-40
Section 3	69	HZ Chainage 233.35	53	349	HZ Chainage 208.53	-71
Section 4	278.5	HZ Chainage 346.11	50	177	HZ Chainage 346.11	-88
Section 5	293	HZ Chainage 629.68	27	161.5	HZ Chainage 469.96	-83
Section 6	78	HZ Chainage 705.21	21	178	HZ Chainage 867.23	-32
Section 7	288	HZ Chainage 1087.76	45	180	HZ Chainage 1087.76	-62

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Table A-11: Penstock 3: Location of Max. and Min. Weld Deviation

	Penstock 3					
	Approximate Location of Max. Deviation (deg.)	Chainage that had Max. Deviation	Max. Deviation (mm)	Approximate Location of Min. Deviation (deg.)	Chainage that had Min. Deviation	Min. Deviation (mm)
Section 1	66	HZ Chainage 77.08	41.22	202.5	HZ Chainage 92.01	-48.86
Section 2	90	HZ Chainage 167.06	55.88	187	HZ Chainage 181.71	-51.04
Section 3	259	HZ Chainage 247.77	51.64	337.5	HZ Chainage 247.77	-47.8
Section 4	255	HZ Chainage 428.21	27.93	183	HZ Chainage 401.94	-51.97
Section 5	100.5	HZ Chainage 550.90	26.62	180	HZ Chainage 591.11	-48.82
Section 6	254	HZ Chainage 889.95	25.25	171.5	HZ Chainage 889.95	-61.75
Section 7	288.5	HZ Chainage 1066.55	32.7	181.5	HZ Chainage 1066.55	-94.63

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Appendix B
Penstock Refurbishment Statistics

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B.1 Weld Statistics

Table B-1: Longitudinal Weld Statistics - Penstock 1

Item	Description	Number	Units
1	2016 Total Seams Repaired/Refurbished	346	Count
2	2016 South Seams Repaired/Refurbished	173	Count
3	2016 North Seams Repaired/Refurbished	173	Count
4	2017 Longitudinal Seams Repaired/Refurbished	31	Count
5	Repaired/Refurbished 2016 – Inspected 2017 Internal Longitudinal Seams with Defects	29	Count
6	2017 Welds Showing Defects from Original Construction	2	Count
7	2017 South Internal Seams Repaired/Refurbished	10	Count
8	2017 North Internal Seams Repaired/Refurbished	21	Count
9	2018 Internal Seams Not Inspected	678	Count
10	2018 Total Seams Repaired/Refurbished	1	Count
11	2018 Inspection Passed on Refurbished Welds	46	Count
12	2018 Inspection Passed on Original Welds	28	Count
13	Seam Total (Intake to Powerhouse)	870	Count
14	Approximate Visual (VT) and Magnetic Particle (MT) Length 2018	1098	ft
15	Approximate Seam Repair/Refurbishment Length 2017	279	ft
16	Approximate Seam Repair/Refurbishment Length 2016	3114	ft
17	Approximate 2016 Repair/Refurbishment Vs Total Penstock	39.77	%
18	Approximate 2017 Repair/Refurbishment Vs Total Penstock	3.56	%
19	2017 Defects on 2016 Welds	8.38	%
20	2018 defects on 2017 Welds	0.00	%
21	2018 defects on Original Weld	1.52	%

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Table B-2: Longitudinal Weld Statistics - Penstock 2

Item	Description	Number	Units
1	2017 Longitudinal Seams Repaired/Refurbished	182	Count
2	2017 Welds Showing Defects from Original Construction	182	Count
3	2017 South Internal Seams Repaired/Refurbished	91	Count
4	2017 North Internal Seams Repaired/Refurbished	91	Count
5	2018 Internal Seams Not Inspected	384	Count
6	2018 Total Seams Repaired/Refurbished	2	Count
7	2018 Total North Seams Repaired/Refurbished	2	Count
8	2018 Total South Seams Repaired/Refurbished	0	Count
9	2018 Inspection Passed on Refurbished Welds	18	Count
10	2018 Inspection Passed on Original Welds	98	Count
11	Seam Total (Intake to Powerhouse)	870	Count
12	Approximate Visual (VT) and Magnetic Particle (MT) Length 2018	702	ft
13	Approximate Seam Repair/Refurbishment Length 2017	2492	ft
14	2017 defects on Original Welds	21	%
15	2018 defects on 2017 Welds	0.00	%
16	2018 defects on Original Weld	2.30	%

Table B-3: Longitudinal Weld Statistics - Penstock 3

Item	Description	Number	Units
1	2018 Internal Seams Not Inspected	347	Count
2	2018 Total Seams Repaired/Refurbished	390	Count
3	2018 Total South Seams Repaired/Refurbished	192	Count
4	2018 Total North Seams Repaired/Refurbished	198	Count
5	2018 Inspection Passed on Refurbished Welds	0	Count
6	2018 Inspection Passed on Original Welds	171	Count
7	Seam Total (Intake to Powerhouse)	870	Count
8	Approximate Seam Repair/Refurbishment Length 2018	3369	ft
9	2018 defects on Original Weld	48.75	%

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Appendix C
Penstock Condition Assessment Trackers

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Date: July 16th 7:30

PENSTOCK 1 WELD PROGRESS TRACKER

| | | |

Date: 12/6/2018
Rev: E

PENSTOCK 2 WELD PROGRESS TRACKER

INTAKE

| | | |

Date: June 20, 2018

PENSTOCK 3 WELD PROGRESS TRACKER

Intake

CAN#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
South	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP

Doorsheet #1 Location — Doorsheet #2 Location — Tested Seams — Tested Seams — Tested Seams — Appr

CAN#	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
South	FP	FP	FP	FP	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP

Tested Seams — Doorsheet #3 Location

CAN #	121	122	123	124	125	126	127	128	129	130	131	132	132b	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	FP	FP	FP	FP	FP	FP	FP	NI	NI	FP	FP	NI	NI	FP	NI	FP	NI	FP	NI	FP	NI	FP	FP	FP	NI	FP	FP	FP	NI	FP	FP	FP	NI	NI	NI	NI	NI	FP	NI	NI	FP	FP	NI	NI	NI	NI	NI
South	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	FP	FP	FP	FP	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	FP	NI	FP	FP	NI	NI	NI	NI	NI	FP	FP	FP	NI	FP	NI	FP	NI	NI	NI	NI	NI	NI	NI	NI	NI

Approx. Manway #2 Location — Surge Tank

CAN #	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
North	NI	NI	NI	NI	NI															NI	NI	NI	NI	NI	FP	NI	NI	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	FP	FP	FP	NI	NI	NI	NI	NI	NI	NI				NI	NI				CH	
South																NI				NI	NI	NI	NI	NI	FP	FP	NI	FP	FP	FP	FP	FP	NI	FP	FP	NI	FP	NI	FP	FP	NI	FP	FP	FP	FP	NI	NI	NI	NI	NI	NI	NI								

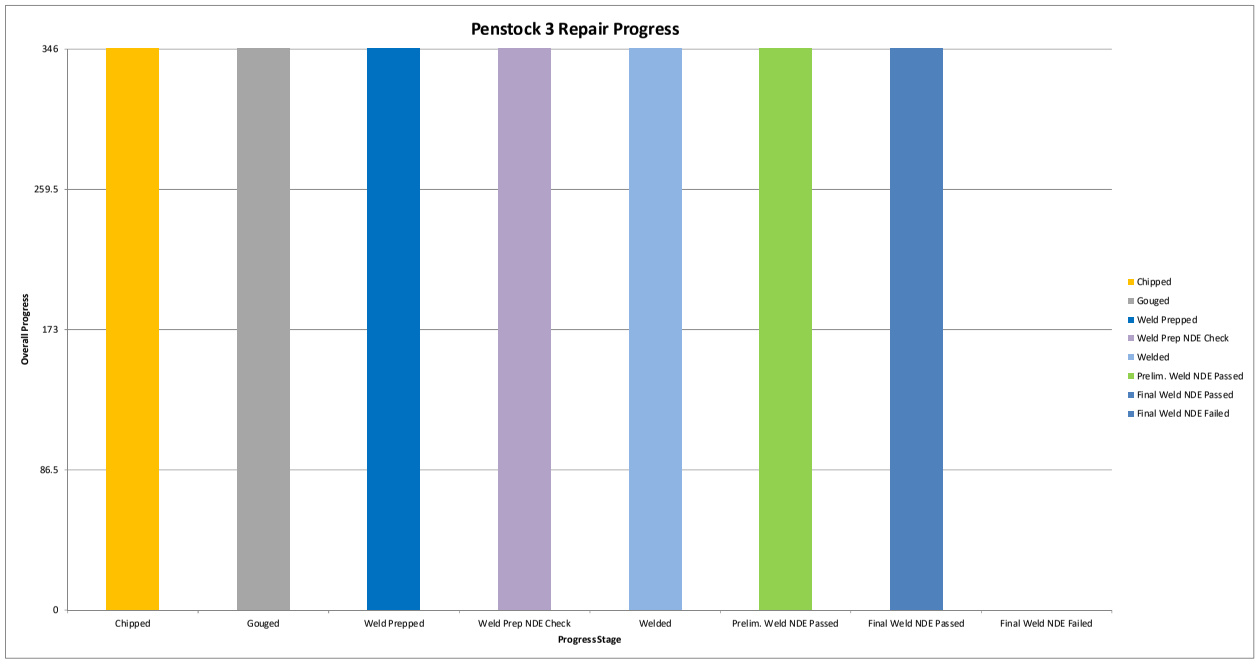
CAN#	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
North							NI								NI													NI	NI							NI					NI					NI					NI		NI	NI	NI	NI	NI	NI	NI	NI
South						NI										NI									NI	NI									NI																				CH	NI	NI	NI	NI	NI

CAN#	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
North	NI		FP	PIP	PIP	PIP	NI	NI	NI	FP	NI	FP	FP	PIP	FP	PIP	FP	NI	FP	FP	PIP	NI	PIP	NI	NI	PIP	PIP	NI	FP	FP	FP	FP	FP	NI	PIP	NI	NI	PIP	NI	PIP	NI	PIP		NI		NI	NI	NI	NI	NI		NI	NI			NI		NI		
South	NI	FP		NI	NI	NI	FP	FP	PIP	FP	NI	NI	FP	FP	FP	FP	FP	FP	PIP	FP	PIP	NI	NI	NI	NI	FP	FP	FP	PIP	FP	NI	PIP	NI	FP	FP	PIP	PIP	NI	NI	PIP	NI	PIP		NI		NI	NI	NI	NI	NI										

CAN#	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420
North		CH										NI																NI									NI																								
South						NI														NI																																																

Legend		
NI	=	No Indications
CH	=	Chipped
G	=	Gouged
P	=	Weld Preperation Complete
1P	=	First Inspection Passed
W	=	Welded
PIP	=	Preliminary Inspection Pass
FP	=	Final Inspection Passed
FF	=	Final Inspection Failed

	Total
Total Welds in Inspection Area:	**838**
Total Welds with No Indications:	**171**
Total Seams Chipped:	**393**
Total Seams Gouged:	**390**
Total Seams Prepped:	**390**
Total Weld Prep Inspection Passed:	**390**
Total New Weld Inspection Passed (Prelim):	**390**
Total Welds Completed:	**390**
Total Welds Final Check Complete:	**368**



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Schedule 1, Attachment 3

Final Report for Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3

Hatch Ltd.

March 28, 2019

newfoundland labrador hydro

HATCH

Newfoundland and Labrador Hydro

Final Report

For

Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3

H357395-00000-240-066-0002
Rev. 0
March 28, 2019

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Newfoundland and Labrador Hydro

Final Report

For

Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3

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Rev. 0
March 28, 2019

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Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3

H357395-00000-240-066-0002

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which is valid for the year 2019

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador PROFESSIONAL ENGINEERS AND GEOSCIENTISTS
GREG SAUNDERS
SIGNATURE
Mar. 28, 2019
DATE
NEWFOUNDLAND & LABRADOR

2019-03-28	**0**	**Final**	**M. Pyne**	**Z. Kenneally**	**G. Saunders**
DATE	**REV.**	**STATUS**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**

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Appendix A Testing Results Summary

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A.2 2018 Testing Summary

Appendix B Penstock Refurbishment Statistics

B.1 Weld Statistics

Appendix C Penstock Condition Assessment Trackers

Appendix D Cost Tables

Executive Summary

Newfoundland and Labrador Hydro (NL Hydro) engaged Hatch to conduct a condition assessment of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. Due to the nature of the 2018 outage schedule and NL Hydro's reporting requirements for items such as winter readiness and capital budget applications, the Condition Assessment report will be developed in three phases, as shown below.

- Report 1 – Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3.
- Report 2 – Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3.
- Report 3 – Penstocks No. 1, 2 and 3 Life Extension Options.

All three penstocks were inspected as part of a Level II Condition Assessment. Inspections and data collection included: detailed weld inspection, material testing, 3D scanning and water pressure monitoring.

The weld inspections consisted of, at a minimum, pressure washing, buffing, visually inspecting and magnetic particle inspecting the longitudinal welds at a frequency of 1 in every 10 cans for the total penstock length. The overview of the inspections consists of the following:

- Penstock No. 1 was inspected from August 13 to 24, 2018. Refurbished welds completed in 2016 and 2017 show no sign of additional degradation.
- Penstock No. 2 was inspected from September 17 to 28, 2018. Refurbished welds completed in 2017 show no sign of degradation.
- Penstock No. 3 was inspected from May 14 to June 21, 2018. This was the first detailed inspection carried out and extensive weld metal corrosion and cracking was discovered, similar to what was found during the first inspections of Penstocks No. 1 and No. 2 in 2016 and 2017. Approximately 1027 m (3369 feet) of internal weld refurbishment was completed on Penstock No. 3.

Material samples were removed from Penstock No. 3 to determine the grade of steel and compare with samples removed from Penstock No. 1

Laser scans were completed to create a more accurate 3D model of the penstock geometry. The data showed similar peaking in all three penstocks consequently the FEA model results for Penstock No. 1 can be extrapolated to the similarly constructed Penstock No. 2 and No. 3. This geometric data is also valuable for future use should NL Hydro wish to review the penstocks for geometric changes, such as settlement.

In conjunction with the laser scans, pressure transducers were installed at key locations on all three penstocks and connected to a data logging device to assess any internal pressure transients. Data collection is currently on-going, and this data will be analyzed and compared to data obtained in 2017 on Penstock No. 1. To provide meaningful analysis data collection needs to take place over a longer period of time so trends can be observed. This data collection should continue until a life extension option is implemented for Penstocks No. 1, 2, and 3. Hatch will provide a preliminary commentary based on a three-month data collection. This data and analysis will be presented in a standalone document at a later date, however, this information is not expected to impact any of the findings or recommendations contained in this report.

The penstocks have been in service for approximately 50 years. These are aging assets and as such require regular inspection and maintenance. To ensure the long-term operation of these assets, refurbishment is required. This report outlines various refurbishment options of which a select few will be chosen by Hydro for further analysis by Hatch. This work will be completed in the second quarter of 2019.

Several life extension options were reviewed in this report for the purposes of comparison. However, preliminary estimates suggest full weld refurbishment and application of a corrosion resistant coating would be the best option for the rehabilitation of the penstocks. The preliminary estimates for refurbishment are approximately $14,000,000 to $16,000,000 per penstock.

Based on the current operational history, refurbishments and current operating procedures, it is Hatch's opinion the penstock's current condition will provide uninterrupted service through the 2019 winter season. Hatch recommends annual inspection of the penstocks should continue until a life extension strategy is implemented within the next 3-5 years.

1. Introduction

NL Hydro engaged Hatch to conduct a Level II Condition Assessment of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. The findings from the condition assessment will ensure the penstocks are in reliable operating condition for the 2019 production season and will assist in verifying potential penstock life extension refurbishments.

The contents of this report build on the initial assessment of the inspections, testing and refurbishments completed to date. Due to the time intensive nature of inspection, data collection, analysis and refurbishment option evaluations this work will be completed in three phases each of which will have a report issued upon its completion. This second Report completes the second phase of the work and provides further detail on each penstock condition in addition to refurbishment options. The following are the three report titles.

- Report 1 – Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2 and 3.
- Report 2 – Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3.
- Report 3 – Penstocks No. 1, 2 and 3 Life Extension Options.

The Bay d'Espoir Hydroelectric Generating Facility is comprised of four buried penstocks, three of which are connected to the main powerhouse containing six generating units. Each penstock bifurcates near the powerhouse to feed each unit through separate spherical valves. Units No.1 and No. 2 along with Penstock No. 1 were built in 1967. Units No. 3 and No. 4 along with Penstock No. 2 were built shortly after in 1968. The final addition to Powerhouse No.1 was completed in 1969 and consisted of the installation of generation Units No. 5 and No. 6 as well as Penstock No. 3. The penstocks run approximately 1,200 m (3,900 feet) in length and are constructed from a series of carbon steel cans[1] that vary in length, diameter and thickness.

Penstock No. 1 experienced multiple ruptures during 2016 and 2017 in longitudinal seams in an area upstream of the surge tank. A detailed description of these ruptures can be found in Hatch's "Repair and Failure Investigation" report dated May 17, 2017. These ruptures resulted in multiple inspections in 2016 and 2017 that discovered approximately 950 m (3116 feet) of longitudinal weld seams that had deteriorated primarily due to corrosion and required refurbishment. As Penstock No. 1 and No. 2 are very similar and of the same age Hatch recommended that Penstock No. 2 undergo similar inspections where similar deterioration was discovered resulting in 500 m (1640 feet) of seam refurbishment. As a result, NL Hydro engaged Hatch to complete a failure investigation.

[1] Lengths of penstock that are approximately 2.74 m (9 feet) long and constructed of two hemispheres of rolled plates longitudinally welded together to form a circumference.

Recommendations from the final "Repair and Failure Investigation" report May 17, 2018 for the November 2017 rupture of Penstock No. 1 included further assessment of Penstock No. 1 during the summer of 2018, along with further assessment of Penstock No. 2 and 3 during the next available outage. NL Hydro initiated the 2018 assessments of all three penstocks based upon these recommendations. The purpose of this report is to provide a thorough assessment of the current condition of all three penstocks, provide a preliminary review of various life extension options and to collect data to assist in recommendations for Report 3 "Penstocks No. 1, 2 and 3 Life Extension" to be issued late in the second quarter of 2019.

All three penstocks were inspected as part of a Level II Condition Assessment during the summer of 2018. Penstock No. 1 was inspected from August 13 to 24, 2018, and showed no sign of degradation of previously refurbished weld seams or reinforcing plate fillet welds. However, weld refurbishment was required on a single seam that was not previously inspected. Penstock No. 2 was inspected from September 17 to 28, 2018, and showed no sign of degradation of previously refurbished weld seams. However, there were two weld refurbishments required on seams that were not previously inspected. Penstock No. 3 had not undergone the same inspection regime as Penstock No. 1 and Penstock No. 2. The first detailed inspection of Penstock No. 3 took place from May 14 to June 21, 2018, and similar problems with the longitudinal weld seams, as encountered in Penstock No. 1 and Penstock No. 2, were also found in this penstock. As a result, Penstock No. 3 underwent significant refurbishment prior to return to service in late June 2018.

2. Condition Assessment Methodology

Previous inspections of the penstocks utilized a can numbering based on manhole locations which varied by penstock. As this numbering system was not consistent for all three penstocks, it was not utilized for the Level II condition assessments carried out in 2018. The new numbering system refers to the first can at the intake as Can No. 1 for all penstocks and progresses numerically from the intake structure towards the surge tanks (approximately Can No. 250 to No. 260 depending on penstock) and finally to the powerhouse (Can No. 400).

Due to the length of the penstocks, the number of weld seams and the time available during shutdowns, an inspection methodology was employed that would quickly identify problem areas and provide a comprehensive overview of the overall condition of all three penstocks. All three penstocks were inspected as part of a Level II Condition Assessment. Inspections included: detailed weld inspection, material testing and water pressure monitoring.

The general scope of the inspection was to pressure wash, buff, magnetic particle and visually inspect the longitudinal welds at a frequency of 1 can in every 10 cans for the total length of the penstock. If welds that warranted refurbishment were discovered during inspection, a further 5 cans upstream and 5 cans downstream of this area would be subject to the same level of inspection. This method allows for an overview of the total penstock condition and an increased inspection frequency in areas that showed signs of damage. The weld inspection and subsequent refurbishments, completed on each penstock, were evaluated following inspection by NDE techniques. The inspection techniques used for the longitudinal and circumferential weld seams of Penstock No. 1, 2, and 3 were visual inspection (VT) and Magnetic Particle Inspection (MT) carried out by Canadian Government Standards Board (CGSB) certified NDE Technicians.

All three of the penstocks have sections that are prone to general deformation/sagging and peaking of weld seams. This is particularly true in sections where the penstock diameter (D) is more than 400 times larger than the penstock wall thickness (t) ($D/t > 400$). Due to previous out of round concerns, the high D/t ratio, and high residual stresses observed in previously tested welds, it was decided that further review of the overall shape of the penstock was required. To assess these concerns and obtain information pertaining to the shape of the penstock, a 3D laser scan was completed to measure the roundness and weld seam peaking for each penstock.

Also, in a similar matter to mechanical tests that were carried out on Penstock No. 1 and No. 2, a plate coupon from Penstock No. 3 was also sent to a testing laboratory. The penstock plate material sample test results were used to determine the metallurgical properties of the weld and base metal and to compare them to the steel specifications listed on the drawings. In addition to the mechanical testing, chemical analysis of the welds and parent metal were completed along with a macro and microscopic examination of the weld

cross sections. These tests were completed to determine if there were any anomalies that could have contributed to the accelerated corrosion and subsequent cracking of the seams.

During the major refurbishment of Penstock No. 2 in 2017, rolled angle rings were discovered on the exterior of the penstock. These rings were not found on Penstock No. 1 but excavations on Penstock No. 3 in 2018 indicated rings similar in cross section to the ones found on Penstock No. 2. These rings were not of sufficient depth/thickness and/or frequency to provide additional support to Penstocks No. 2 and No. 3 while under pressure. In our opinion, these rings were more likely used to assist in field erection and weld fit up of the half can sections and adjacent circumferential seams. During internal inspections of Penstock No. 1, there was frequent evidence of poor alignment which required localized mechanical deformation of the penstock shell to achieve a fit up that would allow welding of the seams during original construction more than 50 years ago. It is believed that the fabricator installed these rings on Penstock No. 2 and No. 3 to reduce the fit up and installation issues encountered on the previously constructed Penstock No.1.

Following the data collection of Penstock No. 1 in November 2017, which included collection of pressure and strain data, Hatch recommended similar data collection for Penstocks No. 2 and 3. As a result of this recommendation, NL Hydro installed pressure transducers on Penstocks No. 2 and 3 along with additional ones on Penstock No. 1 and connected them to a data logger. Data collection is currently on-going, and Hatch recommends Hydro collect data over the next few years to generate historical data that can be used to analyze and interpret the long-term operational trends of the penstocks.

3. Penstock Inspections and Refurbishments

3.1 Previous Inspections and Major Refurbishments

To compare the refurbishments and overall condition of the penstocks, it is important to compare the initial inspection findings.

The initial inspections and major refurbishments of all three penstocks did not occur within the same year. Penstock No. 1 (2016), Penstock No. 2 (2017) and Penstock No. 3 (2018) found cracking in the form of linear indications along the top and bottom edge of the weld seams. In addition to the linear weld cracking, the weld seams had noticeable deterioration of the weld cap in the form of general corrosion (weld metal loss), localized pitting corrosion of varying degrees throughout the sections of penstocks, and preferential corrosion of the heat affected zone (HAZ) resulting in areas of low material thickness, edges and therefore high stress concentrations or "notches" in the upper and bottom portion of the weld edge. All three penstocks exhibited cracking and linear indications of weld seams. These indications were predominantly located in the longitudinal seams.



Figure 3-1: Sample of Deteriorated Longitudinal Weld Seam

The previous repairs consisted of:

1. Penstock No. 1 required refurbishment from Can No. 1 through Can No. 173, which resulted in a total refurbished weld seam length of approximately 950 m (3116 feet) (a total of 346 seams at 2.74 m (9 feet) per seam).
2. Penstock No. 2 required refurbishment from Can No. 1 through Can No. 91, which resulted in a total refurbished length of approximately 500 m (1640 feet) (a total of 182 seams at 2.74 m (9 feet) per seam).
3. Penstock No. 3 required refurbishment from Can No. 1 through Can No. 132, excluding a single seam at Can No. 65. After Can No.132 refurbishments were intermittent from Can No. 132 through Can No. 175, Can No. 205 through Can No. 225 and Can No. 302 through Can No. 342. The total length of this refurbishment was approximately 1030 m (3378 feet).

An overview of the refurbishments can be seen in Figure 3-2. For a detailed breakdown of inspections, repairs and general locations per penstock refer to P1 CA Tracker, P2 CA Tracker and P3 CA Tracker provided in Appendix C.

Where refurbishment was required, the indications identified by MT inspection were removed by gouging the full profile of the weld seam and HAZ with care not to remove the full thickness of the weld metal. Following the completion of gouging and subsequent grinding for cleanup of the seam, the seams were inspected visually and by MT to ensure no cracks or indications remained and sound weld metal was present prior to the start of refurbishment. The seams were then welded and after a hold time of 48 hours they were inspected by VT and MT methods to verify weld quality.

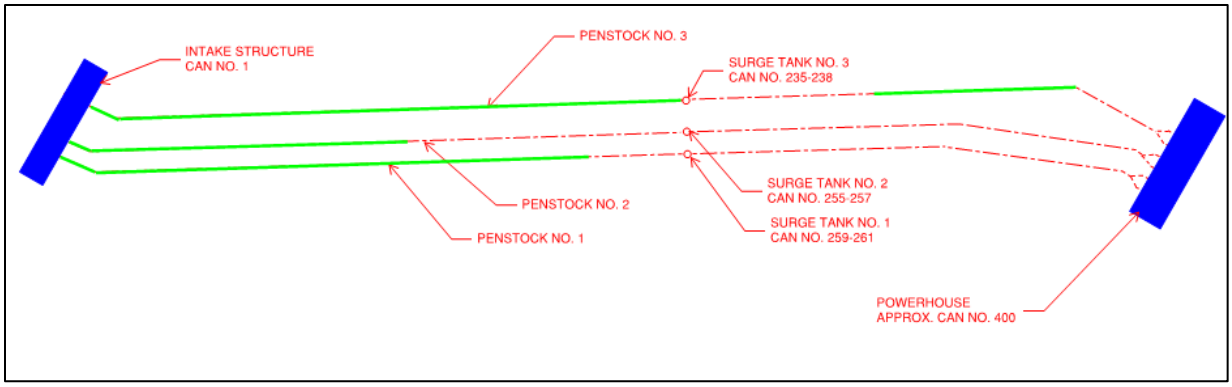

Figure 3-2: Concept Sketch of Penstock Refurbishment Overview (Green Indicates Refurbished Areas)

3.2 Level II Condition Assessment 2018

The inspections and refurbishments of Penstocks No. 1, 2, and 3 were quantified during each penstock shutdown using inspection and refurbishment spreadsheets called trackers. These were used as progress aids as they identified can/seam locations. The data from these trackers was later used for statistical analysis welds, findings on weld quality, and refurbishment lengths.

3.2.1 Penstock No. 1

Penstock No. 1 was inspected from August 13 to 24, 2018. The inspection started adjacent to the intake and progressed through the penstock towards the powerhouse. The inspection followed a 1 can in every 10 cans frequency. Additionally, all cans in the 2016 rupture area from Can No. 91 through Can No. 102 were inspected to assess the effectiveness of the refurbishment.

The inspection encompassed the full-length penstock and included 102 weld seams. Of the 102 weld seams inspected, 56 were previously refurbished weld seams and/or reinforcing plate locations. The inspection verified that the welds remain intact and show no signs of

degradation. Additionally, the inspection included 46 weld seams that were not repaired previously. Out of the 46 weld seams inspected, only the south seam on Can No. 215 had a defect requiring refurbishment, resulting in a total longitudinal weld seam refurbishment length of approximately 2.74 m (9 feet). Since the first inspections conducted in 2016 approximately 61% of longitudinal weld seams have been inspected.

The surge tank transition in Penstock No.1 showed evidence of cracking as water was visible leaking through the weld seams. As this is not a structural connection and due to the schedule, the transition was not refurbished at that time. Hatch addressed this issue in "Project Completion Memorandum" H352666-00000-240-030-0002 for Penstock No. 1. While not a structural issue, there is no critical time line for this refurbishment, however, Hatch recommends these cracks be refurbished during the next planned refurbishment of this penstock.

During the inspection, three new instrument trees were installed on Penstock No. 1 similar to those utilized previously during 2017/2018. The pressure transducers were installed on Penstock No. 1 to determine if there are any pressure transients occurring within the penstock.

3.2.2 Penstock No. 2

Penstock No. 2 was inspected from September 17 to 28, 2018. The inspection started at the intake and progressed downstream, with a one can in ten frequency.

The inspection encompassed the entire penstock and included 120 weld seams of which 18 were previously refurbished. The inspection verified that the welds remain intact and show no signs of degradation. Additionally, the inspection included 102 weld seams that were not repaired previously. Out of the 102 weld seams inspected, only the north seams on Can No. 230 and Can No. 270 required refurbishment resulting in a total longitudinal weld seam refurbishment length of approximately 5.49 m (18 feet). Since the first inspections conducted in 2017 approximately 40% of longitudinal weld seams have been inspected.

Penstock No. 2 surge tank transition cracked seams were re-welded in 2017 and visually appeared intact during the 2018 inspection. While there were no evident signs of leakage, detailed testing was not completed as this is not a structural concern. During the next shut down, it is recommended to perform spot MT to determine if the re-welded sections remain in good condition and are crack free.

Penstock No. 2 was noted to have "stiffener" rings present on the upstream sections; an excavated stiffener ring can be seen in Figure 3-3. The stiffener rings were fabricated by rolling a 5"x3"x3/8" angle spaced roughly every 3.66 m (12 feet). These rings are not of sufficient size or spacing to act as pressure retaining elements. As previously discussed, in Section 2 of this report, these rings were likely used to assist in field erection and weld fit up.

It should be noted that the quality of the penstock fit up was noted to be superior to that of Penstock No. 1, likely due to the use of external rings during assembly.



Figure 3-3: Excavated Stiffener Ring – Penstock No. 2

The Bay d'Espoir Operations group had scheduled the application of two coating samples to determine how they would respond over time to exposure to the penstock's interior environment. The two samples to be tested were originally intended to consist of a Galvatech 2000 Primer/MC Tar and a Mio Zinc Primer/MC Tar. The samples were to utilize two different primers as noted above and be applied on a tee section (capturing the intersection of a longitudinal and circumferential weld). During the assessment, the required curing time and application environmental conditions (humidity, dry bulb and wet bulb temperatures) for the Galvatech 2000 primer were not met, and this primer was not applied. Based on this issue, instead two locations were selected for application of the Mio Zinc primer coat and two top coats of MC Tar. The coating preparation and MC Tar finish coat can be seen in Figure 3-4.



Figure 3-4: Coating Prep (Left) Final MC Tar (Right) – Penstock No. 2

During the inspection, three new instrument trees were installed on Penstock No. 2. Each instrument tree consisted of a pressure transducer connection, a drain, and a high point vent. The pressure transducers were installed on Penstock No. 2. to determine if there are any pressure transients occurring within the penstock and to provide data to be used for further analysis provided in a later document. A typical pressure transducer tree is shown in Figure 3-5.



Figure 3-5: Pressure Transducer Instrument Tree – Penstock No. 2

3.2.3 Penstock No. 3

The Penstock No. 3 condition assessment and refurbishment took place from May 14 to June 21, 2018. During the shutdown, 561 longitudinal weld seams were inspected, and 390 longitudinal weld seams were refurbished, resulting in a total longitudinal weld seam refurbishment length of approximately 1030 m (3378 feet).

The inspection began with entry through a manhole at Can No. 118. Planned inspection frequency was 1 can every 10; however, initial findings showed the upstream section of Penstock No. 3 required major refurbishment similar to that of Penstock No. 1 and No. 2. Further inspection downstream indicated refurbishment in this section was also required. The 5.18 m (1717 feet) diameter section (excluding Can No. 65) was refurbished, Can No. 132 to Can No. 175; Can No. 205 to Can No. 225; and Can No. 302 to Can No. 342 sections were also refurbished intermittently. The areas between these sections had a minimum inspection frequency of 1 can every 10. The end of the refurbishment areas was determined when 5 cans passed inspection both upstream and downstream of the refurbished can. Since the inspection conducted in 2018 approximately 67% of longitudinal weld seams have been inspected.

The inspection identified seams in the downstream portion of the penstock, Can No. 240 to Can No. 295 and downstream of Can No. 345, that indicated the beginning stages of preferential corrosion of the heat affected zone. No refurbishment was performed in this area

as the noted corrosion was deemed minimal and low risk, therefore does not pose an immediate threat to operability. Refer to Hatch project memo H357358-00000-240-030-0001 "Minor Weld Indications in Penstock 3" for further discussion.

A coupon was removed from Can No. 222 and sent for mechanical testing and chemical analysis. The testing determined the plate was of similar composition and strength as the plates tested for the other two penstocks. Findings are discussed later in this report.

Similar to Penstock No. 1 and No. 2, the surge tank transition on Penstock No. 3 displayed cracking as well as visible water leakage through weld seams. As this is not a structural connection, and due to the schedule, the transition was not refurbished at this time. Hatch addressed this issue in "Project Completion Memorandum" H352666-00000-240-030-0002 for Penstock No. 1. Hatch recommends this be completed during the next planned refurbishment of Penstock No. 3.

Penstock No. 3 was discovered to have rings present on the upstream sections similar to those found on Penstock No. 2. These are believed to be fabrication aids similar to Penstock No. 2.

During the inspection, four new instrument trees were installed on Penstock No. 3 similar to those utilized on Penstock No. 2. The pressure transducers were installed on Penstock No. 3 to determine if there are any pressure transients occurring in the penstock and to provide data.

3.3 Testing

An extensive array of examination and mechanical testing was completed on coupons removed from various locations along the length of the penstocks. The coupon locations from Penstock No. 1 (2016) included one coupon from Section 8, one coupon from Section 16, and one coupon from Section 17. Penstock No. 3 (2018) had one coupon removed from Can No. 222. The coupons consisted of plate sections containing both base and weld metal. These samples underwent mechanical and chemical testing to determine if there were metallurgical abnormalities that could cause or contribute to failures of the penstock pressure boundary such as low tensile strength and high hardness. Test results indicated that there does not appear to be any metallurgical strength anomalies in the base metal or weld metal for any of the penstock material coupons tested. In all instances, the tested tensile strengths exceeded the minimum requirements of the specified steels from the design drawings.

The chemical analysis of the weld metal and base metals measured levels of sulphur, in all of the samples, that was higher than currently found in today's welding consumables and structural steels.

High amounts of sulphur can produce porosity in the weld metal and heat affected zones, primarily at the surface which can contribute to accelerated pitting corrosion. It is our opinion

the higher sulphur content could be a contributing factor in the accelerated corrosion and pitting of the welds and HAZ.

Refer to Appendix A.1 for a detailed summary of the mechanical testing completed on Penstock No. 1, 2 and 3.

The specifications and previous inspection reports indicate Penstock No. 1 and No. 2 had an interior coating of coal tar epoxy. There does not appear to be any information regarding the interior coating of Penstock No. 3 and based on communications with NL Hydro operations, regarding previous inspections it is our understanding no internal coating was utilized on Penstock No. 3. It is our opinion this is the main reason for the extent of the pitting corrosion of this penstock.

In order to confirm this for the assessment of Penstock No. 3 in 2018, samples were taken from two areas to confirm if an internal coating is present. Internal samples were retrieved from a section near the surge tank and can section 345-350 of the penstock. The samples were sent to Cambridge Testing and Materials in Mississauga, Ontario, and are awaiting results for further analysis in the second quarter of 2019.

3.4 Data Collection

3.4.1 2017 Data Collection

In November 2017, during the shutdown for the third rupture of Penstock No. 1, strain gauges and pressure transducers were installed for data collection. The data collected was analyzed and results and conclusions based on the analysis were presented in Hatch's "Repair and Failure Investigation" report dated May 17, 2017.

The strain gauges provided stress magnitude data and displayed any transients for various operating zones and conditions (e.g., speed no load, unit ramp up and load rejection).

NL Hydro also provided data from their Supervisory Control and Data Acquisition System (SCADA) system which aided with interpretation of the collected strain and pressure data.

The data collected from 2017 will be used in conjunction with data collected from 2018 and 2019 for analysis in Report 3 "Penstocks No. 1, 2 and 3 Life Extension Options" to be issued in the second quarter of 2019.

3.4.2 2018 Data Collection

During each of the shutdowns for Penstocks No. 1, 2, and 3, instrumentation trees were welded on the external (top) of each penstock for installation of pressure transducers.

With the data logger, the pressure transducers will measure and collect operational data. With this data, Hatch will analyze the pressure transients for anomalies and compare the results with the 2017 recorded pressure and stress/strain data.

3.4.3 2018/2019 Data Analysis

Hatch was supplied with approximately 3 months of operational pressure data for Penstocks No. 1, 2, and 3 from October 02, 2018 to January 22, 2019. In addition to the pressure data, NL Hydro also provided operational power generation (MW) readings for Units 1 to 6 for the same 3-month period. The data is high level data sampled once every minute.

Analysis of the penstock pressure data determined that modification to the data collection system is required. As such the pressure data will be issued separately as an appendix to this report once the recommended three months of data have been collected. While the pressure data provides valuable information regarding the penstock operating environment, this information does not impact the findings of this report as the observed peaking is more gradual than that analyzed in the previous stress analysis model, therefore the as-built geometry would have reduced residual and operational stresses.

Laser Scan and Inverts

In 2018, Allnorth (an external survey company) completed 3D Laser Scan Inspections on Penstock No. 1, 2 and 3 during each of the three shutdowns. All three inspections utilized Leica C10 3D Laser Scanner – ACLLS-007 technology and the inspections for both Penstock No. 2 and 3 started at the intake gate and proceeded downstream to just upstream of the bifurcation. The laser inspection of most of Penstock No. 1 was completed by a different contractor, EPCO, thus only the areas not surveyed previously were completed by All North.

Refer to Appendix A for the tables showing the maximum, minimum, and average out of roundness for the laser scans completed on Penstocks No. 1, 2, and 3. This information can be compared with out of roundness tolerances used by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Sec. VIII division 1 which stated the difference between the maximum and minimum inside diameters at any cross-section shall not exceed 1% of the nominal diameter at the cross section under consideration.

The penstock has three different diameters over its length. Based on the diameter, the following are the maximum acceptable out of round tolerances.

- 5.18 m (17 feet) I.D. section: 52 mm (2.04 in.)
- 4.57 m (15 feet) I.D. section: 46 mm (1.83 in.)
- 4.11 m (13.5 feet) I.D. section: 41 mm (1.62 in.)

For this analysis, the penstocks were put into 7 sections and compared (3 sections for the 17' I.D., 2 for the 15' I.D. and 2 for the 13.5' I.D.). To be conservative, the maximum and minimum values were compared across multiple scanned cross sections in each of the 7 sections. The Table 3-1 summarizes the maximum out of roundness.

Table 3-1: Penstocks Out of Roundness

Penstock Diameter	Maximum Out of Roundness Measured by Laser Scan	Maximum Permissible Out of Roundness from ASME VIII
5.18 m (17' I.D.)	124 mm (4.88 in.)	51.8 mm (2.04 in.)
4.57 m (15' I.D.)	138 mm (5.43 in.)	45.7 mm (1.80 in.)
4.11 m (13.5' I.D.)	127 mm (5 in.)	41.1 mm (1.62 in.)

The scanned sections were also analyzed for the longitudinal weld seam peaking as shown in Table 3-2 below.

Table 3-2: Weld Seam Maximum Peaking

Penstock Diameter	Maximum Measured Peak	Maximum Permissible Out of Roundness from ASME VIII
5.18 m (17' I.D.)	60 mm (2.36 in.)	51.8 mm (2.04 in.)
4.57 m (15' I.D.)	28 mm (1.10 in.)	45.7 mm (1.80 in.)
4.11 m (13.5' I.D.)	35 mm (1.38 in.)	41.1 mm (1.62 in.)

The results show the penstock shell is very flexible and does not meet the generally accepted tolerances for out of roundness in the unpressured condition. Also, the peaking at the longitudinal joints does not meet the acceptable tolerance with respect to weld seam fit up for pressure vessels.

This condition has existed since installation, and in our opinion, does not present an immediate concern for refurbished welds.

4. Finite Element and Fatigue Analysis

Further analysis and comparison were completed on the laser scan data and out of roundness measurements recorded. Originally, this data was intended to be used for FEA analysis, however given the extent of out of roundness and similarity to previously scanned and measured data; Hatch has deemed the best approach is to forgo a new FEA analysis and use the stress multiplier model that was created from past FEA models during the analysis of Penstock No. 1 in 2017/2018. This model is accurate provided Penstocks No. 2 and 3 have comparable pressures to the FEA model used to produce the stress multiplier model. Data collection is currently on-going and more historical data is needed to extrapolate and ensure an accurate model is produced to represent the long-term operational trend of the penstocks. Hatch will analyze this data and determine if it validates the existing FEA model. This will be included in a standalone document to be issued at a later date.

5. Current Condition and Life Expectancy Estimation

All three penstocks have had similar repairs completed due to longitudinal weld deterioration and cracking. The completed refurbishments have focused on stabilization of the penstocks. Based on the condition of the penstocks the likelihood of continued operation without failures is unlikely without intervention. It is Hatch's belief that major failures/ruptures are unlikely in the next 5 years. However, due to the deteriorated state, lack of corrosion protection, water chemistry and accumulated damage, it is likely that pin hole leaks and micro crack leaks could occur in the coming years.

In general, the refurbishments to date have been completed on longitudinal seams due to the amount of risk associated with major failures. Refurbishments were completed on welds that exhibited significant weld material loss, notching, and/or cracks. However, it should be noted that the penstocks have not been refurbished to a new condition and there are still many locations of welds with material loss, notching, and surface indications. As the penstocks have no current means of corrosion resistance, deterioration will continue, and these areas will eventually be considered high risk if no action is taken.

6. Refurbishment or Replacement Options

Refurbishment or replacement options were investigated for each penstock. The options selected are as follows:

1. Refurbishment of deteriorated weld seams, both longitudinally and circumferentially, and re-coating the interior of the penstock.
2. Replacement options for each penstock

    A Full penstock replacement

    B Replacement of penstock 17' ID section
3. Refurbishment of deteriorated weld seams and installation of a fiber-reinforced plastic (FRP) liner.
4. Refurbishment of deteriorated weld seams and installation of reinforcing plates over all longitudinal and circumferential weld seams.
5. Installation of a steel liner inside the existing penstock with grout injection to fill void space to existing penstock.
6. Encasement of the existing penstock in a concrete ring approximately 2 feet thick.

The following options present varying degrees of life extension. Referencing published material from the American Society of Civil Engineers (ASCE), the design life of a steel penstock is normally in the range of 40-80 years with proper maintenance (ASCE, Guidelines for Evaluating Aging Penstocks). As corrosion has been a major contributing factor relating to metal loss and in particular the welds, maintenance of a coating system is extremely important to the longevity.

Refurbishment options include replacement of the internal coating but not the external coating. Inspection of the external coating on Penstocks No. 1, 2, and 3 from the brief sections that have been excavated during the penstock refurbishments and condition assessment have shown the coating is still intact. Additionally, wall thickness measurements were taken along the length of the penstock and showed no signs of metal loss due to external corrosion.

With adequate maintenance of the coating systems, full replacement and installation of a new penstock will have an estimated design life of approximately 80 years. Hatch estimates the refurbishment options that include replacement of the interior coating will provide an additional life extension of at least 40 years provided there is no breakdown of the internal or external coating system.

6.1 Refurbishment of Existing Penstocks

The first refurbishment option investigated for life extension of the penstocks includes completion of the weld refurbishment that started in 2015. This will include full inspection of all seams, both longitudinal and circumferential, and refurbishment of all deteriorated seams (Note: all options with refurbishment consider 50% refurbishment rate of unrefurbished longitudinal and circumferential seams). Following the completion of weld refurbishment, the penstock internals will have abrasive blasting to bare metal and a new internal coating installed. The current coating option priced is for three coat paint system by the Wasser Corporation.

Table 6-1: Proposed Coating System

Coat Number	Product	DFT
First	MC-Zinc 100	3.0 to 5.0 mils DFT
Second	MC-Tar 100	5.0 to 7.0 mils DFT
Third	MC-Tar 100	5.0 to 7.0 mils DFT
Total	**N/A**	**13.0 to 19.0 mils DFT**

The first coat would consist of MC-Zinc primer and be followed by two coats of MC-Tar moisture cure urethane that has similar performance to the coal tar epoxy that was originally installed, having a life span of approximately 15-20 years (recoating should be planned for every 15 years). The benefit of using the moisture cure product is that there will be significantly less environmental control and equipment required in the penstock during application. Other products can be assessed for this service however a large emphasis should be placed on the environmental application requirements (i.e. the internal penstock temperature, humidity, dew point, etc.). Hatch considers this important as Hydro and other companies like Newfoundland Transshipment Limited have experienced difficulties in the past with trying to apply other coatings in high humidity environmental.

Refurbishment of the welds is required to ensure that the newly applied coating is not compromised from existing cracking. If cracks are present it will lead to premature coating failure in those areas. This can be completed via grinding if the defect is removed within 2.0 mm. If the excavation is beyond 2.0 mm it would require the deposition of addition weld metal.

The penstocks should have regular interior inspections. Hatch would recommend doing an internal inspection after the first year of operation after coating is applied to assess if any installation issues caused delamination of the coating and repair as required. After the initial warranty inspection, the frequency would be reduced to one interior inspection every 6 years. The interior inspection would be largely focused on coating condition and would include visual inspection and adhesion testing.

Table 6-2: Refurbishment of Existing Penstock Cost

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$1,056,000	$1,101,000	$1,044,000
Backfill Manipulation	$20,000	$20,000	$20,000
Longitudinal Weld Refurbishment	$1,350,000	$1,800,000	$1,300,000
Circumferential Weld Refurbishment	$6,000,000	$6,000,000	$6,000,000
Doorsheet Removal and Re-installation	$60,000.00	$60,000.00	$60,000.00
Blasting/Coating	$3,000,000	$3,000,000	$3,000,000
Rescue / Safety	$130,000	$130,000	$60,000
EPCM(10%)	$1,056,000	$1,101,000	$1,044,000
Contingency (20%)	$2,112,000	$2,202,000	$2,088,000
Total	**$14,784,000**	**$15,414,000**	**$14,616,000**

6.2 Penstock Replacement

6.2.1 Replacement (A)

The second option investigated for the penstock's life extension includes full replacement or replacement of specific sections. Full replacement includes newly constructed cans from the intake imbedded thimble to the surge tank tee and from the surge tank tee to the section beneath the switchyard. Plate thickness should be increased in some areas, in particular the upper 17ft. diameter section, and a corrosion allowance added. The design would meet current standards. The full replacement option guarantees the longest life extension but comes at the greatest cost. A replacement penstock could be constructed in parallel to the existing to minimize penstock downtime, but this would require excavation and rock blasting to create a trench which comes at a higher risk to the adjacent penstocks and at an additional cost. The options estimated for this report did not include any cost for trench excavation.

Complete replacement poses considerable challenges as some of the existing sections are virtually irreplaceable or replaceable at great cost. These locations include the intake thimble, surge tank tee, sections under the substation, and sections under the powerhouse. Due to the challenges associated with complete replacement it was determined that the replacement option would not include these sections. It is Hatch's opinion a partial penstock replacement represented a more viable approach.

The remaining sections would be considered field tie points where the new penstock sections would be connected to the existing. The irreplaceable sections would then be internally inspected, refurbished as required and coated. Internal and external coating would need to

be applied to newly constructed sections as well (cost estimates include costing for the recommended coating system).

Table 6-3: Full Replacement Cost Estimate Per Penstock

Construction Activity	Cost
Mob/Demob (10% of Site Work)	$3,436,750
Backfill Manipulation	$500,000
Replacement Steel (Material/Shipping/Fab)	$21,600,000
Reinforcing Steel	$1,187,500
Demo of Existing Penstock Sections	$1,000,000
Blasting/Coating	$5,000,000
Site Labour and Cranes	$5,000,000
Rescue / Safety	$80,000
EPCM (10%)	$3,436,750
Contingency (20%)	$6,873,500
Total	**$48,114,500**

6.2.2 Replacement (B)

Based on the recent refurbishment history and the results of the stress analysis the section of the penstock that has had the most problems would be the 17-foot section located upstream of the Surge Tank. This estimate considers only replacing this section with material and design to current standards and fully refurbishing and re-coating the remaining penstock sections.

Table 6-4: Partial Replacement and Refurb Cost Estimate Per Penstock

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$1,614,250	$1,624,250	$1,609,250
Backfill Manipulation	$100,000	$100,000	$100,000
Longitudinal Weld Refurbishment	$1,350,000	$1,450,000	$1,300,000
Circumferential Weld Refurbishment	$4,000,000	$4,000,000	$4,000,000
Demo of Existing 17' ID Section	$300,000	$300,000	$300,000
Replacement Steel for 17' ID	$5,320,000	$5,320,000	$5,320,000
Blasting/Coating	$3,210,000	$3,210,000	$3,210,000
Site Labour and Cranes	$1,762,500	$1,762,500	$1,762,500
Rescue / Safety	$100,000	$100,000	$100,000
EPCM (10%)	$1,614,250	$1,624,250	$1,609,250
Contingency (20%)	$3,228,500	$3,248,500	$3,218,500
Total	**$22,599,500**	**$22,739,500**	**$22,529,500**

6.3 Weld Refurbishment and FRP Liner

Similar to Option 1, this option includes completion of weld refurbishment for all weld seams and substitutes a paint coating system with the installation of an FRP liner. An FRP liner would have a longer lifespan compared to a coal tar epoxy. Preliminary estimates indicate the FRP liner is multiple times the cost of a MC-Tar epoxy but has a much longer lifespan, ranging from 25-50 years with proper resin selection and adequate maintenance. Due to the high velocity flow and turbulence in some area's penstocks, maintenance may be required in areas such as the intake thimble, elbows, tees, reducers, and the bifurcation.

The FRP liner materials currently under review require the penstock internal to be abrasively blasted to a "white metal" SSPC-SP-5 finish. Additionally, current review of FRP liner materials indicates considerable work would be required to ensure the surface is sufficiently uniform for proper installation and adhesion. This would be required at areas of pitting/crevices in excess of 1.5 mm. This resurfacing could be completed by weld buildup and grinding or by the use of poly filler compounds. The cost of resurfacing was not included in the estimate. Preliminary research indicates this as a feasible but high cost option, however further research must be conducted as material selection could present liner cracking concerns with penstock shape changes during water up (pressurization) and dewatering (depressurization).

Table 6-5: Weld Refurbishment and FRP Liner Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,417,725	$2,462,725	$2,412,725
Backfill Manipulation	$20,000	$20,000	$20,000
Longitudinal Weld Refurbishment	$1,350,000	$1,800,000	$1,300,000
Circumferential Weld Refurbishment	$6,000,000	$6,000,000	$6,000,000
Doorsheet Removal and Re-installation	$60,000	$60,000	$60,000
Blasting / FRP Liner	$16,687,250	$16,687,250	$16,687,250
Rescue / Safety	$60,000	$60,000	$60,000
EPCM (10%)	$2,417,725	$2,462,725	$2,412,725
Contingency (20%)	$4,835,450	$4,925,450	$4,825,450
Total	**$33,848,150**	**$34,478,150**	**$33,778,150**

6.4 Refurbishment with Reinforcing Plates

Building on the requirements of Option 1, reinforcing plates could be installed internally over all existing weld seams. Following the weld refurbishment, reinforcing plates similar to that installed in Penstock No. 1 (Nov. 2017) would be installed to stiffen the existing penstock and

provide additional protection to the weld seams. Abrasive blasting to bare metal and installation of a coating system would still be required for penstock longevity.

Table 6-6: Refurbishment and Reinforcing Plates Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,161,250	$2,206,250	$2,156,250
Backfill Manipulation	$20,000	$20,000	$20,000
Longitudinal Weld Refurbishment	$1,350,000	$1,800,000	$1,300,000
Circumferential Weld Refurbishment	$6,000,000	$6,000,000	$6,000,000
Conduct Roundness Correction	$3,600,000	$3,600,000	$3,600,000
Installation of Reinforcing Plates	$7,080,000	$7,080,000	$7,080,000
Doorsheet Removal and Re-installation	$60,000	$60,000	$60,000
Blasting/Coating	$3,000,000	$3,000,000	$3,000,000
Rescue / Safety	$60,000	$60,000	$60,000
Site Labour For Repad Installations	$442,500	$442,500	$442,500
EPCM (10%)	$2,161,250	$2,206,250	$2,156,250
Contingency (20%)	$4,322,500	$4,412,500	$4,312,500
Total	**$30,257,500**	**$30,887,500**	**$30,187,500**

6.5 Internal Steel Liner

This option investigated the installation of a steel liner inside the existing penstock. The liner would be designed to be fully pressure retaining providing a new smaller diameter penstock inside the existing. Grout would need to be injected to fill the void between the 2 steel structures, providing support and load transfer to the exterior shell and exterior soil. The new steel sections would be sized for ½" (12.7mm) plate throughout the length of the penstock and would require an internal coating. For the grouting, couplings or structural connections would be welded into the gap between the new liner and existing penstock to support construction prior to grout injection. Installation of steel liner without grouting was reviewed but based on the existing deformation insuring the new shell is in continuous contact would be difficult and require installation of the new shell in many segments. Additionally, the amount of welding required could cause damage to the exterior coating of the existing penstock and the direct contact of the new internal liner to existing shell could create a galvanic cell.

Table 6-7: Internal Steel Liner Cost Estimate (A)

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,836,450	$2,881,450	$2,831,450
Backfill Manipulation	$60,000	$60,000	$60,000
Longitudinal Weld Refurbishment	$1,350,000	$1,800,000	$1,300,000
Circumferential Weld Refurbishment	$6,000,000	$6,000,000	$6,000,000
Liner Steel	$17,100,000	$17,100,000	$17,100,000
HSS Reinforcing	$280,000	$280,000	$280,000
Cranes	$200,000	$200,000	$200,000
Jacking & Steel Placement	$600,000	$600,000	$600,000
Blasting/Coating	$2,374,500	$2,374,500	$2,374,500
Rescue/Safety	$400,000	$400,000	$400,000
EPCM (10%)	$2,836,450	$2,881,450	$2,831,450
Contingency (20%)	$5,672,900	$5,762,900	$5,662,900
Total	**$39,710,300**	**$40,340,300**	**$39,640,300**

Table 6-8: Internal Steel Liner Grouted Cost Estimate (B)

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,883,075	$2,928,075	$2,878,075
Backfill Manipulation	$20,000	$20,000	$20,000
Longitudinal Weld Refurbishment	$1,350,000	$1,800,000	$1,300,000
Circumferential Weld Refurbishment	$6,000,000	$6,000,000	$6,000,000
Liner Steel	$17,100,000	$17,100,000	$17,100,000
HSS Reinforcing	$280,000	$280,000	$280,000
Cranes	$200,000	$200,000	$200,000
Jacking & Steel Placement	$600,000	$600,000	$600,000
Grouting	$506,250	$506,250	$506,250
Blasting/Coating	$2,374,500	$2,374,500	$2,374,500
Rescue/Safety	$400,000	$400,000	$400,000
EPCM (10%)	$2,883,075	$2,928,075	$2,878,075
Contingency (20%)	$5,766,150	$5,856,150	$5,756,150
Total	**$40,363,050**	**$40,993,050**	**$40,293,050**

6.6 Concrete Ring Encasement

This option investigates the installation of a external steel reinforced concrete ring with a thickness of approximately 2 feet. The penstocks would first have all weld refurbishments completed and a coating system applied (similar to that described in Section 6.1). Excavation operations would commence once sections of the penstock were refurbished, and then concrete placement would begin. Support steel would be required and total support of the penstock during forming and concrete placement would be challenging. Similar to the replacement options, some sections would not be accessible for encasement, although some of these areas are already encased in concrete. Once again, these specific sections will have internal reinforcement to ensure life expectancy is similar throughout the entire penstock.

Table 6-9: Concrete Ring Encasement Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,939,700	$2,984,700	$2,934,700
Backfill Manipulation	$3,200,000	$3,200,000	$3,200,000
Longitudinal Weld Refurbishment	$1,350,000	$1,800,000	$1,300,000
Circumferential Weld Refurbishment	$6,000,000	$6,000,000	$6,000,000
Reinforcing Steel	$1,187,500	$1,187,500	$1,187,500
Doorsheet Removal and Re-installation	$60,000	$60,000	$60,000
Concrete	$14,625,000	$14,625,000	$14,625,000
Cranes	$200,000	$200,000	$200,000
Blasting/Coating	$2,374,500	$2,374,500	$2,374,500
Rescue/Safety	$400,000	$400,000	$400,000
EPCM (10%)	$2,939,700	$2,984,700	$2,934,700
Contingency (20%)	$5,879,400	$5,969,400	$5,869,400
Total	**$41,155,800**	**$41,785,800**	**$41,085,800**

7. Option Comparison

Due to the complexity of the various options it was decided to include a brief comparison matrix ranking the options based on five key factors, see Table 7-2. The factors used for the comparison were reliability, cost, schedule/phasing and risk.

Reliability- Considers the long-term reliable operation of the penstocks unimpeded by outages.

The majority of the options scored high on reliability excluding FRP lining. Due to the strict application processes and the elastic deformation (change in shape when pressurizing or depressurizing) of the penstock there is a possibility of localized failures or cracks in the liner occurring. Similar reliability issues could occur with a new steel liner installation due to galvanic reactions between the existing and new steel if water leaks into the interstitial space between the two steel shells.

Cost – Based on the estimated capital cost of the various options. Costing was provided in the previous sections.

The estimates were based on industry norms for estimating and do not consider inflation and cost adders associated with phasing the project over multiple outages. Additional cost savings would be possible if Hydro was purchasing equipment or materials in advance and free issue these items to contractors

Schedule/Phasing – Some of the options allow for application in a phased manner.

This decreases down time and allows for more cash flow flexibility. Option 2 would be the most difficult to phase due to existing irreplaceable infrastructure. It could be phased by section to make it more attractive however the outages would be substantial.

Risk – Risk during operation and construction were considered.

Risk scores are similar based on the majority of the options being largely interior work. However, replacement would be subject to weather delays, risk to bedding wash out, and would require lifting and other construction related issues around and over operational penstocks.

Prior to completing the ranking matrix, the life extension options were first analyzed with listed advantages and disadvantages as shown in Table 7-1. This table complements the ranking matrix and lists some of the reasoning for decided weighting for the ranking matrix.

Table 7-1: Option Comparison Table

Item Number	Description	Advantages	Disadvantages
1	Refurbish circumferential and unrefurbished longitudinal welds of penstock followed by water blasting to bare metal and re-coating of penstock internal	1. Lower risk of failure 2. Lower cost 3. Work is internal and weather delays would be minimal 4. Reduction in surface roughness via new coating system. 5. Smaller labor force required and can be staged over multiple outages. 6. No large civil works required, minimal risk to existing infrastructure. 7. Minimal lifts over operational penstocks.	1. Multiple outages required. 2. Flexible 17’ diameter section remains. 3. Poor fabrication alignment issues remain. 4. Interior is repaired but exterior coating from original construction remains. Life extension is limited by external coating condition. 5. No inclusion of corrosion allowance on existing wall thickness. Therefore, coating needs to remain intact over the lifespan of the penstock. Essentially the coating system should be budgeted for replacement every 15-20 years. 6. Existing bedding and drainage system cannot be upgraded. Bedding remains in contact with the penstock in areas checked. However, some sections of the bedding were saturated during inspection.
2A/B	Replace sections of penstock	1. Low risk of failure 2. New sections can be constructed to meet current standards 3. Reduction of Surface roughness via application of new coating. 4. Existing flexible 17’ diameter section is removed. 5. Inclusion of corrosion allowance would be included in wall thickness. Reduces risk of corrosion effect on the penstock shell. This would allow initial recoating interval to be greater (approximately 25-30 years). After the first recoating the interval would revert back to 15-20 years. 6. Life extension up to 80 years depending on maintenance schedule. 7. Bedding and drainage could be upgraded during replacements.	1. High cost for total replacement. 2. Long outage required. 3. High likelihood of weather delays. 4. Lifts over operational penstocks. 5. Heavy civil works required that could cause damage to existing infrastructure. 6. Demo of existing penstock sections would leave bedding system exposed to elements which could lead to compromised bedding and/or washouts. 7. Road transport of steel will require special permits for transport due to size and most likely be shipped in sections. This requires at least 2 longitudinal joints in the field per can. 8. Barge transport could be expensive due to the volume of steel cans. 9. Supply of required steel would have to be ordered one year in advance and free issued to contractors.
3	Install fiberglass liner	1. Construction can be phased 2. Work is all internal and weather delays would be minimal 3. Decreased roughness due to new fibreglass liner 4. Composite liner allows for increased strength when combined with existing steel. 5. Failure of fiberglass coating is easily identified by discoloration at delamination sites. 6. Highly resistant to corrosive environments	1. High cost 2. Multiple outages required 3. Work is confined space and additional ventilation will be required. 4. Extensive refurbishment required to smooth entire penstock internal surface due to application limitations. 5. Fiberglass delamination is could occur during watering up due to excessive peaking at longitudinal seams and general flexibility of the 17’ diameter sections. 6. If leakage occurs, determining extent is impossible without removal of fiberglass liner. This could lead to corrosion of steel penstock behind fiberglass liner. Fiberglass liner has insufficient thickness to retain entire pressure, consequently steel integrity is still required. 7. Environmental requirements are difficult to attain inside of the penstock.
4	Install internal reinforcing	1. Lower risk of failure 2. Construction can be phased 3. Work is all internal and weather delays would be minimal 4. Increased reinforcement over welded areas	1. High cost 2. Multiple outages required 3. Possible flow disturbances caused by plates protruding into flow contributing to head loss 4. Reduced flow through penstock do to repetitive pressure disturbances. 5. Refurbishment of existing welds is required prior to installation and with refurbishment there is no advantage to additional plate reinforcement.
5A/B	Install steel liner inside penstocks and pump epoxy grout into interstitial space.	1. Composite structure consisting of existing steel, new grout layer and new steel liner would be considerably stronger than current arrangement. 2. Construction can be phased. 3. Majority of work is internal and not subject to weather delays. 4. Increased rigidity due to increased thickness and reduced diameter.	1. High cost 2. Multiple outages required, or increased outage length required. 3. Installation of caps required at terminations if phased to ensure grout is not saturated. 4. Lack of access for full penetration welds. Could require backing rings. 5. Higher head loss due to reduced cross-section. 6. Risk of galvanic corrosion between new liner and existing steel due to minimal grout layer. This is often encountered in double bottom bulk storage tanks. Typically, these would require large separations between new and existing steel (6” and up) along with some type of cathodic protection. 7. Existing peaked sections could lead to failure of the grout section after repeated watering and dewatering cycles. 8. Due to deformation of existing penstock ensuring complete contact of internal liner without grout poses considerable challenges. Not considered technically viable at this time.

Item Number	Description	Advantages	Disadvantages
6	Install concrete ring that externally encases the existing	1. Lower risk of failure. 2. Construction can be phased. 3. Increased rigidity and reinforcing on penstock shell. 4. External repairs would be simpler on exposed concrete sections.	1. High cost 2. Extensive excavation works 3. Supporting penstock during construction (forming/placing concrete) will be challenging 4. Multiple outages will be required. 5. Lifting and placing concrete over operational penstocks 6. Increased rigidity may cause increased reactions as there is no longer any flex in the system. 7. Repairs to interior lining would be difficult in the event of failure. 8. Could cause failure of buried storm culverts due to the increase in weight. 9. Concrete has poor performance in tension. Not considered a technically viable option at this time.

Table 7-2: Refurbishment Option Matrix

Item Number	Option	Reliability	Cost	Schedule/Phasing	Risk	Total
1	Refurbish and Coat	4	5	5	4	90%
2A	Replace Existing	5	1	1	2	45%
2B	Replace Existing + Refurbishment	5	4	3	3	75%
3	Install FRP Liner	2	2	5	2	55%
4	Install Internal Reinforcement	4	3	5	3	75%
5	Install Steel Liner	2	2	5	2	55%
6	Encase Penstock in Concrete Ring	5	2	1	2	50%

8. Conclusions

Following the 2018 shutdowns of Penstocks No. 1, 2, and 3, each of the three penstocks have undergone a large-scale inspection and refurbishment of the sections upstream of the surge tank and for Penstock No. 3 the section downstream of the surge tank.

The three penstocks required refurbishment of the longitudinal seams due to significant weld metal loss from general corrosion, localized pitting corrosion, and preferential pitting corrosion of the HAZ. The weld metal loss has resulted in the formation of linear indications (i.e., cracking) along both edges of the weld. The 2018 inspection and refurbishment of Penstock No. 3 found the penstock in similar condition to that of Penstock No. 1 and No. 2 but with more refurbishment required downstream of the surge tank than the other two penstocks.

Based on the current condition of the penstocks and the lack of corrosion protection, Hatch cannot guarantee no further leakages or micro cracks (if not already present) will occur for each of the three penstocks. Hatch believes the probability of a major rupture or failure is low within the next 5 years however, a pin hole leak or micro crack could eventually lead to a rupture or failure.

The reviewed pressure data showed events of interest and additional data is required for these events. Three months is an insufficient period to analyze data to determine, provide commentary on trends and compare this with previously recorded data. Several years of data collection and monitoring is more appropriate for this type of installation and Hatch recommends continual data collection until a life extension option is implemented. Hatch will utilize results over the next 3 months to provide preliminary commentary in a later document.

The 2018 inspection of Penstocks No. 1 and 2 indicates the refurbishments completed in 2016 and 2017 show no deterioration since the previous shutdown. Approximately 8.4% of the Penstock No. 1 refurbished welds showed deterioration when re-inspected in 2017 but since the reinforcement and additional refurbishment carried out in 2017, no new indications were found in these areas during the 2018 inspection.

Mechanical testing was completed on Penstock No.1, 2 and 3 and shows the materials used for fabrication meet or exceed the design specifications. Metallurgically the material does not appear to have any characteristics that would have caused a failure. There are high readings of sulphur within the base and weld metals tested. It is Hatch's belief this makes the penstock welds sensitized to corrosion when compared to typical steels when left unprotected.

The surveys completed indicate the penstocks are not within specified tolerances of the ASME BPVC. The excess peaking will cause higher stresses than typical code calculated stresses and will need to be evaluated in conjunction with the operational pressure data once available. However, it appears that weld repairs completed to date have sufficient ductility to allow for this deformation during water up. Stress analysis based on the collected survey and

pressure data will be completed for the final report "Penstocks No. 1, 2 and 3 Life Extension" in the second quarter of 2019.

Penstocks No. 1 and No. 2 have reached 50 years in service. The internal coating of Penstocks No. 1 and No. 2 have failed in numerous locations and there is a possibility that Penstock No. 3 was never internally coated.

The unrefurbished sections of the three penstocks, including circumferential seams, are showing signs of weld metal loss and preferential pitting corrosion of the HAZ and in the future will need to be protected by application of a coating to avoid further deterioration.

Based on completed inspections, refurbishments and current operating procedures as recommended by Hatch in previous reports, there have been no ruptures or recurring indications in the longitudinal seams. As a result, Hatch believes the refurbishment methodology has been successful in stabilizing the penstocks and the penstock's current condition will provide uninterrupted service through the 2019 winter season. Hatch recommends annual inspection of the penstocks should continue until a life extension strategy is implemented within the next 3-5 years. Hatch also believes that the refurbishment of backfill around Penstock No. 1, as outlined in Report H356043-00000-240-230-0003, may be deferred until the execution of the selected life extension work is completed.

Considering the welded joints in the refurbished areas have remained crack free, this would indicate that full strength defect free welds are able to undergo this deformation without crack propagation and complete removal and reinstatement of correctly rolled flush patches is not required. When welded seams are left unprotected and subject to continued corrosion this stress intensification factor becomes too much for the steel to handle. Survey data was checked for comparison against the FEA stress multiplier model's maximum peaking values and both maximums were comparable. The rate of change of the penstock inside radius on either side of the peaked seam for the stress multiplier model is much more gradual, therefore the actual stresses based on this geometry would be less than that of the current FEA model.

Preliminary cost estimates for six options have been presented as part of Report 2. Based on our analysis only one of the five options, Option 1, is feasible. After carefully reviewing the data collected, the yearly inspection of the completed refurbishments, and cost estimates it is Hatch's belief that at this time refurbishment of the penstocks, Option 1, is the most desirable solution. With refurbishment of the remaining seams (removal of surface cracks, deposition of new weld metal where required) and the application of a new protective coating, the life of the penstocks could be extended for an additional 20 years. Further life extension could be accomplished depending on maintenance of the new coating, maintenance of existing backfill and maintaining the current reduction in rough zone operation.

Table 8-1: Penstock Cost Estimate Comparison

	Penstock No. 1	Penstock No. 2	Penstock No. 3	Total
1. Refurbish and Coat	$14,784,000	$15,414,000	$14,616,000	**$44,814,000**
2A. Replace Existing	$48,114,500	$48,114,500	$48,114,500	**$144,343,500**
2B. Replace Existing + Refurb	$22,599,500	$22,739,500	$22,529,500	**$67,868,500**
3. Install FRP Liner	$33,848,150	$34,478,150	$33,778,150	**$102,104,450**
4. Install Internal Reinforcement	$30,257,500	$30,887,500	$30,187,500	**$91,332,500**
5. Install Steel Liner	$39,710,300	$40,340,300	$39,640,300	**$119,690,900**
6. Encase Penstock in Concrete Ring	$41,155,800	$41,785,800	$41,085,800	**$124,027,400**

Construction methodologies, estimates and schedules associated with shortlisted options selected by Hydro will be examined in much greater detailed and presented in Report 3.

Appendix A
Testing Results Summary

A.1 Penstock No. 1 – 2016 Testing Summary

A.1.1 2016 Testing Results

Penstock No. 1 had three coupons removed and the following testing was completed on each sample:

- Radiographic Examination
- Macroetch Evaluation
- Microstructural Examination
- Vickers Hardness Traverse
- Transverse Weld Tensile Testing
- Weld Metal Chemical Analysis
- Base Metal Chemical Analysis

Penstock No. 1 had an analysis completed on internal samples that were coating the penstock (existing coating and organics) to determine the coating system used and for testing of organics. The following tests were performed for organics:

- Low Nutrient Bacteria (LNB)
- Iron-Related Bacteria (IRB)
- Anaerobic Bacteria (ANA)
- Acid-Producing Bacteria (APB)
- Sulfate-Reducing Bacteria (SRB)

A galvanic analysis was completed on the three coupons from Penstock No. 1.

A water analysis was completed in 2016 as part of the Penstock No. 1 testing.

A.1.2 ASTM A285 Gr. C Sample – Penstock No. 1 (Section 16)

As part of the root cause analysis performed in 2016-2017 for the assessment of Penstock No. 1, a 460 mm x 460 mm (18" x 18") coupon was removed from Penstock No. 1 and sent for analysis. The test results are as follows.

Radiographic Examination

The radiographic examination showed no rejectable defects. Porosity was detected but was in the range of acceptable limits.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed a profile consistent with "Preferential Heat Affected Zone Corrosion".
- Both sections exhibited cracks propagating from the toes of the weld.
- One section exhibited porosity on the face of the weld.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line locations on either side of the weld, where cracks were observed in the macroexamination.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Viewing at a higher magnification, cavities can be seen at both weld toes. Both cavities were filled with corrosion product.
- Transgranular cracking was present within the corrosion cavities. Both cracks were propagating through the HAZ.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 169 to 198
- Hardness values for the HAZ ranged from 143 to 173
- Hardness values for the Base material ranged from 139 to 151

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of base metal = 69.5 ksi (480 MPa)

The tensile specimen fractured in the base metal indicating the UTS of the weld metal meets the requirements of being higher than the UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable, it is 2X the normal percentage.

Base Metal Chemical Analysis

The base metal chemistry is consistent with ASTM A285 Gr C material.

Coating System Asbestos and Quantitation Test

Coating system was identified as a Coal Tar Epoxy.

No presence of asbestos was detected in the coating system.

A.1.3 CSA G40.8 Gr. B Sample – Penstock No. 1 (Section 17)

A 460 mm x 460 mm (18" x 18") coupon of CSA G40.8B was removed from Penstock 1 (Section 17) for testing and incorporated a portion of one of the circumferential weld seams.

Radiographic Examination

The radiographic examination showed no rejectable defects. Porosity was detected but was in the range of acceptable limits.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed the weld had pitting along the inside diameter surface within the HAZ (at the weld toes).

- No cracks or inclusions were exhibited in either of the sections.
- Both sections showed there was complete penetration and complete fusion was observed throughout the weld.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 170 to 214
- Hardness values for the HAZ ranged from 168 to 214
- Hardness values for the Base material ranged from 174 to 185

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line on either side of the weld and labeled "FL" and "FL+1mm" as instructed by the customer.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1 mm location.
- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of weld metal = 84.5 ksi (582.6 MPa)

The tensile specimen fractured in the weld zone in a ductile manner. Even though this test failed in the weld metal, the UTS of the weld metal is significantly higher than the normal UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable at 0.018%, it is still above normal levels.

Total carbon, manganese, phosphorus, sulphur, and silicon values are all within specifications.

Base Metal Chemical Analysis

The base metal chemistry is consistent with CSA 40.8 Gr B material.

Total carbon, manganese, phosphorus, sulphur, and silicon values are all within composition specifications for UNS grade G15240 (1524) steel.

A.1.4 ASTM A285 Gr. C – Penstock No. 1 (Section 8)

A second coupon of ASTM A285 Gr. C was removed from Penstock No. 1 (Section 8). This coupon incorporated a portion of one of the circumferential weld seams.

Radiographic Examination

The radiographic examination showed no rejectable defects.

Macroetch Evaluation

A Photomacroetch of the weld was prepared from two different sections of the coupon etched in 2% Nital. A stereo microscope was then used to examine the samples for general comments on weld imperfections.

- Both sections showed the weld had pitting along the inside diameter surface within the HAZ (at the weld toes).
- No cracks or inclusions were exhibited in either of the sections.
- Both sections showed there was complete penetration and complete fusion was observed throughout the weld.

Vickers Hardness Traverse

Both macroetch sections were re-polished according to ASTM E3-11 and subjected to a Vickers Hardness Traverse. The Vickers Hardness readings were performed according to

ASTM E92-16 using a 10kgf test force and indentations were measured at 100x magnification.

- Hardness values for the weld metal ranged from 153 to 181
- Hardness values for the HAZ ranged from 121 to 158
- Hardness values for the Base material ranged from 130 to 158

Hardness values are within the range of normal expected values for this type of material and E4918 (E7018) welding consumables.

Microstructural Examination

The two sections used in the previous Vickers hardness traverse were re-prepared according to ASTM E3-11 for microstructural examination. The specimens were etched in 2% Nital and examined using an optical microscope at various magnifications. The examination was performed at and near the fusion line on either side of the weld, arbitrarily named "Side A" and "Side B" for CMTL identification purposes. These locations were labeled "FL" and "FL+1 mm" as instructed by the customer.

- Microstructure examination showed ferrite and pearlite in both specimens.
- Both specimens displayed a relatively coarse grain HAZ on either side of the FL locations; with "Side A" having more ferrite observed and "Side B" having more pearlite with a more distinct coarse grain HAZ.
- Both specimens displayed a more refined structured HAZ consisting of fairly uniform mixture of pearlite and ferrite on the FL+1mm locations.
- Some sulphide inclusions were found dispersed throughout the material at higher magnification.

Transverse Weld Tensile

- Ultimate Tensile Strength (UTS) of weld metal = 63.5 ksi (437.8 MPa)

The tensile specimen fractured in the weld zone in a ductile manner. Even though this test failed in the weld metal, the UTS of the weld metal is significantly higher than the normal UTS of the base metal.

Weld Metal Chemical Analysis

The chemistry indicated on the attached report is consistent with an E4918 (E7018) electrode.

The sulphur content is below the maximum allowable of 0.035% (CSA W48, Table 1); however, according to Lincoln and Air Liquide specification sheets, the normal level of sulphur in the deposited weld metal for standard SMAW electrodes is 0.008% to 0.013% with

E4918 (E7018) normally around 0.011%. Thus, even though the sulphur content is below the maximum allowable at 0.023%, it is still above normal levels.

Total Carbon, Manganese, Phosphorus, Sulphur, and Silicon values are all within specifications.

Base Metal Chemical Analysis

Chemical Analysis is similar to the chemical composition limits of ASTM A285 Grade C steel, with the exception of sulphur.

A.1.5 Organic Samples – Penstock No. 1

For the assessment conducted on Penstock No. 1 in 2016-2017, organic samples were taken and tested. The following organic tests were performed by Acuren (Mississauga, Ontario).

- Low Nutrient Bacteria (LNB)
- Iron-Related Bacteria (IRB)
- Anaerobic Bacteria (ANA)
- Acid-Producing Bacteria (APB)
- Sulfate-Reducing Bacteria (SRB)

Final readings of testing indicate the following:

- Negative readings for IRB and SRB
- Weak positive reading for LNB, ANA, and APB

A.1.6 Galvanic Testing

Potential difference measurements were taken on the three coupons removed from Penstock No. 1. They generally indicate that a galvanic cell between the weld metal and base metal is present and the weld metal, in particular the heat affected zone, was more susceptible to pitting corrosion than the base metal.

A.1.7 Water Analysis – Penstock No. 1

Water testing data was collected from 1965, 1980, 1988, 1992, 1993, 1994, 1995, 1996 and 2016. Testing between 1965 and 2016 yielded similar Langelier saturation index (LSI) results. However, the most recent water test indicates a change in water chemistry. We recommend additional testing to confirm these results.

The available data from 1965-2016 was used to compute the LSI, which is used to quantify the corrosive behavior of a specific water source. This calculation takes the pH, alkalinity, Total Dissolved Solids (TDS), temperature and calcium all into account rather than strictly depending on the pH value.

The LSI ranks water corrosion potential on a scale typically between -5 to 4, with -5 being highly corrosive and 4 having a high likely hood of scale buildup. When applying the LSI to the Bay d'Espoir water samples the following values were obtained:

Table A-1: LSI vs Water Sample Year

Year	LSI	Year	LSI
1965	-4.77	1994	-5.72
1980	-6.57	1995	-5.69
1988	-5.02	1996	-4.75
1992	-5.71	-	-
1993	-5.65	2016	-3.9

In several instances the LSI ratings calculated were outside of the typical range, indicating the water is more corrosive than typical water bodies. These values would indicate that the water flowing through the penstock would be considered highly corrosive.

A.2 2018 Testing Summary

A.2.1 Mechanical Testing - Penstock No. 3

Macro Examination

The photomacrograph in Figure A-1 below shows the appearance. The macro shows a clean weld exhibiting columnar weld grains with good fusion, no cracking or weld defects.

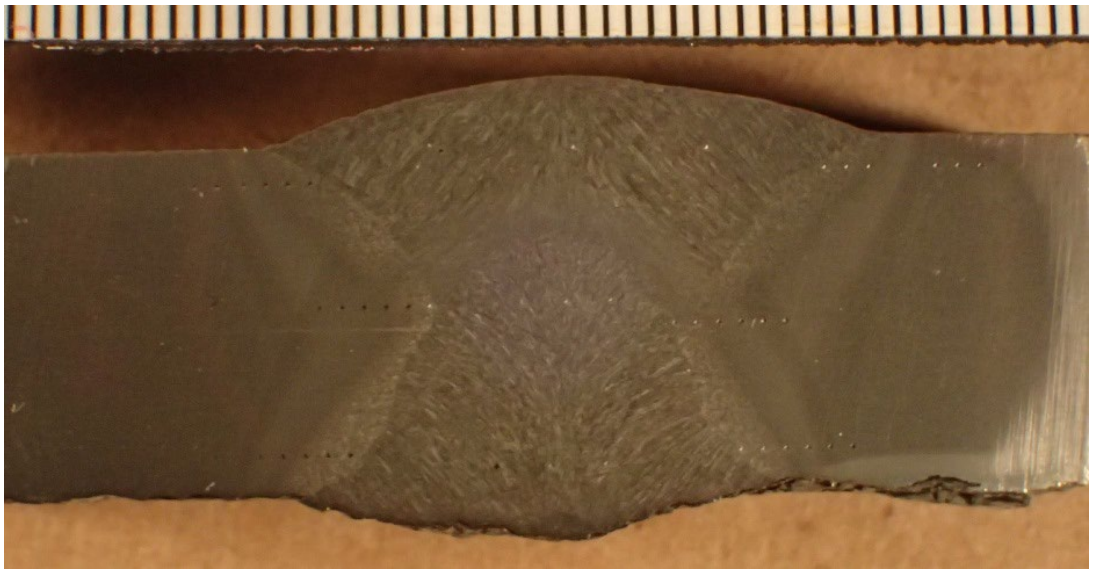

Figure A-1: Weld Macro Examination – Penstock 3

Microstructural Evaluation

A cross section of the weld was cut and prepared for a micro examination, polishing the cut to a 1µm finish and etched with a 5% Nital solution according to ASTM E3-11 standards. The micro examination revealed a fine grain, low carbon steel with few inclusions, typical of a structural quality steel.

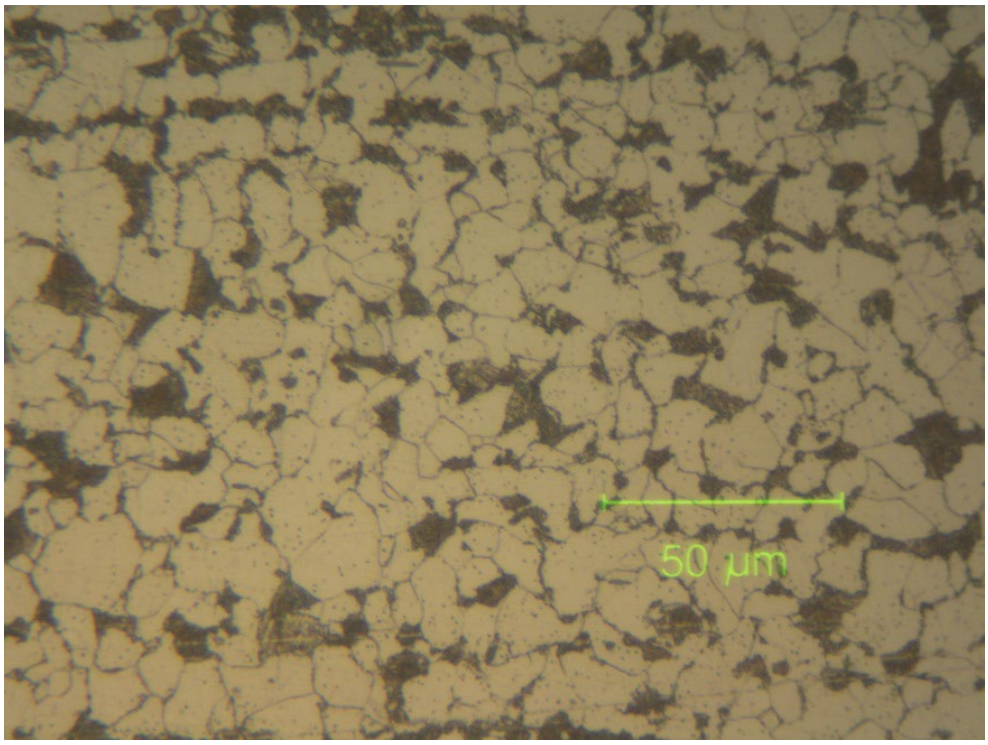

Figure A-2: Weld Micro Examination - Penstock 3

Vickers Hardness

Vickers hardness testing (HV10) using a 10-kg test load according to ASTM E3-11, was completed on the specimen. Three rows were tested according to ASTM E92-16 standards. Hardness values in these regions are stated below:

- Base Metal: 160 to 182 HV10
- HAZ: 183 to 223 HV10
- Weld: 183 to 201 HV10

Weld Tensile Results

Two specimens were sectioned and removed transverse to the weld in the sample using ASTM A370 specifications. The specimens were tested on a calibrated instron 8800 tensile machine with both resulting in a ductile fracture in the parent material. The numerical results are noted in the table below.

Table A-2: Tensile Tests Results - Penstock 3 Coupon

Sample	Area (in^2)	Load (lbs)	UTS (ksi)	Type of Fracture	Location
T1	0.429	31 880	74.3	Ductile	Parent
T2	0.422	34 510	81.8	Ductile	Parent

Weld / Base Metal Chemical Analysis

A sample from both the plate and weld metal were analyzed using a conventional ICP instrument following ASTM D1976 Standard to determine the metal's chemistry. The material was found to be plain carbon steel with no significant amounts of nickel, chromium or molybdenum. The table summarizes both plate and weld metal chemistry in comparison with ASTM A612 and A285 standards.

Table A-3: Penstock No. 3 Coupon Chemical Analysis

Elements	Chemical Composition (%wt.)			
	Plate Metal	Weld Metal	ASTM A612	ASTM A285
Carbon	0.15	0.1	0.25 Max	0.28 Max
Nickel	0.02	0.02	Trace	-
Sulphur	0.023	0.021	0.05 Max	0.035 Max
Chromium	0.02	0.02	Trace	-
Aluminum	Trace	Trace	Trace	-
Copper	0.03	0.06	0.35 Max	-
Manganese	1.41	1.49	1.00-1.50	0.98 Max
Molybdenum	Trace	0.01	Trace	-
Silicon	0.44	0.40	0.15-0.50	-
Phosphorus	0.021	0.024	0.04 Max	0.035 Max

The plate sample is not consistent with the chemical requirements of ASTM A285. The manganese content found exceeds the max %wt, and the levels of silicon exceed that of

A285 as well. Based on the report, the chemical composition indicates it is more suited towards the ASTM A612 standard.

Charpy Impact Testing

Twelve charpy specimens were machined from the welded plate to meet dimensional requirements of ASTM A370. The specimens were cut transversely to the weld with notch for testing perpendicular to the top and bottom surfaces of the plate. The specimens were chilled in a bath for at least 10 minutes to obtain a test temperature of -20°C. The bath was monitored and calibrated with a digital thermometer along with the charpy impact machine verified as per ASTM E23. The testing was completed on full size charpy impact specimens (10mm x 10mm), which can be seen in the table below.

Table A-4: Penstock No. 3 Coupon – Charpy Impact Testing Results

RPC ID	Notch Location	Test Temperature (°C)	Energy Absorbed		Average Energy Absorbed Ft-lbs (Joules)
			Ft - lbs	Joules	
2315	WC	-20	12	16.2	11.6 ft-lbs (15.8 J)
2316	WC	-20	11	14.9	
2317	WC	-20	12	16.2	
2318	FL	-20	13	17.6	12.1 ft-lbs (16.5 J)
2319	FL	-20	10	13.6	
2320	FL	-20	13.5	18.3	
2321	FL +2	-20	75	101.7	60.5 ft-lbs (82 J)
2322	FL +2	-20	71	96.2	
2323	FL +2	-20	35.5	48.1	
2324	FL +5	-20	71.5	96.9	68.8 ft-lbs (93.4 J)
2325	FL +5	-20	67	90.8	
2326	FL +5	-20	68	92.2	

Where:

- WC = Weld Center
- FL = Fusion Line of Weld
- FL+2 = Fusion Line +2 mm FL+5 = Fusion Line +5 mm

A standard consumable used for welding of steels for Penstocks No. 1, 2, and 3 during the timeframe of construction would be that of the SMAW E6010/6011 or E7018. A typical impact energy value of ASTM A285 Grade C and a E6010/6011 or E7018 would produce a minimum average impact energy of 27 J at -20°C. Given that the base metal sample is suspected to be of a higher grade of steel, the impact energies for the FL+2 and FL+5 appear to be reasonable. However, the weld metal and HAZ samples produced below average impact energies.

A.2.2 Penstock No. 1 and No. 3 Mechanical Testing Comparison

RPC indicates the coupon analyzed from Penstock No. 3 to be most consistent with ASTM A612. Of the three coupons taken from Penstock No. 1, the CSA G40.8B coupon is most mechanically similar to the ASTM A612. The report conducted by RPC compared the Penstock No. 3 sample to the ASTM A285 standard whereas the results and drawings align with the CSA G40.8 Gr. B standard. The mechanical testing for 2016 was conducted by Cambridge Materials (Mississauga, Ontario). For more accurate and comparable results, it would be beneficial to conduct all mechanical testing at the same facility (reduce lab error), have the same format of testing completed on all samples.

Microstructural

Samples were prepared for microstructural examination and the Penstock No. 1 coupon was etched using a 2% Nital solution whereas Penstock No. 3 used a 5% Nital solution. The micrograph of the Penstock No. 3 coupon was completed on the base metal and shows a fine grain low carbon steel with few inclusions. The Penstock No. 1 coupon micrograph was completed on the fusion line (FL) and FL+1mm locations noting some sulphide inclusions present dispersed throughout the material and a HAZ with a refined and relatively coarse grain structure.

Vickers Hardness

The table below compares the hardness values obtained from the two separate samples in Penstock No. 1 along with the recent RPC test results for Penstock No. 3.

Table A-5: Vickers Hardness Results

Vickers Number	Penstock 1 Sample – ASTM A285			Penstock 3 Sample			Penstock 1 Sample – CSA G40.8 Gr B		
	Base Metal	HAZ	Weld Metal	Base Metal	HAZ	Weld Metal	Base Metal	HAZ	Weld Metal
Low	130	121	153	160	183	183	174	168	170
High	158	158	181	182	223	201	185	214	214

It can be noted that the Penstock No. 3 hardness test results correlate best with the Penstock No. 1 CSA G40.8B hardness numbers (right section of table).

Weld Tensile

The tensile test results below show a comparative summary between the 2016 samples for penstock 1 and 2018 samples for penstock 3.

Table A-6: Tensile Test Results

Sample	UTS (ksi)	Type of Fracture	Location	Standard Range (ksi)
Penstock 3 T1 (A612)	74.3	Ductile	Parent	81-101
Penstock 3 T2 (A612)	81.8	Ductile	Parent	81-101
Penstock 1 CSA G40.8 Gr B	84.5	Ductile	Parent	65-85
Penstock 1 ASTM A285	63.5	Ductile	Parent	55-75

RPC indicated the chemical analysis for the Penstock No. 3 coupon is most consistent with ASTM A612. Comparing the tensile test results with the A612 standard, the tensiles are slightly lower than standard.

A.2.3 Laser Scan and Inverts

The laser surveys of the interior of the penstocks was used to determine the interior shape of the penstock and confirm the level of peaking present. The results for each of the penstocks, was used to compare the level of deviation in ovality as shown in Table A-7. Table A-8 compares the level of peaking found at the welds as an average for all three Penstocks. Through analysis of the data, the location of the maximum and minimum weld deviation around the penstock for each section was noted and can be seen in Tables A-9 to A-11. Zero degrees was taken at the top of the penstock and continued clockwise around the penstock. Since the laser scan inspection completed by All North was only taken from the surge tank downward, Penstock 1 was only compared using this section.

Table A-7: Deviation in Penstock Ovality Comparison

	Location (m)	Length of Section (m)	# of Chainages in Section	Overall Average Deviations (mm)	Average Min. Deviation (mm)	Average Max. Deviation (mm)
Section 1	0.00-101.4 0.00-119.47	101.4 119.47	6 10	-3.96	-29.83	23.03
Section 2	101.4-200.49 119.47-244.53	99.09 125.06	3 8	-2.67	-25	35.04
Section 3	200.49-341.15 244.53-382.31	140.66 137.78	5 7	-2.18	-48.2	36.09
Section 4	341.15-433.65 382.31-492.46	92.5 110.15	3 5	-3.49	-60.33	30.68
Section 5	433.65-629.8 492.46-692.41	196.15 200.01	8 7	-4.43	-41.63	16.57
Section 6	692.41-953.37 628.8-889.64 692.41-953.37	260.96 260.84 260.96	12 9 9	-1.37	-16.79	17.11
Section 7	953.37-1163.48 889.64-1128.00 953.37-1163.48	210.11 238.36 210.11	11 10 6	-1.09	-35.32	20.40

Penstock 1
Penstock 2
Penstock 3

Table A-8: Peaking at Welds Comparison Across Penstocks No. 1, 2, and 3

	North Welds			South Welds		
	Average Peaking(mm)	Max. peak (mm)	Min. peak (mm)	Average Peaking (mm)	Max. peak (mm)	Min. peak (mm)
Section 1	5.1	60	-17	5.4	41	-23
Section 2	13.0	36	-6	16.8	56	-19
Section 3	6.8	29	-23	3.2	31	-30
Section 4	-2.4	28	-67	-4.8	17	-46
Section 5	1.7	24	-31	-2.1	18	-28
Section 6	3.7	35	-15	5.2	20	-12
Section 7	9.3	35	-21	7.6	27	-7

Table A-9: Penstock 1: Location of Max. and Min. Weld Deviation

Penstock 1						
	Approximate Location of Max. Deviation (deg.)	Chainage that had Max. Deviation	Max. Deviation (mm)	Approximate Location of Min. Deviation (deg.)	Chainage that had Min. Deviation	Min. Deviation (mm)
Section 1						
Section 2						
Section 3						
Section 4						
Section 5						
Section 6	99	HZ Chainage 54.96	27.07	186.75	HZ Chainage 54.96	-30
Section 7	274.5	HZ Chainage 264.18	34.94		HZ Chainage 416.74	-86.78

Table A-10: Penstock 2: Location of Max. and Min. Weld Deviation

	Penstock 2					
	Approximate Location of Max. Deviation (deg.)	Chainage that had Max. Deviation	Max. Deviation (mm)	Approximate Location of Min. Deviation (deg.)	Chainage that had Min. Deviation	Min. Deviation (mm)
Section 1	261	HZ Chainage 43.17	60	165.5	HZ Chainage 73.46	-33
Section 2	60	HZ Chainage 180.70	26	201	HZ Chainage 180.70	-40
Section 3	69	HZ Chainage 233.35	53	349	HZ Chainage 208.53	-71
Section 4	278.5	HZ Chainage 346.11	50	177	HZ Chainage 346.11	-88
Section 5	293	HZ Chainage 629.68	27	161.5	HZ Chainage 469.96	-83
Section 6	78	HZ Chainage 705.21	21	178	HZ Chainage 867.23	-32
Section 7	288	HZ Chainage 1087.76	45	180	HZ Chainage 1087.76	-62

Table A-11: Penstock 3: Location of Max. and Min. Weld Deviation

	Penstock 3					
	Approximate Location of Max. Deviation (deg.)	Chainage that had Max. Deviation	Max. Deviation (mm)	Approximate Location of Min. Deviation (deg.)	Chainage that had Min. Deviation	Min. Deviation (mm)
Section 1	66	HZ Chainage 77.08	41.22	202.5	HZ Chainage 92.01	-48.86
Section 2	90	HZ Chainage 167.06	55.88	187	HZ Chainage 181.71	-51.04
Section 3	259	HZ Chainage 247.77	51.64	337.5	HZ Chainage 247.77	-47.8
Section 4	255	HZ Chainage 428.21	27.93	183	HZ Chainage 401.94	-51.97
Section 5	100.5	HZ Chainage 550.90	26.62	180	HZ Chainage 591.11	-48.82
Section 6	254	HZ Chainage 889.95	25.25	171.5	HZ Chainage 889.95	-61.75
Section 7	288.5	HZ Chainage 1066.55	32.7	181.5	HZ Chainage 1066.55	-94.63

Appendix B
Penstock Refurbishment Statistics

B.1 Weld Statistics

Table B-1: Longitudinal Weld Statistics - Penstock 1

Item	Description	Number	Units
1	2016 Total Seams Repaired/Refurbished	346	Count
2	2016 South Seams Repaired/Refurbished	173	Count
3	2016 North Seams Repaired/Refurbished	173	Count
4	2017 Longitudinal Seams Repaired/Refurbished	31	Count
5	Repaired/Refurbished 2016 – Inspected 2017 Internal Longitudinal Seams with Defects	29	Count
6	2017 Welds Showing Defects from Original Construction	2	Count
7	2017 South Internal Seams Repaired/Refurbished	10	Count
8	2017 North Internal Seams Repaired/Refurbished	21	Count
9	2018 Internal Seams Not Inspected	678	Count
10	2018 Total Seams Repaired/Refurbished	1	Count
11	2018 Inspection Passed on Refurbished Welds	46	Count
12	2018 Inspection Passed on Original Welds	28	Count
13	Seam Total (Intake to Powerhouse)	870	Count
14	Approximate Visual (VT) and Magnetic Particle (MT) Length 2018	1098	ft
15	Approximate Seam Repair/Refurbishment Length 2017	279	ft
16	Approximate Seam Repair/Refurbishment Length 2016	3114	ft
17	Approximate 2016 Repair/Refurbishment Vs Total Penstock	39.77	%
18	Approximate 2017 Repair/Refurbishment Vs Total Penstock	3.56	%
19	2017 Defects on 2016 Welds	8.38	%
20	2018 defects on 2017 Welds	0.00	%
21	2018 defects on Original Weld	1.52	%

Table B-2: Longitudinal Weld Statistics - Penstock 2

Item	Description	Number	Units
1	2017 Longitudinal Seams Repaired/Refurbished	182	Count
2	2017 Welds Showing Defects from Original Construction	182	Count
3	2017 South Internal Seams Repaired/Refurbished	91	Count
4	2017 North Internal Seams Repaired/Refurbished	91	Count
5	2018 Internal Seams Not Inspected	384	Count
6	2018 Total Seams Repaired/Refurbished	2	Count
7	2018 Total North Seams Repaired/Refurbished	2	Count
8	2018 Total South Seams Repaired/Refurbished	0	Count
9	2018 Inspection Passed on Refurbished Welds	18	Count
10	2018 Inspection Passed on Original Welds	98	Count
11	Seam Total (Intake to Powerhouse)	870	Count
12	Approximate Visual (VT) and Magnetic Particle (MT) Length 2018	702	ft
13	Approximate Seam Repair/Refurbishment Length 2017	2492	ft
14	2017 defects on Original Welds	21	%
15	2018 defects on 2017 Welds	0.00	%
16	2018 defects on Original Weld	2.30	%

Table B-3: Longitudinal Weld Statistics - Penstock 3

Item	Description	Number	Units
1	2018 Internal Seams Not Inspected	347	Count
2	2018 Total Seams Repaired/Refurbished	390	Count
3	2018 Total South Seams Repaired/Refurbished	192	Count
4	2018 Total North Seams Repaired/Refurbished	198	Count
5	2018 Inspection Passed on Refurbished Welds	0	Count
6	2018 Inspection Passed on Original Welds	171	Count
7	Seam Total (Intake to Powerhouse)	870	Count
8	Approximate Seam Repair/Refurbishment Length 2018	3369	ft
9	2018 defects on Original Weld	48.75	%

Appendix C
Penstock Condition Assessment Trackers

Date: July 16th 7:30

PENSTOCK 1 WELD PROGRESS TRACKER

| | | |

Date: 3/28/2019
Rev: E

PENSTOCK 2 WELD PROGRESS TRACKER

| | | |

Date: June 24, 2018

PENSTOCK 3 WELD PROGRESS TRACKER

Intake

CAN#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
South	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP

Doorsheet #1 Location

Doorsheet #2 Location

Tested Seams

Tested Seams

Tested Seams

Appr

CAN#	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
South	FP	FP	FP	FP	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP

Tested Seams

Doorsheet #3 Location

CAN #	121	122	123	124	125	126	127	128	129	130	131	132	132b	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
North	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	FP	FP	FP	FP	FP	FP	FP	NI	NI	FP	FP	NI	NI	FP	NI	FP	NI	FP	NI	FP	NI	FP	FP	FP	NI	FP	FP	FP	NI	FP	FP	FP	NI	NI	NI	NI	NI	FP	NI	NI	FP	FP	NI	NI	NI	NI
South	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	FP	FP	FP	FP	FP	NI	NI	NI	FP	NI	NI	NI	FP	NI	NI	NI	NI	NI	FP	FP	NI	FP	FP	NI	NI	NI	NI	NI	FP	FP	FP	NI	FP	NI	FP	NI	NI	NI	NI	NI	NI	NI	NI	NI

Approx. Manway #2 Location

Surge Tank

CAN #	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
North	NI	NI	NI	NI	NI															NI	NI	NI	NI	NI	FP	NI	NI	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	FP	FP	NI	NI	NI	NI	NI	NI			NI	NI					CH	
South																NI				NI	NI	NI	NI	NI	FP	FP	NI	FP	FP	FP	FP	FP	NI	FP	FP	NI	FP	NI	FP	FP	NI	FP	FP	FP	FP	NI	NI	NI	NI	NI	NI	NI								

CAN#	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
North							NI								NI													NI	NI								NI					NI				NI					NI		NI	NI	NI	NI	NI	NI	NI	NI
South						NI										NI									NI	NI																				CH	NI	NI	NI	NI	NI									

CAN#	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
North	NI		FP	FP	FP	FP	NI	NI	NI	FP	NI	FP	FP	FP	FP	FP	FP	NI	FP	FP	FP	NI	FP	NI	NI	FP	FP	NI	FP	FP	FP	FP	FP	NI	FP	NI	NI	FP	NI	FP	NI	FP		NI		NI	NI	NI	NI	NI		NI	NI			NI			
South	NI	FP		NI	NI	NI	FP	FP	FP	FP	NI	NI	FP	FP	FP	FP	FP	FP	FP	FP	FP	NI	NI	NI	NI	FP	FP	FP	FP	FP	NI	FP	NI	FP	FP	FP	FP	NI	NI	FP	NI	FP		NI		NI	NI	NI	NI	NI									

Legend		
NI	=	No Indications
CH	=	Chipped
G	=	Gouged
P	=	Weld Preperation Complete
1P	=	First Inspection Passed
W	=	Welded
PIP	=	Preliminary Inspection Pass
FP	=	Final Inspection Passed
FF	=	Final Inspection Failed

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BAY D'ESPOIR
PENSTOCK 3 INSPECTION TRACKER

Date: June 21, 2018

| | | |

Appendix D
Cost Tables

Estimate - Refurbishment BDE
Price Per 3 Penstocks

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	3000	m3	$20					$60,000	
2	**Welding / Labour**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	All in Rates from previous penstock repair
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	900	m	$2,000					$1,800,000	All in Rates from previous penstock repair
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	All in Rates from previous penstock repair
2.4		Welding repair of circumferential weld seams - Penstock No. 1	3000	m	$2,000					$6,000,000	All in Rates from previous penstock repair
2.5		Welding repair of circumferential weld seams - Penstock No. 2	3000	m	$2,000					$6,000,000	All in Rates from previous penstock repair
2.6		Welding repair of circumferential weld seams - Penstock No. 3	3000	m	$2,000					$6,000,000	All in Rates from previous penstock repair
2.7		Removal of doorsheets for entry (6 each)	18			10	$100		4	$72,000	
2.8		Re-installation of removed doorsheets (6 each)	18			10	$150		4	$108,000	
2.9		Safety personnel / rescue attendants - Penstock 1								$130,000	
2.10		Safety personnel / rescue attendants - Penstock 2								$130,000	
2.11		Safety personnel / rescue attendants - Penstock 3								$60,000	
3	**Blast / Recoat**										
3.1		Blast to bare metal and recoat penstock interior		3	$3,000,000					$9,000,000	
3.2											
4	**Mobilization**										
4.1		Mobilization / Demobilization was estimated at 10% of the total.								$3,201,000	
5	**EPCM**										
5.1		EPCM costs were estimated at 10% of the total.								$3,201,000	
6	**Contingency**										
6.1		Contingency was estimated at 20% of the total.								$6,402,000	
7	**Total**									**$44,814,000**	

Estimate - Replacement BDE

Price per 1 Penstock

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	25000	m3	$20					$500,000	
2	**Welding / Labour**										
2.1		Replacement steel for each Penstock (fab and shipping)	2700	tonnes	$8,000					$21,600,000	
2.2		Safety personnel and rescue attendants	40	days		10	$100		2	$80,000	
2.3		Cranes	200	days	$2,500					$500,000	
2.4		Site Labour	200	days		10	$150		15	$4,500,000	
2.5		Reinforcing Steel	125	tonnes	$8,000					$1,000,000	
2.6		Install reinforcing steel								$187,500	
2.7		Demo of existing Penstock								$1,000,000	
4	**Blast / Recoat**										
4.1		Coating Penstock Internal and External	1							$5,000,000	
5	**Mobilization**										
5.1		Mobilization / Demobilization was estimated at 10% of the total.								$3,436,750.00	
6	**EPCM**										
6.1		EPCM costs were estimated at 10% of the total.								$3,436,750.00	
7	**Contingency**										
7.1		Contingency was estimated at 20% of the total.								$6,873,500.00	
8	**Total**									$48,114,500	

Estimate - Replacement BDE - Replace 17' ID and Refurb the rest
Price per 3 Penstock

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	5000	m3	$20					$300,000	
2	**Welding / Labour**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	All in Rates from previous penstock repair
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	725	m	$2,000					$1,450,000	All in Rates from previous penstock repair
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	All in Rates from previous penstock repair
2.4		Welding repair of circumferential weld seams - Penstock No. 1	2000	m	$2,000					$4,000,000	All in Rates from previous penstock repair
2.5		Welding repair of circumferential weld seams - Penstock No. 2	2000	m	$2,000					$4,000,000	All in Rates from previous penstock repair
2.6		Welding repair of circumferential weld seams - Penstock No. 3	2000	m	$2,000					$4,000,000	All in Rates from previous penstock repair
2.7											
2.8		Replacement steel for each Penstock (all in cost) - 17' ID	665	tonnes	$8,000				3	$15,960,000	
2.9		Safety personnel and rescue attendants	50	days		10	$100		2	$300,000	
2.10		Cranes	75	days	$1,000					$225,000	
2.11		Site Labour	75	days		10	$150		15	$5,062,500	
2.12		Demo of existing Penstock (135 cans)							3	$900,000	
3	**Blast / Recoat**										
3.1		Coating Penstock Internal and External (17') + internal for remainder	3							$9,630,000	
4	**Mobilization**										
4.1		Mobilization / Demobilization was estimated at 10% of the total.								$4,847,750.00	
5	**EPCM**										
5.1		EPCM costs were estimated at 10% of the total.								$4,847,750.00	
6	**Contingency**										
6.1		Contingency was estimated at 20% of the total.								$9,695,500.00	
7	**Total**									**$67,868,500**	

Estimate - FRP BDE
Price per 3 Penstocks

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	3000	m3	$20					$60,000	
1.2											
2	**Welding**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	900	m	$2,000					$1,800,000	
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	
2.4		Welding repair of circumferential weld seams - Penstock No. 1	3000	m	$2,000					$6,000,000	
2.5		Welding repair of circumferential weld seams - Penstock No. 2	3000	m	$2,000					$6,000,000	
2.6		Welding repair of circumferential weld seams - Penstock No. 3	3000	m	$2,000					$6,000,000	
2.7		Removal of doorsheets for entry (6 each)	18			10	$100		4	$72,000	
2.8		Re-installation of removed doorsheets (6 each)	18			10	$150		4	$108,000	
2.9		Safety personnel and rescue attendants [x3 Penstocks]	30	days		10	$100		2	$180,000	
3	**Blast / Recoat**										
3.1		Water blasting to bare metal	15830	m2	$25				3	$3,561,750	
3.2		FRP Liner		1					3	$46,500,000	
4	**Mobilization**										
4.1		Mobilization / Demobilization was estimated at 10% of the total.								$7,293,175.00	
5	**EPCM**										
5.1		EPCM costs were estimated at 10% of the total.								$7,293,175.00	
6	**Contingency**										
6.1		Contingency was estimated at 20% of the total.								$14,586,350	
7	**Total**									**$102,104,450**	

Estimate - Reinforce BDE
Price per 3 Penstock

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	3000	m3	$20					$60,000	
2	**Labour**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	900	m	$2,000					$1,800,000	
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	
2.4		Welding repair of circumferential weld seams - Penstock No. 1	3000	m	$2,000					$6,000,000	
2.5		Welding repair of circumferential weld seams - Penstock No. 2	3000	m	$2,000					$6,000,000	
2.6		Welding repair of circumferential weld seams - Penstock No. 3	3000	m	$2,000					$6,000,000	
2.7		Removal of doorsheets for entry (6 each)	18			10	$100		4	$72,000	
2.8		Re-installation of removed doorsheets (6 each)	18			10	$150		4	$108,000	
2.9		Install interior reinforcing								$1,327,500	
2.10		Conduct roundness correction on Penstock	1200	can		10	$100		3	$10,800,000	
2.11		Safety personnel and rescue attendants [x3 Penstocks]	30	days		10	$100		2	$180,000	
3	**Material**										
3.1		Installation of steel reinforcing plates (x3 Penstocks)	885	tonnes	$8,000				3	$21,240,000	
4	**Blast / Recoat**										
4.1		Blast to bare metal and recoat penstock interior	1						3	$9,000,000	
5	**Mobilization**										
5.1		Mobilization / Demobilization was estimated at 10% of the total.								$6,523,750.00	
6	**EPCM**										
6.1		EPCM costs were estimated at 10% of the total.								$6,523,750.00	
7	**Contingency**										
7.1		Contingency was estimated at 20% of the total.								$13,047,500	
9	**Total**									**$91,332,500**	

Estimate - Steel Liner BDE
Price per 3 Penstock

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	9000	m3	$20					$180,000	
2	**Labour / Materials**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	900	m	$2,000					$1,800,000	
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	
2.4		Welding repair of circumferential weld seams - Penstock No. 1	3000	m	$2,000					$6,000,000	
2.5		Welding repair of circumferential weld seams - Penstock No. 2	3000	m	$2,000					$6,000,000	
2.6		Welding repair of circumferential weld seams - Penstock No. 3	3000	m	$2,000					$6,000,000	
2.7		Cranes	200	days	$1,000				3	$600,000	
2.8		Liner steel (all in cost)	1800	tonnes	$8,000	10	$150			$51,300,000	
2.9		HSS reinforcing (all in cost)	35	tonnes	$8,000				3	$840,000	
2.10		Jacking / Steel Placement Cost	200	days		10	$100		3	$1,800,000	
2.11		Rescue/Safety	200	months		10	$100		2	$1,200,000	
3	**Water Blast / Recoat**										
3.1		Coating steel liner internal	15830	m2	$150				3	$7,123,500	
4	**Mobilization**										
4.1		Mobilization / Demobilization was estimated at 10% of the total.								$8,549,350.00	
5	**EPCM**										
5.1		EPCM costs were estimated at 10% of the total.								$8,549,350.00	
6	**Contingency**										
6.1		Contingency was estimated at 20% of the total.								$17,098,700	
7	**Total**									**$119,690,900**	

Estimate - Steel Liner + Grouting BDE
Price per 3 Penstock

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	3000	m3	$20					$60,000	
2	**Labour / Materials**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	900	m	$2,000					$1,800,000	
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	
2.4		Welding repair of circumferential weld seams - Penstock No. 1	3000	m	$2,000					$6,000,000	
2.5		Welding repair of circumferential weld seams - Penstock No. 2	3000	m	$2,000					$6,000,000	
2.6		Welding repair of circumferential weld seams - Penstock No. 3	3000	m	$2,000					$6,000,000	
2.7		Cranes	600	days	$1,000					$600,000	
2.8		Liner steel (all in cost)	1800	tonnes	$8,000	10	$150			$51,300,000	
2.9		HSS reinforcing (all in cost)	105	tonnes	$8,000					$840,000	
2.10		Concrete Cost	225	m3	$2,250					$1,518,750	
2.11		Jacking / Steel Placement Cost	200	days		10	$100		3	$1,800,000	
2.12		Rescue/Safety	200	months		10	$100		2	$1,200,000	
3	**Water Blast / Recoat**										
3.1		Coating steel liner internal	47490	m2	$150					$7,123,500	
4	**Mobilization**										
4.1		Mobilization / Demobilization was estimated at 10% of the total.								$8,689,225.04	
5	**EPCM**										
5.1		EPCM costs were estimated at 10% of the total.								$8,689,225.04	
6	**Contingency**										
6.1		Contingency was estimated at 20% of the total.								$17,378,450	
7	**Total**									**$121,649,150**	

Estimate - ConcreteEncasement
Price per 3 Penstock

No.		Description	Quantity	Unit	$/Unit	Hours	$/Hour	Material Cost	Labour Cost	Cost	Comments
1	**Excavation**										
1.1		Excavation and backfill re-instatement of buried Penstock	480000	m3	$20					$9,600,000	
2	**Labour / Materials**										
2.1		Welding repair of longitudinal weld seams - Penstock No. 1	675	m	$2,000					$1,350,000	
2.2		Welding repair of longitudinal weld seams - Penstock No. 2	900	m	$2,000					$1,800,000	
2.3		Welding repair of longitudinal weld seams - Penstock No. 3	650	m	$2,000					$1,300,000	
2.4		Welding repair of circumferential weld seams - Penstock No. 1	3000	m	$2,000					$6,000,000	
2.5		Welding repair of circumferential weld seams - Penstock No. 2	3000	m	$2,000					$6,000,000	
2.6		Welding repair of circumferential weld seams - Penstock No. 3	3000	m	$2,000					$6,000,000	
2.7		Removal of doorsheets for entry (6 each)	18			10	$100		4	$72,000	
2.8		Re-installation of removed doorsheets (6 each)	18			10	$150		4	$108,000	
2.9		Cranes	200	days	$1,000					$600,000	
2.10		Concrete (all in cost)	6500	m3	$2,250					$43,875,000	
2.11		Reinforcing Steel	125	tonnes	$8,000					$3,000,000	
2.12		Install reinforcing steel								$562,500	
2.13		Rescue/Safety	200	months		10	$100		2	$1,200,000	
3	**Water Blast / Recoat**										
3.1		Coating steel liner internal	15830	m2	$150				3	$7,123,500	
4	**Mobilization**										
4.1		Mobilization / Demobilization was estimated at 10% of the total.								$8,859,100.00	
5	**EPCM**										
5.1		EPCM costs were estimated at 10% of the total.								$8,859,100.00	
6	**Contingency**										
6.1		Contingency was estimated at 20% of the total.								$17,718,200	
7	**Total**									**$124,027,400**	

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Schedule 1, Attachment 4

Final Report for Penstock No.'s 1, 2 and 3 Life Extension Options

Hatch Ltd.

July 26, 2019

newfoundland labrador hydro

HATCH

Newfoundland and Labrador Hydro

Final Report

For

Penstock No.'s 1, 2 and 3 Life Extension Options

H357395-00000-240-066-0003
Rev. 0
July 26, 2019

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Newfoundland and Labrador Hydro

Final Report

For

Penstock No.'s 1, 2 and 3 Life Extension Options

H357395-00000-240-066-0003
Rev. 0
July 26, 2019

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Penstock No.'s 1, 2 and 3 Life Extension Options

H357395-00000-240-066-0003

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HATCH LTD
MIRC #: 01626
To practice Professional Engineering
in Newfoundland and Labrador.
Permit No. as issued by PEG D0090
which is valid for the year 2019

REGISTERED PROFESSIONAL ENGINEER
ANTHONY CHISLETT
SIGNATURE
26-07-2019
DATE
NEWFOUNDLAND & LABRADOR

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Executive Summary

Newfoundland and Labrador Hydro (NL Hydro) engaged Hatch to conduct a condition assessment of Penstock No.'s 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. Due to the nature of the 2018 outage schedule and NL Hydro's reporting requirements for items such as winter readiness and capital budget applications, the Condition Assessment report was developed in three phases, as shown below.

Report 1 – Bay d'Espoir Level II Condition Assessment of Penstock No.'s 1, 2 and 3.

Report 2 – Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2 and 3.

Report 3 – Penstock No.'s 1, 2 and 3 Life Extension Options.

All three penstocks were inspected as part of a Level II Condition Assessment. Inspections and data collection included: detailed weld inspection, material testing, 3D scanning and water pressure monitoring.

The weld inspections consisted of, at a minimum, pressure washing, buffing, visually inspecting and magnetic particle inspection of the longitudinal welds at a frequency of 1 in every 10 cans for the total penstock length. The overview of the inspections consists of the following:

- Penstock No. 1 was inspected from August 13 to 24, 2018. Refurbished welds completed in 2016 and 2017 show no sign of additional degradation.
- Penstock No. 2 was inspected from September 17 to 28, 2018. Refurbished welds completed in 2017 show no sign of degradation.
- Penstock No. 3 was inspected from May 14 to June 21, 2018. This was the first detailed inspection carried out and extensive weld metal corrosion and cracking was discovered, similar to what was found during the earlier inspections of Penstocks No. 1 and No. 2 in 2016 and 2017. Approximately 1027 m (3369 ft) of internal weld refurbishment was completed on Penstock No. 3 in 2018.

Material samples were removed from Penstock No. 3 to determine the grade of steel and compare with samples removed from Penstock No. 1.

Laser scans were completed to create a more accurate 3D model of the penstock geometry. The data showed similar peaking in all three penstocks and consequently the FEA model results for Penstock No. 1 can be extrapolated to the similarly constructed Penstock No. 2 and No. 3. This geometric data is also valuable for future use should NL Hydro wish to review the penstocks for geometric changes, such as settlement.

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In conjunction with the laser scans, pressure transducers were installed at key locations on all three penstocks and connected to a data logging device to assess any internal pressure transients. Data collection is currently on-going, and this data will be analyzed and compared to data obtained in 2017 on Penstock No. 1. To provide meaningful analysis, data collection needs to take place over a longer period of time, so trends can be observed. This data collection should continue until a life extension option is implemented for Penstock No.'s 1, 2, and 3. Hatch will provide a preliminary commentary based on the ongoing data collection. This data and analysis will be presented in a standalone document at a later date, however, this information is not expected to impact any of the findings or recommendations contained in this report.

The penstocks have been in service for approximately 50 years. These are aging assets and as such require regular inspection and maintenance. To ensure the reliable long-term operation of these assets, refurbishment is required. This report details the refurbishment options that were chosen by NL Hydro for further analysis by Hatch.

Three life extension options were reviewed in this report for the purpose of further analysis and comparison of life extension options for the penstocks' refurbishment. A more detailed consideration of cost estimates suggest full weld refurbishment and application of a corrosion resistant coating is the suggested option for the rehabilitation of the penstocks.

The cost estimates for the weld refurbishment option (Option 1) are in the range of $25M to $30M per penstock.

The estimated costs are heavily influenced by the total length of the circumferential seams. To be conservative Hatch estimated 50 percent of all remaining seams require refurbishment. For example, the 17 foot section has a circumferential length of approximately 53 feet of which about of a third of the inspection, gouging and welding would be in the most difficult, overhead, position. NL Hydro could improve the accuracy of the estimates and possible reliability of the system with more detailed inspection of the circumferential seams.

With adequate maintenance of the coating systems, full replacement and installation of a new penstock can have an estimated design life of approximately 80 years. Hatch estimates the refurbishment options that include replacement of the interior coating will provide an additional life extension of at least 40 years provided there is no breakdown of the internal or external coating system.

Based on the current operational history, refurbishments and current operating procedures, it was Hatch's opinion the penstock's current condition will provide uninterrupted service through the 2019 winter season. This proved to be correct as no service interruptions occurred during the 2018-2019 winter season. Hatch recommends annual inspection of the penstocks should continue until a life extension program is implemented within the next 3- 5 years, as detailed elsewhere within this report.

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1. Introduction

NL Hydro engaged Hatch to conduct a Level II Condition Assessment of Penstocks No.'s 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. The findings from the condition assessment will ensure the penstocks are in reliable operating condition for the 2019 production season and will assist in verifying penstock life extension refurbishment options.

The contents of this report builds on the initial refurbishment/replacement analysis provided in the previous report; providing more detail into the three selected refurbishment/replacement options NL Hydro selected for further analysis. Due to the time intensive nature of inspection, data collection, analysis and refurbishment option evaluations, this work was completed in three phases each of which has had a report issued upon its completion. This third report completes the third phase of the work and provides further details on three refurbishment options chosen by NL Hydro for further analysis by Hatch. The following are the three report titles.

- Report 1 – Bay d'Espoir Level II Condition Assessment of Penstock No.'s 1, 2 and 3.
- Report 2 – Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2 and 3.
- Report 3 – Penstock No.'s 1, 2 and 3 Life Extension Options.

The Bay d'Espoir Hydroelectric Generating Facility is comprised of four buried penstocks, three of which are connected to the main powerhouse containing six generating units. Each penstock bifurcates near the powerhouse to feed each unit through separate spherical valves. Units No.1 and No. 2 along with Penstock No. 1 were built in 1967. Units No. 3 and No. 4 along with Penstock No. 2 were built shortly after in 1968. The final addition to Powerhouse No.1 was completed in 1969 and consisted of the installation of generation Units No. 5 and No. 6 as well as Penstock No. 3. The penstocks run approximately 1,200 m (3,900 ft) in length and are constructed from a series of carbon steel cans[1] that vary in length, diameter and thickness.

The purpose of this report is to provide a more thorough review of the life extension options recommended for the penstock repair/refurbishment that were provided in Report 2 "Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2 and 3" issued in the first quarter of 2019. The AACE Class 4 cost estimates included in this report are based on recent pricing information received from local construction companies, some of whom were involved with the refurbishment work on Penstock No.'s 1, 2, and 3.

[1] Lengths of penstock that are approximately 2.74 m (9 ft) long and constructed of two hemispheres of rolled plates longitudinally welded together to form a circumference.

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To make this report more concise, the following sections that were included in Report 2 – Condition Assessment and Refurbishment Options for Penstock No. 1, 2 and 3, have not been included in this report:

- Condition Assessment Methodology
- Penstock Inspections and Refurbishments
- Finite Element and Fatigue Analysis
- Current Condition and Life Expectancy

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2. Refurbishment or Replacement Options

Refurbishment or replacement options were investigated for each penstock. The options that NL Hydro has selected for Hatch's further review are as follows:

1. Refurbishment of deteriorated weld seams, both longitudinally and circumferentially, and re-coating the interior of the penstock (previously labelled Option 1 in Report 2 - H357395-00000-240-066-0002).
2. Replacement of penstock 17' ID section, weld refurbishment and recoating of the full penstock (previously labelled Option 2B in Report 2 - H357395-00000-240-066-0002).
3. Refurbishment of deteriorated weld seams, recoating of the entire penstock and installation of reinforcing plates over the longitudinal and circumferential weld seams of the 17 ft. section (previously labelled Option 4 in Report 2 - H357395-00000-240-066-0002).

The following options present varying degrees of life extension. Referencing published material from the American Society of Civil Engineers (ASCE), the design life of a steel penstock is normally in the range of 40-80 years with proper maintenance (ASCE, Guidelines for Evaluating Aging Penstocks). Since corrosion has been a major contributing factor relating to metal loss and in particular the welds, maintenance of a coating system is extremely important to the longevity.

Refurbishment options include replacement of the internal coating but not the external coating. Inspection of the external coating on Penstock No.'s 1, 2, and 3 from the brief sections that have been excavated during the penstock refurbishments and condition assessment have shown the coating is still intact. Additionally, wall thickness measurements were taken along the length of the penstock and showed no signs of metal loss due to external corrosion.

With adequate maintenance of the coating systems, full replacement and installation of a new penstock can have an estimated design life of approximately 80 years. Hatch estimates the refurbishment options that include replacement of the interior coating will provide an additional life extension of at least 40 years provided there is no breakdown of the internal or external coating system.

The AACE Class 4 cost estimates included in this report are based on recent pricing information received from a local construction companies, some of whom were involved with the refurbishment work on Penstock No.'s 1, 2 and 3. Additionally, information provided by local painting and fabrication companies were used to assist in the development of these cost estimates for the given options (supporting information can be found in Appendix A).

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2.1 Refurbishment and Re-coating of Existing Penstocks

The first refurbishment option investigated for life extension of the penstocks includes completion of the weld refurbishment that started in 2016. This will include full inspection of all seams, both longitudinal and circumferential, and refurbishment of all deteriorated seams (Note: all options with weld refurbishment used a 50 percent refurbishment rate of non-refurbished longitudinal seams, as well as a 50 percent refurbishment rate of all circumferential seams).

As identified in previous reports, the circumferential seams have not yet been refurbished for multiple reasons. The stress in the penstock due to internal pressure is twice that in the longitudinal seams versus the circumferential seams. Past refurbishments concentrated on the longitudinal seams due to the higher probability of failure resulting from the increased stress (as all failures were on longitudinal seams). Longitudinal seam refurbishment was the target to ensure timely return of service and safe operation given the planned condition assessment and monitoring of the penstocks. Preliminary inspection indicated the circumferential seams were not in as bad condition as that of the longitudinal seams. Hence, due to the lower risk and lower priority of the circumferential welds, thorough inspection of circumferential seams was not conducted at this time. Therefore, due to outage time available, location of failures, higher stress, and condition of longitudinal seams, only longitudinal seams were refurbished. However, life extension of the penstocks must remediate all areas that could produce a negative effect on the penstocks long term operation.

Refurbishment of all cracked or severely corroded welds is required to ensure that a newly applied coating is not compromised from poor weld seam condition. If cracks are present, it could lead to premature coating failure in those areas. If weld imperfections do not run deeper than 2mm, they can be eliminated by grinding out the defect with no additional welding required. However, if the weld defects are deeper than 2mm it is recommended the defect be removed and the weld be repaired to bring it to original condition.

Each circumferential seam in the 17-foot ID section is approximately 53.4 feet versus that of 18 feet of longitudinal seams for the one can. Since the circumference results in a much longer seam length, the overall resulting cost of refurbishment is suspected to be greater for the circumferential seams. Based on the corrosion and cracking investigated thus far, a value of 50 percent refurbishment was selected to represent a conservative number for the circumferential seams. This number is an estimate as there has been limited inspection of the circumferential welds to date.

Following the completion of weld refurbishment, the penstock internals will have abrasive blasting to bare metal and a new internal coating installed. The following blasting and coating methodology were considered for all three refurbishment options mentioned within this report. The current coating option priced is for three coat paint system by the Wasser Corporation (Table 2-1).

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Table 2-1: Proposed Coating System

Coat Number	Product	DFT
First	MC-Zinc 100	3.0 to 5.0 mils DFT
Second	MC-Tar 100	5.0 to 7.0 mils DFT
Third	MC-Tar 100	5.0 to 7.0 mils DFT
Total	**N/A**	**13.0 to 19.0 mils DFT**

The first coat would consist of MC-Zinc primer and be followed by two coats of MC-Tar moisture cure urethane that has similar performance to the coal tar epoxy that was originally installed, having a life span of approximately 15-20 years (recoating should be planned for every 15 years). The benefit of using the moisture cure product is that there will be significantly less environmental control and equipment required in the penstock during application. Other products can be assessed for this service; however, a large emphasis should be placed on the environmental application requirements (i.e., the internal penstock temperature, humidity, dew point, etc.). Hatch considers this important as NL Hydro and other companies such as Newfoundland Transshipment Limited have experienced difficulties in the past with trying to apply other coatings in high humidity environments.

The penstocks should have regular interior inspections following refurbishment work. Hatch recommends performing internal inspection after the first year of operation, with the system applied, to assess if any installation issues caused delamination of the coating and have repairs completed if required. After the initial warranty inspection, the frequency would be reduced to one interior inspection every 6 years. The interior inspection would be largely focused on coating condition and would include visual inspection and adhesion testing.

The total circumferential weld length was determined based on the number of cans (and associated seams) in each section of the penstocks multiplied by the circumference of that section. The penstock was broken up into three sections (17ft., 15.3ft.and 13.5ft.), the approximate number of cans for the 17ft. section was determined and multiplied by the circumference of the 17ft. section, the same process was used for the other two sections. Since no circumferential seams have been previously refurbished, half of the total circumferential length has been assumed for the estimated refurbished length as presented in Tables 2-2, 2-3, and 2-4.

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Table 2-2: Circumferential Weld Lengths - Penstock No. 1

Section	Cans	# of Cans	50% Refurbished	Diameter ft	Circumferential Length (ft)
17 ft dia.	1-121	121	60.5	17	3231
15.3 ft dia.	121-230	109	54.5	15.3	2619
13.5 ft dia.	230-400	170	85	13.5	3605
			Total Circumferential Length (ft.)		9455

Table 2-3: Circumferential Weld Lengths – Penstock No. 2

Section	Cans	# of Cans	50% Refurbished	Diameter ft	Circumferential Length (ft)
17 ft dia.	1-128	128	64	17	3418
15.3 ft dia.	128-237	109	54.5	15.3	2620
13.5 ft dia.	237-400	163	81.5	13.5	3457
			Total Circumferential Length (ft.)		9495

Table 2-4: Circumferential Weld Lengths – Penstock No. 3

Section	Cans	# of Cans	50% Refurbished	Diameter ft	Circumferential Length (ft)
17 ft dia.	1-136	136	68	17	3,632
15.3 ft dia.	136-291	155	77.5	15.3	3,725
13.5 ft dia.	291-400	109	54.5	13.5	2,311
			Total Circumferential Length (ft.)		9,668

The total longitudinal weld seam length of the non-refurbished welds was estimated using the weld refurbished trackers, which were prepared during the various refurbishment projects. A summary is provided in Tables 2-5, 2-6, and 2-7.

Table 2-5: Longitudinal Weld Length - Penstock No. 1

Location	Length Previously Refurbished (ft)	Total Length of Penstock (ft)	Length not Refurbished (ft)	Both North/South Side (ft)	50% of Welds Assumed to be Refurbished (ft)
Can 1-173 Can 215 only South side	1,520	3,883	2,363	4,726	2,363

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Table 2-6: Longitudinal Weld Length - Penstock No. 2

Location	Length Previously Refurbished (ft)	Total Length of Penstock (ft)	Length not Refurbished (ft)	Both North/South Side (ft)	50% of Welds Assumed to be Refurbished (ft)
Can 1-91 Can 230 and 270 only North side	752	3,896	3,144	6,288	3,144

Table 2-7: Longitudinal Weld Length - Penstock No. 3

Location	Length Previously Refurbished (total) (ft)	Total Length of Penstock (North and south) (ft)	Length not Refurbished (ft)	50% of Welds Assumed to be Refurbished (ft)
Approximation based on CAN 1-132; 132-175; 205-225; 302-342	3,500	7,420	3,920	1,960

Table 2-8 provides a summary of both the circumferential and longitudinal repair lengths for each penstock.

Table 2-8: Total Weld Refurbishment Lengths

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Total Circumferential Repair Length (ft)	9,455	9,495	9,668
Total Longitudinal Repair Length (ft)	2,363	3,144	1,960
Total Repair Length (ft)	11,818	12,639	11,628

Table 2-9 presents the AACE Class 4 cost estimate for Option1. Appendix B provides additional cost breakdown.

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Table 2-9: Refurbishment and Re-coating Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Contractor Mob/Demob	$1,670,000	$1,740,000	$1,600,000
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000
Doorsheet Removal and Re-installation	$110,000	$110,000	$110,000
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000
Contractor Living out Allowance (LOA)	$700,000	$700,000	$700,000
Rescue / Safety	$480,000	$480,000	$480,000
TOTAL DIRECT COST	**$19,110,000**	**$19,890,000**	**$18,740,000**
EPCM(12% of direct)	$2,290,000	$2,390,000	$2,250,000
Temp site facilities and services (3% of direct)	$570,000	$600,000	$560,000
Owner's costs (5%)	$960,000	$990,000	$940,000
TOTAL INDIRECT COST	**$3,820,000**	**$3,980,000**	**$3,750,000**
Contingency (15% of direct + indirect)	$3,440,000	$3,580,000	$3,370,000
TOTAL COST	**$26,370,000**	**$27,450,000**	**$25,860,000**

2.2 Replacement of 17 ft. Diameter Section and Weld Refurbishment

Based on the recent refurbishment history and the results of the stress analysis, the part of the penstock which has required the most refurbishment is the 17 ft section which is located upstream of the Surge Tank. The cost estimate for this option (Option 2) considers replacing this section with materials designed to current standards, fully refurbishing all existing deteriorated welds and coating the penstock (refer to Section 2.1 for painting/coating methodology and refer to Table 2-15 for cost estimate). The 17 foot section will be coated in the shop with the exception of the field joints which will be coated on site along with the remainder of the unreplaced portion of the penstock.

The cost for replacing the 17 ft diameter section will be impacted by the constructability of a large diameter penstock, and the remote location of the site. The most significant constructability concern is the delivery of cans to the site. Shop manufacturing the cans will be far cheaper and produce a higher quality product. New penstock sections can be fabricated in St. John's in 10 ft widths and 17 ft in diameter. Once fabricated, inspected, and painted, they can be shipped. Local transportation companies have provided budgetary estimates and indicated that two can sections can be shipped to the site on a low bed transport. Note, 17 ft is the upper limit set by the Department of Transportation for transport without escorts. Escort costs could increase transportation by up to 60 percent. This increase in cost was not considered in the cost estimate developed for this option.

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Plate for fabrication of new can sections would need to be purchased requiring a two to three-month lead time due to the large tonnage quantity. Purchasing the plate as a free issue item would save the contractor markup on the material.

Shop fabrication is the most efficient and best way to control quality. The longitudinal seams would be welded using Submerged Arc automatic welding method and inspected using radiographic or ultrasonic inspection. Hatch recommends using ultrasonic inspection as it is more efficient and does not cause a shutdown of production during the inspection period.

Additional constructability considerations include:

1. Available site laydown area for equipment and penstock cans.
2. Access around operating penstocks, especially Penstock No. 2.
3. Access road condition.
4. Earthworks, backfill removal and bedding material supply installation for the new penstock section. Sand for bedding would likely need to be supplied from a significant distance.
5. Drainage under the penstock would need to be addressed.
6. Room and Board availability for the construction crew.
7. Length of available outage for demolition and construction.
8. Some contractors have used automatic or semiautomatic welding equipment for circumferential welds in the field. This possibility could be further investigated with contractors. Automatic welding requires significant hoarding around the welded joints and may not be practical for a thin shelled (approximately 5/8 inch) penstock.
9. There will be significantly higher costs for the NDE in the field plus availability of UT technicians on an as required basis could be a problem. Hatch recommends spot checking the circumferential joints due to the lower stress in these joints. Cost could be as high as four times the cost of shop inspection depending on the number of site visits.

The same methodology for determining weld refurbishment lengths for Option 1 was used, where the weld seam refurbishment lengths associated for the 17 ft. section was not included. The weld repair lengths for Option 2 are presented in Tables 2-10, 2-11, 2-12, 2-13, and 2-14.

Table 2-10: Circumferential Weld Lengths - Penstock No. 1

Section	Cans	# of Cans	50% Refurbished	Diameter	Circumferential Length (ft)
15.3 ft dia.	121-230	109	54.5	15.3	2620
13.5 ft dia.	230-400	170	85	13.5	3605
				Total Circumferential Length (ft)	6225

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Table 2-11: Circumferential Weld Lengths - Penstock No. 2

Section	Cans	# of Cans	50% Refurbished	Diameter	Circumferential Length (ft)
15.3 ft dia.	128-237	109	54.5	15.3	2620
13.5 ft dia.	237-400	163	81.5	13.5	3457
				Total Circumferential Length (ft.)	6077

Table 2-12: Circumferential Weld Lengths - Penstock No. 3

Section	Cans	# of Cans	50% Refurbished	Diameter	Circumferential Length (ft)
15.3 ft dia.	136-291	155	77.5	15.3	3725
13.5 ft dia.	291-400	109	54.5	13.5	2311
				Total Circumferential Length (ft.)	6036

Table 2-13: Longitudinal Weld Lengths - Penstocks No. 1, 2 and 3

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Total Longitudinal Repair Length (ft.)	2363	2829	1924

Table 2-14: Total Weld Refurbishment Lengths

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Total Circumferential Repair Length (ft)	6225	6077	6036
Total Longitudinal Repair Length (ft)	2363	2829	1924
Total Repair Length (ft)	8588	8906	7960

Table 2-15 presents the AACE Class 4 cost estimate for Option 2.

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Table 2-15: Partial Replacement and Refurbishment Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Contractor Mob/Demob	$2,790,000	$2,890,000	$2,580,000
Backfill Removal, Reinstatement and Bedding	$830,000	$830,000	$830,000
Longitudinal Weld Refurbishment	$1,760,000	$2,330,000	$1,380,000
Circumferential Weld Refurbishment	$7,060,000	$7,050,000	$6,800,000
Doorsheet Removal and Re-installation	$70,000	$70,000	$70,000
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000
Purchasing of steel -17' ID	$1,420,000	$1,460,000	$1,270,000
Installation Penstock 1 - 17' ID	$3,450,000	$3,550,000	$3,090,000
Shipping	$340,000	$350,000	$370,000
Cranes (rate plus Mob/Demob)	$770,000	$770,000	$770,000
Site Fabrication	$8,820,000	$9,130,000	$7,940,000
Demo of Existing Penstock	$880,000	$880,000	$880,000
Contractor Living out Allowance (LOA)	$1,130,000	$1,130,000	$1,130,000
Rescue / Safety	$720,000	$720,000	$720,000
TOTAL DIRECT COSTS	**$33,740,000**	**$34,860,000**	**$31,390,000**
EPCM(12% of direct)	$4,050,000	$4,180,000	$3,770,000
Temp site facilities and services (3% of direct)	$1,010,000	$1,050,000	$940,000
Owner's costs (5%)	$1,690,000	$1,740,000	$1,570,000
TOTAL INDIRECT COSTS	**$6,750,000**	**$6,970,000**	**$6,280,000**
Contingency (25% of direct + indirect)	$10,120,000	$10,460,000	$9,420,000
TOTAL COST	**$50,610,000**	**$52,290,000**	**$47,090,000**

2.3 Refurbishment with Reinforcing Plates

Building on the requirements of Option 1, reinforcing plates could be installed internally over all longitudinal and circumferential weld seams of the 17 ft. diameter section; noting that all deteriorated welds would need to be refurbished first before reinforcing plates could be welded on. Following the weld refurbishment of the penstock, plates similar to those installed in Penstock No. 1 (November 2017) would be installed in the 17ft. section, to stiffen the existing penstock (at the peaked seams) and provide additional protection to the weld seams. The reinforcing plates will need to be cut, rolled (to the same radius as the penstock), inserted into the penstock, fit to place, and then welded (refer to Appendix C for details). Following the completion of welding the reinforcing plates, Magnetic Particle testing (MT) and Visual testing (VT) is required on the fillet welds, as well as corrosion protection. Abrasive blasting to bare metal and installation of a coating system would still be required to prevent further corrosion of the steel penstock and to protect the welds (refer to section 2.1, for blasting/coating methodology).

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The same weld lengths (both circumferential and longitudinal) from Option 1 was used in determining the weld refurbishment portion of the cost for this option. Table 2-16 presents the AACE Class 4 cost estimate for Option 3.

Table 2-16: Refurbishment with Reinforcing Plates Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,230,000	$2,300,000	$2,200,000
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000
Doorsheet Removal and Re-installation	$100,000	$100,000	$100,000
Site Labour For Repad Installations	$5,450,000	$5,450,000	$5,450,000
Shipping	$20,000	$20,000	$20,000
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000
Contractor Living out Allowance (LOA)	$920,000	$920,000	$920,000
Rescue / Safety	$600,000	$600,000	$600,000
TOTAL DIRECT COST	**$24,870,000**	**$26,250,000**	**$25,140,000**
EPCM(12%)	$2,980,000	$3,150,000	$3,020,000
Temp site facilities and services (3% of direct)	$750,000	$790,000	$750,000
Owner's costs (5%)	$1,240,000	$1,310,000	$1,260,000
TOTAL INDIRECT COST	**$4,970,000**	**$5,250,000**	**$5,030,000**
Contingency (15% of direct + indirect)	$4,480,000	$4,730,000	$4,530,000
TOTAL COST	**$34,320,000**	**$36,230,000**	**$34,700,000**

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3. Option Comparison

Due to the complexity of the various options, it was decided to include a brief comparison matrix ranking the options based on four key factors as presented in Table 3-2. The factors used for the comparison were reliability, cost, schedule/phasing and risk.

Reliability- considers the long-term reliable operation of the penstocks unimpeded by outages.

All the options scored high on reliability.

Cost – based on the estimated capital cost of the various options. Costing was provided in the previous sections of this report.

The estimates were based on industry norms and contractor consultations and do not consider inflation and cost adders associated with phasing the project over multiple outages. Potential cost savings would be possible if NL Hydro purchased materials in advance and free issued these items to a contractor.

Schedule/Phasing – all options allow for implementation in a phased manner.

Implementing the life extension program in a phased approach decreases the length of outages and allows for more cash flow flexibility. Option 2 would be the most difficult to phase due to existing irreplaceable infrastructure. It could be phased by section to make it more attractive; however, the outages would be substantial.

Risk – risk during construction were considered.

Risk scores are similar based on the majority of the options being largely interior work. However, the partial replacement option (Option 2) would be subject to weather delays, risk to bedding wash out, and would require lifting and other logistical construction related issues due to working around and over operating penstocks.

Prior to completing the ranking matrix, the life extension options were first analyzed with listed advantages and disadvantages as shown in Table 3-1. This table complements the ranking matrix and lists some of the reasoning for decided scoring for this ranking matrix.

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Table 3-1: Option Comparison Table

Option Number	Description	Advantages	Disadvantages
1	Refurbish circumferential and non-refurbished longitudinal welds of penstock followed by water blasting to bare metal and internal re-coating of penstock	1. Lower risk of failure. 2. Lowest cost of the three options. 3. Work is internal and weather delays would be minimal. 4. Reduction in surface roughness via new coating system. 5. Smaller labor force required and can be staged over multiple outages. 6. No large civil works required, minimal risk to existing infrastructure. 7. Minimal lifts over operational penstocks.	1. Multiple outages required. 2. Flexible 17' diameter section remains. 3. Poor fabrication alignment issues remain. 4. Interior is repaired but exterior coating from original construction remains. Life extension is limited by external coating condition. 5. No inclusion of corrosion allowance on existing wall thickness. Therefore, coating needs to remain intact over the lifespan of the penstock. Essentially the coating system should be budgeted for replacement every 15-20 years. 6. Existing bedding and drainage system cannot be upgraded. Bedding remains in contact with the penstock in areas checked. However, some sections of the bedding were saturated during inspection.
2	Replacement of the 17ft. Section	1. Low risk of failure. 2. New sections can be constructed to meet current standards. 3. Reduction of surface roughness. 4. Existing flexible 17' diameter section is removed. 5. Inclusion of corrosion allowance would be included in wall thickness. Reduces risk of corrosion effect on the penstock shell. This would allow initial recoating interval to be greater (approximately 25-30 years). After the first recoating the interval would revert back to 15-20 years. 6. Life extension up to 80 years depending on maintenance schedule. 7. Bedding and drainage could be upgraded during replacements.	1. Highest cost of the three options. 2. Long outage required. 3. High likelihood of weather delays. 4. Lifts over operational penstocks. 5. Heavy civil works required that could cause damage to existing infrastructure. 6. Demo of existing penstock sections would leave bedding system exposed to elements which could lead to compromised bedding and/or washouts. 7. Road transport of steel will require special permits for transport due to size and most likely be shipped in sections. This requires at least 2 longitudinal joints in the field per can. 8. Barge transport could be expensive due to the volume of steel cans. 9. Supply of required steel would have to be ordered one year in advance (long procurement period).
3	Refurbishment with reinforcing plates	1. Lower risk of failure. 2. Construction can be phased. 3. Work is all internal and weather delays would be minimal. 4. Increased reinforcement over welded areas.	1. Multiple outages required. 2. Possible flow disturbances caused by plates protruding into flow contributing to head loss. 3. Reduced flow through penstock do to repetitive pressure disturbances. 4. Refurbishment of existing welds is required prior to installation, thus there is no cost saving by a reduction in refurbishment cost by installing reinforcement plates over the welds. 5. Contractors stated very difficult to undertake due to handling large plates inside a confined space with no crane access. This poses a significant logistical challenge. Deemed by contractors as not a practical option.

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Table 3-2: Refurbishment Option Matrix

Option Number	Option Description	Ranking Factors (out of 5)				
		Reliability	Cost	Schedule / Phasing	Risk	Total Score
1	Refurbishment and Re-coating	4	5	5	4	90%
2	Partial Replacement and Refurbishment	5	3	3	3	70%
3	Refurbishment with Reinforcing Plates	4	4	5	3	80%

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4. Conclusions

Based on the current condition of the penstocks and the lack of corrosion protection, Hatch cannot guarantee that further leakages or micro cracks (if not already present) will not occur for each of the three penstocks. Hatch believes the probability of a major rupture or failure is relatively low within the next 5 years; however, a pin hole leak or micro crack could eventually lead to a rupture or failure.

Penstocks No. 1 and No. 2 have been in service 50 years and the internal coating in these penstocks has failed. There is a possibility that Penstock No. 3 was never internally coated.

The non-refurbished sections of the three penstocks, including circumferential seams, are showing signs of weld metal loss and preferential pitting corrosion of the HAZ. In the future these areas will need to be protected by application of a coating to avoid further deterioration.

Based on completed inspections, refurbishments, and current operating procedures as recommended by Hatch in previous reports, there have been no ruptures or recurring indications in the longitudinal seams. As a result, Hatch believes the refurbishment methodology has been successful in stabilizing the penstocks and the penstock's current condition as it provided uninterrupted service through the 2019 winter season. Hatch recommends that annual inspection of the penstocks should continue until a life extension program is completed. Hatch also believes that the refurbishment of backfill around Penstock No. 1, as outlined in Report H356043-00000-240-230-0003, may be deferred until the execution of the selected life extension work is completed.

Hatch noted the following constructability concerns related to the 17ft. section replacement option (Option 2); access around the operating penstocks (especially Penstock No. 2), site access due to road conditions and available laydown area for equipment and penstock cans. Additionally, concerns were noted regarding the local availability of suitable bedding material, drainage under the penstock would require refurbishment and the fact that this option would require a long outage for demolition and construction. These constructability concerns make this option less desirable. It should be noted, that similar work required for the other two options has been completed successfully in the past and any constructability concerns related to either of these options are well understood and are manageable. Other than the amount of time it will take to refurbish and or reinforce the circumferential seams, Hatch does not see any major constructability concerns with Options 1 or 3.

AACE Class 4 cost estimates for three options have been presented as part of this Report 3 and a comparison of these costs is shown in Table 4-1. The least cost option is Option 1 - Refurbishment of weld seams and application of a new protective coating.

After carefully reviewing the data collected, the yearly inspection of the completed refurbishments, and cost estimates, it is Hatch's opinion at this time that Refurbishment Option 1 is the recommended life extension strategy. With refurbishment of the remaining seams (removal of surface cracks, deposition of new weld metal where required) and the

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application of a new protective coating, the service life of the penstocks could be extended for an additional 20 years. Further life extension could be accomplished depending on maintenance of the new coating, maintenance of existing backfill and maintaining the current reduction in rough zone operation. It is in Hatch's opinion that the reinforcing plate option does not provide any significant additional life extension benefits in relation to the high costs involved in the installation of reinforcing plates.

One of the biggest contributing factors to the overall cost of each option is the extent of the weld refurbishment of the circumferential seams. The current cost estimates have assumed 50 percent will need refurbishment. This assumption is based upon the findings of the Condition Assessment, however, a maximum of 10 percent to 15 percent of the circumferential welds were inspected. Additional inspection of these seams would likely increase the accuracy of the estimate by providing a larger sample size. The previous refurbishment of the three penstocks concentrated on the longitudinal seams as these are subject to twice the internal pressure stress as are the circumferential seams and the ruptures occurred in the longitudinal seams.

Based on inspections of the circumferential seams we know there is pitting corrosion in these seams. To understand the condition of these seams in the various sections of the penstock a more detailed scale removal and magnetic particle inspection could be performed, as noted above. It is possible that further inspection could reduce the requirements for significant weld refurbishment and increase the recommended refurbished period from three to five years to five to ten years. As most of the weld pitting corrosion occurred in the 17 ft section it is Hatch's opinion these portions of all three penstocks should be inspected, refurbished as needed, in particular the circumferential seams, and protected with a suitable coating system. This work should be completed in the next 5 years. Depending on the findings of the potential circumferential seam inspections and regular yearly penstock inspections the weld refurbishment and protective coating application for the remaining penstock sections could be completed in 10 years.

In addition, coating manufactures could potentially provide a system to coat the currently non-refurbished circumferential seams with minimal preparation and provide an expected coating service life of up to fifteen to twenty years.

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Table 4-1: Cost Estimate Comparison

	Penstock No. 1	Penstock No. 2	Penstock No. 3	Total
Option 1: Refurbishment and Re-coating	$26,370,000	$27,450,000	$25,860,000	**$79,680,000**
Option 2: Partial Replacement and Refurbishment	$50,610,000	$52,290,000	$47,090,000	**$149,990,000**
Option 3: Refurbishment with Reinforcing Plates	$34,320,000	$36,230,000	$34,700,000	**$105,250,000**

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Appendix A
Construction, Fabrication and Painting Supporting Documents

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List of Supporting Documents

#	Supporting Document
1	[redacted] Pricing for Weld Refurbishment and 17ft. Section Replacement Option
2	[redacted] Pricing for Weld Refurbishment and 17ft. Section Replacement Option - Comments
3	[redacted] – Budgetary Quote for Painting/Blasting
4	[redacted] – Painting/Blasting Cost Estimate
5	[redacted] – Penstock Demolition and Removal Estimate
6	Shipment of Penstock Cans – Estimate and Comments
7	Penstock Plate Costs

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From: Saunders, Greg
To: O"Grady, Kathleen
Cc: Drake, Dylan
Subject: FW: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing
Date: Friday, June 14, 2019 2:36:04 PM
Attachments: image003.png
image004.png
image007.png
image008.png

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Friday, June 14, 2019 2:35 PM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: Fwd: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing

Sent from my iPhone

Begin forwarded message:

[redacted]

Subject: RE: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing

[redacted]

Option 7 with no Civil or Coating.

17' Diameter Replacement			
	Penstock #1	Penstock #2	Penstock #3
Total	23,227,564.42	23,920,523.33	21,148,687.73
Weld Refurbishment			
15.3 ft dia. Section	2619.6	2619.6	3725.1
13.5 ft dia. Section	3605	3456.5	2311.4
Total Circumferential Repair Length (ft)	6224.6	6076.1	6036.5
Total Longitudinal Repair Length (ft)	1800.4	2581.7	1337.1
Total Repair Length (ft)	8025	8657.8	7373.6
Sub Total	$ 13,448,655.95	$ 14,300,114.91	$ 12,472,085.64
Total	$ 33,254,797.40	$ 35,174,999.09	$ 32,038,456.53





Subject: RE: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing



The information below aligns with cost per liner M which we have submitted previously excluding coating.

Greg

Weld Refurbishment only:

	Penstock #1	Penstock #2	Penstock #3
Circumferential Repair Length (ft)			
17ft dia. Section	3231.1	3418.1	3631.7
15.3 ft dia. Section	2619.6	2619.6	3725.1
13.5 ft dia. Section	3605	3456.5	2311.4
Total Circumferential Repair Length (ft)	9455.7	9494.2	9668.3
Total Longitudinal Repair Length (ft)	2362.9	3144.2	1899.6
Total Repair Length (ft)	11818.6	12638.4	11567.8

Total	$ 19,806,141.45	$ 20,874,884.18	$ 19,566,370.88

Greg

From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Cc: DylanDrake@nlh.nl.ca
Subject: FW: NL Hydro BDE Penstock Replacement Option 17 ft Section
Date: Friday, June 28, 2019 1:33:10 PM
Attachments: image001.png
image003.png

Hi Guys

See the comments from [redacted] next to the questions.

Regards,
Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: Saunders, Greg
Sent: Thursday, June 27, 2019 5:04 PM
To: [redacted]
Cc:
Subject: RE: NL Hydro BDE Penstock Replacement Option 17 ft Section

Thanks

Regards,
Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Thursday, June 27, 2019 5:01 PM
To: Saunders, Greg <greg.saunders@hatch.com>
Cc: [redacted]
Subject: RE: NL Hydro BDE Penstock Replacement Option 17 ft Section

Greg,

I will get back to you first thing tomorrow morning.

[redacted]

From: Saunders, Greg [mailto:greg.saunders@hatch.com]
Sent: Thursday, June 27, 2019 9:31 AM
To: [redacted]
Cc:
Subject: RE: NL Hydro BDE Penstock Replacement Option 17 ft Section

Hi Greg

Hydro reviewed our cost estimates and had some questions for us.

I would like to ask you a couple of questions to make sure we understand what you included or didn't include in your estimate. Also roughly how much contingency you used as we have also included some contingency in our final numbers.

For example:

1. Transportation to BDE full cans or partial needing longitudinal seams welded on site - [redacted] did not include any cost.
2. Site fabrication - [redacted] included fabrication of two half sections into a can on site and included welding 2 to 3 cans into an assembly to drop into the trench.
3. Demolition and disposal of existing penstock - [redacted] did not include demolition costs
4. Civil works, backfill removal, bedding reinstatement, backfill – [redacted] did not include any Civil Works costs
5. Craneage on site - [redacted] did include cranage (250ton at $180/hr + operator at $75/hr regular time OD is after 40hrs) , Mob and demob is around $5000 each so my estimate was good.
6. Housing of workforce in the area – rough idea of the number of workers and duration – [redacted] said the local area will probably max out at 40 people, LOA in the area costs around $180 to $200 per day.
7. Any indirect costs as a percentage of the total – [redacted] included an indirect cost which is around 25%
8. Any constructability concerns you see, in particular access to the middle penstock No. 2. - [redacted] stated there will be issues around Penstock No. 2 but didn't see anything insurmountable

Other notes.

[redacted] assumed a 5 to 6 month schedule for the work. They would work all day shift 10hrs per day 7 days a week and have a rotating crew. The total labour rate for the 70 hrs per week would be $100 per hour.
They included a 10% contingency on the top of their estimate.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL

[redacted]

QUOTE

Quote No: 1576

Date: Jun 28, 2019

Sold To:
Hatch

NL

Business No.: [redacted]

Description	Amount
Re: Penstocks in Bay D'Espoir Our budgetary quote for sandblasting and applying specified coating as per your request is $15-$18 / sq ft.	
HST NOT INCLUDED IN QUOTE. QUOTE VALID FOR 30 DAYS — **Total**	

From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Subject: FW: Bay D"Espoir - Penstock Painting
Date: Friday, June 28, 2019 10:55:08 AM
Attachments: image004.png

Hi

See cost per square foot below.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Friday, June 28, 2019 10:03 AM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: FW: Bay D'Espoir - Penstock

Greg,

See below.

[redacted]

From: [redacted]
Sent: Friday, June 28, 2019 10:00 AM
To: [redacted]
Subject: RE: Bay D'Espoir - Penstock

Hi [redacted]

I would use $18.00 - $22.00 sf. It really depends on the lining they want to use.

Note: Our hose bundle for spraying out the linings is 250' long, we would need access (manways?) 200' from each end of the penstock and then at approx. every 400'.

Regards,

[redacted]

From: [redacted]
Sent: Thursday, June 27, 2019 12:39 PM
To: [redacted]
Subject: RE: Bay D'Espoir - Penstock

Welded.

From: [redacted]
Sent: Thursday, June 27, 2019 12:01 PM
To: [redacted]
Subject: RE: Bay D'Espoir - Penstock

Hi [redacted]
Is it riveted or welded ?

From [redacted]
Sent: Thursday, June 27, 2019 10:45 AM
To: [redacted]
Subject: Bay D'Espoir - Penstock

[redacted]

I was just speaking with an Engineering Company here, Hatch, who is working with Hydro NL on options for repairs on the Bay D'Espoir Penstock. They were asking us some questions on welding and replacing sections of Penstock, etc.

They also asked me if I had any kind of norm and approx. budget method we could give them for their high level analysis of painting the inside of the penstock. If there anything off the cuff you can provide me for this. They say they would wan to apply a Polyurethane product, good for damp atmospheres where it is insite the penstock.

The penstock is almost 3800 ft long and 17 ft in diameter. Area Approx: 200,000 sq ft.

Would you be able to throw a number at this or even an approximate allowance per sq – ft?

Regards,

[redacted]

[redacted]

From: [redacted]
To: O"Grady, Kathleen
Cc: Saunders, Greg; Kenneally, Zachary
Subject: RE: Budgetary Pricing on Penstock Removal
Date: Thursday, June 27, 2019 10:33:18 PM
Attachments: image001.png

Morning all;

I've done up a budget number on the removal of the Penstocks as requested.

I've made a couple assumptions:

1. All fill to remain onsite
2. Concrete support for bottom of tank to remain.
3. Next's years work??

$875,000.00 + Hst

If got any questions give me a call.

[redacted]

[redacted]

From: O'Grady, Kathleen [mailto:kathleen.ogrady@hatch.com]
Sent: June 26, 2019 7:39 PM
To: [redacted]
Cc: Saunders, Greg <greg.saunders@hatch.com>; Kenneally, Zachary <zachary.kenneally@hatch.com>
Subject: Budgetary Pricing on Penstock Removal

Hi Jeff,

Following your discussion with Greg Saunders this morning, we are hoping to get a budgetary cost on the demolition/removal of 17ft. dia sections of penstocks located in Bay d'Espoir. The information is as followed:

	Penstock #1	Penstock #2	Penstock #3
Length	1087 ft.	1120 ft.	1125 ft.

Inside Diameter	17 ft.	17 ft.	17 ft.
Thickness	0.4375inch (11mm)	0.4375inch (11mm)	0.4375inch (11mm)
Approximate Imperial short Tons	521	537	540

The penstocks can be accessed by road. There is approximately 5000 m^3 of backfill that would need to be removed (this is total amount between all three penstocks). Please see attached drawings outlining the sections that require removal.

Thank you for your help!

Regards,
Kathleen

Kathleen O'Grady
Junior Mechancial EIT / Oil and Gas

Tel: +1 709 700 1391
Suite 100, 80 Hebron Way, St. John's
Newfoundland Canada A1A 0L9

HATCH

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From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Subject: FW: Shipment of Penstock to Bay D"Espoir
Date: Thursday, June 27, 2019 10:33:22 AM
Attachments: image004.png

FYI

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
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Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Thursday, June 27, 2019 10:21 AM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: FW: Shipment of Penstock to Bay D'Espoir

From: [redacted]
Sent: Thursday, June 27, 2019 10:20 AM
To: [redacted]
Cc: [redacted]
Subject: RE: Shipment of Penstock to Bay D'Espoir

[redacted]

As a budget

$5500 per load – assuming 2 per truck
17 ft wide at the upper limit for DOT escort so price could go up 60+% if they have to get involved… in case you get over 17 ft wide

[redacted]

From: [redacted]
Sent: June 27, 2019 9:51 AM
To: [redacted]
Cc: [redacted]
Subject: RE: Shipment of Penstock to Bay D'Espoir

[redacted]

I'm working with Hatch to pull together some high level budgets on this. They are looking at options to supply to Hydro.

What's high level estimate to ship a load to Bay D'espoir?

Regards,

[redacted]

[redacted]

From: [redacted]
Sent: Thursday, June 27, 2019 9:26 AM
To: [redacted]
Cc: [redacted]
Subject: RE: Shipment of Penstock to Bay D'Espoir

[redacted]

Yes this wouldn't be an issue for highway or public road transport

[redacted]

From: [redacted]
Sent: June 27, 2019 9:20 AM
To: [redacted]

Cc: [redacted]
Subject: Shipment of Penstock to Bay D'Espoir

Hi [redacted]

Do you know if we would be able to ship a piece penstock pipe 17' in diameter x 10' long to Bay D'Espoir? We can sit the piece of penstock on its end so the height would be 10' and it would be 17' wide.

Thanks,

[redacted]

From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Subject: FW: Penstock Plate
Date: Friday, June 28, 2019 10:57:21 AM

Hi Guys

See cost for the plate. This is $0.82 per pound or $1.81 per kg.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Friday, June 28, 2019 10:08 AM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: RE: Penstock Plate

Hi Greg,
Based on current estimates and current lead time of approximately 2 months, $1,640.00 ton.
In reference to squaring material, our plasma table can handle maximum 40 FT lengths.
Thank you for your inquiry.
[redacted]

From: [redacted]
Sent: Thursday, June 27, 2019 3:10 PM
To: [redacted]
Subject: FW: Penstock Plate

From: Saunders, Greg <greg.saunders@hatch.com>
Sent: Thursday, June 27, 2019 1:44 PM
To: [redacted]
Cc: O'Grady, Kathleen <kathleen.ogrady@hatch.com>; Kenneally, Zachary <zachary.kenneally@hatch.com>
Subject: Penstock Plate

The plate we would be looking for is CSAW300WT or 350WT 27J at -20C

Plate thickness 0.625" and width 10 ft. Each can is 17 feet in diameter so 53.4 feet long. Probably need to be cut in 2 for shipping.

Total weight 850 tons.

Just looking for the mill run delivery time for the plate.

If you can give a rough budget price ($1.00/lb?) for the plate delivered to St. Johns cut and squared that would be great.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
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Suite 100
80 Hebron Way, St. John's, NL
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Fax: (709) 754-2717
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Appendix B
Cost Estimate Breakdown

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Option 1 - Weld Refurbishment and Coating

	Penstock No. 1	Penstock No. 2	Penstock No. 3	
Contractor Mob/Demob	$1,670,000	$1,740,000	$1,600,000	1.
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000	2.
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000	3.
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000	4.
Doorsheet Removal and Re-installation	$110,000	$110,000	$110,000	5.
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000	6.
Contractor LOA	$700,000	$700,000	$700,000	7.
Rescue / Safety	$480,000	$480,000	$480,000	8.
TOTAL DIRECT COST	**$19,110,000**	**$19,890,000**	**$18,740,000**	
EPCM(12% of direct)	$2,290,000	$2,390,000	$2,250,000	
Temp site facilties and services (3% of direct)	$570,000	$600,000	$560,000	
Owner's costs 5%	$960,000	$990,000	$940,000	
TOTAL INDIRECT COST	**$3,820,000**	**$3,980,000**	**$3,750,000**	
Contingency (15% of direct + indirect)	$3,440,000	$3,580,000	$3,370,000	
TOTAL COST	**$26,370,000**	**$27,450,000**	**$25,860,000**	

1. factored 10% of the weld refurb direct cost provieded by [redacted] plus 10% each of all additional items, with the exception of Contractor LOA which was not inlcuded
2. 1000 m^3 per penstock, $50/m^3
3. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
4. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
5. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
6. Assumed $20/sq.ft. ([redacted] estimate of $18/sq.ft. and [redacted] estimate of 18-22sq.ft. For purpose of estimate used a price in between $20/sq.ft.)
7. 40 worker; 90 days: $180 prediem per day + 10 painters; 30 days; $180 prediem per day
8. 120 days; 10hrs shifts; $100/hr; 2 workers; night and day shift

Option 2 - 17ft. Section Replacement

	Penstock No. 1	Penstock No. 2	Penstock No. 3	
Contractor Mob/Demob	$2,790,000	$2,890,000	$2,580,000	1.
Backfill Removal, Reinstatement and Bedding	$830,000	$830,000	$830,000	2.
Longitudinal Weld Refurbishment	$1,760,000	$2,330,000	$1,380,000	3.
Circumferential Weld Refurbishment	$7,060,000	$7,050,000	$6,800,000	4.
Doorsheet Removal and Re-installation	$70,000	$70,000	$70,000	5.
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000	6.
Purchasing of steel -17' ID	$1,420,000	$1,460,000	$1,270,000	7.
Installation Penstock 1 - 17' ID	$3,450,000	$3,550,000	$3,090,000	8.
Shipping	$340,000	$350,000	$370,000	9.
Cranes (rate plus Mob/Demob)	$770,000	$770,000	$770,000	10.
Site Fabrication	$8,820,000	$9,130,000	$7,940,000	11.
Demo of Existing Penstock	$880,000	$880,000	$880,000	12.
Contractor LOA	$1,130,000	$1,130,000	$1,130,000	13.
Rescue / Safety	$720,000	$720,000	$720,000	14.
TOTAL DIRECT COSTS	**$33,740,000**	**$34,860,000**	**$31,390,000**	
EPCM(12% of direct)	$4,050,000	$4,180,000	$3,770,000	
Temp site facilties and services (3% of direct)	$1,010,000	$1,050,000	$940,000	
Owner's costs 5%	$1,690,000	$1,740,000	$1,570,000	
TOTAL INDIRECT COSTS	**$6,750,000**	**$6,970,000**	**$6,280,000**	
Contingency (25% of direct + indirect)	$10,120,000	$10,460,000	$9,420,000	
TOTAL COST	**$50,610,000**	**$52,290,000**	**$47,090,000**	

1. Factor of the weld refurb was taken as well as the factor of replacement cost. 10% of each additional item was included in the price, with the expception of the crane mob/demob being $10,000 and the Contractor LOA, Shipping and Demo not being included for cost
2. $25,000 was included for 15.3 and 13.5 section backfill (to be confirm as 17ft. Section was estimated high)
3. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
4. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
5. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
6. Assumed $20/sq.ft. ([redacted] estimate of $18/sq.ft. and [redacted] estimate of 18-22sq.ft. For purpose of estimate used a price in between $20/sq.ft.)
7. Based on direct cost of 17ft. replacement cost given by [redacted] and weighted each item based on previous estimate
8. Based on direct cost of 17ft. replacement cost given by [redacted] and weighted each item based on previous estimate
9. shipping per 2 cans
10. Based on $180/hr + operator at $75/hr regular time, 150 days + 10 hours + night and day shift
11. Based on direct cost of 17ft. replacement cost given by [redacted] and weighted each item based on previous estimate
12. Based on [redacted] Pricing
13. 40 worker; 150 days: $180 prediem per day + 10 painters; 30 days; $180 prediem per day
14. 180 days; 10hrs shifts; $100/hr; 2 workers; night and day shift

	Penstock No. 1	Penstock No. 2	Penstock No. 3	
Mob/Demob (10%)	$2,230,000	$2,300,000	$2,200,000	1.
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000	2.
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000	3.
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000	4.
Doorsheet Removal and Re-installation	$100,000	$100,000	$100,000	5.
Site Labour For Repad Installations	$5,450,000	$5,450,000	$5,450,000	6.
Shipping	$20,000	$20,000	$20,000	7'.
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000	8.
Contractor LOA	$920,000	$920,000	$920,000	9.
Rescue / Safety	$600,000	$600,000	$600,000	10.
TOTAL DIRECT COST	**$24,870,000**	**$26,250,000**	**$25,140,000**	
EPCM(12%)	$2,980,000	$3,150,000	$3,020,000	
Temp site facilities and services (3% of direct)	$750,000	$790,000	$750,000	
Owner's costs (5%)	$1,240,000	$1,310,000	$1,260,000	
TOTAL INDIRECT COST	**$4,970,000**	**$5,250,000**	**$5,030,000**	
Contingency (15% of direct + indirect)	$4,480,000	$4,730,000	$4,530,000	
TOTAL COST	**$34,320,000**	**$36,230,000**	**$34,700,000**	

1. factored 10% of the weld refurb direct cost provieded by [redacted] plus 10% each of all additional items, with the exception of shipping and Contractor LOA which was not included
2. 1000 m^3 per penstock, $50/m^3
3. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
4. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
5. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
6. 82.5 tonnes of normal welds; 82.5 tonnes of out of position welds; 88hr/tonne; $150/hr. Assumed half the welds were normal welds and half were out of position welds. Out of postiion welds were considered to cost 4 times as much as normal welds.
7. 36 tonnes/trip; 165 tonnes; approximately 5 trips; $3000/trip
8. Assumed $20/sq.ft. ([redacted] estimate of $18/sq.ft. and [redacted] estimate of 18-22sq.ft. For purpose of estimate used a price in between $20/sq.ft.)
9. 40 worker; 120 days: $180 prediem per day + 10 painters; 30 days; $180 prediem per day
10. 150 days; 10hrs shifts; $100/hr; 2 workers; night and day shift

Appendix C
Reinforcing Plate Detail

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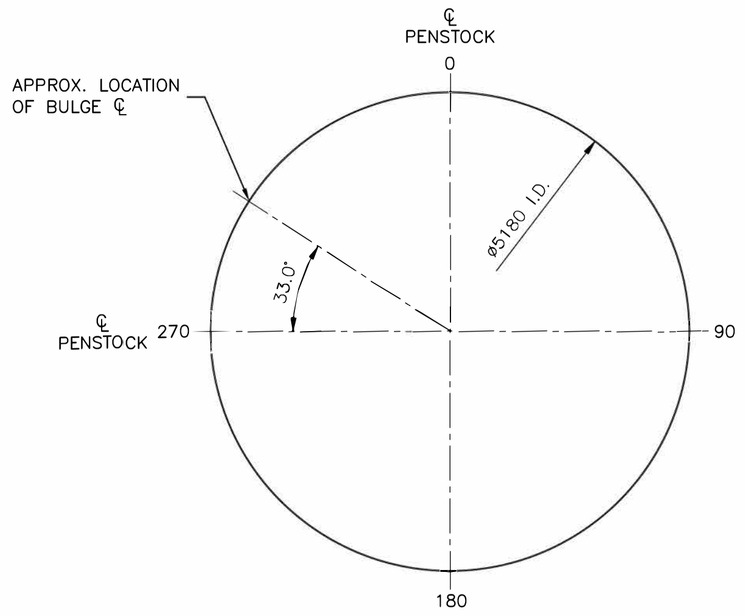
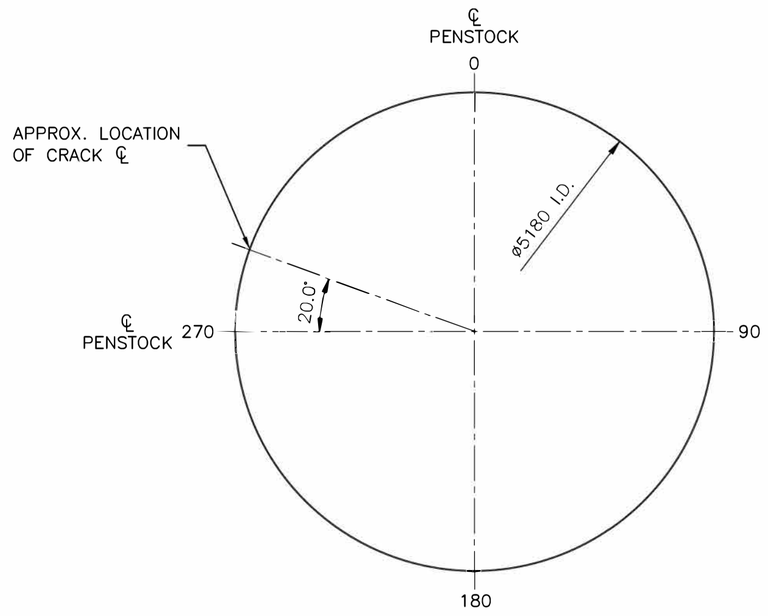


SECTION - CAN 34 (A)
SCALE: 1:50



SECTION - CAN 35 (B)
SCALE: 1:50

INSERT PLATE INSTALLATION SEQUENCE

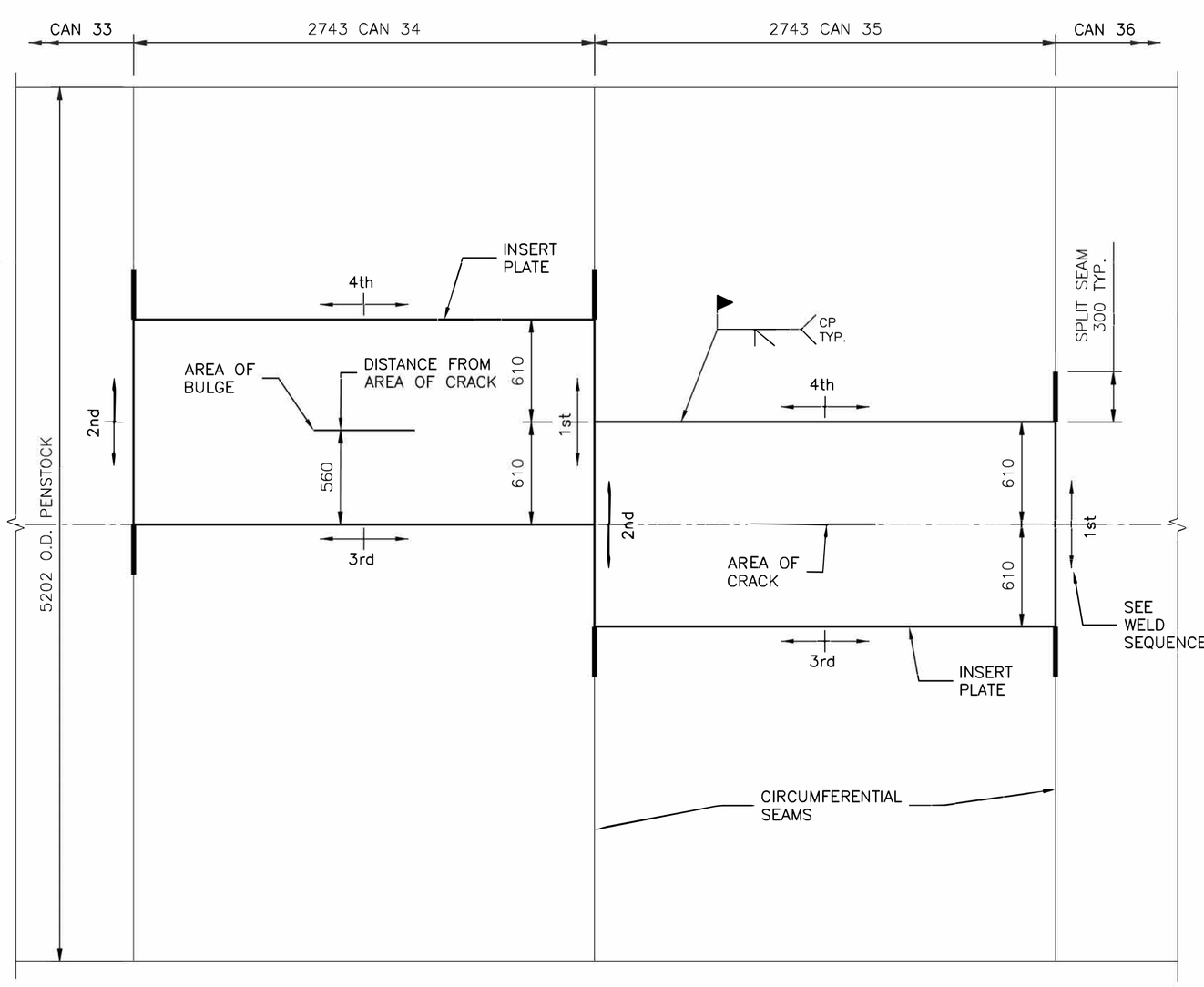
1. INSTALL THE INSERT PLATE FOR CAN 35 FIRST.
2. INSTALL THE INSERT PLATE FOR CAN 34 SECOND.
3. WHERE LONGITUDINAL JOINTS INTERSECT CIRCUMFERENTIAL JOINTS SPLIT THE CIRCUMFERENTIAL SEAM BACK 300mm PRIOR TO FITTING THE INSERT PLATE.
4. REINFORCING PLATES TO BE INSTALLED AS SHOWN ON DRAWING. BUTT WELDS TO BE INSPECTED AND FOUND ACCEPTABLE PRIOR TO THE INSTALLATION OF REINFORCING PLATES.

WELD SEQUENCE FOR DISTORTION CONTROL

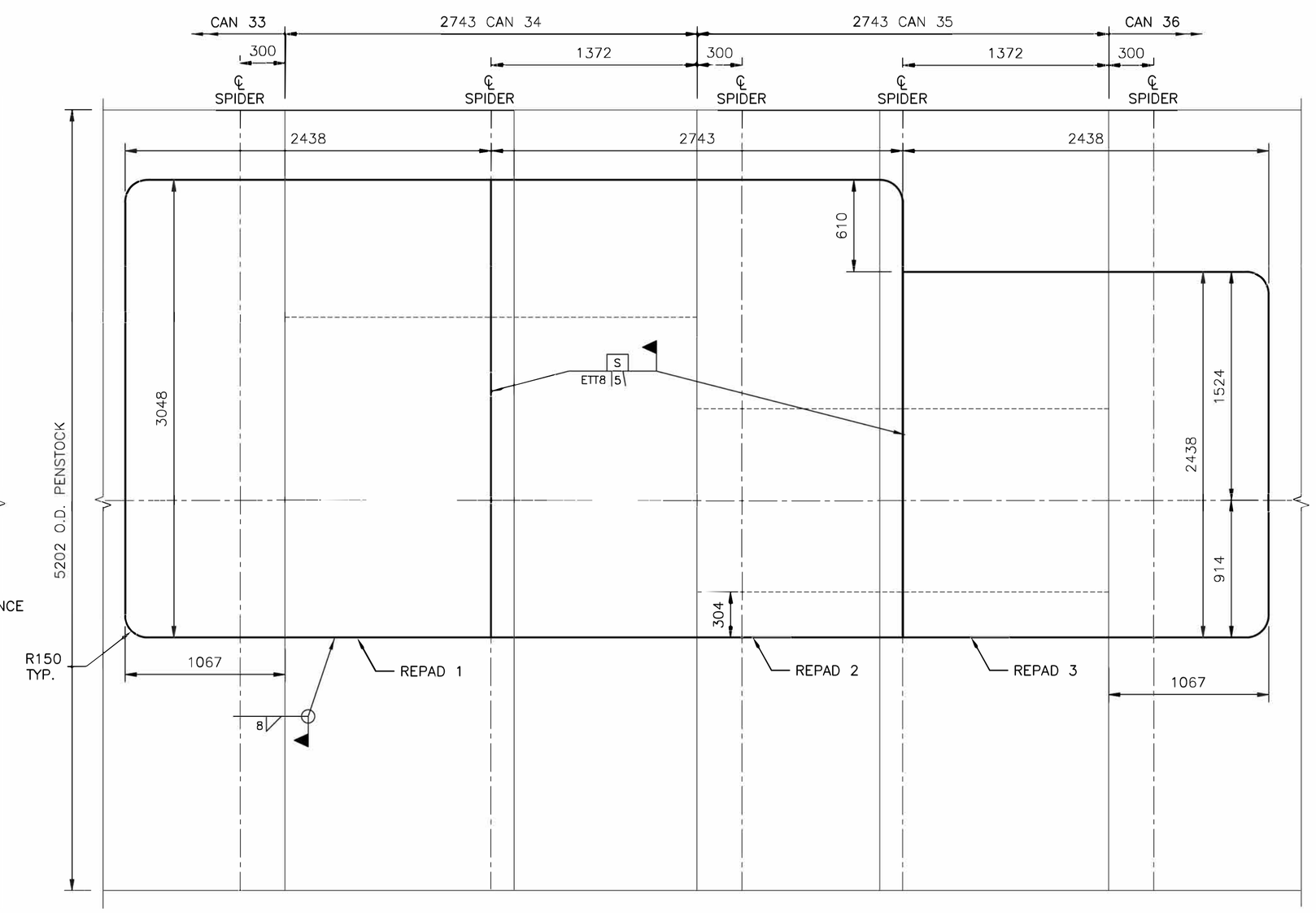
1. TACK WELD INSERT PLATE INTO OPENING AFTER AREA HAS BEEN GROUND AND CLEANED FOR WELDING. TACKS TO BE 50mm MIN. LENGTH AT 150mm c/c.
2. WELDING TO BE PERFORMED ON CIRCUMFERENTIAL SEAMS FIRST STARTING IN THE CENTER AND WORKING TO EDGES EQUALLY BOTH SIDES. SEE ELEVATION C.
3. AFTER TACK WELDING COMPLETE THE FIRST PASS USING THE SAME SEQUENCE AND BACK STEPPING THE WELDING.
4. COMPLETE THE SECOND PASS SAME AS THE FIRST PASS UNTIL THE JOINT IS APPROXIMATELY 50% FILLED.
5. BACK GOUGE TO SOUND METAL ON THE INSIDE AND FILL THE JOINT BY WELDING IN THE SAME SEQUENCE AS ABOVE.
6. COMPLETE THE WELD ON THE EXTERIOR IN THE SAME SEQUENCE AS ABOVE.
7. PERFORM A VT AND MT INSPECTION ON THE INTERIOR AND EXTERIOR SURFACES OF THE WELDS 12 HOURS AFTER WELDING.
8. GRIND THE INTERIOR AND EXTERIOR WELDS FLUSH WITH THE SURFACE.
9. PERFORM A VT AND MT INSPECTION ON THE SURFACE OF THE WELDS AT 48 HOURS AFTER WELDING.
10. COMPLETE RT AND UT INSPECTION OF THE WELDS.
11. THE COMMON CIRCUMFERENTIAL SEAM BETWEEN CAN 34 & CAN 35 SHALL ONLY BE WELDED 50%. THIS PORTION OF THE COMMON SEAM WILL BE COMPLETED WHEN THE INSERT FOR CAN 34 IS INSTALLED.

GENERAL NOTES:

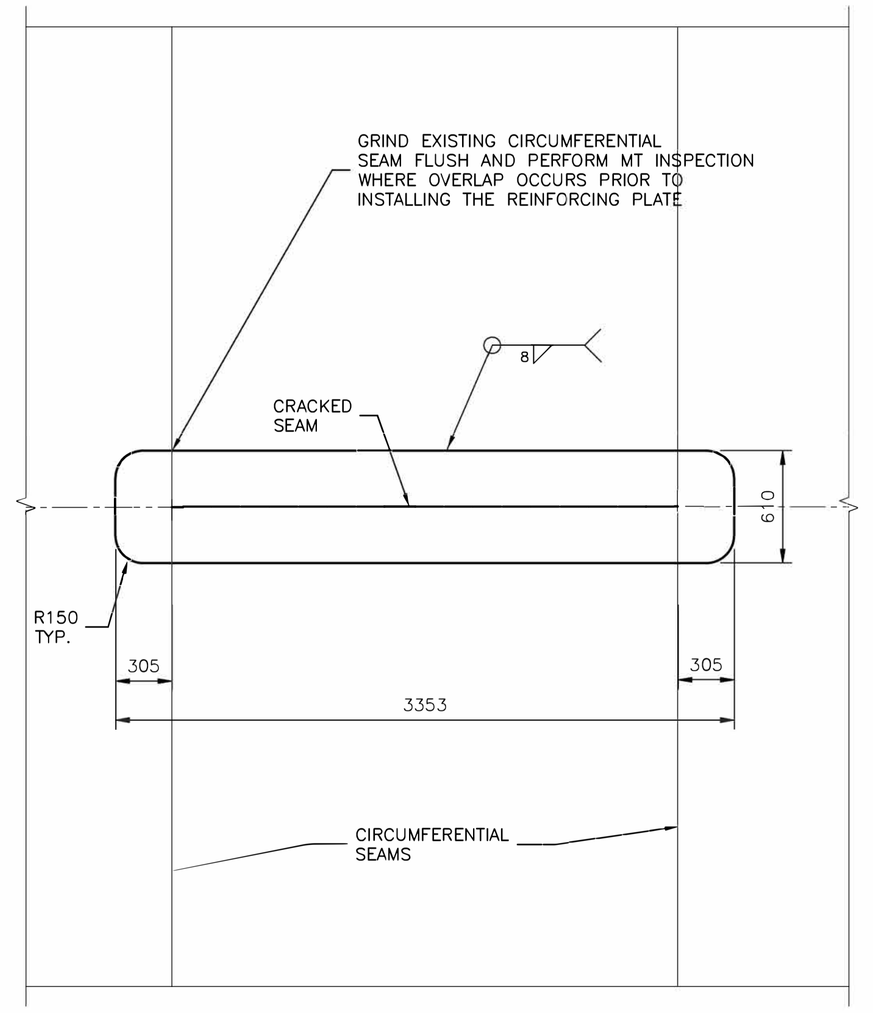
1. ALL DIMENSIONS IN MILLIMETERS.
2. DO NOT SCALE FROM DRAWING.
3. CONTRACTOR MUST VERIFY ALL DIMENSIONS & CONDITIONS ON SITE BEFORE PROCEEDING WITH ANY PORTION OF THIS WORK.
4. ALL STRUCTURAL STEEL IN ACCORDANCE WITH CAN/CSA–G40.20/G40.21. STEEL GRADE SHALL BE PLATE: 350WT U.N.O.
5. ALL STRUCTURAL STEEL WORK TO CAN/CSA S16.1 LATEST EDITION.
6. ALL WELDING IN ACCORDANCE WITH ASME IX BY WELDERS QUALIFIED TO ASME IX
7. ALL CP WELDS SHALL BE INSPECTED AS FOLLOWS:
   –100% VT
   –100% MT
   –100% RT
   –100% UT
   ALL FILLET WELDS TO BE INSPECTED 100% VT, MT
8. ALL FILLET WELDS SHALL BE 8mm ALL AROUND UNLESS NOTED OTHERWISE.
9. EXISTING PENSTOCK WALL THICKNESS: 11mm. ALL INSERT PLATES AND REPAD THICKNESS TO BE 13mm.



ELEVATION - INSERT PLATE (C)
SCALE: 1:25



ELEVATION - EXTERIOR REPAD DETAIL (D)
SCALE: 1:25



ELEVATION - INTERIOR REINFORCING PLATE DETAIL (E)
SCALE: 1:25

DWG.NO.	TITLE
REFERENCE DRAWINGS	

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D
1	JAN.19,2018	ISSUED AS RECORD SET	TB	GS	GS	GS
0	NOV.27,2017	ISSUED FOR CONSTRUCTION	RG	GS	GS	GS
REVISIONS						

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HATCH DRAWING NO. H352666–D–M–0001.1

newfoundland labrador hydro a nalcor energy company

BAY D'ESPOIR HYDROELECTRIC GENERATING FACILITY

PENSTOCK No.1 MODIFICATIONS ELEVATIONS, SECTIONS AND DETAILS SHEET 1 OF 1

ELECT.	
CIVIL	
TRANS.	
MECH.	
P&C	
TELC.	
SCALE:	AS SHOWN
DESIGNED:	G. SAUNDERS
DRAWN:	R. GEORGE
DATE:	NOV.10, 2017
CHECKED:	G. SAUNDERS
APPROVED:	G. SAUNDERS

W.O. NO.

DWG. NO. H352666-D-M-0001-1

REV. 1

C.A.D.

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Schedule 1, Attachment 5

Final Report for Penstock No.'s 1, 2 and 3 Life Extension Options

Hatch Ltd.

March 13, 2020

newfoundland labrador hydro

HATCH

Newfoundland and Labrador Hydro

Final Report

For

Penstock No.'s 1, 2 and 3 Life Extension Options

H357395-00000-240-066-0003
Rev. 1
March 13, 2020

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Newfoundland and Labrador Hydro

Final Report

For

Penstock No.'s 1, 2 and 3 Life Extension Options

H357395-00000-240-066-0003
Rev. 1
March 13, 2020

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Penstock No.'s 1, 2 and 3 Life Extension Options

H357395-00000-240-066-0003

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MIRCHI 01626
To practice Professional Engineering
in Newfoundland and Labrador
Permit No. as issued by PEG-NL D0090
which is valid for the year 2020

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
ANTHONY CHISLETT
SIGNATURE
13-MAR-2020
DATE
NEWFOUNDLAND & LABRADOR

2020-03-13	1	Approved for Use	K. O'Grady	Z. Kenneally, T. Chislett	G. Saunders
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DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY

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Executive Summary

Newfoundland and Labrador Hydro (NL Hydro) engaged Hatch to conduct a condition assessment of Penstock No.'s 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. Due to the nature of the 2018 outage schedule and NL Hydro's reporting requirements for items such as winter readiness and capital budget applications, the Condition Assessment report was developed in three phases, as shown below.

Report 1 – Bay d'Espoir Level II Condition Assessment of Penstock No.'s 1, 2 and 3.

Report 2 – Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2 and 3.

Report 3 – Penstock No.'s 1, 2 and 3 Life Extension Options.

All three penstocks were inspected as part of a Level II Condition Assessment. Inspections and data collection included: detailed weld inspection, material testing, 3D scanning and water pressure monitoring.

The weld inspections consisted of, at a minimum, pressure washing, buffing, visually inspecting and magnetic particle inspection of the longitudinal welds at a frequency of 1 in every 10 cans for the total penstock length. The overview of the inspections consists of the following:

- Penstock No. 1 was inspected from August 13 to 24, 2018. Refurbished welds completed in 2016 and 2017 show no sign of additional degradation.
- Penstock No. 2 was inspected from September 17 to 28, 2018. Refurbished welds completed in 2017 show no sign of degradation.
- Penstock No. 3 was inspected from May 14 to June 21, 2018. This was the first detailed inspection carried out and extensive weld metal corrosion and cracking was discovered, similar to what was found during the earlier inspections of Penstocks No. 1 and No. 2 in 2016 and 2017. Approximately 1027 m (3369 ft) of internal weld refurbishment was completed on Penstock No. 3 in 2018.

Material samples were removed from Penstock No. 3 to determine the grade of steel and compare with samples removed from Penstock No. 1.

Laser scans were completed to create a more accurate 3D model of the penstock geometry. The data showed similar peaking in all three penstocks and consequently the FEA model results for Penstock No. 1 can be extrapolated to the similarly constructed Penstock No. 2 and No. 3. This geometric data is also valuable for future use should NL Hydro wish to review the penstocks for geometric changes, such as settlement.

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In conjunction with the laser scans, pressure transducers were installed at key locations on all three penstocks and connected to a data logging device to assess any internal pressure transients. This data collection should continue until a life extension option is implemented for Penstock No.'s 1, 2, and 3 as all data gathered will assist in understanding the penstocks and may support future design efforts.

The penstocks have been in service for approximately 50 years. These are aging assets and as such require regular inspection and maintenance. To ensure the reliable long-term operation of these assets, refurbishment is required. This report details the refurbishment options that were chosen by NL Hydro for further analysis by Hatch.

Three life extension options were reviewed in this report for the purpose of further analysis and comparison of life extension options for the penstocks' refurbishment.

The cost estimates for the weld refurbishment option (Option 1) are in the range of $25M to $30M per penstock, cost estimates for partial penstock replacement (Option 2) are in the range of $47M to $52M per penstock, and the cost estimates for weld refurbishment with reinforcing plates (Option 3) are in the range of $34M to $36M.

The estimated costs are heavily influenced by the total length of the circumferential seams. To be conservative Hatch estimated 50 percent of all remaining seams require refurbishment. For example, the 17-foot section has a circumferential length of approximately 53 feet of which about of a third of the inspection, gouging and welding would be in the most difficult, overhead, position. NL Hydro could improve the accuracy of the estimates and possible reliability of the system with more detailed inspection of the circumferential seams.

With adequate maintenance of the coating systems, full replacement and installation of a new penstock can have an estimated design life of approximately 80 years. Hatch estimates the refurbishment options that include replacement of the interior coating will provide an additional life extension of at least 40 years provided there is no breakdown of the internal or external coating system and the structural integrity of the penstock is sound.

Revision 0 of this report suggested that Option 1, full weld refurbishment and application of an internal corrosion resistant coating, was the preferred option for the refurbishment of each penstock. However, in September 2019, a failure of a previously rewelded longitudinal seam in Penstock No. 1 indicates there could be a reliability issue with the refurbished welds in Penstock No. 1. To date there have been no failures in the refurbished welds in Penstock No.'s 2 and 3, consequently Hatch recommends the following;

- For Penstocks No.'s 2 and 3, refurbishment Option 1 may be selected as the preferred refurbishment strategy, as the reliability of this approach may be acceptable to NL Hydro.
- For Penstock No. 1, the recent rupture in previously rewelded longitudinal seam would suggest that Option 1 will not provide an acceptable level of long-term reliability, therefore, Option 2 is recommended.

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1. Introduction

NL Hydro engaged Hatch to conduct a Level II Condition Assessment of Penstocks No.'s 1, 2, and 3 at the Bay d'Espoir Hydroelectric Generating Facility during the 2018 operating season. The findings from the condition assessment will ensure the penstocks are in reliable operating condition for the 2019 production season and will assist in verifying penstock life extension refurbishment options.

The contents of this report builds on the initial refurbishment/replacement analysis provided in the previous report; providing more detail into the three selected refurbishment/replacement options NL Hydro selected for further analysis. Due to the time intensive nature of inspection, data collection, analysis and refurbishment option evaluations, this work was completed in three phases each of which has had a report issued upon its completion. This third report completes the third phase of the work and provides further details on three refurbishment options chosen by NL Hydro for further analysis by Hatch. The following are the three report titles.

- Report 1 – Bay d'Espoir Level II Condition Assessment of Penstock No.'s 1, 2 and 3.
- Report 2 – Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2 and 3.
- Report 3 – Penstock No.'s 1, 2 and 3 Life Extension Options.

The Bay d'Espoir Hydroelectric Generating Facility is comprised of four buried penstocks, three of which are connected to the main powerhouse containing six generating units. Each penstock bifurcates near the powerhouse to feed each unit through separate spherical valves. Units No.1 and No. 2 along with Penstock No. 1 were built in 1967. Units No. 3 and No. 4 along with Penstock No. 2 were built shortly after in 1968. The final addition to Powerhouse No.1 was completed in 1969 and consisted of the installation of generation Units No. 5 and No. 6 as well as Penstock No. 3. The penstocks run approximately 1,200 m (3,900 ft) in length and are constructed from a series of carbon steel cans[1] that vary in length, diameter and thickness.

The purpose of this report is to provide a more thorough review of the life extension options recommended for the penstock repair/refurbishment that were provided in Report 2 "Condition Assessment and Refurbishment Options for Penstock No.'s 1, 2 and 3" issued in the first quarter of 2019. The AACE Class 4 cost estimates included in this report are based on recent pricing information received from local construction companies, some of whom were involved with the refurbishment work on Penstock No.'s 1, 2, and 3.

[1] Lengths of penstock that are approximately 2.74 m (9 ft) long and constructed of two hemispheres of rolled plates longitudinally welded together to form a circumference.

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To make this report more concise, the following sections that were included in Report 2 – Condition Assessment and Refurbishment Options for Penstock No. 1, 2 and 3, have not been included in this report:

- Condition Assessment Methodology
- Penstock Inspections and Refurbishments
- Finite Element and Fatigue Analysis
- Current Condition and Life Expectancy

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2. Refurbishment or Replacement Options

Refurbishment or replacement options were investigated for each penstock. The options that NL Hydro has selected for Hatch's further review are as follows:

1. Refurbishment of deteriorated weld seams, both longitudinally and circumferentially, and re-coating the interior of the penstock (previously labelled Option 1 in Report 2 - H357395-00000-240-066-0002).
2. Replacement of penstock 17' ID section, weld refurbishment and recoating of the full penstock (previously labelled Option 2B in Report 2 - H357395-00000-240-066-0002).
3. Refurbishment of deteriorated weld seams, recoating of the entire penstock and installation of reinforcing plates over the longitudinal and circumferential weld seams of the 17 ft. section (previously labelled Option 4 in Report 2 - H357395-00000-240-066-0002).

The following options present varying degrees of life extension. Referencing published material from the American Society of Civil Engineers (ASCE), the design life of a steel penstock is normally in the range of 40-80 years with proper maintenance (ASCE, Guidelines for Evaluating Aging Penstocks). Since corrosion has been a major contributing factor relating to metal loss and in particular the welds, maintenance of a coating system is extremely important to the longevity.

Refurbishment options include replacement of the internal coating but not the external coating. Inspection of the external coating on Penstock No.'s 1, 2, and 3 from the brief sections that have been excavated during the penstock refurbishments and condition assessment have shown the coating is still intact. Additionally, wall thickness measurements were taken along the length of the penstock and showed no signs of metal loss due to external corrosion.

With adequate maintenance of the coating systems, full replacement and installation of a new penstock can have an estimated design life of approximately 80 years. Hatch estimates the refurbishment options that include replacement of the interior coating will provide an additional life extension of at least 40 years provided there is no breakdown of the internal or external coating system.

The AACE Class 4 cost estimates included in this report are based on recent pricing information received from a local construction companies, some of whom were involved with the refurbishment work on Penstock No.'s 1, 2 and 3. Additionally, information provided by local painting and fabrication companies were used to assist in the development of these cost estimates for the given options (supporting information can be found in Appendix A).

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2.1 Refurbishment and Re-coating of Existing Penstocks

The first refurbishment option investigated for life extension of the penstocks includes completion of the weld refurbishment that started in 2016. This will include full inspection of all seams, both longitudinal and circumferential, and refurbishment of all deteriorated seams (Note: all options with weld refurbishment used a 50 percent refurbishment rate of non-refurbished longitudinal seams, as well as a 50 percent refurbishment rate of all circumferential seams).

As identified in previous reports, the circumferential seams have not yet been refurbished for multiple reasons. The stress in the penstock due to internal pressure is twice that in the longitudinal seams versus the circumferential seams. Past refurbishments concentrated on the longitudinal seams due to the higher probability of failure resulting from the increased stress (as all failures were on longitudinal seams). Longitudinal seam refurbishment was the target to ensure timely return of service and safe operation given the planned condition assessment and monitoring of the penstocks. Preliminary inspection indicated the circumferential seams were not in as bad condition as that of the longitudinal seams. Hence, due to the lower risk and lower priority of the circumferential welds, thorough inspection of circumferential seams was not conducted at this time. Therefore, due to outage time available, location of failures, higher stress, and condition of longitudinal seams, only longitudinal seams were refurbished. However, life extension of the penstocks must remediate all areas that could produce a negative effect on the penstocks long term operation.

Refurbishment of all cracked or severely corroded welds is required to ensure that a newly applied coating is not compromised from poor weld seam condition. If cracks are present, it could lead to premature coating failure in those areas. If weld imperfections do not run deeper than 2mm, they can be eliminated by grinding out the defect with no additional welding required. However, if the weld defects are deeper than 2mm it is recommended the defect be removed and the weld be repaired to bring it to original condition.

Each circumferential seam in the 17-foot ID section is approximately 53.4 feet versus that of 18 feet of longitudinal seams for the one can. Since the circumference results in a much longer seam length, the overall resulting cost of refurbishment is suspected to be greater for the circumferential seams. Based on the corrosion and cracking investigated thus far, a value of 50 percent refurbishment was selected to represent a conservative number for the circumferential seams. This number is an estimate as there has been limited inspection of the circumferential welds to date.

Following the completion of weld refurbishment, the penstock internals will have abrasive blasting to bare metal and a new internal coating installed. The following blasting and coating methodology were considered for all three refurbishment options mentioned within this report. The current coating option priced is for three coat paint system by the Wasser Corporation (Table 2-1).

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Table 2-1: Proposed Coating System

Coat Number	Product	DFT
First	MC-Zinc 100	3.0 to 5.0 mils DFT
Second	MC-Tar 100	5.0 to 7.0 mils DFT
Third	MC-Tar 100	5.0 to 7.0 mils DFT
Total	**N/A**	**13.0 to 19.0 mils DFT**

The first coat would consist of MC-Zinc primer and be followed by two coats of MC-Tar moisture cure urethane that has similar performance to the coal tar epoxy that was originally installed, having a life span of approximately 15-20 years (recoating should be planned for every 15 years). The benefit of using the moisture cure product is that there will be significantly less environmental control and equipment required in the penstock during application. Other products can be assessed for this service; however, a large emphasis should be placed on the environmental application requirements (i.e., the internal penstock temperature, humidity, dew point, etc.). Hatch considers this important as NL Hydro and other companies such as Newfoundland Transshipment Limited have experienced difficulties in the past with trying to apply other coatings in high humidity environments.

The penstocks should have regular interior inspections following refurbishment work. Hatch recommends performing internal inspection after the first year of operation, with the system applied, to assess if any installation issues caused delamination of the coating and have repairs completed if required. After the initial warranty inspection, the frequency would be reduced to one interior inspection every 6 years. The interior inspection would be largely focused on coating condition and would include visual inspection and adhesion testing.

The total circumferential weld length was determined based on the number of cans (and associated seams) in each section of the penstocks multiplied by the circumference of that section. The penstock was broken up into three sections (17ft., 15.3ft.and 13.5ft.), the approximate number of cans for the 17ft. section was determined and multiplied by the circumference of the 17ft. section, the same process was used for the other two sections. Since no circumferential seams have been previously refurbished, half of the total circumferential length has been assumed for the estimated refurbished length as presented in Tables 2-2, 2-3, and 2-4.

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Table 2-2: Circumferential Weld Lengths - Penstock No. 1

Section	Cans	# of Cans	50% Refurbished	Diameter ft	Circumferential Length (ft)
17 ft dia.	1-121	121	60.5	17	3231
15.3 ft dia.	121-230	109	54.5	15.3	2619
13.5 ft dia.	230-400	170	85	13.5	3605
			Total Circumferential Length (ft.)		9455

Table 2-3: Circumferential Weld Lengths – Penstock No. 2

Section	Cans	# of Cans	50% Refurbished	Diameter ft	Circumferential Length (ft)
17 ft dia.	1-128	128	64	17	3418
15.3 ft dia.	128-237	109	54.5	15.3	2620
13.5 ft dia.	237-400	163	81.5	13.5	3457
			Total Circumferential Length (ft.)		9495

Table 2-4: Circumferential Weld Lengths – Penstock No. 3

Section	Cans	# of Cans	50% Refurbished	Diameter ft	Circumferential Length (ft)
17 ft dia.	1-136	136	68	17	3,632
15.3 ft dia.	136-291	155	77.5	15.3	3,725
13.5 ft dia.	291-400	109	54.5	13.5	2,311
			Total Circumferential Length (ft.)		9,668

The total longitudinal weld seam length of the non-refurbished welds was estimated using the weld refurbished trackers, which were prepared during the various refurbishment projects. A summary is provided in Tables 2-5, 2-6, and 2-7.

Table 2-5: Longitudinal Weld Length - Penstock No. 1

Location	Length Previously Refurbished (ft)	Total Length of Penstock (ft)	Length not Refurbished (ft)	Both North/South Side (ft)	50% of Welds Assumed to be Refurbished (ft)
Can 1-173 Can 215 only South side	1,520	3,883	2,363	4,726	2,363

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Table 2-6: Longitudinal Weld Length - Penstock No. 2

Location	Length Previously Refurbished (ft)	Total Length of Penstock (ft)	Length not Refurbished (ft)	Both North/South Side (ft)	50% of Welds Assumed to be Refurbished (ft)
Can 1-91 Can 230 and 270 only North side	752	3,896	3,144	6,288	3,144

Table 2-7: Longitudinal Weld Length - Penstock No. 3

Location	Length Previously Refurbished (total) (ft)	Total Length of Penstock (North and south) (ft)	Length not Refurbished (ft)	50% of Welds Assumed to be Refurbished (ft)
Approximation based on CAN 1-132; 132-175; 205-225; 302-342	3,500	7,420	3,920	1,960

Table 2-8 provides a summary of both the circumferential and longitudinal repair lengths for each penstock.

Table 2-8: Total Weld Refurbishment Lengths

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Total Circumferential Repair Length (ft)	9,455	9,495	9,668
Total Longitudinal Repair Length (ft)	2,363	3,144	1,960
Total Repair Length (ft)	11,818	12,639	11,628

Table 2-9 presents the AACE Class 4 cost estimate for Option1. Appendix B provides additional cost breakdown.

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Table 2-9: Refurbishment and Re-coating Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Contractor Mob/Demob	$1,670,000	$1,740,000	$1,600,000
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000
Doorsheet Removal and Re-installation	$110,000	$110,000	$110,000
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000
Contractor Living out Allowance (LOA)	$700,000	$700,000	$700,000
Rescue / Safety	$480,000	$480,000	$480,000
TOTAL DIRECT COST	**$19,110,000**	**$19,890,000**	**$18,740,000**
EPCM(12% of direct)	$2,290,000	$2,390,000	$2,250,000
Temp site facilities and services (3% of direct)	$570,000	$600,000	$560,000
Owner's costs (5%)	$960,000	$990,000	$940,000
TOTAL INDIRECT COST	**$3,820,000**	**$3,980,000**	**$3,750,000**
Contingency (15% of direct + indirect)	$3,440,000	$3,580,000	$3,370,000
TOTAL COST	**$26,370,000**	**$27,450,000**	**$25,860,000**

2.2 Replacement of 17 ft. Diameter Section and Weld Refurbishment

Based on the recent refurbishment history and the results of the stress analysis, the part of the penstock which has required the most refurbishment is the 17 ft section which is located upstream of the Surge Tank. The cost estimate for this option (Option 2) considers replacing this section with materials designed to current standards, fully refurbishing all existing deteriorated welds and coating the penstock (refer to Section 2.1 for painting/coating methodology and refer to Table 2-15 for cost estimate). The 17-foot section will be coated in the shop with the exception of the field joints which will be coated on site along with the remainder of the unreplaced portion of the penstock.

The cost for replacing the 17 ft diameter section will be impacted by the constructability of a large diameter penstock, and the remote location of the site. The most significant constructability concern is the delivery of cans to the site. Shop manufacturing the cans will be far cheaper and produce a higher quality product. New penstock sections can be fabricated in St. John's in 10 ft widths and 17 ft in diameter. Once fabricated, inspected, and painted, they can be shipped. Local transportation companies have provided budgetary estimates and indicated that two can sections can be shipped to the site on a low bed transport. Note, 17 ft is the upper limit set by the Department of Transportation for transport without escorts. Escort costs could increase transportation by up to 60 percent. This increase in cost was not considered in the cost estimate developed for this option.

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Plate for fabrication of new can sections would need to be purchased requiring a two to three-month lead time due to the large tonnage quantity. Purchasing the plate as a free issue item would save the contractor markup on the material.

Shop fabrication is the most efficient and best way to control quality. The longitudinal seams would be welded using Submerged Arc automatic welding method and inspected using radiographic or ultrasonic inspection. Hatch recommends using ultrasonic inspection as it is more efficient and does not cause a shutdown of production during the inspection period.

Additional constructability considerations include:

1. Available site laydown area for equipment and penstock cans.
2. Access around operating penstocks, especially Penstock No. 2.
3. Access road condition.
4. Earthworks, backfill removal and bedding material supply installation for the new penstock section. Sand for bedding would likely need to be supplied from a significant distance.
5. Drainage under the penstock would need to be addressed.
6. Room and Board availability for the construction crew.
7. Length of available outage for demolition and construction.
8. Some contractors have used automatic or semiautomatic welding equipment for circumferential welds in the field. This possibility could be further investigated with contractors. Automatic welding requires significant hoarding around the welded joints and may not be practical for a thin shelled (approximately 5/8 inch) penstock.
9. There will be significantly higher costs for the NDE in the field plus availability of UT technicians on an as required basis could be a problem. Hatch recommends spot checking the circumferential joints due to the lower stress in these joints. Cost could be as high as four times the cost of shop inspection depending on the number of site visits.

The same methodology for determining weld refurbishment lengths for Option 1 was used, where the weld seam refurbishment lengths associated for the 17 ft. section was not included. The weld repair lengths for Option 2 are presented in Tables 2-10, 2-11, 2-12, 2-13, and 2-14.

Table 2-10: Circumferential Weld Lengths - Penstock No. 1

Section	Cans	# of Cans	50% Refurbished	Diameter	Circumferential Length (ft)
15.3 ft dia.	121-230	109	54.5	15.3	2620
13.5 ft dia.	230-400	170	85	13.5	3605
				Total Circumferential Length (ft)	6225

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Table 2-11: Circumferential Weld Lengths - Penstock No. 2

Section	Cans	# of Cans	50% Refurbished	Diameter	Circumferential Length (ft)
15.3 ft dia.	128-237	109	54.5	15.3	2620
13.5 ft dia.	237-400	163	81.5	13.5	3457
				Total Circumferential Length (ft.)	6077

Table 2-12: Circumferential Weld Lengths - Penstock No. 3

Section	Cans	# of Cans	50% Refurbished	Diameter	Circumferential Length (ft)
15.3 ft dia.	136-291	155	77.5	15.3	3725
13.5 ft dia.	291-400	109	54.5	13.5	2311
				Total Circumferential Length (ft.)	6036

Table 2-13: Longitudinal Weld Lengths - Penstocks No. 1, 2 and 3

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Total Longitudinal Repair Length (ft.)	2363	2829	1924

Table 2-14: Total Weld Refurbishment Lengths

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Total Circumferential Repair Length (ft)	6225	6077	6036
Total Longitudinal Repair Length (ft)	2363	2829	1924
Total Repair Length (ft)	8588	8906	7960

Table 2-15 presents the AACE Class 4 cost estimate for Option 2.

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Table 2-15: Partial Replacement and Refurbishment Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Contractor Mob/Demob	$2,790,000	$2,890,000	$2,580,000
Backfill Removal, Reinstatement and Bedding	$830,000	$830,000	$830,000
Longitudinal Weld Refurbishment	$1,760,000	$2,330,000	$1,380,000
Circumferential Weld Refurbishment	$7,060,000	$7,050,000	$6,800,000
Doorsheet Removal and Re-installation	$70,000	$70,000	$70,000
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000
Purchasing of steel -17' ID	$1,420,000	$1,460,000	$1,270,000
Installation Penstock 1 - 17' ID	$3,450,000	$3,550,000	$3,090,000
Shipping	$340,000	$350,000	$370,000
Cranes (rate plus Mob/Demob)	$770,000	$770,000	$770,000
Site Fabrication	$8,820,000	$9,130,000	$7,940,000
Demo of Existing Penstock	$880,000	$880,000	$880,000
Contractor Living out Allowance (LOA)	$1,130,000	$1,130,000	$1,130,000
Rescue / Safety	$720,000	$720,000	$720,000
TOTAL DIRECT COSTS	**$33,740,000**	**$34,860,000**	**$31,390,000**
EPCM(12% of direct)	$4,050,000	$4,180,000	$3,770,000
Temp site facilities and services (3% of direct)	$1,010,000	$1,050,000	$940,000
Owner's costs (5%)	$1,690,000	$1,740,000	$1,570,000
TOTAL INDIRECT COSTS	**$6,750,000**	**$6,970,000**	**$6,280,000**
Contingency (25% of direct + indirect)	$10,120,000	$10,460,000	$9,420,000
TOTAL COST	**$50,610,000**	**$52,290,000**	**$47,090,000**

2.3 Refurbishment with Reinforcing Plates

Building on the requirements of Option 1, reinforcing plates could be installed internally over all longitudinal and circumferential weld seams of the 17 ft. diameter section; noting that all deteriorated welds would need to be refurbished first before reinforcing plates could be welded on. Following the weld refurbishment of the penstock, plates similar to those installed in Penstock No. 1 (November 2017) would be installed in the 17ft. section, to stiffen the existing penstock (at the peaked seams) and provide additional protection to the weld seams. The reinforcing plates will need to be cut, rolled (to the same radius as the penstock), inserted into the penstock, fit to place, and then welded (refer to Appendix C for details). Following the completion of welding the reinforcing plates, Magnetic Particle testing (MT) and Visual testing (VT) is required on the fillet welds, as well as corrosion protection. Abrasive blasting to bare metal and installation of a coating system would still be required to prevent further corrosion of the steel penstock and to protect the welds (refer to section 2.1, for blasting/coating methodology).

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The same weld lengths (both circumferential and longitudinal) from Option 1 was used in determining the weld refurbishment portion of the cost for this option. Table 2-16 presents the AACE Class 4 cost estimate for Option 3.

Table 2-16: Refurbishment with Reinforcing Plates Cost Estimate

	Penstock No. 1	Penstock No. 2	Penstock No. 3
Mob/Demob (10%)	$2,230,000	$2,300,000	$2,200,000
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000
Doorsheet Removal and Re-installation	$100,000	$100,000	$100,000
Site Labour For Repad Installations	$5,450,000	$5,450,000	$5,450,000
Shipping	$20,000	$20,000	$20,000
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000
Contractor Living out Allowance (LOA)	$920,000	$920,000	$920,000
Rescue / Safety	$600,000	$600,000	$600,000
TOTAL DIRECT COST	**$24,870,000**	**$26,250,000**	**$25,140,000**
EPCM(12%)	$2,980,000	$3,150,000	$3,020,000
Temp site facilities and services (3% of direct)	$750,000	$790,000	$750,000
Owner's costs (5%)	$1,240,000	$1,310,000	$1,260,000
TOTAL INDIRECT COST	**$4,970,000**	**$5,250,000**	**$5,030,000**
Contingency (15% of direct + indirect)	$4,480,000	$4,730,000	$4,530,000
TOTAL COST	**$34,320,000**	**$36,230,000**	**$34,700,000**

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3. Option Comparison

Due to the complexity of the various options, it was decided to include a brief comparison matrix ranking the options based on four key factors as presented in Table 3-2. The factors used for the comparison were reliability, cost, schedule/phasing and risk.

Reliability- considers the long-term reliable operation of the penstocks unimpeded by outages.

All the options scored high on reliability.

Cost – based on the estimated capital cost of the various options. Costing was provided in the previous sections of this report.

The estimates were based on industry norms and contractor consultations and do not consider inflation and cost adders associated with phasing the project over multiple outages. Potential cost savings would be possible if NL Hydro purchased materials in advance and free issued these items to a contractor.

Schedule/Phasing – all options allow for implementation in a phased manner.

Implementing the life extension program in a phased approach decreases the length of outages and allows for more cash flow flexibility. Option 2 would be the most difficult to phase due to existing irreplaceable infrastructure. It could be phased by section to make it more attractive; however, the outages would be substantial.

Risk – risk during construction were considered.

Risk scores are similar based on the majority of the options being largely interior work. However, the partial replacement option (Option 2) would be subject to weather delays, risk to bedding wash out, and would require lifting and other logistical construction related issues due to working around and over operating penstocks.

Prior to completing the ranking matrix, the life extension options were first analyzed with listed advantages and disadvantages as shown in Table 3-1. This table complements the ranking matrix and lists some of the reasoning for decided scoring for this ranking matrix.

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Table 3-1: Option Comparison Table

Option Number	Description	Advantages	Disadvantages
1	Refurbish circumferential and non-refurbished longitudinal welds of penstock followed by water blasting to bare metal and internal re-coating of penstock	1. Reduced risk of failure, in particular areas where the penstock diameter is smaller, plate thickness is greater, and the longitudinal seam peaking is smaller. 2. Lowest cost of the three options. 3. Work is internal and weather delays would be minimal. 4. Reduction in surface roughness via new coating system. 5. Smaller labor force required and can be staged over multiple outages. 6. No large civil works required, minimal risk to existing infrastructure. 7. Minimal lifts over operational penstocks.	1. Multiple outages required. 2. Flexible 17’ diameter section remains. 3. Poor fabrication alignment issues remain. 4. Interior is repaired but exterior coating from original construction remains. Life extension is limited by external coating condition. 5. No inclusion of corrosion allowance on existing wall thickness. Therefore, coating needs to remain intact over the lifespan of the penstock. Essentially the coating system should be budgeted for replacement every 15-20 years. 6. Existing bedding and drainage system cannot be upgraded. Bedding remains in contact with the penstock in areas checked. However, some sections of the bedding were saturated during inspection. 7. Due to a failure of a previously rewelded longitudinal seam in September 2020, there are concerns about the long term reliability of this refurbishment method.
2	Replacement of the 17ft. Section	1. Low risk of failure and highest level of reliability. 2. New sections can be constructed to meet current standards. 3. Reduction of surface roughness. 4. Existing flexible 17’ diameter section is removed. 5. Inclusion of corrosion allowance would be included in wall thickness. Reduces risk of corrosion effect on the penstock shell. This would allow initial recoating interval to be greater (approximately 25-30 years). After the first recoating the interval would revert back to 15-20 years. 6. Life extension up to 80 years depending on maintenance schedule. 7. Bedding and drainage could be upgraded during replacements.	1. Highest cost of the three options. 2. Long outage required. 3. High likelihood of weather delays. 4. Lifts over operational penstocks. 5. Heavy civil works required that could cause damage to existing infrastructure. 6. Demo of existing penstock sections would leave bedding system exposed to elements which could lead to compromised bedding and/or washouts. 7. Road transport of steel will require special permits for transport due to size and most likely be shipped in sections. This requires at least 2 longitudinal joints in the field per can. 8. Barge transport could be expensive due to the volume of steel cans. 9. Supply of required steel would have to be ordered one year in advance (long procurement period).
3	Refurbishment with reinforcing plates	1. Lower risk of failure. 2. Construction can be phased. 3. Work is all internal and weather delays would be minimal. 4. Increased reinforcement over welded areas.	1. Multiple outages required. 2. Possible flow disturbances caused by plates protruding into flow contributing to head loss. 3. Reduced flow through penstock do to repetitive pressure disturbances. 4. Refurbishment of existing welds is required prior to installation, thus there is no cost saving by a reduction in refurbishment cost by installing reinforcement plates over the welds. 5. Contractors stated very difficult to undertake due to handling large plates inside a confined space with no crane access. This poses a significant logistical challenge. Deemed by contractors as not a practical option.

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Table 3-2: Refurbishment Option Matrix

Option Number	Option Description	Ranking Factors (out of 5)				
		Reliability	Cost	Schedule / Phasing	Risk	Total Score
1	Refurbishment and Re-coating	2	5	5	3	75%
2	Partial Replacement and Refurbishment	5	3	3	3	70%
3	Refurbishment with Reinforcing Plates	3	4	4	3	70%

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4. Conclusions

Based on the current condition of the penstocks and the lack of corrosion protection, Hatch cannot guarantee that further leakages or micro cracks (if not already present) will not occur for each of the three penstocks. Hatch believes the probability of a major rupture or failure is relatively low within the next 5 years; however, a pin hole leak or micro crack could eventually lead to a rupture or failure.

Penstock No.'s 1 and 2 have been in service 50 years and the internal coating in these penstocks has failed. There is a possibility that Penstock No. 3 was never internally coated.

The non-refurbished sections of the three penstocks, including circumferential seams, are showing signs of weld metal loss and preferential pitting corrosion of the HAZ. In the future these areas will need to be protected by application of a coating to avoid further deterioration.

Based on the rupture that occurred in a previously rewelded longitudinal seam in the 17 ft diameter section of Penstock No. 1, there are some concerns about the long-term reliability of this method of weld refurbishment. As there have been no failures in the longitudinal seams of the smaller diameter sections of any of the penstocks or the larger 17 ft diameter sections of Penstock No.'s 2 or 3, Hatch believes the refurbishment methodology has been successful in stabilizing most of the penstock sections. Hatch recommends that annual inspection of the penstocks should continue until a life extension program is completed. Hatch also suggests that the refurbishment of backfill around Penstock No. 1, as outlined in Report H356043-00000-240-230-0003, may be deferred until the execution of the selected life extension work is completed.

Hatch noted the following constructability concerns related to the 17 ft section replacement option (Option 2); access around the operating penstocks (especially Penstock No. 2), site access due to road conditions and available laydown area for equipment and penstock cans. Additionally, concerns were noted regarding the local availability of suitable bedding material, drainage under the penstock would require refurbishment and the fact that this option would require a long outage for demolition and construction. These constructability concerns make this option less desirable. It should be noted, that similar work required for the other two options has been completed successfully in the past and any constructability concerns related to either of these options are well understood and are manageable. Other than the amount of time it will take to refurbish and or reinforce the circumferential seams, Hatch does not see any major constructability concerns with Options 1 or 3.

AACE Class 4 cost estimates for three options have been presented as part of this Report 3 and a comparison of these costs is shown in Table 4-1. The least cost option is Option 1 - Refurbishment of weld seams and application of a new protective coating.

Based on the results of the Option Matrix (Table 3-2), the three refurbishment options show very similar outcomes (i.e. the total scores are very close). Looking at the numbers in detail, Option 1 is the lowest cost approach, but has the lowest long-term reliability. Conversely,

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Option 2 is the highest cost approach, and is expected to provide the highest level of reliability. Option 3 is expected to have slightly higher level of reliability than Option 1 but at a higher cost than Option 1, thus there does not appear to be is sufficient benefit achieved to warrant a recommendation of Option 3.

Consideration should be given to selecting a preferred option for each penstock individually, and not necessarily adopting a common strategy for all three penstocks.

After carefully reviewing the data collected, the yearly inspection of the previously completed refurbishments, the cost estimates for each penstock, and SNC Lavalin's draft report into the 2019 rupture of Penstock No. 1, Hatch recommends the following;

- For Penstock No.'s 2 and 3, refurbishment Option 1 may be selected as the preferred refurbishment strategy as these two penstocks have not shown signs of failure in the rewelded longitudinal seams. Therefore, the reliability of this approach may be acceptable to NL Hydro.
- For Penstock No. 1, the recent rupture in previously rewelded longitudinal seam would suggest that Option 1 will not provide an acceptable level of long-term reliability, therefore, Option 2 is recommended.

Hatch is not aware of NL Hydro's weighting systems and decision-making processes used for major capital projects. It is therefore suggested that NL Hydro complete an internal assessment of cost versus reliability to determine which refurbishment option(s) best suits their long-term objectives prior to preceding with implementation of any of the recommended options.

With refurbishment of the remaining seams (removal of surface cracks, deposition of new weld metal where required) and the application of a new protective coating, the service life of the penstocks could be extended for an additional 20 years. Further life extension could be accomplished depending on maintenance of the new coating, maintenance of existing backfill and maintaining the current reduction in rough zone operation. It is in Hatch's opinion that the reinforcing plate option does not provide any significant additional life extension benefits in relation to the high costs involved in the installation of reinforcing plates.

One of the biggest contributing factors to the overall cost of each option is the extent of the weld refurbishment of the circumferential seams. The current cost estimates have assumed 50 percent will need refurbishment. This assumption is based upon the findings of the Condition Assessment, however, a maximum of 10 percent to 15 percent of the circumferential welds were inspected. Additional inspection of these seams would likely increase the accuracy of the estimate by providing a larger sample size. The previous refurbishment of the three penstocks concentrated on the longitudinal seams as these are subject to twice the internal pressure stress as are the circumferential seams and the ruptures occurred in the longitudinal seams.

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Based on inspections of the circumferential seams we know there is pitting corrosion in these seams. To understand the condition of these seams in the various sections of the penstock a more detailed scale removal and magnetic particle inspection could be performed, as noted above. It is possible that further inspection could reduce the requirements for significant weld refurbishment and increase the recommended refurbished period from three to five years to five to ten years. As most of the weld pitting corrosion occurred in the 17 ft section it is Hatch's opinion these portions of all three penstocks should be inspected, refurbished as needed, in particular the circumferential seams, and protected with a suitable coating system. This work should be completed in the next 5 years. Depending on the findings of the potential circumferential seam inspections and regular yearly penstock inspections the weld refurbishment and protective coating application for the remaining penstock sections could be completed in 10 years.

In addition, coating manufactures could potentially provide a system to coat the currently non-refurbished circumferential seams with minimal preparation and provide an expected coating service life of up to fifteen to twenty years.

Table 4-1: Cost Estimate Comparison

	Penstock No. 1	Penstock No. 2	Penstock No. 3	Total
Option 1: Refurbishment and Re-coating	$26,370,000	$27,450,000	$25,860,000	**$79,680,000**
Option 2: Partial Replacement and Refurbishment	$50,610,000	$52,290,000	$47,090,000	**$149,990,000**
Option 3: Refurbishment with Reinforcing Plates	$34,320,000	$36,230,000	$34,700,000	**$105,250,000**

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Appendix A
Construction, Fabrication and Painting Supporting Documents

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List of Supporting Documents

#	Supporting Document
1	[redacted] Pricing for Weld Refurbishment and 17ft. Section Replacement Option
2	[redacted] Pricing for Weld Refurbishment and 17ft. Section Replacement Option - Comments
3	[redacted] – Budgetary Quote for Painting/Blasting
4	[redacted] – Painting/Blasting Cost Estimate
5	[redacted] – Penstock Demolition and Removal Estimate
6	Shipment of Penstock Cans – Estimate and Comments
7	Penstock Plate Costs

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From: Saunders, Greg
To: O"Grady, Kathleen
Cc: Drake, Dylan
Subject: FW: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing
Date: Friday, June 14, 2019 2:36:04 PM
Attachments: image003.png
image004.png
image007.png
image008.png

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Friday, June 14, 2019 2:35 PM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: Fwd: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing

Sent from my iPhone

Begin forwarded message:

[redacted]

Subject: RE: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing

[redacted]

Option 7 with no Civil or Coating.

17' Diameter Replacement			
	Penstock #1	Penstock #2	Penstock #3
Total	23,227,564.42	23,920,523.33	21,148,687.73
Weld Refurbishment			
15.3 ft dia. Section	2619.6	2619.6	3725.1
13.5 ft dia. Section	3605	3456.5	2311.4
Total Circumferential Repair Length (ft)	6224.6	6076.1	6036.5
Total Longitudinal Repair Length (ft)	1800.4	2581.7	1337.1
Total Repair Length (ft)	8025	8657.8	7373.6
Sub Total	$ 13,448,655.95	$ 14,300,114.91	$ 12,472,085.64
Total	$ 33,254,797.40	$ 35,174,999.09	$ 32,038,456.53

[redacted]

Subject: RE: BDE Penstock #1,2 and 3 - Weld Refurbishment Pricing

[redacted]

The information below aligns with cost per liner M which we have submitted previously excluding coating.

Greg

Weld Refurbishment only:

	Penstock #1	Penstock #2	Penstock #3
Circumferential Repair Length (ft)			
17ft dia. Section	3231.1	3418.1	3631.7
15.3 ft dia. Section	2619.6	2619.6	3725.1
13.5 ft dia. Section	3605	3456.5	2311.4
Total Circumferential Repair Length (ft)	9455.7	9494.2	9668.3
Total Longitudinal Repair Length (ft)	2362.9	3144.2	1899.6
Total Repair Length (ft)	11818.6	12638.4	11567.8

		$	$
Total	$ 19,806,141.45	20,874,884.18	19,566,370.88

Greg

From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Cc: DylanDrake@nlh.nl.ca
Subject: FW: NL Hydro BDE Penstock Replacement Option 17 ft Section
Date: Friday, June 28, 2019 1:33:10 PM
Attachments: image001.png
image003.png

Hi Guys

See the comments from [redacted] next to the questions.

Regards,
Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: Saunders, Greg
Sent: Thursday, June 27, 2019 5:04 PM
To: [redacted]
Cc:
Subject: RE: NL Hydro BDE Penstock Replacement Option 17 ft Section

Thanks

Regards,
Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Thursday, June 27, 2019 5:01 PM
To: Saunders, Greg <greg.saunders@hatch.com>
Cc: [redacted]
Subject: RE: NL Hydro BDE Penstock Replacement Option 17 ft Section

Greg,

I will get back to you first thing tomorrow morning.

[redacted]

From: Saunders, Greg [mailto:greg.saunders@hatch.com]
Sent: Thursday, June 27, 2019 9:31 AM
To: [redacted]
Cc:
Subject: RE: NL Hydro BDE Penstock Replacement Option 17 ft Section

Hi Greg

Hydro reviewed our cost estimates and had some questions for us.

I would like to ask you a couple of questions to make sure we understand what you included or didn't include in your estimate. Also roughly how much contingency you used as we have also included some contingency in our final numbers.

For example:

1. Transportation to BDE full cans or partial needing longitudinal seams welded on site - [redacted] did not include any cost.
2. Site fabrication - [redacted] included fabrication of two half sections into a can on site and included welding 2 to 3 cans into an assembly to drop into the trench.
3. Demolition and disposal of existing penstock - [redacted] did not include demolition costs
4. Civil works, backfill removal, bedding reinstatement, backfill – [redacted] did not include any Civil Works costs
5. Craneage on site - [redacted] did include cranage (250ton at $180/hr + operator at $75/hr regular time OD is after 40hrs) , Mob and demob is around $5000 each so my estimate was good.
6. Housing of workforce in the area – rough idea of the number of workers and duration – [redacted] said the local area will probably max out at 40 people, LOA in the area costs around $180 to $200 per day.
7. Any indirect costs as a percentage of the total – [redacted] included an indirect cost which is around 25%
8. Any constructability concerns you see, in particular access to the middle penstock No. 2. - [redacted] stated there will be issues around Penstock No. 2 but didn't see anything insurmountable

Other notes.

[redacted] assumed a 5 to 6 month schedule for the work. They would work all day shift 10hrs per day 7 days a week and have a rotating crew. The total labour rate for the 70 hrs per week would be $100 per hour.
They included a 10% contingency on the top of their estimate.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL

[redacted]

QUOTE

Quote No: 1576

Date: Jun 28, 2019

Sold To:
Hatch

NL

Business No.: [redacted]

Description	Amount
Re: Penstocks in Bay D'Espoir Our budgetary quote for sandblasting and applying specified coating as per your request is $15-$18 / sq ft.	
HST NOT INCLUDED IN QUOTE. QUOTE VALID FOR 30 DAYS — **Total**	

From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Subject: FW: Bay D"Espoir - Penstock Painting
Date: Friday, June 28, 2019 10:55:08 AM
Attachments: image004.png

Hi

See cost per square foot below.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Friday, June 28, 2019 10:03 AM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: FW: Bay D'Espoir - Penstock

Greg,

See below.

[redacted]

From: [redacted]
Sent: Friday, June 28, 2019 10:00 AM
To: [redacted]
Subject: RE: Bay D'Espoir - Penstock

Hi [redacted]

I would use $18.00 - $22.00 sf. It really depends on the lining they want to use.

Note: Our hose bundle for spraying out the linings is 250' long, we would need access (manways?) 200' from each end of the penstock and then at approx. every 400'.

Regards,

[redacted]

From: [redacted]
Sent: Thursday, June 27, 2019 12:39 PM
To: [redacted]
Subject: RE: Bay D'Espoir - Penstock

Welded.

From: [redacted]
Sent: Thursday, June 27, 2019 12:01 PM
To: [redacted]
Subject: RE: Bay D'Espoir - Penstock

Hi [redacted]
Is it riveted or welded ?

From [redacted]
Sent: Thursday, June 27, 2019 10:45 AM
To: [redacted]
Subject: Bay D'Espoir - Penstock

[redacted]

I was just speaking with an Engineering Company here, Hatch, who is working with Hydro NL on options for repairs on the Bay D'Espoir Penstock. They were asking us some questions on welding and replacing sections of Penstock, etc.

They also asked me if I had any kind of norm and approx. budget method we could give them for their high level analysis of painting the inside of the penstock. If there anything off the cuff you can provide me for this. They say they would wan to apply a Polyurethane product, good for damp atmospheres where it is insite the penstock.

The penstock is almost 3800 ft long and 17 ft in diameter. Area Approx: 200,000 sq ft.

Would you be able to throw a number at this or even an approximate allowance per sq – ft?

Regards,

[redacted]

[redacted]

From: [redacted]
To: O"Grady, Kathleen
Cc: Saunders, Greg; Kenneally, Zachary
Subject: RE: Budgetary Pricing on Penstock Removal
Date: Thursday, June 27, 2019 10:33:18 PM
Attachments: image001.png

Morning all;

I've done up a budget number on the removal of the Penstocks as requested.

I've made a couple assumptions:

1. All fill to remain onsite
2. Concrete support for bottom of tank to remain.
3. Next's years work??

$875,000.00 + Hst

If got any questions give me a call.

[redacted]

[redacted]

From: O'Grady, Kathleen [mailto:kathleen.ogrady@hatch.com]
Sent: June 26, 2019 7:39 PM
To: [redacted]
Cc: Saunders, Greg <greg.saunders@hatch.com>; Kenneally, Zachary <zachary.kenneally@hatch.com>
Subject: Budgetary Pricing on Penstock Removal

Hi Jeff,

Following your discussion with Greg Saunders this morning, we are hoping to get a budgetary cost on the demolition/removal of 17ft. dia sections of penstocks located in Bay d'Espoir. The information is as followed:

	Penstock #1	Penstock #2	Penstock #3
Length	1087 ft.	1120 ft.	1125 ft.

Inside Diameter	17 ft.	17 ft.	17 ft.
Thickness	0.4375inch (11mm)	0.4375inch (11mm)	0.4375inch (11mm)
Approximate Imperial short Tons	521	537	540

The penstocks can be accessed by road. There is approximately 5000 m^3 of backfill that would need to be removed (this is total amount between all three penstocks). Please see attached drawings outlining the sections that require removal.

Thank you for your help!

Regards,
Kathleen

Kathleen O'Grady
Junior Mechancial EIT / Oil and Gas

Tel: +1 709 700 1391
Suite 100, 80 Hebron Way, St. John's
Newfoundland Canada A1A 0L9

HATCH

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From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Subject: FW: Shipment of Penstock to Bay D"Espoir
Date: Thursday, June 27, 2019 10:33:22 AM
Attachments: image004.png

FYI

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
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Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Thursday, June 27, 2019 10:21 AM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: FW: Shipment of Penstock to Bay D'Espoir

From: [redacted]
Sent: Thursday, June 27, 2019 10:20 AM
To: [redacted]
Cc: [redacted]
Subject: RE: Shipment of Penstock to Bay D'Espoir

[redacted]

As a budget

$5500 per load – assuming 2 per truck
17 ft wide at the upper limit for DOT escort so price could go up 60+% if they have to get involved… in case you get over 17 ft wide

[redacted]

From: [redacted]
Sent: June 27, 2019 9:51 AM
To: [redacted]
Cc: [redacted]
Subject: RE: Shipment of Penstock to Bay D'Espoir

[redacted]

I'm working with Hatch to pull together some high level budgets on this. They are looking at options to supply to Hydro.

What's high level estimate to ship a load to Bay D'espoir?

Regards,

[redacted]

[redacted]

From: [redacted]
Sent: Thursday, June 27, 2019 9:26 AM
To: [redacted]
Cc: [redacted]
Subject: RE: Shipment of Penstock to Bay D'Espoir

[redacted]
Yes this wouldn't be an issue for highway or public road transport

[redacted]

From: [redacted]
Sent: June 27, 2019 9:20 AM
To: [redacted]

Cc: [redacted]
Subject: Shipment of Penstock to Bay D'Espoir

Hi [redacted]

Do you know if we would be able to ship a piece penstock pipe 17' in diameter x 10' long to Bay D'Espoir? We can sit the piece of penstock on its end so the height would be 10' and it would be 17' wide.

Thanks,

[redacted]

From: Saunders, Greg
To: O"Grady, Kathleen; Kenneally, Zachary
Subject: FW: Penstock Plate
Date: Friday, June 28, 2019 10:57:21 AM

Hi Guys

See cost for the plate. This is $0.82 per pound or $1.81 per kg.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
Ph: (709) 701-0081
Fax: (709) 754-2717
Cell: (709) 690 1932
e-mail: greg.saunders@hatch.com web : www.hatch.ca

From: [redacted]
Sent: Friday, June 28, 2019 10:08 AM
To: Saunders, Greg <greg.saunders@hatch.com>
Subject: RE: Penstock Plate

Hi Greg,
Based on current estimates and current lead time of approximately 2 months, $1,640.00 ton.
In reference to squaring material, our plasma table can handle maximum 40 FT lengths.
Thank you for your inquiry.
[redacted]

From: [redacted]
Sent: Thursday, June 27, 2019 3:10 PM
To: [redacted]
Subject: FW: Penstock Plate

From: Saunders, Greg <greg.saunders@hatch.com>
Sent: Thursday, June 27, 2019 1:44 PM
To: [redacted]
Cc: O'Grady, Kathleen <kathleen.ogrady@hatch.com>; Kenneally, Zachary <zachary.kenneally@hatch.com>
Subject: Penstock Plate

[redacted]

The plate we would be looking for is CSAW300WT or 350WT 27J at -20C

Plate thickness 0.625" and width 10 ft. Each can is 17 feet in diameter so 53.4 feet long. Probably need to be cut in 2 for shipping.

Total weight 850 tons.

Just looking for the mill run delivery time for the plate.

If you can give a rough budget price ($1.00/lb?) for the plate delivered to St. Johns cut and squared that would be great.

Regards,

Greg Saunders P.Eng.
Hatch St. John's, General Manager
Hatch Limited
Suite 100
80 Hebron Way, St. John's, NL
A1A 0L9
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Fax: (709) 754-2717
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Appendix B
Cost Estimate Breakdown

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Option 1 - Weld Refurbishment and Coating

	Penstock No. 1	Penstock No. 2	Penstock No. 3	
Contractor Mob/Demob	$1,670,000	$1,740,000	$1,600,000	1.
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000	2.
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000	3.
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000	4.
Doorsheet Removal and Re-installation	$110,000	$110,000	$110,000	5.
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000	6.
Contractor LOA	$700,000	$700,000	$700,000	7.
Rescue / Safety	$480,000	$480,000	$480,000	8.
TOTAL DIRECT COST	**$19,110,000**	**$19,890,000**	**$18,740,000**	
EPCM(12% of direct)	$2,290,000	$2,390,000	$2,250,000	
Temp site facilties and services (3% of direct)	$570,000	$600,000	$560,000	
Owner's costs 5%	$960,000	$990,000	$940,000	
TOTAL INDIRECT COST	**$3,820,000**	**$3,980,000**	**$3,750,000**	
Contingency (15% of direct + indirect)	$3,440,000	$3,580,000	$3,370,000	
TOTAL COST	**$26,370,000**	**$27,450,000**	**$25,860,000**	

1. factored 10% of the weld refurb direct cost provieded by [redacted] plus 10% each of all additional items, with the exception of Contractor LOA which was not inlcuded
2. 1000 m^3 per penstock, $50/m^3
3. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
4. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
5. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
6. Assumed $20/sq.ft. ([redacted] estimate of $18/sq.ft. and [redacted] estimate of 18-22sq.ft. For purpose of estimate used a price in between $20/sq.ft.)
7. 40 worker; 90 days: $180 prediem per day + 10 painters; 30 days; $180 prediem per day
8. 120 days; 10hrs shifts; $100/hr; 2 workers; night and day shift

Option 2 - 17ft. Section Replacement

	Penstock No. 1	Penstock No. 2	Penstock No. 3	
Contractor Mob/Demob	$2,790,000	$2,890,000	$2,580,000	1.
Backfill Removal, Reinstatement and Bedding	$830,000	$830,000	$830,000	2.
Longitudinal Weld Refurbishment	$1,760,000	$2,330,000	$1,380,000	3.
Circumferential Weld Refurbishment	$7,060,000	$7,050,000	$6,800,000	4.
Doorsheet Removal and Re-installation	$70,000	$70,000	$70,000	5.
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000	6.
Purchasing of steel -17' ID	$1,420,000	$1,460,000	$1,270,000	7.
Installation Penstock 1 - 17' ID	$3,450,000	$3,550,000	$3,090,000	8.
Shipping	$340,000	$350,000	$370,000	9.
Cranes (rate plus Mob/Demob)	$770,000	$770,000	$770,000	10.
Site Fabrication	$8,820,000	$9,130,000	$7,940,000	11.
Demo of Existing Penstock	$880,000	$880,000	$880,000	12.
Contractor LOA	$1,130,000	$1,130,000	$1,130,000	13.
Rescue / Safety	$720,000	$720,000	$720,000	14.
TOTAL DIRECT COSTS	**$33,740,000**	**$34,860,000**	**$31,390,000**	
EPCM(12% of direct)	$4,050,000	$4,180,000	$3,770,000	
Temp site facilties and services (3% of direct)	$1,010,000	$1,050,000	$940,000	
Owner's costs 5%	$1,690,000	$1,740,000	$1,570,000	
TOTAL INDIRECT COSTS	**$6,750,000**	**$6,970,000**	**$6,280,000**	
Contingency (25% of direct + indirect)	$10,120,000	$10,460,000	$9,420,000	
TOTAL COST	**$50,610,000**	**$52,290,000**	**$47,090,000**	

1. Factor of the weld refurb was taken as well as the factor of replacement cost. 10% of each additional item was included in the price, with the expception of the crane mob/demob being $10,000 and the Contractor LOA, Shipping and Demo not being included for cost
2. $25,000 was included for 15.3 and 13.5 section backfill (to be confirm as 17ft. Section was estimated high)
3. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
4. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
5. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
6. Assumed $20/sq.ft. ([redacted] estimate of $18/sq.ft. and [redacted] estimate of 18-22sq.ft. For purpose of estimate used a price in between $20/sq.ft.)
7. Based on direct cost of 17ft. replacement cost given by [redacted] and weighted each item based on previous estimate
8. Based on direct cost of 17ft. replacement cost given by [redacted] and weighted each item based on previous estimate
9. shipping per 2 cans
10. Based on $180/hr + operator at $75/hr regular time, 150 days + 10 hours + night and day shift
11. Based on direct cost of 17ft. replacement cost given by [redacted] and weighted each item based on previous estimate
12. Based on [redacted] Pricing
13. 40 worker; 150 days: $180 prediem per day + 10 painters; 30 days; $180 prediem per day
14. 180 days; 10hrs shifts; $100/hr; 2 workers; night and day shift

	Penstock No. 1	Penstock No. 2	Penstock No. 3	
Mob/Demob (10%)	$2,230,000	$2,300,000	$2,200,000	1.
Backfill Removal and Reinstatement	$50,000	$50,000	$50,000	2.
Longitudinal Weld Refurbishment	$2,480,000	$3,260,000	$2,060,000	3.
Circumferential Weld Refurbishment	$9,920,000	$9,850,000	$10,180,000	4.
Doorsheet Removal and Re-installation	$100,000	$100,000	$100,000	5.
Site Labour For Repad Installations	$5,450,000	$5,450,000	$5,450,000	6.
Shipping	$20,000	$20,000	$20,000	7'.
Blasting/Coating	$3,700,000	$3,700,000	$3,560,000	8.
Contractor LOA	$920,000	$920,000	$920,000	9.
Rescue / Safety	$600,000	$600,000	$600,000	10.
TOTAL DIRECT COST	**$24,870,000**	**$26,250,000**	**$25,140,000**	
EPCM(12%)	$2,980,000	$3,150,000	$3,020,000	
Temp site facilities and services (3% of direct)	$750,000	$790,000	$750,000	
Owner's costs (5%)	$1,240,000	$1,310,000	$1,260,000	
TOTAL INDIRECT COST	**$4,970,000**	**$5,250,000**	**$5,030,000**	
Contingency (15% of direct + indirect)	$4,480,000	$4,730,000	$4,530,000	
TOTAL COST	**$34,320,000**	**$36,230,000**	**$34,700,000**	

1. factored 10% of the weld refurb direct cost provieded by [redacted] plus 10% each of all additional items, with the exception of shipping and Contractor LOA which was not included
2. 1000 m^3 per penstock, $50/m^3
3. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
4. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
5. Cost was based on [redacted] direct cost for weld refrub. In order to break out cost further, each item included in the overall unit pricing was factored based on how items were weighted in previous estimate
6. 82.5 tonnes of normal welds; 82.5 tonnes of out of position welds; 88hr/tonne; $150/hr. Assumed half the welds were normal welds and half were out of position welds. Out of postiion welds were considered to cost 4 times as much as normal welds.
7. 36 tonnes/trip; 165 tonnes; approximately 5 trips; $3000/trip
8. Assumed $20/sq.ft. ([redacted] estimate of $18/sq.ft. and [redacted] estimate of 18-22sq.ft. For purpose of estimate used a price in between $20/sq.ft.)
9. 40 worker; 120 days: $180 prediem per day + 10 painters; 30 days; $180 prediem per day
10. 150 days; 10hrs shifts; $100/hr; 2 workers; night and day shift

Appendix C
Reinforcing Plate Detail

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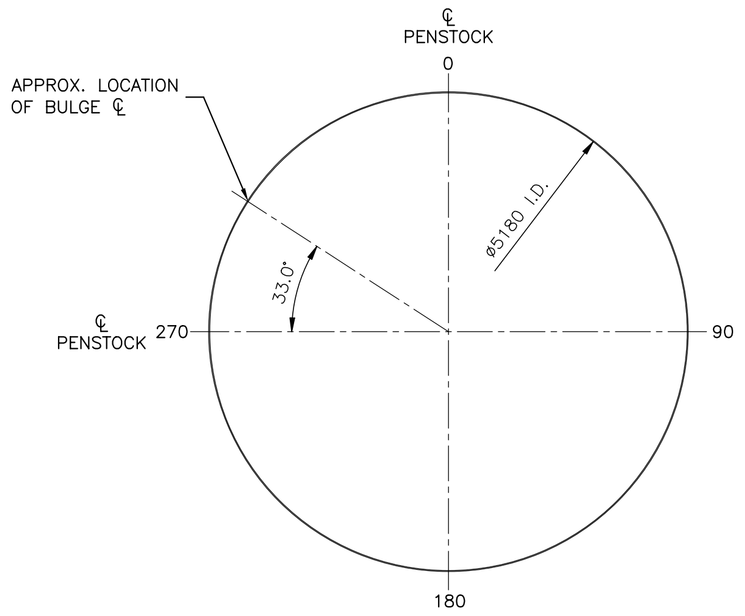
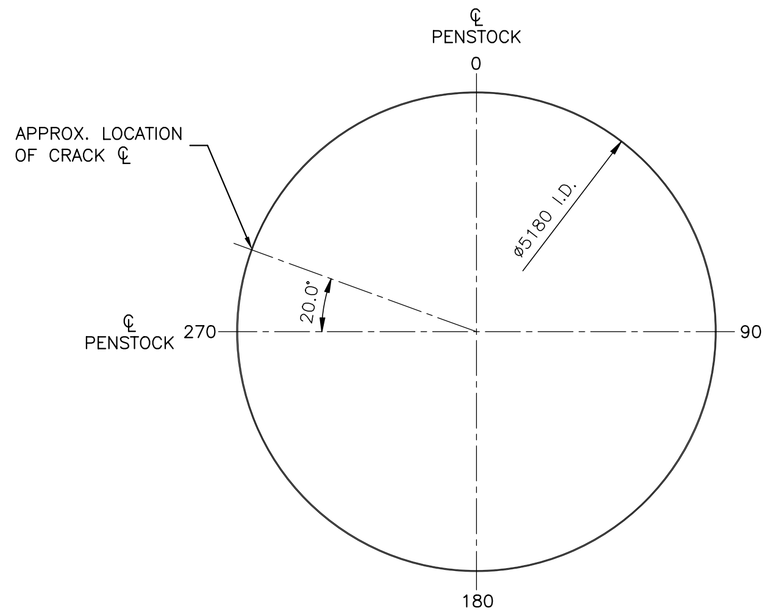


SECTION - CAN 34
SCALE: 1:50
A



SECTION - CAN 35
SCALE: 1:50
B

INSERT PLATE INSTALLATION SEQUENCE

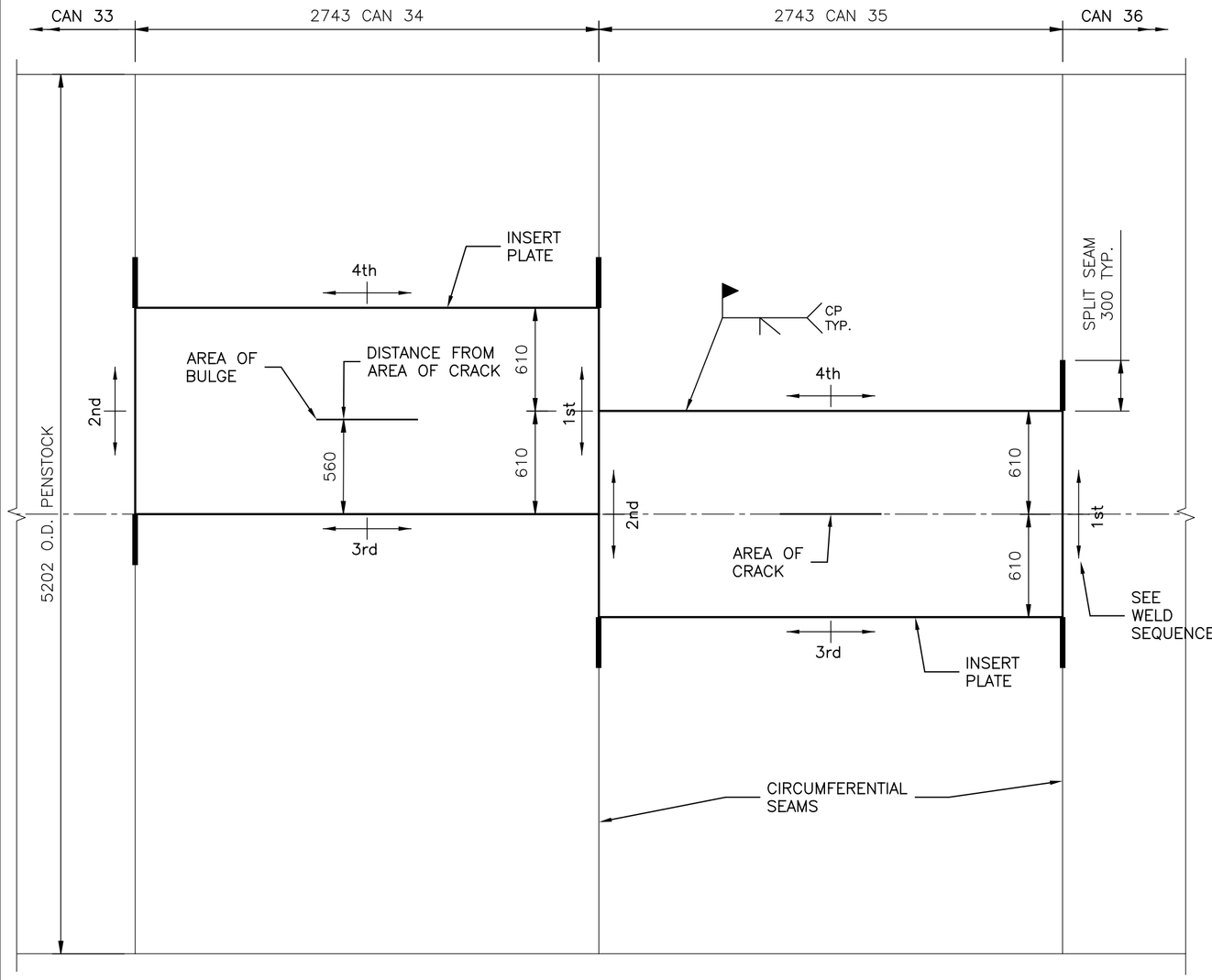
1. INSTALL THE INSERT PLATE FOR CAN 35 FIRST.
2. INSTALL THE INSERT PLATE FOR CAN 34 SECOND.
3. WHERE LONGITUDINAL JOINTS INTERSECT CIRCUMFERENTIAL JOINTS SPLIT THE CIRCUMFERENTIAL SEAM BACK 300mm PRIOR TO FITTING THE INSERT PLATE.
4. REINFORCING PLATES TO BE INSTALLED AS SHOWN ON DRAWING. BUTT WELDS TO BE INSPECTED AND FOUND ACCEPTABLE PRIOR TO THE INSTALLATION OF REINFORCING PLATES.

WELD SEQUENCE FOR DISTORTION CONTROL

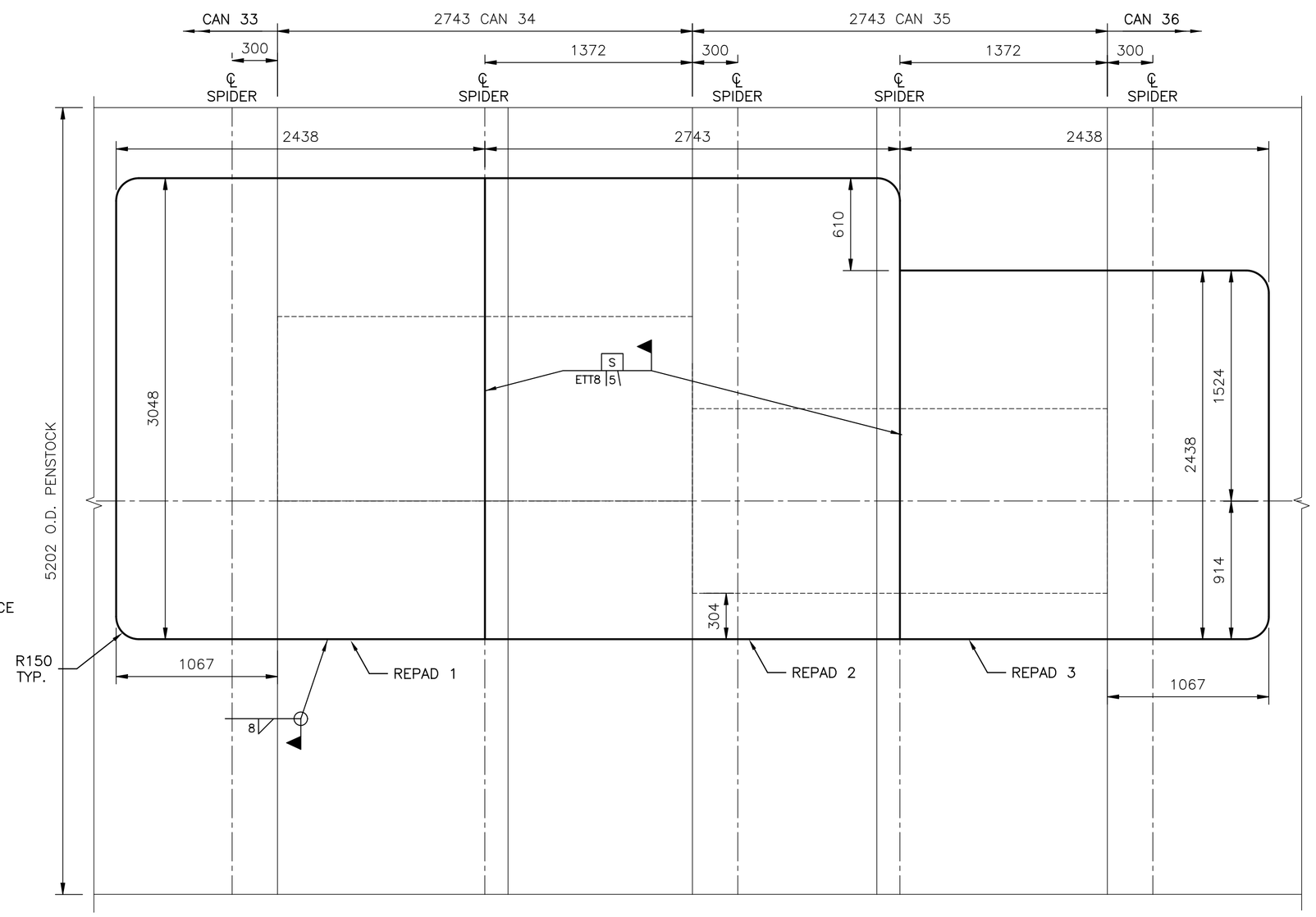
1. TACK WELD INSERT PLATE INTO OPENING AFTER AREA HAS BEEN GROUND AND CLEANED FOR WELDING. TACKS TO BE 50mm MIN. LENGTH AT 150mm c/c.
2. WELDING TO BE PERFORMED ON CIRCUMFERENTIAL SEAMS FIRST STARTING IN THE CENTER AND WORKING TO EDGES EQUALLY BOTH SIDES. SEE ELEVATION C.
3. AFTER TACK WELDING COMPLETE THE FIRST PASS USING THE SAME SEQUENCE AND BACK STEPPING THE WELDING.
4. COMPLETE THE SECOND PASS SAME AS THE FIRST PASS UNTIL THE JOINT IS APPROXIMATELY 50% FILLED.
5. BACK GOUGE TO SOUND METAL ON THE INSIDE AND FILL THE JOINT BY WELDING IN THE SAME SEQUENCE AS ABOVE.
6. COMPLETE THE WELD ON THE EXTERIOR IN THE SAME SEQUENCE AS ABOVE.
7. PERFORM A VT AND MT INSPECTION ON THE INTERIOR AND EXTERIOR SURFACES OF THE WELDS 12 HOURS AFTER WELDING.
8. GRIND THE INTERIOR AND EXTERIOR WELDS FLUSH WITH THE SURFACE.
9. PERFORM A VT AND MT INSPECTION ON THE SURFACE OF THE WELDS AT 48 HOURS AFTER WELDING.
10. COMPLETE RT AND UT INSPECTION OF THE WELDS.
11. THE COMMON CIRCUMFERENTIAL SEAM BETWEEN CAN 34 & CAN 35 SHALL ONLY BE WELDED 50%. THIS PORTION OF THE COMMON SEAM WILL BE COMPLETED WHEN THE INSERT FOR CAN 34 IS INSTALLED.

GENERAL NOTES:

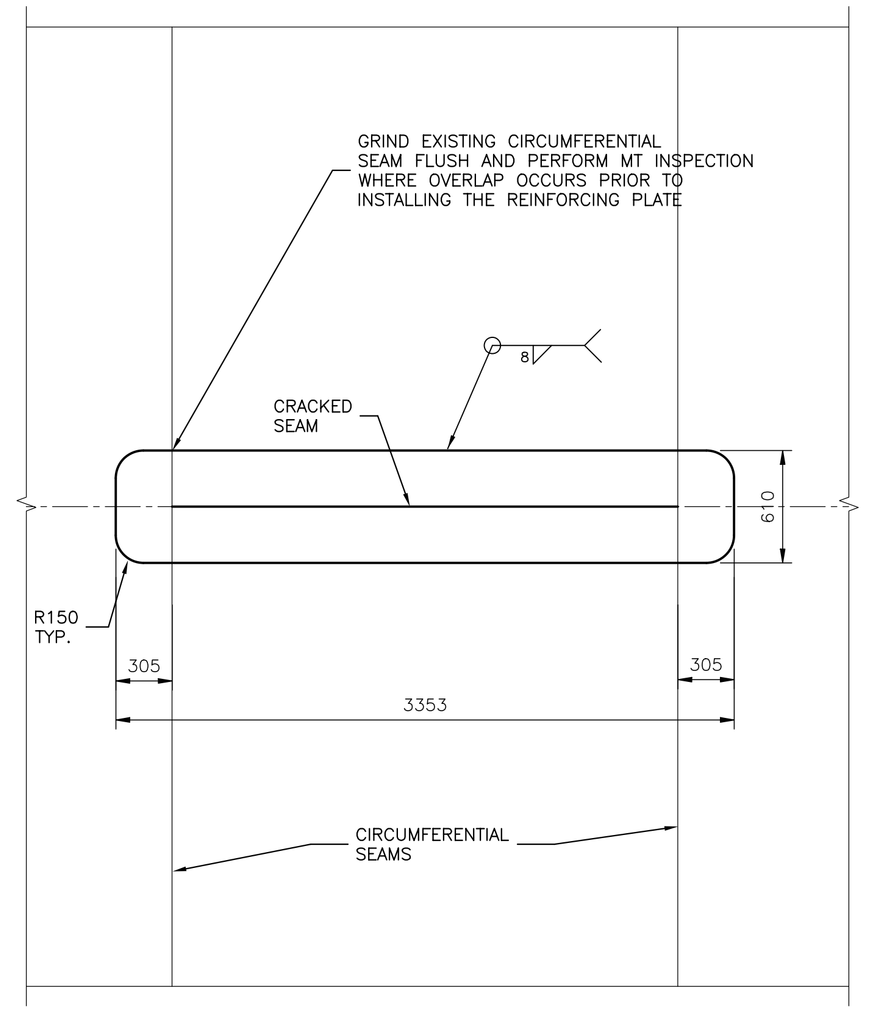
1. ALL DIMENSIONS IN MILLIMETERS.
2. DO NOT SCALE FROM DRAWING.
3. CONTRACTOR MUST VERIFY ALL DIMENSIONS & CONDITIONS ON SITE BEFORE PROCEEDING WITH ANY PORTION OF THIS WORK.
4. ALL STRUCTURAL STEEL IN ACCORDANCE WITH CAN/CSA–G40.20/G40.21. STEEL GRADE SHALL BE PLATE: 350WT U.N.O.
5. ALL STRUCTURAL STEEL WORK TO CAN/CSA S16.1 LATEST EDITION.
6. ALL WELDING IN ACCORDANCE WITH ASME IX BY WELDERS QUALIFIED TO ASME IX
7. ALL CP WELDS SHALL BE INSPECTED AS FOLLOWS:
   –100% VT
   –100% MT
   –100% RT
   –100% UT
   ALL FILLET WELDS TO BE INSPECTED 100% VT, MT
8. ALL FILLET WELDS SHALL BE 8mm ALL AROUND UNLESS NOTED OTHERWISE.
9. EXISTING PENSTOCK WALL THICKNESS: 11mm. ALL INSERT PLATES AND REPAD THICKNESS TO BE 13mm.



ELEVATION - INSERT PLATE
SCALE: 1:25
C



ELEVATION - EXTERIOR REPAD DETAIL
SCALE: 1:25
D



ELEVATION - INTERIOR REINFORCING PLATE DETAIL
SCALE: 1:25
E

DWG.NO.	TITLE
	REFERENCE DRAWINGS

NO.	DATE	DESCRIPTION	DWN.	DESIGN.	CHK.	APP'D
1	JAN.19,2018	ISSUED AS RECORD SET	TB	GS	GS	GS
0	NOV.27,2017	ISSUED FOR CONSTRUCTION	RG	GS	GS	GS
		REVISIONS				

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HATCH

HATCH PROJECT NO. H352666
HATCH DRAWING NO. H352666–D–M–0001.1

newfoundland labrador hydro a nalcor energy company

BAY D'ESPOIR HYDROELECTRIC GENERATING FACILITY

PENSTOCK No.1 MODIFICATIONS ELEVATIONS, SECTIONS AND DETAILS SHEET 1 OF 1

ELECT.	SCALE:	AS SHOWN	
CIVIL	DESIGNED:	G. SAUNDERS	
TRANS.	DRAWN:	R. GEORGE	
MECH.	DATE:	NOV.10, 2017	
P&C	CHECKED:	G. SAUNDERS	
TELC.	APPROVED:	G. SAUNDERS	

W.O. NO.

DWG. NO. H352666-D-M-0001-1

REV. 1

C.A.D.

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Schedule 1, Attachment 6

Penstock No. 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstocks 1-3 Inspection Project

Kleinschmidt Associates

November 2019



PENSTOCK NO. 3
INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:

Newfoundland and Labrador Hydro
St. John's, Newfoundland and Labrador

Prepared by:

Kleinschmidt

Halifax, Nova Scotia
www.KleinschmidtGroup.com

2670021_001RP
November 2019

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PENSTOCKS 1-3 INSPECTION PROJECT

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LIST OF ABBREVIATIONS

ASCE	AMERICAN SOCIETY OF CIVIL ENGINEERS
ASME	AMERICAN SOCIETY OF MECHANICAL ENGINEERS
CH	CHAINAGE (IN METRES)
CMS	CUBIC METRES PER SECOND
FU	ULTIMATE TENSILE STRESS
FY	YIELD STRESS
GWH	GIGAWATT HOURS
KPA	KILO-PASCALS
KLEINSCHMIDT	KLEINSCHMIDT ASSOCIATES
MW	MEGAWATTS
NLH	NEWFOUNDLAND AND LABRADOR HYDRO
SPRAT	SOCIETY OF PROFESSIONAL ROPE ACCESS TECHNICIANS
STA	STATION (IN FEET)
TRR	TECHNICAL ROPE AND RESCUE
UT	ULTRASONIC THICKNESS

PENSTOCK NO. 3
INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in March 2019 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

Kleinschmidt conducted an inspection of Penstock No. 3 in April 2019, a 1,100-metre-long buried steel penstock, tappering 5.2 metres in diameter (at the intake) to 4.1 metres in diameter at the powerhouse bifurcation. At its flattest point, the penstock has a 0.0% slope and has a 20% slope at its steepest. There are at least three areas of access for Penstock No. 3, one at the well in the intake structure, three manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

In 2016, cracking was identified in Penstock No. 1 and Kleinschmidt was contracted to assist with the weld repair design. After repairing Penstock 1 in 2016, and having Kleinschmidt inspect Penstock No. 2 later in 2016, NLH repaired similar weld deterioration of Penstock No. 2 in 2017 and repaired welds in Penstock 3 in 2018. Penstock No. 3 was installed in 1968, a year after the No. 1 and No. 2 penstocks, with similar plate materials, thicknesses, and weld procedures. Due to the weld issues and corrosion in all 3 penstocks, NLH has initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock 3 inspection was to assess the integrity of the welds and to complete steel thickness measurements to evaluate current condition and potential life extension of the penstock.

Kleinschmidt's April 2019 inspection of Penstock No. 3 consisted of a visual walk-over of the penstock exterior, and a detailed examination of the condition of the interior of the penstock. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which included cleaning and visually inspecting the steel shell and the longitudinal and

circumferential welds. The interior inspection also included non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell.

Overall, the penstock was in fair condition. The penstock has not significantly ovalized, the plate thickness was comparable to the construction drawings, and the interior of the shell has a layer of rust with moderate corrosion and pitting common for a 50-year-old penstock. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3.

The exterior inspection found a sinkhole just downstream of the surge tank on the left side of the penstock and is discussed in Section 3.3. The surrounding area also shows various signs of settlement that have occurred over time. It is not believed that this is an immediate threat to the penstock integrity but the hole should be filled this year and the next time the penstock is dewatered in 2020 the soil around the sink hole should be removed to confirm the extent of erosion and confirm there are no other voids in the immediate area. The area should then be repaired with properly graded and compacted rock when the penstock is dewatered to restore a uniform surface with an erosion resistant material. There is also some concern regarding effective drainage in the area as discussed in Section 3.3.

Measurements of the penstock shell thickness indicate minimal loss of material thickness. Some mild to moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, sections of the penstock should have significant service life remaining that could be extended another 50 to 80 years with an internal coating.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.22. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.23, which is not acceptable for late 1960 steel pipe. Note that the computed stresses are higher and safety factors lower than the 2016 analysis because more thickness measurements were taken during this inspection than during the 2016 inspection, and the measurements had a wider range of values that resulted in confidence interval thickness values that were, in some cases, lower than used in the 2016 stress analysis. Also note that this is stress at the joints, and assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used, as discussed in Section 4, if RT weld testing is performed to verify the integrity of

the welds. A higher joint efficiency would result in favourable factors of safety; however, considering the known weld issues, a higher joint efficiency is not justified at this time. A more accurate surge stress analysis using actual wicket gate closure times and data from the pressure transducers would be helpful in providing more accurate stress numbers. This should be completed in 2020 to better understand the risks.

The base plate material away from the joints has a maximum stress ratio of 0.85 and a safety factor of 1.75, which is acceptable and could tolerate 3 mm (1/8") of material loss from design thickness in most cases.

This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses. We therefore anticipate that the penstock has an additional 80 years of useful service life (est. 2099), provided that the penstock interior is coated before the steel deteriorates further and is adequately maintained and monitored. In addition to recoating the penstock in the next 10 years, Kleinschmidt recommends continued monitoring of the exterior of the penstock for signs of leakage and detailed inspection of the interior every year until the penstock is recoated.

PENSTOCK NO. 3
INSPECTION AND EVALUATION

BAY D'ESPOIR PENSTOCKS 1-3 INSPECTION PROJECT

1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in March 2019 to inspect and evaluate the condition of Penstock No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

In 2016, cracking was identified in Penstock No. 1 due to weld degradation and Kleinschmidt was contracted to assist with the weld repair design. Another crack in Penstock No. 1 prompted a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods and significant refurbishment of the welds followed.

Penstock No. 3 was installed in 1968, a year after the No. 1 and No. 2 penstocks, with similar plate materials, thicknesses, and weld procedures. The cracking found in Penstock No. 1 and similar weld deterioration found in Penstock No. 2 in 2016 raised concerns about the weld integrity of Penstock No. 3 and NLH elected to have Kleinschmidt complete a detailed inspection and evaluation in 2017. The main focus of the inspection was to assess the integrity of the welds and to complete steel thickness measurements to evaluate potential life extension of the penstock and appurtenances. Non-destructive testing of the welds were not performed as part of the 2017 scope of work, but the welds were inspected and tested using magnetic particle testing (MP) methods in 2018 as part of a Level II Condition Assessment performed by Hatch. The 2018 assessment and NDT of the welds in Penstock No. 3 found similar issues as found in Penstock Nos. 1 and 2 and weld repairs were made in June 2018 before returning the penstock to service loads.

This report presents Kleinschmidt's evaluation of Penstock No. 3 in its current condition following significant weld repairs made in 2018, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 feet (176 metres) and seven generating units with a total capacity of 604 megawatts (MW). The development comprises four intake structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks Nos. 1, 2, and 3 have surge towers approximately 2,400 feet (727 metres) upstream of the powerhouse. The first phase of the project construction involved the installation of two intake structures and a four-unit powerhouse with Penstocks No. 1 and No. 2 connecting the two intakes to the powerhouse. The second phase consisted of installing Penstock No. 3 with a third intake and two additional units in the powerhouse. A separate intake structure and powerhouse for Unit No. 7, connected by Penstock No. 4 was built in 1970. Penstock No. 3 supplies Units No. 5 and No. 6. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock No. 3 is buried along its entire length from the intake to the powerhouse. There are three large manholes located on the crown of the penstock: (1) approximately halfway between the powerhouse and surge tower, (2) at the surge tower, and (3) halfway between the intake and the surge tower.

Appendix A includes the original 1968 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 7/16 inches at the intake to 1 5/8 inches at the bifurcation upstream of the powerhouse (plate thicknesses are expressed in inches because the original design was based on inches matching the drawings provided). The penstock is constructed of A285, G40.88 and HSB 50 steel. The penstock is 17.0 feet in diameter until STA 12+41 (CH 376.2), then 15.25 feet in diameter between STA 12+41 (CH 376.2) and STA 27+50 (CH 833.3) where it then reduces to 13.5 feet in diameter for the remaining 1,581 feet (479.1 metres) to the bifurcation. The welds are generally double V groove full penetration welds. The penstock slope varies from approximately 0 degrees to 20 degrees just upstream of the bifurcation.

A majority of the penstock has a cover of 2 feet (0.61 metres) of clayey soil and 1 foot (0.30 metres) minimum of riprap. The penstock is deeply buried as it crosses under the switchyard and goes into the powerhouse. The penstock has drainage long its length with several weirs where the drainage daylights to the ditches and wells for inspection and monitoring.

3.0 INSPECTION

Christopher Vella, P.Eng. of Kleinschmidt, inspected the interior and exterior of Penstock No. 3 on April 1 through April 3, 2019, with the assistance of personnel from Acuren Group, Inc. (Acuren) and NLH. NLH personnel assisted with safety procedures, permitting, and site access, and answered questions about the history, operation, and maintenance of the station. Acuren rope access personnel assisted with safe access, confined space entry protocols, communication, and were on standby at the penstock entry for rescue, if needed.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying any pitting or cracking, and an overall general condition assessment of the interior of the shell. The exterior of the buried penstock was examined for signs of leakage. Acuren personnel performed MP on approximately 10% of the longitudinal welds from inside the penstock and took ultrasonic thickness (UT) measurements from approximately 10% of the cans[1] for the portion of penstock inspected. The inspection was terminated at the surge tank due to the danger of falling ice from the surge tank as discussed below. The field data is included in Appendices C and D, respectively.

TABLE 3-1 DEFINITIONS

TERM	DEFINITION
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible and remediation is required within 1 year

[1] A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint.

3.1 WORKING CONDITIONS

Kleinschmidt's inspection team entered the penstock at the intake structure of Penstock No. 3 each day. Acuren assisted with confined space entrance and rigging for fall restraint. The inspection started at the headgate and progressed to the surge tank where chucks of ice, exceeding 4 inches thick, were found under the surge tank shaft (Photo 1, Appendix B). It appears an ice shell formed on the inside of the steel skin of the surge tank. This is a relatively common occurrence for surge tanks located in cold winter regions, even when the tanks are insulated. The ice shell has no significant impact on operation, except (like in this case) when the surge tank is dewatered early in the spring, before the ice has melted, and the air temperature is above freezing. In these conditions, the ice can break away from the shell and fall down into the penstock. The penstock beneath the surge tank is incased in concrete providing significant impact resistance so no damage to the penstock is expected from the falling ice and none was observed; however, the falling ice posed a danger to the inspection team. The team identified the potential for an individual to be impacted from falling ice as they passed under the surge tank and passage would be required multiple times for multiple individuals. The team also identified the potential for chucks of ice sliding down the penstock to impact individuals downstream of the surge tank. Due to these hazards and in consultation with NLH the decision was made to stop the inspection at the surge tank as the potential hazard to the inspection team was deemed too great to proceed. Due to falling ice concerns, it is recommended that future penstock inspections at this site take place no sooner than May 1st.

The first day of inspection was cut short due to low oxygen level alarms that occurred about 150 metres from the intake. It was found that the intake building and venting louvers were closed along with the manholes prior to the inspection team's arrival. It is believed that the rust and organics in the penstock may have been enough to lower the oxygen below acceptable levels while the penstock was dewatered but closed up. All manholes were opened and the intake building was left open overnight to provide adequate ventilation. Oxygen levels were found normal the following day and the inspection proceeded. It is recommended for future inspections that the penstock manholes and intake vents be opened at least 2 days prior to the inspection and remain open until the inspection is complete.

The inspection started at the headgate, and leakage around the gate was mainly at the top corners of the gate and from the left bottom corner as seen in Photo 2. The leakage was not enough to hinder the inspection. The left side seal leakage observed in the 2017 inspection was not observed during this inspection. The interior of the penstock was damp and much of the organics had been cleaned away during the previous penstock repairs.

The exterior of the penstock was first inspected on April 2, 2019. The ground surface was generally rock covered with steep slopes in many areas and short vegetation (Photo 16). Several areas still had snow cover hindering the inspection. Deeply buried sections under the dam and switchyard were not inspected from the exterior. The exterior of Penstock No. 3 was walked again on May 7 while on site for the Penstock No. 2 inspection. This allowed inspection of Penstock No. 3 without snow cover.

3.2 INTERIOR INSPECTION

The interior of the penstock was inspected from April 1 to 3, 2019. The penstock was fabricated with about 435 "Cans". A can in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used in this report to reference location in the penstock during the inspection with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded from the interior at various locations. Shell thickness measurements were taken with a Panametrics Model 38DL Plus Ultrasonic thickness gauge. A dual element D799 transducer was used and the readings were taken in the "standard" mode. In "standard" mode the paint thickness does not affect the steel thickness readings if the paint thickness is below 1/64 (0.0156) inch (15.6 mils). The gauge was calibrated before the field measurements to an accuracy of 0.001 inch. Due to the fact that both the field measurements and Appendix A drawings give shell thicknesses in inches, this evaluation did so as well. Metric equivalents are given in parenthesis.

Thickness readings were recorded from the interior of the penstock generally near the invert of the penstock, typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the pipe. All references to penstock left and right are also oriented looking

downstream. Appendix D provides the Acuren report of shell thickness readings and Table D-1 and Table D-2 in Appendix D summarizes the average shell thickness readings and stresses respectively for each section of penstock. A summary of this data is provided in Table 4-1.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 INTERIOR SURFACE, COATING AND JOINT CONDITION

Penstock No. 3 is fabricated from 30 different plate sizes ranging from 7/16 to 1 5/8 inches with 21 of these plate sizes occurring downstream of the surge tank. Inspection thickness readings were taken at 7 of plates upstream of the surge tank, ranging from 7/16-inch (11 millimetres) to 3/4-inch (19 millimetres). Many of these sections exhibited little to no appreciable material loss compared to drawings with thickness readings averaging about 4.6% greater than the listed original plate thickness. This percentage is higher than previously reported but is not representative of the entire length of penstock as was reported previously. The greater thickness is common for steel construction from this era when steel plate was frequently rolled out slightly thicker than called for in the design to account for fabrication tolerances. There are a few localized exceptions where 3 locations had readings averaging less than the design plate thickness. These locations had an average thickness no more than 2.1% thinner than design, so the difference is insignificant. The majority of thickness measurements were taken beside the welds where Acuren cleaned the weld and adjacent area with a sandpaper brush wheel on a grinder to facilitate MP testing of the welds and UT readings. Appendix D provides the Acuren report of the MP and UT testing.

The interior of the penstock is generally in fair condition with scattered moderate corrosion and pitting with tubercles and growth. Pitting was minor to moderate, relative to the plate thickness, and detailed pit measurements were not taken. A significant number of weld repairs were observed as expected and the previous weld repair work made this inspection a little easier as much of the organic build up had been removed.

The welded joints were in fair condition and did not have any apparent visible cracks or excessive deterioration (see Photos 3 thru 13). The repaired welds from 2018 were in good condition and relatively clean with some surface rust. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK" before the penstock was put back into service. The inspection of the welds for this inspection concentrated on the unrepaired welds but also picked up a several of the repaired welds. Welds in Penstock No. 3 were cleaned with a grinder with a sandpaper wheel attachment then wiped clean and painted with a white contrast paint to facilitate the MP weld test. MP testing included 48 full length longitudinal welds and a few feet of 16 circumferential welds. An initial visual inspection of the weld was conducted concentrating on condition of the bead in regard to pitting, corrosion or cracking, and undermining or washout. The welds were also impacted with a geologists hammer to assess the integrity of the weld joints. Corrosion of the original welds was fair for all with light to moderate pitting. The new or repaired welds were in good condition with only insignificant surface rust just starting and no degradation. No indications or significant issues were identified.

3.2.2 APPURTENANCES

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock No. 3 has three large manholes and a bifurcation at the powerhouse.

The manhole near can 147 (Photo 18) and the manhole at the surge tank were in fair condition with moderate corrosion of the interior surface of the manholes.

Drainage pipes and culverts were noted to be in fair condition and a broken culvert was noted downstream of the surge tank. A monitoring weir was identified with flow through the weir. Flow was not estimated in the field as it was apparent that a majority of the flow was due to snow melt. Drainage is shown along the length of the penstock in Drawing F2106-C-1 (Appendix A); however, the termination of the drainage plumbing and weirs are not shown.

The headgate and intake structure were in good condition with only minor leakage of the headgate apparent from the bottom left corner of the headgate when looking upstream (Photo 2).

3.2.3 SURGE TANK

The surge tank transition welds were visually inspected from the invert of the penstock from a safe distance. Due to falling ice concerns, the inspector could not stand under the surge tank opening or get proceed beyond it. Emphasis was given to the areas where welds were cracked at the base of the surge tank for Penstock No. 2. The area was wet, but leakage was not identified. The welds appear to have been tested but not refurbished as was done for the penstock. This area is incased in concrete so a rupture is unlikely but leakage between the steel and concrete and can occur and cause erosion of the concrete and surrounding soil.

3.3 EXTERIOR INSPECTION

Kleinschmidt began the exterior inspection on April 2 at the intake and moved downstream completing the inspection at the switchyard the same day. The interior weld testing and UT measurements performed by Acuren continued inside the penstock while Mr. Vella walked the exterior. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 16 and 17. Kleinschmidt observed the exterior ground surface for signs of leakage while walking the length of the penstock. Signs of leakage that were looked for include sloughing of the ground over the penstock and other depressions mainly. The penstock exterior was semi-covered in snow hindering the exterior inspection and no obvious indications were observed during the April inspection. There is a drainage ditch to the left of the surge tank and a monitoring shack (Photo 19). Upstream of the monitoring shack there are a pair of culverts that empty into a larger culvert and the small area between is full of rock and sediment significantly blocking the smaller culverts (Photo 20). The rock and sediment should be cleaned out to restore the function of the culverts prior to the 2020 spring runoff.

The exterior of Penstock 3 was inspected again May 8 during the Penstock 2 inspection visit so that the penstock could be viewed in the absence of snow and while it was operational. The weather was sunny, cool, and no snow was present on the penstock. A sink hole was discovered 9 feet downstream of the surge tank concrete on the left side of the penstock (Photos 21 and 22). The hole was about 4 feet in diameter and 4 feet deep. This hole was not visible during the April inspection and appears to be recent as the exposed roots were covered in mud, not washed off in the rain. There were also no weeds or moss growing on the exposed soil suggesting the hole is fairly new. Upon reviewing the weld repairs and 2018 Hatch inspection report, it is noted that the

surge tank transition area was not repaired and that the transition areas in the other 2 penstocks have had observed weld cracks. It is possible there is ongoing leakage from this area that is travelling between the steel and concrete and eroding the soil on its way to the drainage system. Because the area is incased in concrete the leakage and weld crack, if present, is unlikely to result in a blowout. The area should be reviewed, tested, and repaired as needed during the next dewatering. It is also possible that this area has internal erosion from snow melt and rain over the years through this poorly graded soil and when the frost melted in this area it resulted in collapse of a void that had been forming. The surrounding area also shows various signs of settlement that have occurred over time (Photo 23 and 24). The soil around the sink hole should be removed to confirm the extent of erosion and the area repaired with properly graded rock when the penstock is dewatered to restore a uniform surface with an erosion resistant material.

There is an observation well about 20 feet downstream of the surge tank on the left side (Photo 25). The lid was removed, and no flow was observed at the bottom (Photo 26). There has been rain recently and surface water was observed so the absence of water in a drainage well raises the possibility that the drainage system in the area is not functioning properly. The recent sink hole and visual evidence of previous settlement in the area also suggests the drainage system in the area is not functioning properly. It is recommended that the well be inspected from the bottom, which will require fall protection and confined space access procedures. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage.

The ditching on the left side of penstock 3 should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage (Photo 24).

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 LOADING CONDITIONS AND ALLOWABLE STRESSES

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix D. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 and 24,000 psi was used for CSA G40.8 Grade B. The yield strength of HSB 50 was assumed to be 50,000 psi; however, no reference was located for this value. No ultimate tensile strength was assumed so that allowable stresses in the evaluation were based on the yield strength criteria for HSB 50 steel (33,333 psi).

The welded seams are not as strong as the original base material; these strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used if further weld testing is performed to verify the integrity of the welds. Per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds needing higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal o1perating conditions;
- stresses in the penstock under flood conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 SHELL STRESSES INDUCED BY INTERNAL PRESSURE

Table 4-1 summarizes the statistical analysis of our steel-shell thickness data and internal pressure steel stress analysis results. See Appendix C for detailed thickness data and stress calculations. Average thickness and a 97.5% confidence interval (CI) were calculated for each station. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 feet (182 metres) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 feet (271 metres) at the powerhouse and linearly reducing to 660 (201m) feet at the surge tower and then matching the FSL of 597 feet (182 metres) at the intake. The maximum stress ratio is 1.22 for this load case, greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.23, unacceptable for late 1960 steel pipe. However, an increase in the joint efficiency through weld testing that verifies the joints integrity would improve these values. For the plate steel away from the joints, the material has a maximum stress ratio of 0.85 and a safety factor of 1.75, which is acceptable for present day design.

TABLE 4-1 SUMMARY OF THICKNESS DATA AND STRESSES DUE TO INTERNAL PRESSURE

CAN	MAX JOINT STRESS[1,3] (psi)	DYNAMIC HOOP STRESS INCREASE[1,3] (psi)	TOTAL WATER HAMMER STRESS[1,3] (psi)	ALLOWABLE STRESS (psi)	STRESS RATIO[1,2,3]	FACTOR OF SAFETY AGAINST YIELD
1	5,439	548	6,348	17,000	0.37	3.94
10	6,941	884	6,745	17,000	0.40	3.71
20	9,594	1,368	8,010	17,000	0.47	3.12
30	13,913	1,940	10,860	17,000	0.64	2.30
40	17,565	2,109	11,517	17,000	0.68	2.17
50	16,644	2,196	11,776	17,000	0.69	2.12
60	20,819	2,652	14,030	17,000	0.83	1.78
70	20,426	3,332	17,237	17,000	1.01	1.45
80	23,992	3,771	19,068	17,000	1.12	1.31
90	22,001	3,950	19,601	17,000	1.15	1.28
100	24,110	4,432	21,649	24,000	0.90	1.66
110	24,953	4,679	22,548	24,000	0.94	1.60
120	24,453	5,291	25,198	24,000	1.05	1.43
130	23,421	5,184	24,434	24,000	1.02	1.47
140	23,321	4,385	20,486	24,000	0.85	1.76
150	22,465	4,425	21,305	24,000	0.89	1.69
160	22,786	4,508	23,238	24,000	0.97	1.55
170	21,702	3,839	20,962	24,000	0.87	1.72
180	22,904	4,329	24,818	24,000	1.03	1.45
190	21,559	4,709	26,918	24,000	1.12	1.34
200	22,521	4,249	23,906	24,000	1.00	1.51
210	22,618	4,823	26,999	24,000	1.12	1.33
220	25,290	4,022	29,312	24,000	1.22	1.23
230	5,439	4,514	25,673	24,000	1.07	1.40

[1] Joint efficiency of 0.7 included

[2] Total stress / Allowable stress

[3] Uses 97.5% confidence thickness

[4] SF = Fy/Total stress

4.3 GENERAL BUCKLING INDUCED BY EXTERNAL LOADS

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 103 psf and the depth of soil cover on the penstock was assumed to be 3 feet. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off road vehicle loads or equipment. The snow and live load combination uses a reduced snow and live load of 75 percent of each.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis.
- Similar to Penstocks 1 and 2, the penstock appears to be located in cohesive fine grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated for the 15.25-foot-diameter pipe due to shell dead load, soil cover, live load, and snow load was 4.31 psi. This is less than the allowable buckling pressure of 10.24 psi. The penstock below the surge tank was not re-analyzed as new data was not obtained.

4.3.1 SURCHARGE LOAD ANALYSIS

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest average measured steel thickness values were used. See Table 4-2.

TABLE 4-2 SUMMARY OF SURCHARGE LOAD ANALYSIS

PENSTOCK DIAMETER (ft)	ALLOWABLE EXTERNAL PRESSURE (psi)	SNOW LOAD (psi)	SNOW + 100 PSF LIVE LOAD (psi)
17.00	5.06	3.80	4.15
15.25	10.24	3.97	4.31

There were no vehicular surcharge analysis conducted for the shallowly buried penstock as there is no location for traffic to cross the penstock. Where vehicular traffic can cross the penstock, additional analyses were not completed due to the depth of the buried penstock at these locations (intake and switchyard) as well as the results of the analysis for similar conditions in Penstock No. 2 that was completed by Kleinschmidt in 2016. The analysis for Penstock No. 2 showed the soil pressures due to an HS-20 truck load per AASHTO Standard Specifications (AWWA 2004), which is a 72,000-pound, three-axle truck with axles spaced at 14 feet from the front axle to middle axle then variable from 14 feet to 28 feet to the rear axle was approximately five times less than the allowable buckling loads at that location. For this section of the penstock, live loads have minimal increase in soil pressures to the penstock given the depth of overburden.

4.3.2 SUBATMOSPHERIC INTERNAL PENSTOCK PRESSURE ANALYSIS

Subatmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and no detailed hydrodynamic model was created, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 square metres (3.07 square feet), which is well below the area provided by the approximately 5.1-square-metre (55-square-foot) existing openings.

4.4 LOCAL BUCKLING AND STRESSES

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and it becomes permanently deformed. Boulders and rocks could be a source of point loads but no serious deformations were noted in the inspection. The penstock is continuously supported by the soil so it is unlikely there are excessive local buckling stresses in the penstock.

4.5 LOCAL WELD CONDITIONS

As noted in Section 1.0, NLH discovered a 0.6-metre-long (2-foot-long) crack in Penstock No. 1 in May 2016. Kleinschmidt responded and assisted with the design of the crack repair, *Crack Investigation and Repair Report – Penstock No. 1 Bay d'Espoir Hydroelectric Development* (June 2016). Kleinschmidt's investigation theorized that the crack, which occurred near a weld, was caused by an improper weld procedure during construction that resulted in incomplete fusion. After repairing the crack NLH rewatered the penstock, a second crack then opened in the Penstock No. 1 in September 2016. This crack led to a detailed weld investigation that has found many other microscopic cracks in the welds. Detailed weld inspections in 2017 and 2018 determined the weld repairs required and repairs carried out in the same years. For this inspection Acuren performed MP tests on the full length of 48 longitudinal welds and a few feet of 16 circumferential welds for this inspection. No cracks or indications were discovered.

5.0 CONCLUSIONS

Based on our inspection findings and evaluation, the existing steel penstock has at least another 50 years of remaining service life. No cracks were found in this penstock and the inside surface was in fair condition. New welds and remaining original welds were in good condition and did not have any apparent visible or tested cracks. Both the longitudinal and circumferential welds appeared adequate with no sign of significant deterioration along the weld edges.

5.1 SHELL CONDITION AND THICKNESS

Measurements of the penstock shell thickness indicate minimal loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior. Assuming similar rates of material loss, the penstock should have 50 to 80 years of service life remaining if an internal coating is applied. The base plate material away from the joints can tolerate up to 3 millimetres (1/8 inch) further material loss and maintain a stress ratio below 1.0.

5.2 INTERNAL PRESSURE STRENGTH

More thickness measurements were taken during this inspection than during the 2017 inspection and the measurements had a wider range of values that resulted in CI thickness values that were in some cases lower than previously used in the stress analysis. Stress ratios for a combined static and dynamic internal pressures peak at 1.22 (Table 4-1). This indicates that the penstock does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.23, which is not acceptable for late 1960 steel pipe. As noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 REMAINING SERVICE LIFE

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor. The service life of the penstock is based on the welds and is unknown until further testing is performed to confirm weld integrity. With the weld testing performed to date and repair work that has been done the penstock is safe for continued operation for the next 5 to 10 years. If RT testing of the welds is performed with positive results and providing that the penstock interior is coated before the steel deteriorates further than the penstock could be safely operated an additional 50 to 80 years. As noted above, it is recommended that RT testing of the welds is performed to verify weld integrity and allow a higher joint efficiency to be used. The MT testing of welds to date does not satisfy the requirements of ASCE No. 79 to increase the joint efficiency. As noted previously the base plate material away from the joints can tolerate up to 3 millimetres (1/8 inch) further material loss and maintain a stress ratio below 1.0. It is recommended that a more accurate surge analysis be conducted using wicket gate closure times to confirm penstock stresses.

6.0 RECOMMENDATIONS

The penstock is fair condition and Kleinschmidt has only a few recommendations. These recommendations include:

- recoating the interior of the penstock (within 10 years);
- Surge Analysis using actual wicket gate closure time (within 1 year);
- repair of the sinkhole (within 1 year);
- inspection and repair of the drainage system (within 2 years);
- monitoring of the exterior for signs of leakage (Bi-weekly); and
- continued inspections of the interior (Yearly).

6.1 COATING

Kleinschmidt recommends coating the interior of the penstock in the next 10 years. At this stage, Kleinschmidt is unable to estimate the rate of corrosions for the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20-40 years or more. If the penstock is recoated prior to significant steel deterioration every 20-40 years, NLH can anticipate extending the life of the penstock nominally another 80 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated, but it is difficult to tell its condition.

6.2 EXTERIOR INSPECTION

The sinkhole downstream of the surge tank should be repaired this year. The soil around the sinkhole should be removed to confirm the extent of the erosion and the area repaired with properly graded rock when the penstock is dewatered to restore a uniform surface with an erosion restant material.

It is recommended that the observation well downstream, and to the left of the surge tank, be inspected from the bottom. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage.

The ditching on the left side of Penstock 3 should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage.

Kleinschmidt recommends repairing culvert damage described previously as well as continuing to monitor the exterior of the penstocks for signs of leakage. Drain pipes should also be monitored at times with consistent weather conditions.

6.3 INTERIOR INSPECTIONS

6.3.1 GENERAL EVALUATION

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. These inspections should give a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless if the coating has been replaced or not, the detailed inspections can be extended to a 5 to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval. Extensive weld testing and repairs have appeared to have adequately addressed weld issues, except that the transition into the surge tank does not appear to have been repaired for Penstock 3 and there have been noted issues with the transition section. Repairs to this area should be made during the next dewatering.

A more accurate surge stress analysis using actual wicket gate closure times and data from the pressure transducers would be helpful in providing more accurate stress numbers. This should be completed in 2020 to better understand the risks.

7.0 REFERENCES

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SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Hydro Engineer

CMV:FSH:SCB

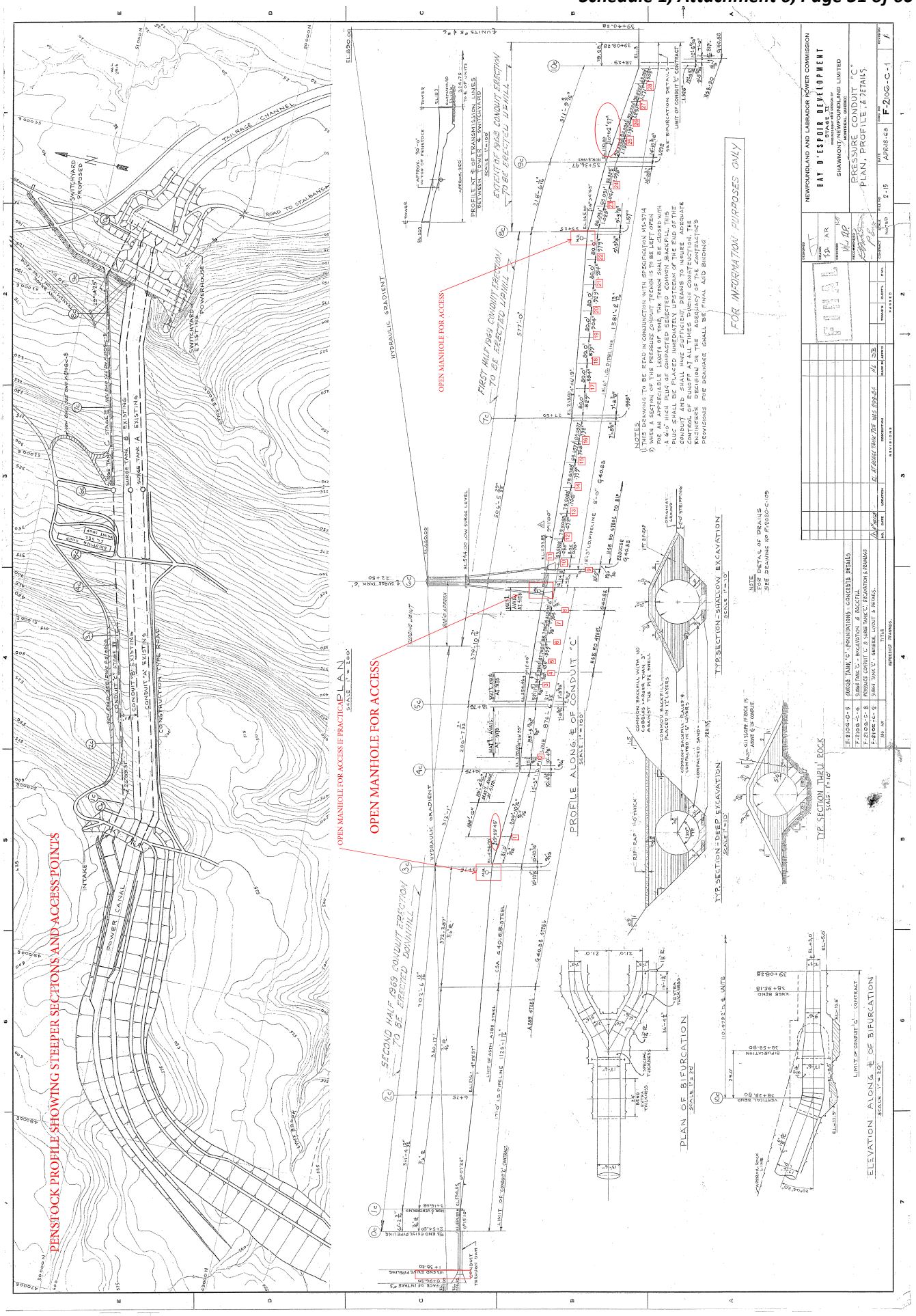
REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
CHRISTOPHER M. VELLA
SIGNATURE
Nov 14, 2019
DATE
NEWFOUNDLAND & LABRADOR

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEG Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
KLEINSCHMIDT ASSOCIATES CANADA INC
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by PEGNL N0708
which is valid for the year 2019

J:\2670\021\Docs\Penstock 3\2670021_001RP_Bay d'Espoir Penstock 3 Inspection Report FINAL.docx

APPENDIX A

PENSTOCK LAYOUT DRAWINGS


PENSTOCK PROFILE SHOWING STEEPER SECTIONS AND ACCESS POINTS
OPEN MANHOLE FOR ACCESS IF PRACTICAL
OPEN MANHOLE FOR ACCESS
OPEN MANHOLE FOR ACCESS
PLAN
SCALE 1" = 200'
PROFILE ALONG ℄ OF CONDUIT "C"
SCALE 1" = 100'
TYP. SECTION - SHALLOW EXCAVATION
TYP. SECTION - DEEP EXCAVATION
TYP. SECTION THRU ROCK
PLAN OF BIFURCATION
ELEVATION ALONG ℄ OF BIFURCATION
FOR INFORMATION PURPOSES ONLY
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
STAGE II
SHAWMONT, NEWFOUNDLAND LIMITED
PRESSURE CONDUIT "C"
PLAN, PROFILE & DETAILS
F-2106-C-1

APPENDIX B

PHOTOGRAPHS



PHOTO 1 ICE CHUCK UNDER SURGE TANK



PHOTO 2 LEAKAGE AT BOTTOM LEFT CORNER OF GATE



PHOTO 3 LONGITUDINAL WELDS TESTED SOUTH SIDE OF CANS 13 AND 14



PHOTO 4 LONGITUDINAL WELD TESTED BOTTOM OF CAN 22



PHOTO 5 TYPICAL MARKINGS FOR REPAIRED AND TESTED WELDS



PHOTO 6 MAGNETIC PARTICLE TESTING OF LONGITUDINAL WELD NORTH SIDE OF CAN 31



PHOTO 7 CIRCUMFERENTIAL AND LONGITUDINAL WELDS TESTED CAN 44N



PHOTO 8 CIRCUMFERENTIAL WELD TESTED BETWEEN CANS 59 AND 60



PHOTO 9 REPAIRED AND PREVIOUSLY TESTED WELD. NEW SUPERFICIAL RUST.



PHOTO 10 REPAIRED WELD IN GOOD CONDITION.



PHOTO 11 LONG AND CIRC WELDS TESTED ON CAN 150S



PHOTO 12 ORIGINAL LONG WELD ON CAN 150 CLEANED AND TESTED. LIGHT PITTING.



PHOTO 13 ORIGINAL LONG WELD ON CAN 231 CLEANED AND TESTED. LIGHT PITTING.



PHOTO 14 TYPICAL PLATE CONDITION NEAR CAN 101.



PHOTO 15 TYPICAL PLATE CONDITION NEAR CAN 200



PHOTO 16 LOOKING DOWNSTREAM ALONG PENSTOCK 3 EXTERIOR FROM INTAKE



PHOTO 17 TYPICAL COVER OVER PENSTOCK 3



PHOTO 18 LOOKING UPSTREAM AT MANHOLE NEAR CAN 147



PHOTO 19 DRAIN MONITORING SHED LOCATED LEFT OF THE FIRST MANHOLE ON PENSTOCK 3



PHOTO 20 PLUGGED DRAIN PIPES UPSTREAM OF MONITORING SHED. AREA FULL OF SEDIMENT



PHOTO 21 SINKHOLE AT SURGE TANK (MAY 8TH)



PHOTO 22 SINKHOLE AT SURGE TANK (MAY 8TH)



PHOTO 23 DOWNSTREAM LEFT SIDE OF PENSTOCK 3 STANDING AT SURGE TANK (MAY 8TH)



PHOTO 24 WET AREA LEFT SIDE OF PENSTOCK 3 FROM SURGE TANK (MAY 8TH)



PHOTO 25 DRAINAGE OBSERVATION WELL DOWNSTREAM OF THE SURGE TANK (MAY 8TH)



PHOTO 26 INSIDE DRAINAGE OBSERVATION WELL DOWNSTREAM OF SURGE TANK (MAY 8TH)

APPENDIX C

WELD TEST

Acuren Group Inc.
1 Austin Street
St. John's, NL, Canada A1B 4C1
www.acuren.com
Phone: 709.753.2100
Fax: 709.753.7011

A Higher Level of Reliability

NONDESTRUCTIVE EXAMINATION

CLIENT: **Kleinschmidt**

DATE: **April 01/02, 2019**
ACUREN JOB #: **183-19-10KLE002-0001**
REPORT #: **MT-020419AR-001 R0**
CONTRACT/PO: **N/A** WO: **N/A**

ATTENTION: **Chris Vella**
WORK LOCATION: **Bay D'Espoir, NL**
PROJECT: **NL Hydro Bay D'Espoir Penstock**
ITEM(S) EXAMINED: **Internal welds**

PART #: **Penstock # 3** MATERIAL: **Carbon Steel** THICKNESS: **See Below**
SCOPE: **To perform a magnetic particle examination as per client's request.**
TYPE OF INSPECTION: **Magnetic Particle**

TEST DETAILS:

ACCEPTANCE STANDARD: **Client information**	REVISION: **N/A**
PROCEDURE/TECHNIQUE: **CAN-MT-14P001**	REVISION: **R15 / June 18, 2018**
TYPE: **Wet Visible**	METHOD: **Yoke**
PARTICLE BRAND: **Magnaflux** PRODUCT NO: **7HF**	CURRENT: **AC** MT INSTRUMENT: **Contour probe**
PARTICLE COLOUR: **Black**	MT INSTRUMENT S/N: **23490** CAL DUE: **April 26, 2019**
SUSPENSION: **Oil**	LIFT CHECK BEFORE USE: **Yes** LIFT WEIGHT S/N: **1257**
CONTRAST PAINT: **Magnaflux** PRODUCT NO: **WCP-2**	LIGHTING EQUIPMENT: **Natural / Yoke leg light / headlamp**
MAG TIME (SECONDS): **15** BLACKLIGHT MAKE: **N/A**	BLACKLIGHT MAKE: **N/A** S/N: **N/A**
TECHNIQUE DEMONSTRATED OVER A PAINTED SURFACE?: **No**	LIGHT METER S/N: **11010159** CAL DUE: **April 4, 2019**
	LIGHT INTENSITY: **>100fc (1076 lx)**
TEST SURFACE CONDITION: **Clean bare metal / As welded**	TEST SURFACE TEMPERATURE: **-19°C to 49°C**

RESULTS:

As per client's request a magnetic particle examination was performed on penstock number 3 internal, starting at the head gate (Can #1) and continuing downstream.

1- **Out of every 10 cans 2 full horizontal seams were examined.**
2- **Every 15th circ weld, an accessible 2' area was examined.**

The examination continued downstream as far as the surge tower (Can #230) and stopped there due to outside factors.

See page 2-4 for a list of welds examined and pictures.

No relevant indications were noted at the time of examination.

Client acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (www.acuren.com/serviceterms) in effect when the services were ordered.

	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY
CLIENT:		
ACUREN TECHNICIAN:	**Andrew Rideout** 1st Technician **CGSB II # 14136**	**Gord Nixon** 2nd Technician **CGSB II # 10852**

REVIEWER: 04/03/2019

DTR NO.: N/A

ACUREN

ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **MT-020419AR-001 R0**

Kleinschmidt

Can Number	Details		Can Number	Details
2	North Horizontal		120	South Horizontal
2/3	Circ		120/121	Circ
3	North Horizontal		121	South Horizontal
12	South Horizontal		130	South Horizontal
13	South Horizontal		132	South Horizontal
17/18	Circ		135/136	Circ
12	Bottom Horizontal		140	South Horizontal
13	Bottom Horizontal		141	South Horizontal
31	North Horizontal		150	South Horizontal
31/32	Circ		150/151	Circ
34	North Horizontal		151	South Horizontal
42	North Horizontal		160	South Horizontal
44	North Horizontal		161	South Horizontal
44/45	Circ		165/166	Circ
53	South Horizontal		170	North Horizontal
55	South Horizontal		171	North Horizontal
59/60	Circ		180	North Horizontal
62	South Horizontal		180/181	Circ
64	South Horizontal		181	North Horizontal
71	South Horizontal		190	North Horizontal
74	South Horizontal		195/196	Circ
75/76	Circ		196	South Horizontal
81	South Horizontal		204	South Horizontal
82	South Horizontal		205	North Horizontal
90	South Horizontal		211	South Horizontal
91/92	Circ		211/212	Circ
92	South Horizontal		212	South Horizontal
100	South Horizontal		220	South Horizontal
101	South Horizontal		222	South Horizontal
105/106	Circ		230	South Horizontal
110	South Horizontal		230/231	Circ
111	South Horizontal		231	South Horizontal

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CLIENT: _____ _____
CLIENT PRINTED NAME — CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

ACUREN

TECHNICIAN: **Andrew Rideout** (1st Technician, **CGSB II # 14136**) — **Gord Nixon** (2nd Technician, **CGSB II # 10852**)

REVIEWER: 04/03/2019

DTR NO.: N/A

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ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **MT-020419AR-001 R0**

Kleinschmidt





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CLIENT:	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY
ACUREN TECHNICIAN:	**Andrew Rideout** 1st Technician **CGSB II # 14136**	**Gord Nixon** 2nd Technician **CGSB II # 10852**
REVIEWER:	04/03/2019	

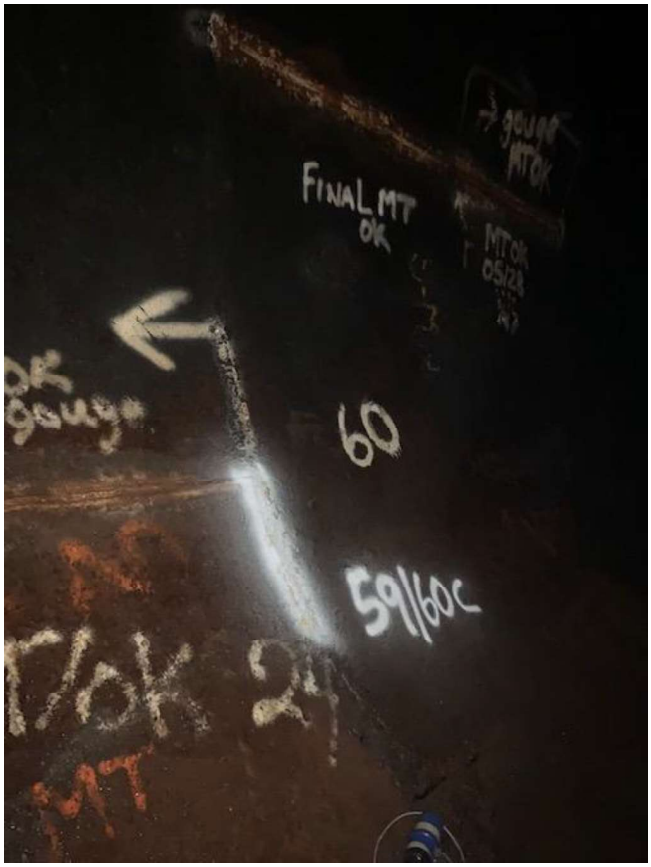
DTR NO.: N/A

(Generated Using: CAN-QUA-02F007 R07 - 07/20/2018)

ACUREN

ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **MT-020419AR-001 R0**

Kleinschmidt





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CLIENT:	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY
ACUREN TECHNICIAN:	**Andrew Rideout** 1st Technician **CGSB II # 14136**	**Gord Nixon** 2nd Technician **CGSB II # 10852**
REVIEWER:	04/03/2019	

DTR NO.: N/A

APPENDIX D

THICKNESS MEASUREMENTS DATA AND STRESS CALCULATIONS

TABLE D-1 THICKNESS MEASUREMENTS AND STRESSES (FSL)

TABLE D-2 WATER HAMMER (DYNAMIC) STRESSES

Acuren Group Inc.
1 Austin Street
St. John's, NL, Canada A1B 4C1
www.acuren.com
Phone: 709.753.2100
Fax: 709.753.7011

A Higher Level of Reliability

NONDESTRUCTIVE EXAMINATION

CLIENT: **Kleinschmidt**

DATE: **April 01/02, 2019**
ACUREN JOB #: **183-19-10KLE002-0001**
REPORT #: **UT-020419AR-001 R0**
CONTRACT/PO: **N/A** WO: **N/A**

ATTENTION: **Chris Vella**
WORK LOCATION: **Bay D'Espoir, NL**
PROJECT: **NL Hydro Bay D'Espoir Penstock**
ITEM(S) EXAMINED: **Penstock # 3**

PART #: **Penstock Number 3** MATERIAL: **Carbon Steel** THICKNESS: **See Below**
SCOPE: **To perform a 0 degree ultrasonic survey as per clients request.**
TYPE OF INSPECTION: **Ultrasonic**

TEST DETAILS:

ACCEPTANCE STANDARD: **Client's Information** REVISION: **N/A**
PROCEDURE/TECHNIQUE: **CAN-UT-14T001** REVISION: **R07 / Nov 30, 2017**
TYPE: **Thickness** METHOD: **Contact**
INSTRUMENT: **Olympus** MODEL: **38 DL Plus** S/N: **120467507** CAL DUE: **July 17, 2019**
CAL. BLOCK: **Step Block** S/N: **2210 15** CABLE-TYPE: **Coaxial** LENGTH: **N/A**
CAL. BLOCK: S/N: COUPLANT: **Sonotech – Sono 600**

Probe & Technique Details:

	Test Angle (°)	Probe Type	Crystal Size	Freq. (MHz)	Serial Number	Damping Ω	Test From	Reference Reflector	Transfer Value	Reference Db	Reference % FSH	Scan Db	Range
1	**0**	**D799**	**0.375"**	**5**	**990973**	**N/A**	**Front**	**FBW**	**N/A**	**46-72**	**80**	**As Req**	**0.5" -5"**
2													
3													

TEST SURFACE CONDITION: **Clean bare metal** TEST SURFACE TEMPERATURE: **Ambient**

RESULTS: (Note: all readings in inches)

As per clients request a 0 degree ultrasonic survey was performed on penstock # 3 internal.
Three locations were examined on every 10th can starting at the head gate (Can # 1) continuing downstream with Can #10, 20, 30 etc.
At each location three readings were taken.
The examined finished at the surge tower (Can # 230) due to outside factors.

See page 2 - 5

Client acknowledges receipt and custody of the report or other work ("Deliverable"). Client agrees that it is responsible for assuring that acceptance standards, specifications and criteria in the Deliverable and Statement of Work ("SOW") are correct. Client acknowledges that Acuren is providing the Deliverable according to the SOW, and not any other standards. Client acknowledges that it is responsible for the failure of any items inspected to meet standards, and for remediation. Client has 15 business days following the date Acuren provides the Deliverable to inspect it, identify deficiencies in writing, and provide written rejection, or else the Deliverable will be deemed accepted. The Deliverable and other services provided by Acuren are governed by a Master Services Agreement ("MSA"). If the parties have not entered into an MSA, then the Deliverable and services are governed by the SOW and the "Acuren Standard Service Terms" (www.acuren.com/serviceterms) in effect when the services were ordered.

CLIENT: _____ _____
CLIENT PRINTED NAME | CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

ACUREN TECHNICIAN: **Andrew Rideout** (1st Technician, CGSB II # 14136) | **Gord Nixon** (2nd Technician)

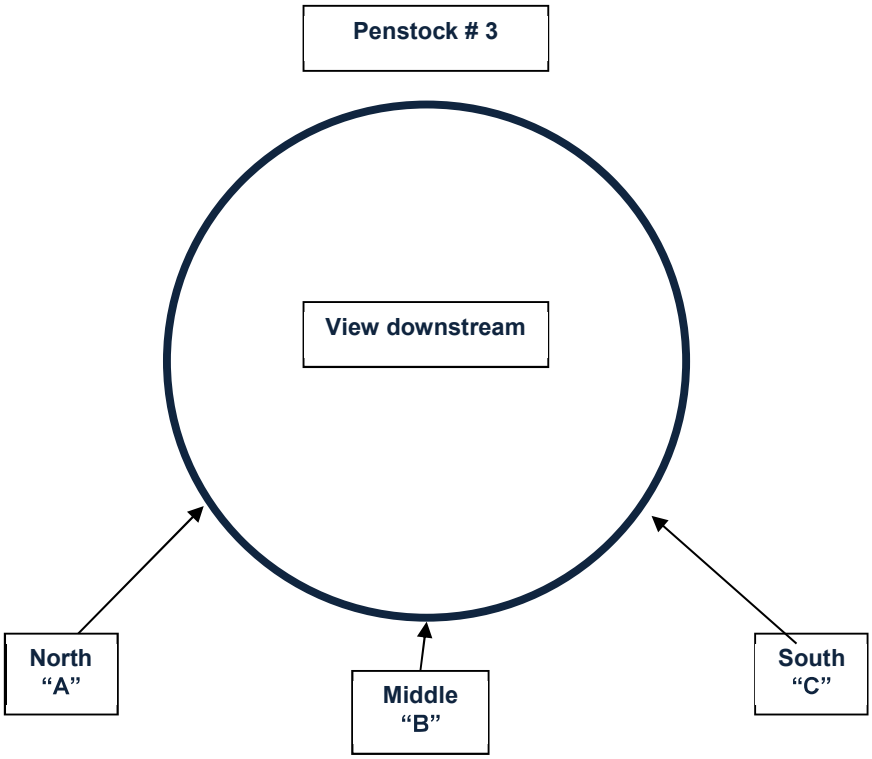
REVIEWER: 04/03/2019

DTR NO.: N/A

ACUREN

ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **UT-020419AR-001 R0**

Kleinschmidt



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CLIENT:	CLIENT PRINTED NAME	CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY	DTR NO.: N/A
ACUREN TECHNICIAN:	**Andrew Rideout** 1st Technician **CGSB II # 14136**	**Gord Nixon** 2nd Technician	
REVIEWER:	04/03/2019		(Generated Using: CAN-QUA-02F007 R07 – 07/20/2018)

ACUREN

ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **UT-020419AR-001 R0**

Kleinschmidt

Can #	Reading #	A	B	C
1	1	0.484	0.470	0.508
1	2	0.484	0.466	0.492
1	3	0.482	0.495	0.506
10	1	0.470	0.514	0.487
10	2	0.467	0.519	0.485
10	3	0.504	0.483	0.483
20	1	0.474	0.457	0.493
20	2	0.473	0.415	0.490
20	3	0.469	0.423	0.436
30	1	0.438	0.417	0.496
30	2	0.407	0.421	0.497
30	3	0.401	0.416	0.499
40	1	0.474	0.490	0.411
40	2	0.474	0.458	0.449
40	3	0.473	0.486	0.419
50	1	0.469	0.499	0.475
50	2	0.477	0.490	0.476
50	3	0.468	0.468	0.474
60	1	0.442	0.460	0.446
60	2	0.455	0.469	0.442
60	3	0.468	0.468	0.467
70	1	0.453	0.417	0.470
70	2	0.453	0.418	0.485
70	3	0.418	0.416	0.463
80	1	0.400	0.452	0.443
80	2	0.406	0.449	0.441
80	3	0.408	0.448	0.409

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CLIENT: _____ _____
CLIENT PRINTED NAME | CLIENT SIGNATURE ACCEPTED & ACKNOWLEDGED BY

ACUREN TECHNICIAN: **Andrew Rideout** (1st Technician, **CGSB II # 14136**) | **Gord Nixon** (2nd Technician)

REVIEWER: 04/03/2019

DTR NO.: N/A

ACUREN

ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **UT-020419AR-001 R0**

Kleinschmidt

Can #	Reading #	A	B	C
90	1	0.455	0.440	0.451
90	2	0.459	0.411	0.449
90	3	0.453	0.411	0.448
100	1	0.411	0.434	0.485
100	2	0.431	0.435	0.484
100	3	0.436	0.477	0.486
110	1	0.433	0.425	0.422
110	2	0.437	0.467	0.442
110	3	0.439	0.424	0.424
120	1	0.458	0.459	0.409
120	2	0.453	0.480	0.406
120	3	0.445	0.446	0.408
130	1	0.440	0.469	0.495
130	2	0.440	0.467	0.468
130	3	0.441	0.472	0.461
140	1	0.572	0.593	0.554
140	2	0.575	0.546	0.555
140	3	0.574	0.572	0.554
150	1	0.576	0.571	0.594
150	2	0.576	0.586	0.598
150	3	0.600	0.586	0.593
160	1	0.592	0.598	0.603
160	2	0.598	0.594	0.601
160	3	0.603	0.593	0.605
170	1	0.763	0.734	0.759
170	2	0.762	0.738	0.776
170	3	0.762	0.756	0.770

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ACUREN

TECHNICIAN: **Andrew Rideout** (1st Technician, CGSB II # 14136) — **Gord Nixon** (2nd Technician)

REVIEWER: 04/03/2019

DTR NO.: N/A

ACUREN

ACUREN JOB # **183-19-10KLE002-0001**
REPORT # **UT-020419AR-001 R0**

Kleinschmidt

Can #	Reading #	A	B	C
180	1	0.640	0.667	0.630
180	2	0.636	0.651	0.628
180	3	0.634	0.649	0.628
190	1	0.654	0.610	0.650
190	2	0.650	0.604	0.646
190	3	0.638	0.608	0.645
200	1	0.701	0.732	0.709
200	2	0.706	0.731	0.709
200	3	0.703	0.717	0.706
210	1	0.648	0.693	0.655
210	2	0.672	0.694	0.657
210	3	0.673	0.697	0.661
220	1	0.629	0.626	0.641
220	2	0.600	0.621	0.604
220	3	0.601	0.622	0.605
230	1	0.743	0.760	0.755
230	2	0.748	0.763	0.758
230	3	0.749	0.769	0.768

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ACUREN TECHNICIAN: **Andrew Rideout** (1st Technician, **CGSB II # 14136**) | **Gord Nixon** (2nd Technician)

REVIEWER: 04/03/2019

DTR NO.: N/A

TABLE D1 - Full Supply Level (FSL)
PENSTOCK THICKNESS MEASURMENTS AND STRESSES

Unit weight of water= 62.4 pcf
Normal pond EL= 597 feet
Joint Efficiency= 0.7 (per Penstock #2 assessment & ASCE 79)
D_1 OD= 17.08 feet
D_2 OD= 15.35 feet

Location (CAN)		Approx Station (ft)[5]	Radius (feet)	Avg. Thickness Reading(in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints	
										Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]
P3	1	4	8.5	0.487	0.4375	11.4%	0.4592	554.82	17000	4060.1	0.24	5800.1	0.34
P3	10	89	8.5	0.490	0.4375	12.1%	0.4544	554.82	17000	4103.0	0.24	5861.4	0.34
P3	20	174	8.5	0.459	0.4375	4.9%	0.4034	554.57	17000	4649.1	0.27	6641.5	0.39
P3	30	259	8.5	0.444	0.4375	1.4%	0.3621	545.85	17000	6244.0	0.37	8920.0	0.52
P3	40	344	8.5	0.459	0.4375	5.0%	0.4042	536.79	17000	6585.3	0.39	9407.5	0.55
P3	50	429	8.5	0.477	0.4375	9.1%	0.4566	527.72	17000	6706.2	0.39	9580.2	0.56
P3	60	514	8.5	0.457	0.4375	4.6%	0.4348	518.65	17000	7964.8	0.47	11378.3	0.67
P3	70	599	8.5	0.444	0.4375	1.4%	0.3911	510.86	17000	9733.4	0.57	13904.9	0.82
P3	80	684	8.5	0.428	0.4375	-2.1%	0.3855	503.61	17000	10708.0	0.63	15297.1	0.90
P3	90	769	8.5	0.442	0.4375	1.0%	0.4061	496.35	17000	10955.8	0.64	15651.2	0.92
P3	100	854	8.5	0.453	0.4375	3.6%	0.3958	489.09	24000	12051.5	0.50	17216.5	0.72
P3	110	939	8.5	0.435	0.4375	-0.6%	0.4070	481.83	24000	12507.8	0.52	17868.3	0.74
P3	120	1024	8.5	0.440	0.4375	0.7%	0.3883	474.57	24000	13934.9	0.58	19907.0	0.83
P3	130	1109	8.5	0.461	0.4375	5.5%	0.4254	467.31	24000	13475.2	0.56	19250.3	0.80
P3	140	1194	8.5	0.566	0.5625	0.6%	0.5371	460.05	24000	11270.4	0.47	16100.6	0.67
P3	150	1279	8.5	0.587	0.5625	4.3%	0.5662	445.65	24000	11815.7	0.49	16879.6	0.70
P3	160	1364	8.5	0.599	0.5625	6.4%	0.5892	422.22	24000	13111.2	0.55	18730.3	0.78
P3	170	1449	8.5	0.758	0.625	21.2%	0.7309	398.80	24000	11986.0	0.50	17122.9	0.71
P3	180	1534	7.65	0.640	0.625	2.5%	0.6147	375.38	24000	14342.6	0.60	20489.5	0.85
P3	190	1619	7.65	0.634	0.625	1.4%	0.5938	364.93	24000	15546.8	0.65	22209.7	0.93
P3	200	1704	7.65	0.713	0.6875	3.7%	0.6900	358.34	24000	13760.0	0.57	19657.2	0.82
P3	210	1789	7.65	0.672	0.599	12.2%	0.6358	348.89	24000	15523.2	0.65	22176.0	0.92
P3	220	1874	7.65	0.617	0.625	-1.4%	0.5880	335.33	24000	17703.0	0.74	25290.0	1.05
P3	230	1959	7.65	0.757	0.75	0.9%	0.7393	321.76	24000	14810.9	0.62	21158.4	0.88

Notes:

Stress

[1] Hoop stress = $Pr/t_{97.5}$

[2] Hoop stress / S_A

[3] Hoop stress / 0.7 $_{\text{joint efficiency}}$

[4] Joint stress / S_A

[5] Station 1+38.2 on Drawing F2106-C-1 is Station 0+00 here

TABLE D2 - Full Supply Level (FSL) + Surge 30%
PENSTOCK THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4
Normal pond EL=	597
Joint Efficiency=	0.7
D_1 OD=	17.08
D_2 OD=	15.33
Hydraulic Gradient at Units	890.00
Hydraulic Gradient at Surge Tank	660.00

Location		Radius (feet)	Avg. Thickness (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints	
									Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]
CAN	**Station**											
1	4	8.5	0.487	0.4375	11.4%	0.4592	554.82	17000	4443.3	0.26	6347.6	0.37
10	89	8.5	0.490	0.4375	12.1%	0.4544	554.82	17000	4721.8	0.28	6745.4	0.40
20	174	8.5	0.459	0.4375	4.9%	0.4034	554.57	17000	5606.8	0.33	8009.7	0.47
30	259	8.5	0.444	0.4375	1.4%	0.3621	545.85	17000	7601.7	0.45	10859.6	0.64
40	344	8.5	0.459	0.4375	5.0%	0.4042	536.79	17000	8061.8	0.47	11516.9	0.68
50	429	8.5	0.477	0.4375	9.1%	0.4566	527.72	17000	8243.4	0.48	11776.3	0.69
60	514	8.5	0.457	0.4375	4.6%	0.4348	518.65	17000	9821.3	0.58	14030.4	0.83
70	599	8.5	0.444	0.4375	1.4%	0.3911	510.86	17000	12066.0	0.71	17237.1	1.01
80	684	8.5	0.428	0.4375	-2.1%	0.3855	503.61	17000	13347.4	0.79	19067.8	1.12
90	769	8.5	0.442	0.4375	1.0%	0.4061	496.35	17000	13720.7	0.81	19601.0	1.15
100	854	8.5	0.453	0.4375	3.6%	0.3958	489.09	24000	15154.1	0.63	21648.8	0.90
110	939	8.5	0.435	0.4375	-0.6%	0.4070	481.83	24000	15783.4	0.66	22547.7	0.94
120	1024	8.5	0.440	0.4375	0.7%	0.3883	474.57	24000	17638.7	0.73	25198.2	1.05
130	1109	8.5	0.461	0.4375	5.5%	0.4254	467.31	24000	17103.7	0.71	24433.8	1.02
140	1194	8.5	0.566	0.5625	0.6%	0.5371	460.05	24000	14340.2	0.60	20486.0	0.85
150	1279	8.5	0.587	0.5625	4.3%	0.5662	445.65	24000	14913.5	0.62	21305.0	0.89
160	1364	8.5	0.599	0.5625	6.4%	0.5892	422.22	24000	16266.5	0.68	23237.9	0.97
170	1449	8.5	0.758	0.625	21.2%	0.7309	398.80	24000	14673.6	0.61	20962.2	0.87
180	1534	7.65	0.640	0.625	2.5%	0.6147	375.38	24000	17372.7	0.72	24818.2	1.03
190	1619	7.65	0.634	0.625	1.4%	0.5938	364.93	24000	18842.9	0.79	26918.4	1.12
200	1704	7.65	0.713	0.6875	3.7%	0.6900	358.34	24000	16734.0	0.70	23905.7	1.00
210	1789	7.65	0.672	0.599	12.2%	0.6358	348.89	24000	18899.3	0.79	26999.1	1.12
220	1874	7.65	0.617	0.625	-1.4%	0.5880	335.33	24000	20518.2	0.85	29311.7	1.22
230	1959	7.65	0.757	0.75	0.9%	0.7393	321.76	24000	17970.8	0.75	25672.5	1.07

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

EXTERNAL PRESSURES EVALUATION

Allowable pressures (kPa)/External Pressures (kPa) Reference # 3, 5 and 8

Diameter 13.5 feet

Height of water above conduit=	0	feet	Live load:	100	psf	Unit Weight of Water=	62.4	pcf	
Height of rip rap above conduit=	1	feet	Snow load:	103	psf	P_v=	0		
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3	
Total Height of Soil=	3	feet				Fill Unit Weight=	120	lb/ft^3	
OD Conduit Diameter=	13.5	feet	ID:	13.6	feet	(soil load) W_c=	5308.2	lb/ft	
						(live load) W_l=	1361.1	lb/ft	100 psf per foot section
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	1406	lb/ft	
B_prime=	0.2330					W_{steel}=	1160	lb/ft	
(coarse grain soils with fines) E_prime=	600	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	3.30	psi	Ratio Q/q_a= 0.240344185
t=	0.665	inches				External pressure with snow load=	4.01	psi	Ratio Q/q_a= 0.292575354
I=	0.0245	$inches^4$				External pressure with snow and live=	4.36	psi	Ratio Q/q_a= 0.317447224
FS=	2								
q_a=	13.72	psi							

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 15.25 feet

Height of water above conduit=	0	feet	Live load:	100	psf	Unit Weight of Water=	62.4	pcf	
Height of rip rap above conduit=	1	feet	Snow load:	103	psf	P_v=	0		
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3	
Total Height of Soil=	3	feet				Fill Unit Weight=	120	lb/ft^3	
OD Conduit Diameter=	15.25	feet	ID:	15.35	feet	(soil load) W_c=	5987.6	lb/ft	
						(live load) W_l=	1535.3	lb/ft	
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	1585.6	lb/ft	
B_prime=	0.233028					W_{steel}=	1214.3	lb/ft	
(coarse grain soils with fines) E_prime=	600	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	3.26	psi	Ratio Q/q_a= 0.317992743
t=	0.617	inches				External pressure with snow load=	3.97	psi	Ratio Q/q_a= 0.388004418
I=	0.0195	$inches^4$				External pressure with snow and live=	4.31	psi	Ratio Q/q_a= 0.421343158
FS=	2								
q_a=	10.24	psi							

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 17 feet

Height of water above conduit=	0	feet	Live load:	100	psf	Unit Weight of Water=	62.4	pcf	
Height of rip rap above conduit=	1	feet	Snow load:	103	psf	P_v=	0		
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3	
Total Height of Soil=	3	feet				Fill Unit Weight=	120	lb/ft^3	
OD Conduit Diameter=	17	feet	ID:	17	feet	(soil load) W_c=	6658	lb/ft	
						(live load) W_l=	1707	lb/ft	100 psf per foot section
Buoyancy Factor R_w=	1	Assume well drained = 1				W_s=	1763.1	lb/ft	
B_prime=	0.2330					W_{steel}=	938.3	lb/ft	
(coarse grain soils with fines) E_prime=	600	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	3.09	psi	Ratio Q/q_a= 0.610550852
t=	0.428	inches				External pressure with snow load=	3.80	psi	Ratio Q/q_a= 0.752264393
I=	0.0066	$inches^4$				External pressure with snow and live=	4.15	psi	Ratio Q/q_a= 0.819746721
FS=	2								
q_a=	5.06	psi							

Schedule 1, Attachment 7

Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project

Kleinschmidt Associates

December 2021



PENSTOCK 3 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
Kleinschmidt Associates

December 2021

Kleinschmidt

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in December of 2020 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development in 2021.

In 2016, cracking was identified in Penstock 1 and Kleinschmidt assisted NLH with the inspection and weld repair design. Penstock 1 was repaired the same year as the inspection. Kleinschmidt inspected Penstock 2 later in 2016 and discovered similar weld deterioration of Penstock 2, which was repaired in 2017. Subsequent to the previous inspections of Penstock 1 and 2, deteriorated welds were repaired in Penstock 3 after inspection in 2018. This is not the full history of issues and repairs for the penstocks but is intended to show a pattern of weld related issues.

As indicated in the record drawings, Penstock 3 was installed in 1968, a year after the Penstock 1 and 2, using similar plate materials, thicknesses, and weld procedures. Due to the three penstocks being of similar age and design and because of the identified weld deterioration and corrosion, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock No. 3 inspection was to assess the integrity of the welds and complete steel thickness measurements to evaluate metal loss and corrosion to determine if the penstock condition is acceptable to operate through another calendar year.

An inspection of Penstock 3 was conducted by Kleinschmidt in August of 2021, which consisted of a visual walk-over of the penstock exterior, and a detailed evaluation of the condition of the interior of the penstock. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which consisted of cleaning and visually inspecting a percentage of the steel shell and the longitudinal and circumferential welds. Non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell were performed during the inspection.

The 2021 inspection revealed minimal loss of material thickness of the penstock shell. The plate thickness was comparable to the record drawings, and the interior of the shell displayed a layer of rust with moderate corrosion and pitting common for a 50-year-old

penstock. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3.

Active but slight seepage was identified coming through the welded joints at the penstock to surge tank transition. Efflorescence and water was observed coming into the penstock from the exterior. This indicates the presence of cracks at the weld locations. This is not a cause for immediate repair as the area is fully encased in concrete mitigating the possibility of a significant breach, but it does further indicate the need for weld refurbishment.

The sinkhole discovered in 2019 downstream of the surge tank on the left side of the penstock has been filled in previous years and appears to have stabilized. The area should continue to be monitored for further erosion.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.33. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.25, which is not acceptable for late 1960 steel pipe. The calculated stresses at the joints assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used for the analysis, as discussed in Section 4, if RT weld testing is performed to verify the integrity of the welds. A higher joint efficiency would result in favourable factors of safety; however, considering the known weld deterioration, a higher joint efficiency is not justified at this time.

The base plate material away from the joints has a maximum stress ratio of 0.93 and a safety factor of 1.79, which is acceptable and could tolerate 3 mm (1/8") of material loss from design thickness in most cases.

This approximately 50-year-old penstock has shown minimal loss of thickness from the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070). However, because of the condition of the existing welds, the 17-ft section of penstock will need to be replaced, the remaining penstock welds refurbished, and the interior re-coated before the steel deteriorates further.

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ACRONYMS

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
CH	Chainage (in metres)
cms	Cubic Metres per Second
ETS	EasternTechnical Services Ltd.
Fu	Ultimate Tensile Stress
Fy	Yield Stress
GWh	Gigawatt Hours
kPa	Kilo-Pascals
Kleinschmidt	Kleinschmidt Associates
MW	Megawatts
NLH	Newfoundland and Labrador Hydro
SPRAT	Society of Professional Rope Access Technicians
STA	Station (in feet)
TRR	Technical Rope and Rescue
UT	Ultrasonic Thickness

1.0 INTRODUCTION

In 2016, cracking was identified by Newfoundland and Labrador Hydro (NLH) in Penstock 1 due to weld degradation and Kleinschmidt assisted with inspection and a weld repair design. However, the discovery of an additional indication in Penstock 1 prompted a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods.

NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished. Penstock 3 was not inspected in 2020 due to the Covid-19 pandemic travel restrictions.

Therefore, the focus of the Penstock 3 inspection in 2021 was to assess the integrity of the welds and to complete steel plate thickness measurements to evaluate the current condition of the steel. The 2021 inspection concentrated on welds that have never been inspected downstream of the surge tank and welds not inspected during the previous year in the upper end of the penstock. The plan was to double the quantity of longitudinal weld testing in the 17-foot (ft) diameter section of the penstock compared to 2019.

The August 2021 inspection of Penstock 3 consisted of weld inspections and steel plate thickness measurements completed by Eastern and TRR. Kleinschmidt engineers Chris Vella and Nicholas Townsend travelled to the Bay d'Espoir Hydro Site to complete an interior and exterior condition assessment of the penstock and assist with the weld inspection.

This report presents our evaluation of the capacity of the penstock in its current condition, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 ft (176 metres [m]) and seven generating units with a total capacity of 604 megawatts (MW). The hydro development is comprised of four intake structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks Nos. 1, 2, and 3 have surge towers approximately 2,400 ft (727 m) upstream of the powerhouse. The first phase of the initial project construction included installation of two intake structures and a four-unit powerhouse with Penstocks 1 and 2 connecting the two intakes to the powerhouse. The second phase of the project consisted of installing Penstock 3 with a third intake and two additional units in the powerhouse. A separate intake structure and powerhouse for Unit No. 7, connected by Penstock 4 was built in 1970. Penstock 3 supplies Units No. 5 and No. 6. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock 3 is a 1,100-m-long buried steel penstock, tapering from 5.2 m in diameter (at the intake) to 4.1 m in diameter at the powerhouse bifurcation. At the flattest point, the penstock has a 0.0% slope and has a 20% slope at the steepest. There are at least three areas to access the interior of Penstock 3, one at the well in the intake structure, three manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Appendix A includes the original 1968 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 7/16 inches at the intake to 1 5/8 inches at the bifurcation upstream of the powerhouse (plate thicknesses in this report are expressed in inches to match the drawings provided). The penstock is constructed of A285, G40.88 and HSB 50 steel. The penstock is 17.0 ft (5.2m) in diameter until STA 12+41 (CH 376.2), 15.25 ft (4.6m) in diameter between STA 12+41 (CH 376.2) and STA 27+50 (CH 833.3) where it then reduces to 13.5 ft (4.1m) in diameter for the remaining 1,581 ft (479.1 m) to the bifurcation. The welds are double V groove full penetration welds.

A majority of the penstock has a cover of 2 ft (0.61 m) of clayey soil and 1 ft (0.30 m) minimum thick layer of riprap. The penstock crosses underneath the switchyard and terminates at the powerhouse. Several weirs are located where the drainage daylights to the ditches and wells for inspection and monitoring purposes.

3.0 INSPECTION

Christopher Vella, P.Eng. and Nicholas Townsend, E.I.T. of Kleinschmidt, inspected the interior and exterior of Penstock 3 on August 16-18, 2021, with the assistance of personnel from Technical Rope and Rescue (TRR), Eastern Technical Services (ETS), and NLH. Ray Buffett of NLH participated in safety talks and assisted with site access and communication. NLH were present to answer questions about the history, operation, and maintenance of the station. ETS assisted with the ultrasonic thickness (UT) and MT testing of the penstock steel and welds. TRR rope access personnel assisted with safe access, confined space entry protocols, communication, and provided standby at the penstock entry for rescue.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying any pitting or cracking, and an overall general condition assessment of the interior of the shell. ETS personnel performed MT weld tests on approximately 28% of the longitudinal welds from inside the 17-ft diameter section of penstock and 13% of the longitudinal welds overall. ETS took UT measurements from approximately 10% of the cans for the portion of penstock inspected.

The exterior of the buried penstock was examined for signs of leakage. For this inspection, all references to penstock left and right are oriented looking downstream.

Table 3-1 Definitions for Condition Assessment

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected, and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible, and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year

References to right and left are from the perspective of someone looking downstream unless noted otherwise.

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on the morning of Monday, August 16, 2021. The inspection team entered the penstock on the same day at the upstream most manhole (manhole #1) of Penstock 3. TRR assisted with confined space entrance and rigging for fall protection. The internal inspection finished on Wednesday August 18th, 2021. The exterior inspection commenced on Tuesday August 17, 2021 and was completed by Kleinschmidt the same day. Kleinschmidt pre-marked welds to be inspected inside of the penstock so TRR and ETS could proceed with the internal inspection and weld testing while Kleinschmidt performed the external inspection. Air quality in the penstock remained good for the duration of the inspection.

The internal penstock inspection commenced at the headgate location. At the time of the inspection, maintenance was being conducted on the headgate and therefore, stoplogs were temporarily installed to replace of the steel headgate. Significant leakage around the stoplogs was noted throughout the inspection as seen in Photos 3 and 4, Appendix B. Excess water in the penstock due to the leakage around the stoplogs increased the difficulty of the interior inspection. A berm consisting of sand bags was installed at the manhole #1 location in an effort to stop the excess water from streaming down the penstock interior. Submersible pumps were used to remove the excess water pooling at the berm location. The interior surface of the penstock was damp with organic growth. The organics upstream of the surge tank had been removed during previous penstock weld repairs, which facilitated the current inspection. More effort was required downstream of the surge tank to remove organics and clean welds as there were a greater quantity of existing welds not previously inspected. The penstock was not completely dewatered, and therefore, the penstock could not be inspected beyond STA. 35+36.47 (Drawing F-2106-C-3).

The exterior inspection was completed in sunny, hot (+30 degrees Celsius) and humid weather conditions. The ground surface was rocky with steep slopes with short vegetation (Photo 20). Some areas were noted to have alder bush growth and taller vegetation that was impeding inspection and sight of the ground surface (Photos 37). The ground was reasonably dry reducing slip potential, with the exception of water present on the

righthand side on the penstock near manhole 1 because of water being pumped out of the penstock due to excess stoplog leakage. There were areas of saturated soil on the left hand side of the penstock located downstream of the surge tank, which was previously noted during the 2019 inspection. The grade followed the penstock slope between the intake and the switchyard. The deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 Interior Inspection

The interior of the penstock was inspected from August 16 to 18, 2021. The penstock consists of approximately 435 "Cans" into the powerhouse scroll case. A can, referred to in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used in this report to reference location within the penstock during the inspection, with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded at the interior surface at various locations. Shell thickness measurements were taken by ETS with a Krautkramer DMS 2 digital Ultrasonic thickness gauge (S/N 01YL2P). A dual element Krautkramer TC560 transducer (S/N 14A01G28) was used, and the readings were taken in the "standard" mode. The gauge was calibrated before the field measurements to an accuracy of 0.001 inch using a calibrated steel bar. Improved thickness reading confidence may be achieved by calibrating the UT gauge with the same material as the penstock; A285 and G40.88 steel. A sample of each penstock steel material can be machined to various thicknesses for the purpose of steel thickness calibration of the UT gauge. Kleinschmidt recommends calibration improvements moving forward for the 2022 penstock inspections. Due to the fact that both the field measurements and Appendix A drawings give shell thicknesses in inches, the evaluation and analysis was completed in Imperial units. Metric equivalents are provided in parenthesis where required.

Thickness readings were recorded from the interior of the penstock generally near the invert of the penstock, typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the penstock. Throughout the inspection, Kleinschmidt took UT thickness readings for the purpose of quality control and to compare results to the ETS readings. All recorded readings by Kleinschmidt were on average 0.5mm (1/64 inch) greater than the readings recorded by ETS. This difference is

not ideal and is likely caused by the different transducers, calibration steel, and UT units. However, this is not detrimental to the analysis and the thinner ETS values are used in the analysis. Appendix D provides the ETS report of shell thickness readings and Table D-1 and Table D-2 in Appendix D summarizes the average shell thickness readings and stresses respectively for each section of penstock. A summary of this data is provided in Table 4-1.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

Penstock 3 is fabricated from 30 different plate sizes ranging from 7/16 to 1 5/8 inches with 21 of these plate sizes occurring downstream of the surge tank. Inspection thickness readings were taken of 7 different plate sizes upstream of the surge tank, ranging from 7/16-inch (11 mm) to 3/4-inch (19 mm). The average change in material thickness upstream of the surge tank was found to be approximately 5.4% thinner than design. The steel plate thicknesses below the surge tank range from 0.638 inches (16 mm) to 1.625 inches (41 mm). The average change in material thickness below the surge tank was found to be approximately 2.5% thinner than design. Appendix D provides the ETS report of the MP and UT testing.

The interior of the penstock is generally in fair condition with consistent moderate corrosion and pitting with tubercles and growth. Pitting was moderate, relative to the plate thickness, and detailed pit measurements were not taken. A significant number of weld repairs were observed and the previous weld repair work made this inspection a little easier as much of the organic build-up had been previously removed.

The repaired welds were in good condition and the original welded joints were in fair condition and did not have any apparent indications or excessive deterioration with the exception of one circumferential weld located between cans 192 and 193 (Photos 12 through 15). The cap of the circumferential weld was found to be separated from the penstock steel on the downstream side of the cap (Photo 15). A steel geologists hammer was used to impact the weld to determine if the weld cap would separate from the weld or penstock steel. The weld did not separate after several strikes of the hammer and no visible cracks propagated throughout the weld.

The repaired welds from 2018 were in good condition and relatively clean with some surface rust and organic buildup. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK" before Penstock 3 was returned to service. The inspection of the welds was concentrated on the unrepaired welds but also included several of the repaired welds. The welds in Penstock 3 were cleaned using a grinder with a sandpaper wheel attachment then wiped clean and painted with a white contrast paint to facilitate the MP weld test. MP testing included 96 full length longitudinal welds and a few feet of 192 circumferential welds. An initial visual inspection of the weld was conducted concentrating on condition of the bead in regard to pitting, corrosion or cracking, and undermining or washout. The welds were also impacted with a geologists hammer to assess the integrity of the weld joints. Corrosion of the original welds was fair for all welds inspected with light to moderate pitting. The new or repaired welds were in good condition with only insignificant surface rust just starting and no degradation. No indications or significant issues were identified.

3.2.2 Appurtenances

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock 3 has three large manholes and a bifurcation at the powerhouse.

The first manhole downstream of the intake, manhole 1, was moderately corroded, and was missing the bottom plate, however, was in fair condition (Photos 23 and 24). Manhole 2 and manhole 3 were moderately corroded and were in fair condition (Photos 33 and 39 respectively).

The penstock drainage pipes and culverts were noted to be in fair condition. Kleinschmidt identified and inspected two monitoring weirs, labelled N–1 and N-2. Drainage weir N-1, located in a wooden shack, was in fair condition and had a small amount of drainage flowing through the weir. Vegetation overgrowth surrounding the shack made inspection of the surrounding area difficult. In comparison, during the 2019 inspection, the culverts in the drainage ditch immediately upstream of weir N-1 were noted to be full of rock and sediment, which was significantly blocking drainage flow. It was undetermined from the current inspection if rock and sediment are still blocking drainage. It is recommended that the vegetation be cleared to facilitate inspection.

Drainage weir N-2 was in fair condition and also had a small amount of drainage flowing through the weir. Moss growth was noted within the drainage pipe and could impede flow estimation. It is recommended that the moss growth be removed. The estimated amount of flow through the drainage system was not determined during the current inspection The drainage layout is depicted along the length of the penstock in Drawing F2106-C-1 (Appendix A); however, the termination of the drainage plumbing and weirs are not shown.

As noted above, during 2021 inspection, maintenance was being conducted on the headgate and stoplogs were temporarily installed in place of the steel intake headgates, therefore, the headgates were not observed. The penstock was not completely dewatered, and therefore the penstock was not inspected beyond STA. 35+36.47. The bifurcation of the penstock as it enters the powerhouse was not inspected.

3.2.3 Surge Tank

During the 2019 inspection of Penstock 3, the surge tank transition welds were not closely inspected due to falling ice concerns. It was noted at that time that the base of the surge tower transition was wet, but no leakage was identified at that time. Penstock 3 was not inspected in 2020 due to Covid. The current inspection of the welds on the right and left side on the downstream section of the transition were observed to be leaking (Photo 18). Efflorescence was observed surrounding the areas of the welds that were leaking water. It is recommended that these welds be repaired in the next 3 to 5 years. Due to the surge tower transition piece being encased in concrete, it is unlikely that a rupture will occur; however, leakage between the steel and the concrete encasement may result in erosion of the concrete, and eventually propagate to the surrounding soil if not repaired.

3.3 Exterior Inspection

Kleinschmidt began the exterior inspection on August 17th at the intake and proceeded to move downstream. The inspection was completed the same day and terminated at the switchyard. The interior weld testing and UT measurements performed by ETS continued inside the penstock while Mr. Vella and Mr. Townsend walked the exterior. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 22 and 28. Kleinschmidt observed the exterior ground surface for evidence of signs of leakage such as sloughing of the soil or depressions while walking the length of the penstock. No obvious indications were observed during the 2021 exterior inspection of the penstock.

During the 2019 exterior inspection of the penstock, a sink hole was discovered 9 ft downstream of the surge tank concrete encasement, located on the left side of the penstock. The hole was about 4 ft in diameter and 4 ft deep. Upon re-inspection in 2021, the area was observed to have a large amount of vegetation and alderbush growth, which made inspection of the area difficult (Photo 35). It is recommended that the vegetation be removed to facilitate future inspections and weekly checks should be performed by NLH. No issues were noted surrounding the area of the sinkhole.

There is an observation well about 20 ft downstream of the surge tank on the left side (Photo 34). No flow was observed, however, there was stagnant water in the bottom of the well. The recent sink hole discovered in 2019 and visual evidence of previous settlement in the area suggest that the drainage system in the area is not functioning properly. It is recommended that the well be inspected from the bottom, which will require fall protection and confined space access procedures. It is recommended that the drainage system be scoped with a camera from the bottom of the well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage.

The ditching on the left side of Penstock 3 should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage (Photos 30 and 46).

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No.79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix D. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 and 24,000 psi was used for CSA G40.8 Grade B. The yield strength of HSB 50 was assumed to be 50,000 psi; however, no reference was located for this value. No ultimate tensile strength was assumed so that allowable stresses in the evaluation were based on the yield strength criteria for HSB 50 steel (33,333 psi).

The strength of the welded seams are reduced compared to the base material. The strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used for the analysis if weld testing is performed to verify the integrity of the welds. As per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds requiring higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- stresses in the penstock under flood conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the analysis of steel shell thickness data and internal pressure steel stress analysis results. See Appendix C for detailed thickness data and stress calculations.

The minimum thickness measurement was determined for each penstock can and was used to calculate the allowable stresses within each penstock section. To calculate the allowable stresses, the minimum thickness measurement was used in contrast to the 97.5% confidence interval (CI) used in previous years. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

Three thickness measurements were taken at each location, A, B, and C, for each can that was inspected with a UT gauge, with nine thickness measurements in total for each can. When analyzing the thickness measurements using the 97.5% CI method, the calculated thickness was significantly less when compared to the minimum measured thicknesses. When the 97.5% CI is applied to a small data group, such as three to nine thickness measurements, it results in wide confidence intervals. Using the minimum steel-shell thickness measurement for the purpose of analysis in lieu of the 97.5% CI thickness, we feel is representative of the remaining penstock plate thickness.

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 ft (182 m) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 ft (271 m) at the powerhouse and linearly reducing to 660 (201 m) ft at the surge tower and then matching the FSL of 597 ft (182 m) at the intake. The maximum stress ratio is 1.33 for increased surge, is greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.25, unacceptable for late 1960 steel pipe. However, an increase in the joint efficiency through weld testing that would verify the joints integrity could potentially improve these values. For the plate steel away from the joints, the material has a maximum stress ratio of 0.93 and a safety factor of 1.79, which is acceptable for present day design.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Max Joint Stress (psi)	Base Material Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress [1,3] (psi)	Allowable Stress (psi)	Joint Stress Ratio[1,2,3]	Base Material Stress Ratio[2,3]	Factor of Safety Against Yield[4] (Joints)	Factor of Safety Against Yield[4] (Base Material)
1	5,934.6	5,400.5	1,780.4	7,715.0	17,000	0.45	0.32	3.37	4.81
6	5,426.1	4,937.8	1,627.8	7,054.0	17,000	0.41	0.29	3.69	5.27
16	6,461.0	5,879.5	1,938.3	8,399.3	17,000	0.49	0.35	3.10	4.42
26	7,026.2	6,393.9	2,107.9	9,134.1	17,000	0.54	0.38	2.85	4.07
35	8,502.8	7,737.6	2,550.8	11,053.7	17,000	0.65	0.46	2.35	3.36
45	9,990.5	9,091.3	2,997.1	12,987.6	17,000	0.76	0.53	2.00	2.86
55	11,698.4	10,645.5	3,509.5	15,207.9	17,000	0.89	0.63	1.71	2.44
65	13,165.2	11,980.3	3,949.6	17,114.7	17,000	1.01	0.70	1.52	2.17
74	14,497.2	13,192.5	4,349.2	18,846.4	17,000	1.11	0.78	1.38	1.97
81	15,437.2	14,047.9	4,631.2	20,068.4	17,000	1.18	0.83	1.30	1.85
91	16,780.1	15,269.9	5,034.0	21,814.1	17,000	1.28	0.90	1.19	1.70
101	17,945.9	16,330.7	5,383.8	23,329.6	24,000	0.97	0.68	1.71	2.45
112	19,216.6	17,487.1	5,765.0	24,981.5	24,000	1.04	0.73	1.60	2.29
122	20,726.3	18,860.9	6,217.9	26,944.2	24,000	1.12	0.79	1.48	2.12
132	17,450.4	15,879.9	5,235.1	22,685.5	24,000	0.95	0.66	1.76	2.52
143	18,203.8	16,565.5	5,461.1	23,665.0	24,000	0.99	0.69	1.69	2.41
153	21,282.8	19,367.4	6,384.8	27,667.7	24,000	1.15	0.81	1.45	2.07
163	22,752.8	20,705.0	6,825.8	29,578.6	24,000	1.23	0.86	1.35	1.93
172	24,555.3	22,345.4	7,366.6	31,921.9	24,000	1.33	0.93	1.25	1.79
183	22,142.5	20,149.7	6,642.8	28,785.3	24,000	1.20	0.84	1.39	1.99
193	21,436.7	19,507.4	6,431.0	27,867.8	24,000	1.16	0.81	1.36	1.95
203	23,858.8	21,711.5	7,157.6	31,016.4	24,000	1.29	0.90	1.23	1.75
211	24,989.4	22,740.4	7,496.8	32,486.3	33,333	0.97	0.68	1.54	2.20
223	26,768.7	24,359.5	8,030.6	34,799.3	33,333	1.04	0.73	1.44	2.05
233	23,576.2	21,454.3	7,072.9	30,649.1	24,000	1.28	0.89	1.24	1.77
240	22,036.5	20,053.2	6,610.9	28,647.4	24,000	1.19	0.84	1.33	1.89
250	25,187.3	22,920.4	7,556.2	32,743.4	33,333	0.98	0.69	1.53	2.18
261	25,672.7	23,362.2	7,701.8	33,374.5	33,333	1.00	0.70	1.50	2.14
271	27,269.9	24,815.6	8,181.0	35,450.9	33,333	1.06	0.74	1.41	2.01
281	25,115.3	22,854.9	7,534.6	32,649.9	33,333	0.98	0.69	1.53	2.19
291	26,090.0	23,741.9	7,827.0	33,917.0	33,333	1.02	0.71	1.47	2.11
300	23,827.5	21,683.1	7,148.3	30,975.8	33,333	0.93	0.65	1.61	2.31
310	22,973.7	20,906.0	6,892.1	29,865.8	33,333	0.90	0.63	1.67	2.39

Can	Max Joint Stress (psi)	Base Material Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress [1,3] (psi)	Allowable Stress (psi)	Joint Stress Ratio[1,2,3]	Base Material Stress Ratio[2,3]	Factor of Safety Against Yield[4] (Joints)	Factor of Safety Against Yield[4] (Base Material)
321	23,522.4	21,405.3	7,056.7	30,579.1	33,333	0.92	0.64	1.64	2.34
331	22,332.4	20,322.5	6,699.7	29,032.1	33,333	0.87	0.61	1.72	2.46
340	21,608.5	19,663.8	6,482.6	28,091.1	33,333	0.84	0.59	1.78	2.54
351	22,700.0	20,657.0	6,810.0	29,510.0	33,333	0.89	0.62	1.69	2.42
360	22,834.9	20,779.8	6,850.5	29,685.4	33,333	0.89	0.62	1.68	2.41
369	22,884.9	20,825.3	6,865.5	29,750.4	33,333	0.89	0.62	1.68	2.40

[1] Joint efficiency of 0.7 included
[2] Total stress / Allowable stress
[3] Uses minimum can thickness
[4] SF = F_y/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 103 psf and the depth of soil cover on the penstock was assumed to be 3 ft. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off road vehicle loads or equipment. The snow and live load combination uses a reduced snow and live load of 75 percent of each.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

Notes:

- No vehicular loading was used in the analysis where the penstock does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake are not used in the analysis.
- Similar to Penstocks 1 and 2, the penstock appears to be located in cohesive fine grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is

not considered an applicable loading condition as we assumed there is adequate drainage.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest measured steel thickness values were used. See Table 4-2.

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	4.11	3.24	3.72
15.25	6.94	3.91	4.39
13.5	12.07	4.30	4.78

There were no vehicular surcharge analysis conducted for the shallow buried penstock as there is no location for traffic to cross the penstock. Where vehicular traffic can cross the penstock, additional analyses were not completed due to the depth of the buried penstock at these locations (intake and switchyard).

4.3.2 Subatmospheric Internal Penstock Pressure Analysis

Subatmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and a detailed hydrodynamic model was not created for this report, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according to the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 m^2 (3.07 ft^2), which is well below the area provided by the approximately 5.1-m^2 (55-ft^2) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and becomes permanently deformed. No deformations were observed by inspection. The penstock is continuously supported by the soil therefore excessive local buckling stresses in the penstock are unlikely.

4.5 Local Weld Conditions

ETS performed MT tests on the full length of 96 longitudinal welds and a few feet of 192 circumferential welds for this August 2021 inspection. No indications were discovered from the MT tests. The circumferential weld between cans 192 and 193 and the leaking welds at the surge tank transition were identified from visual inspection and will require repair within the next 3 to 5 years.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life. However, the 17 ft section of the penstock should be replaced, the remaining welds refurbished and the interior of the penstock re-coated to prevent further corrosion. Replacing the welds from the inside of the penstock only may not fully mitigate the issues in the 17 ft section of penstock and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. This has been highlighted this year with multiple indications discovered in Penstock 1 in previously repaired welds. Indications found in 5-year-old welds indicates that the weld repairs may have a limited life expectancy. All indications were found in the 17-ft diameter section this year indicating again that this section of penstock is particularly prone to weld indications. This section of penstock has the largest diameter and the thinnest plate, is made of a different steel grade than the rest of the penstock and has peaking induced residual stresses at the joints. The 17-ft diameter section of Penstock No. 3 should be replaced to remove the risk of future failures during operation and to provide confidence in the 17 ft section that will not be gained by repairing the welds. The remainder of the penstock should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively within 8 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate minimal loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior penstock surface. Assuming similar rates of material loss, the penstock should have 50 to 80 years of service life remaining if recoated. The base plate material away from the joints can tolerate up to 3 mm (1/8 inch) further material loss and maintain a stress ratio below 1.0.

5.2 Internal Pressure Strength

Stress ratios for a combined static and dynamic internal pressures peak at 1.33 (Table 4-1). This indicates that the penstock does not meet present day design criteria for new penstock design. The thickness of this plate and other plates with high stress ratios should be measured next year and the adjacent plates should be measured to confirm thickness and deterioration in the area. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.25, which is not acceptable for late 1960 steel pipe. As

noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor.

6.0 RECOMMENDATIONS

Penstock 3 17-ft diameter section should be replaced within 8 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- radiographic testing of the welds if possible;
- surge Analysis to verify peak pressure and resulting stresses;
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage;
- continued inspections of the interior including MP weld testing;
- repair of circumferential weld between cans 192 and 193; and
- repair of surge tank transition section welds.

The Surge Analysis should be completed before refurbishment to confirm stresses that may be used in weld sizing. Monitoring for leakage is something that should be done for every penstock regardless of age, construction, or condition. It is an early indicator of issues. Leakage for buried penstocks is most effectively done by monitoring drainage pipes and looking for wet areas and sink holes along the penstock alignment. MP weld testing after coating is applied may not be possible without removing the coating but not unheard of and will be dependent on coating system used. Other forms of weld testing are available that can test through paint such as the MagnaFORM Probe from Olympus. Considering indications were found at previously repaired welds this is something that will require further investigation and consideration.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 8 years. At this stage, Kleinschmidt is unable to estimate the rate of corrosion of the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated

over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20-40 years or more. If the penstock is recoated prior to significant steel deterioration every 20-40 years, NLH can anticipate extending the life of the penstock nominally another 80 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated, but it is difficult to tell its condition.

6.2 Exterior Inspection

The repaired sinkhole downstream of the surge tank should continue to be monitored.

It is recommended that the observation well downstream, and to the left of the surge tank, be inspected from the bottom. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage.

The ditching on the left side of Penstock 3 should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage.

Kleinschmidt recommends repairing culvert damage described previously as well as continuing to monitor the exterior of the penstocks for signs of leakage. Drain pipes should also be monitored at times with consistent weather conditions.

6.3 Interior Inspections

6.3.1 General Evaluation

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. The yearly inspections should provide a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless if the coating has been

replaced or not, the detailed inspections can be extended to a 5 to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval. Extensive weld testing and repairs have appeared to have adequately addressed weld issues, except that the transition into the surge tank was not repaired. Repairs to this area should be made during the next dewatering.

7.0 REFERENCES

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Creager, W. P., and J. D. Justin. 1950. Hydroelectric Handbook. 2nd Edition. Wiley. Minneapolis, Minnesota.

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Hatch. 2019. Newfoundland and Labrador Hydro Final Report for Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3. Rev 0. March 28, 2019.

Kleinschmidt Associates. 2016. Crack Investigation and Repair Report, Penstock No. 1 Bay d'Espoir Hydroelectric Development. Kleinschmidt Technical Report to Newfoundland and Labrador Hydro.

SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Hydro Engineer

CMV:NSS:SCB





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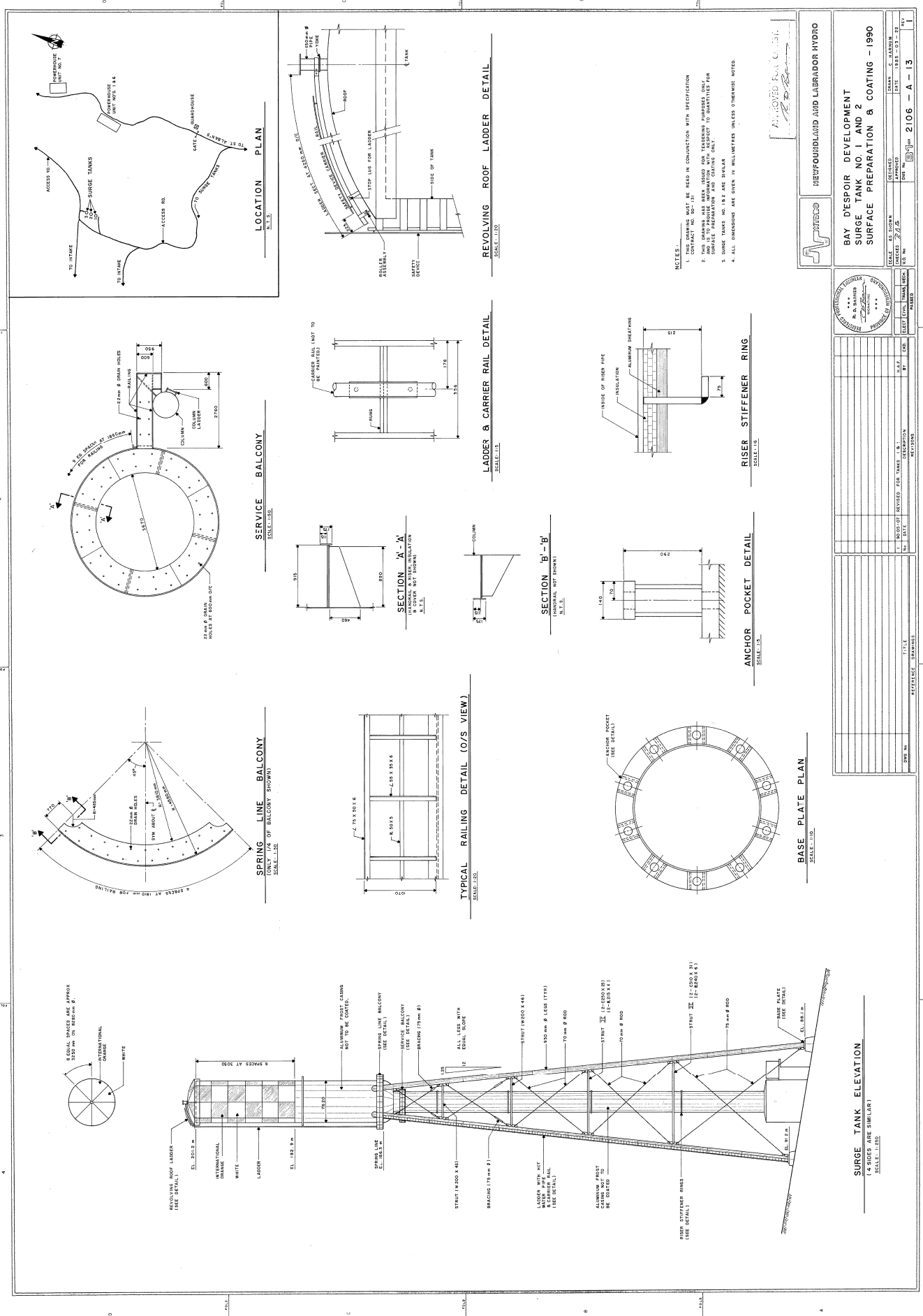
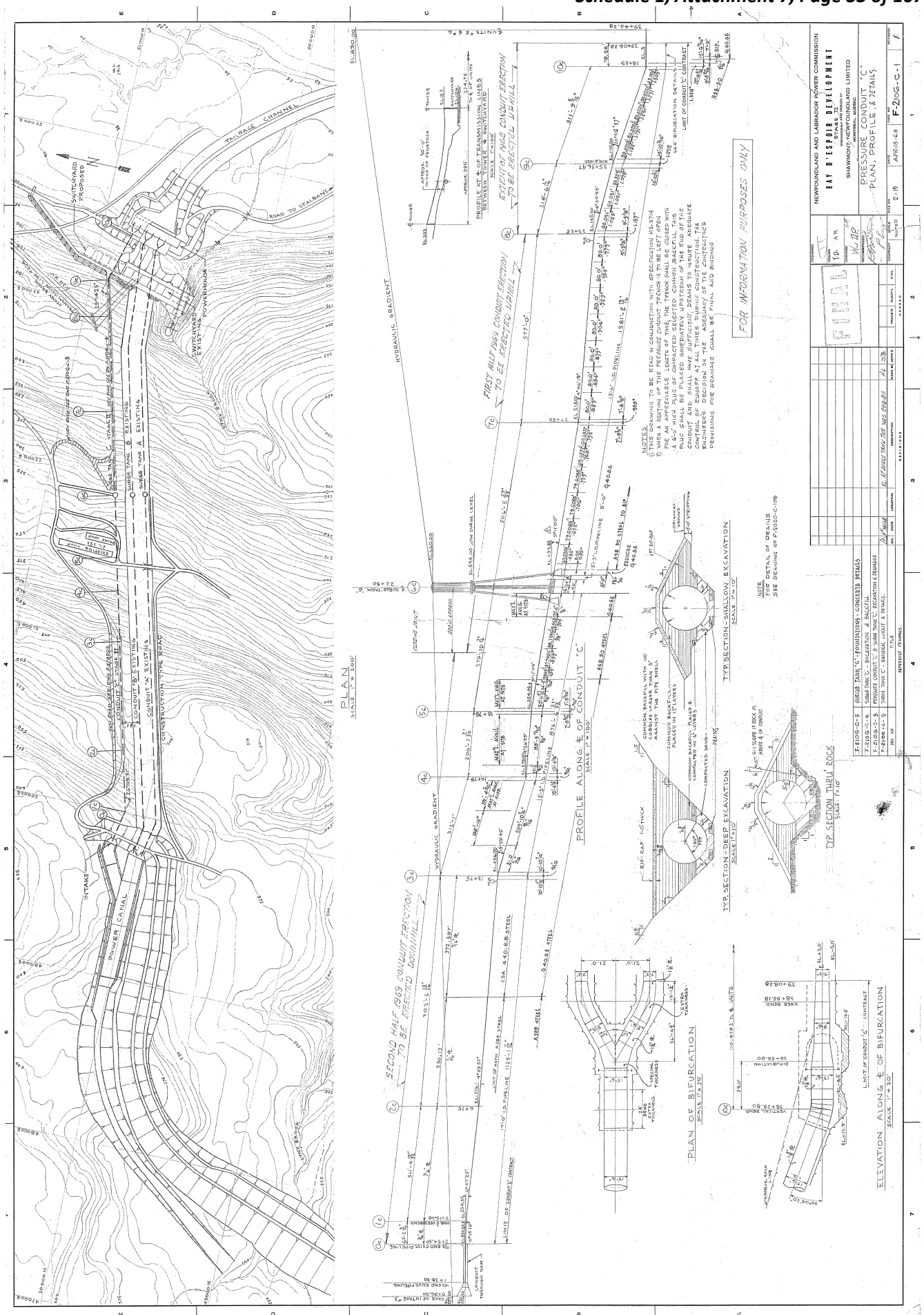
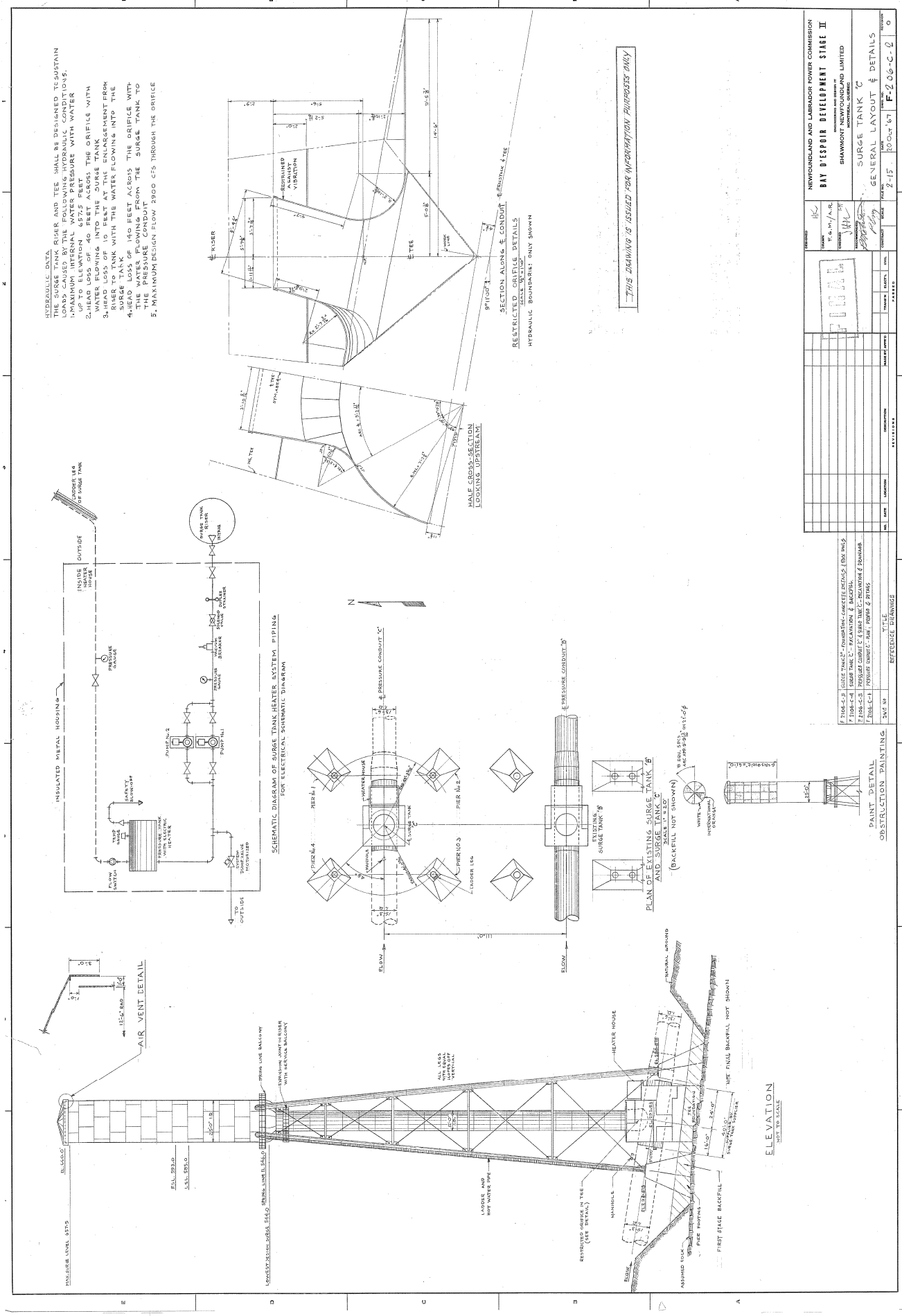
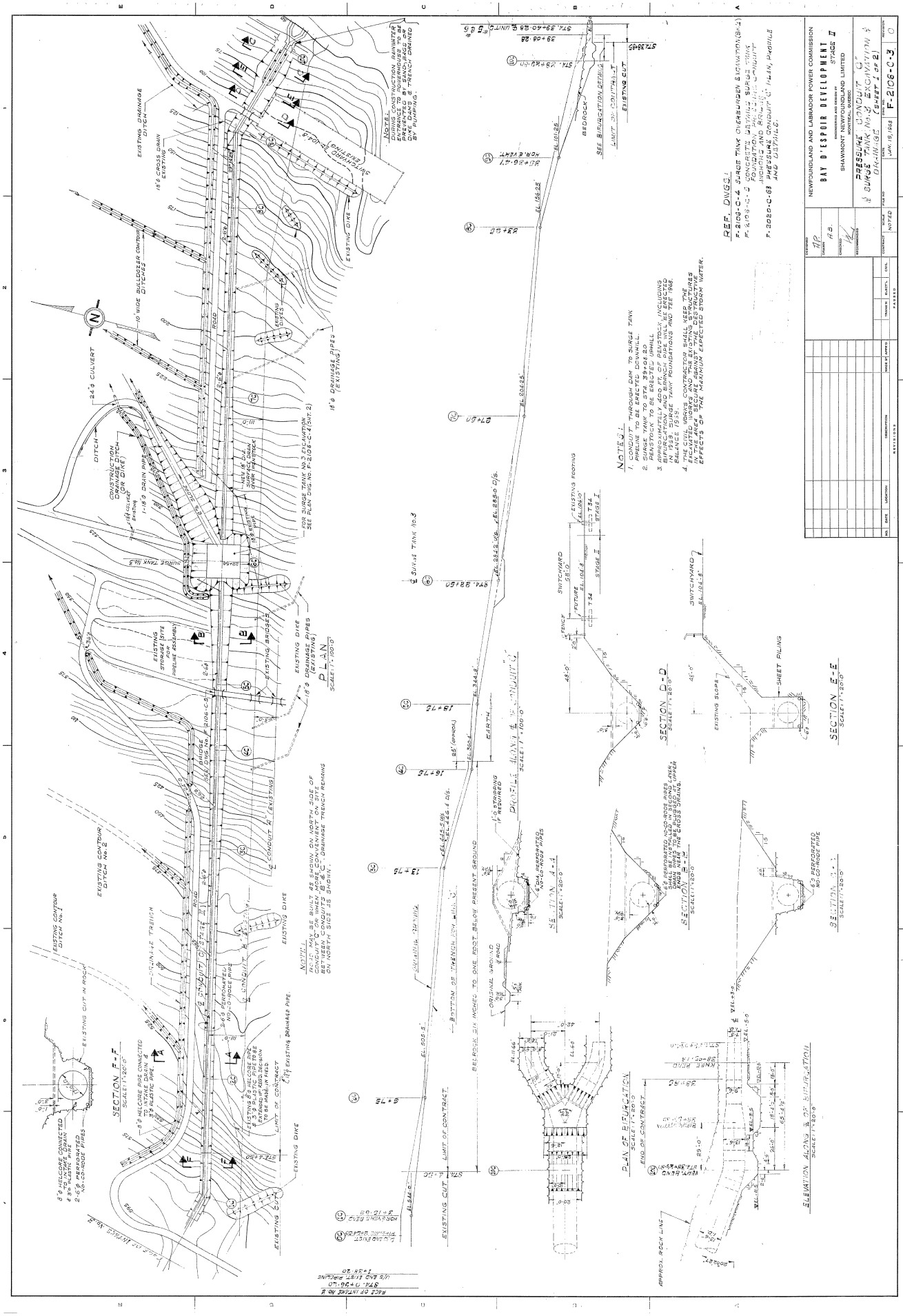
APPENDIX A

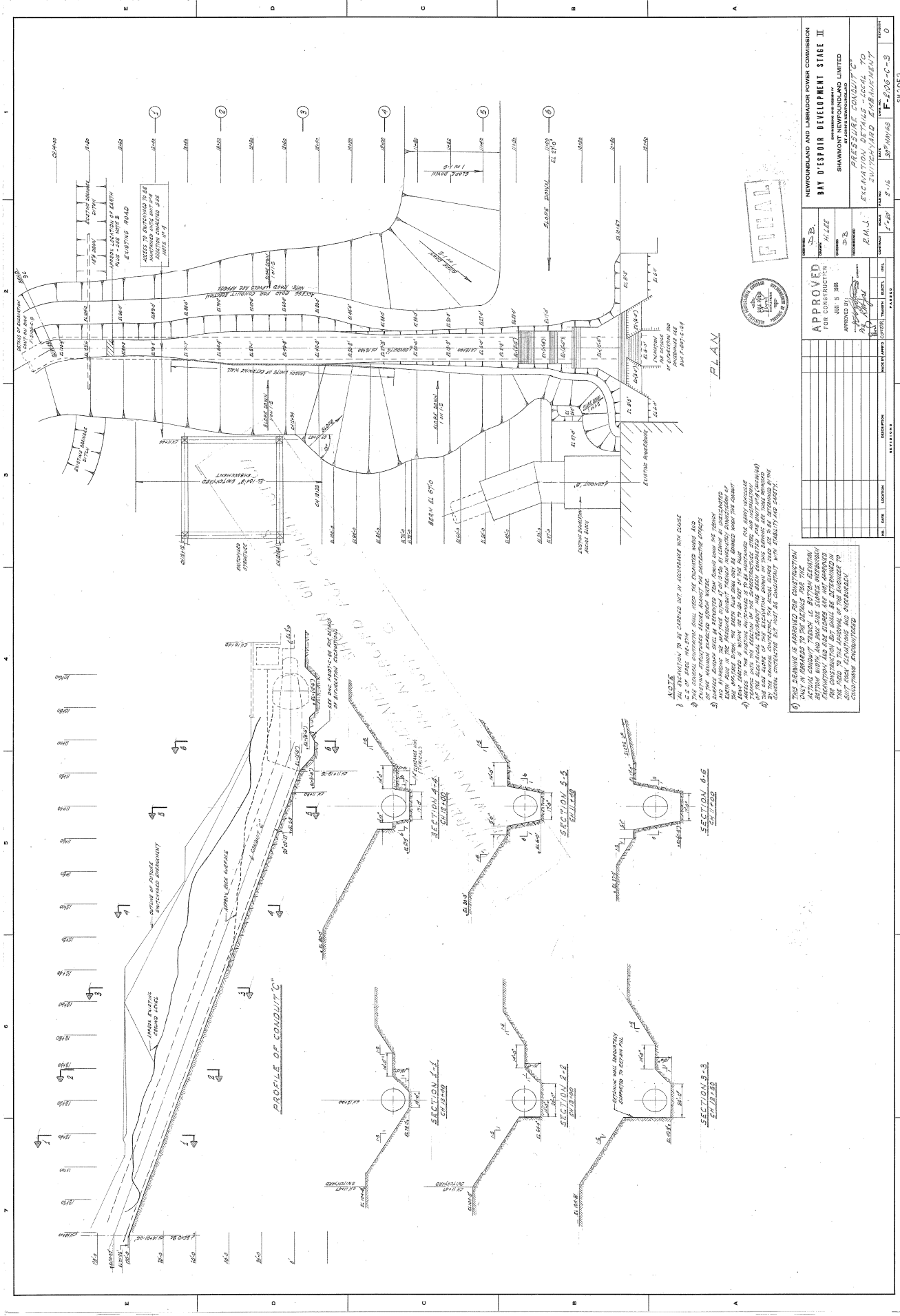
PENSTOCK LAYOUT DRAWINGS

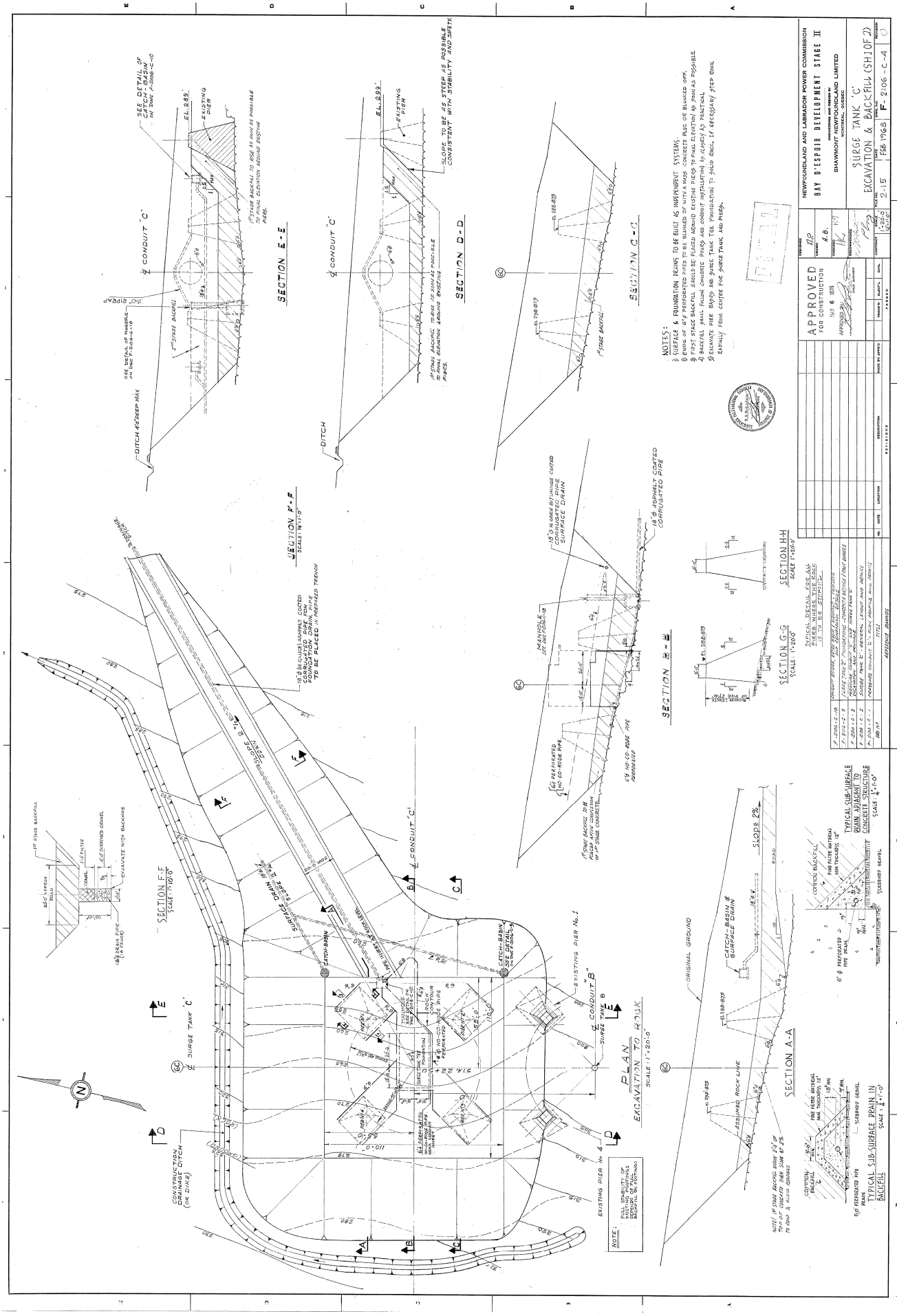

LOCATION PLAN
N.T.S.
REVOLVING ROOF LADDER DETAIL
SCALE 1:20
NOTES:
1. THIS DRAWING MUST BE READ IN CONJUNCTION WITH SPECIFICATION CONTRACT NO. 101.
2. THIS DRAWING HAS BEEN ISSUED FOR TENDERING PURPOSES ONLY AND IS TO PROVIDE INFORMATION WITH RESPECT TO QUANTITIES FOR SURFACE PREPARATION AND COATING ONLY.
3. SURGE TANKS NO.1 & 2 ARE SIMILAR
4. ALL DIMENSIONS ARE GIVEN IN MILLIMETRES UNLESS OTHERWISE NOTED.
APPROVED For Construction
NEWFOUNDLAND AND LABRADOR HYDRO
BAY D'ESPOIR DEVELOPMENT
SURGE TANK NO. 1 AND 2
SURFACE PREPARATION & COATING - 1990
2106 - A - 13
REVISED FOR TANKS 1 & 2
SERVICE BALCONY
SCALE 1:100
LADDER & CARRIER RAIL DETAIL
SCALE 1:5
SECTION 'A'-'A'
SECTION 'B'-'B'
RISER STIFFENER RING
SCALE 1:5
ANCHOR POCKET DETAIL
SCALE 1:5
SPRING LINE BALCONY
TYPICAL RAILING DETAIL (O/S VIEW)
SCALE 1:20
BASE PLATE PLAN
SCALE 1:10
SURGE TANK ELEVATION
SCALE 1:200

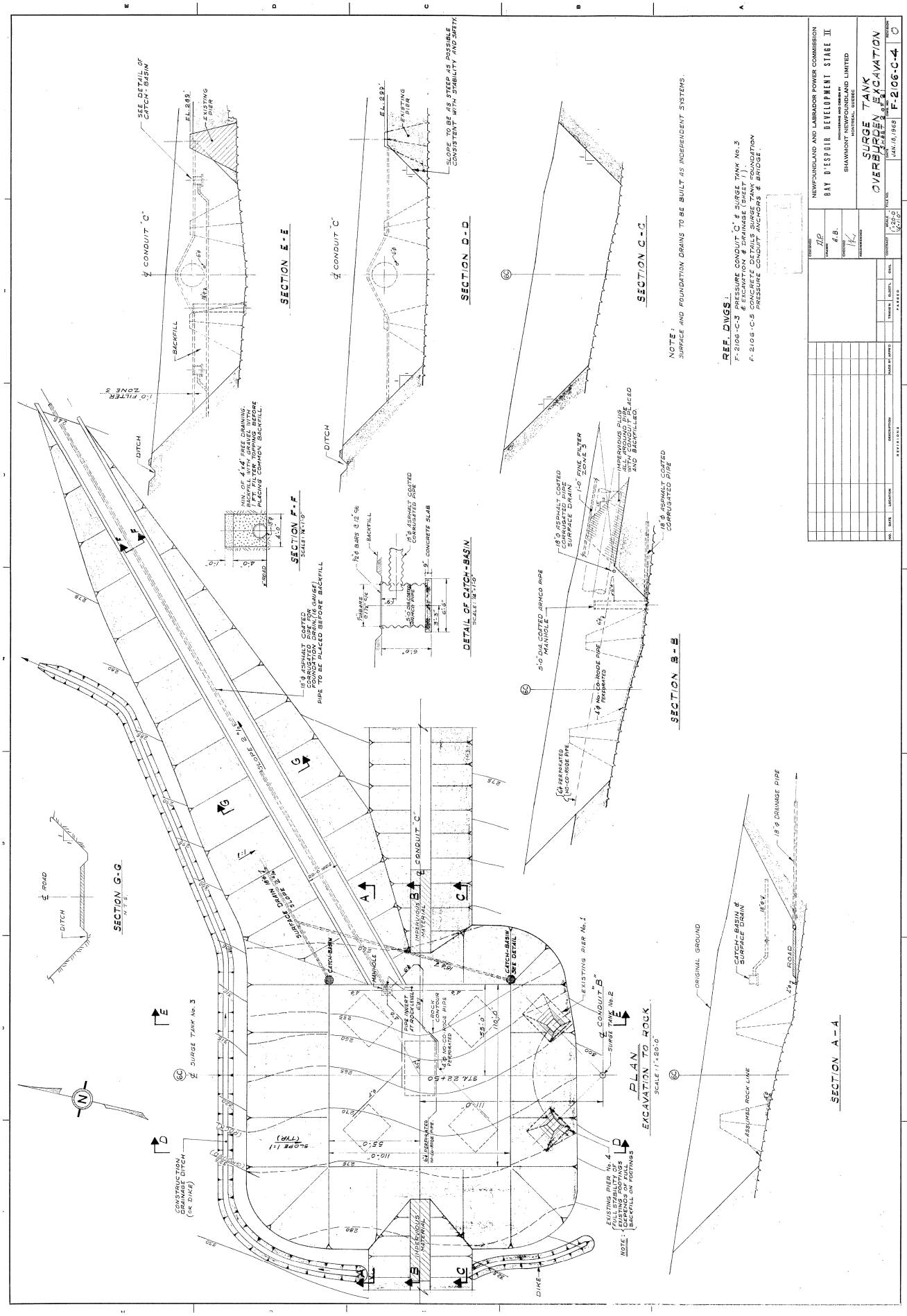

PLAN
SCALE 1" = 200'
PROFILE ALONG ℄ OF CONDUIT "C"
SCALE 1" = 100'
FIRST HALF 96Ø CONDUIT ERECTION TO BE ERECTED UPHILL
SECOND HALF 96Ø CONDUIT ERECTION TO BE ERECTED DOWNHILL
EXTENT OF BASE CONDUIT ERECTION TO BE ERECTED UPHILL
HYDRAULIC GRADIENT
TYP. SECTION - SHALLOW EXCAVATION
SCALE 1" = 10'
TYP. SECTION - DEEP EXCAVATION
SCALE 1" = 10'
TYP. SECTION THRU ROCK
SCALE 1" = 10'
PLAN OF BIFURCATION
SCALE 1" = 20'
ELEVATION ALONG ℄ OF BIFURCATION
SCALE 1" = 20'
NOTES
FOR INFORMATION PURPOSES ONLY
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
STAGE II
SHAWMONT, NEWFOUNDLAND LIMITED
PRESSURE CONDUIT "C"
PLAN, PROFILE & DETAILS
APR/88
F-2106-C-1

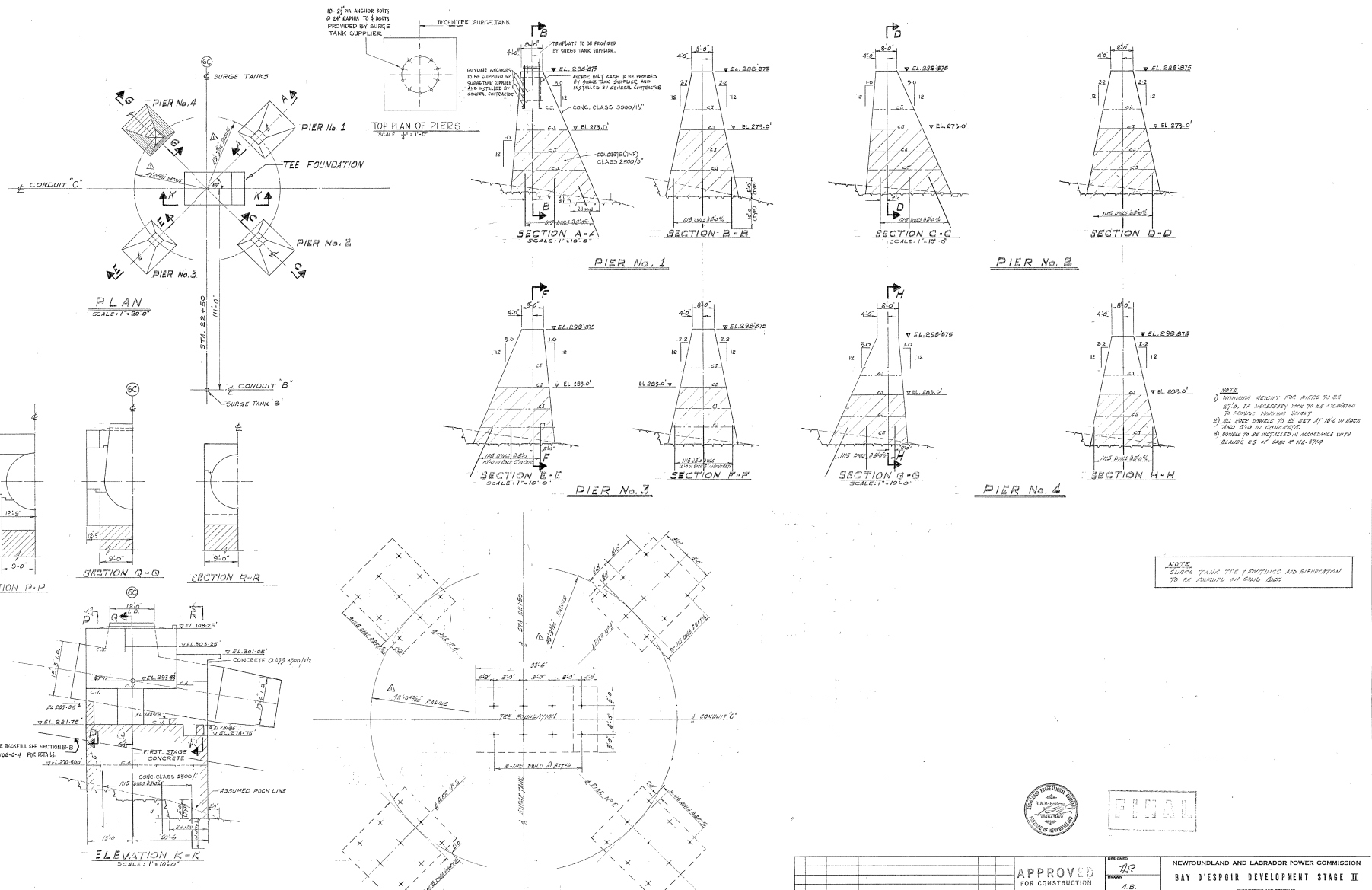

HYDRAULIC DATA
THE SURGE TANK RISER AND TEE SHALL BE DESIGNED TO SUSTAIN LOADS CAUSED BY THE FOLLOWING HYDRAULIC CONDITIONS.
1. MAXIMUM INTERNAL WATER PRESSURE WITH WATER UP TO ELEVATION 657.5 FEET
2. HEAD LOSS OF 40 FEET ACROSS THE ORIFICE WITH WATER FLOWING INTO THE SURGE TANK
3. HEAD LOSS OF 10 FEET AT THE ENLARGEMENT FROM RISER TO TANK WITH THE WATER FLOWING INTO THE SURGE TANK
4. HEAD LOSS OF 140 FEET ACROSS THE ORIFICE WITH THE WATER FLOWING FROM THE SURGE TANK TO THE PRESSURE CONDUIT
5. MAXIMUM DESIGN FLOW 2900 CFS THROUGH THE ORIFICE
THIS DRAWING IS ISSUED FOR INFORMATION PURPOSES ONLY
SECTION ALONG ℄ CONDUIT
RESTRICTED ORIFICE DETAILS
HYDRAULIC BOUNDARIES ONLY SHOWN
HALF CROSS-SECTION LOOKING UPSTREAM
SCHEMATIC DIAGRAM OF SURGE TANK HEATER SYSTEM PIPING FOR ELECTRICAL SCHEMATIC DIAGRAM
INSULATED METAL HOUSING
PLAN OF EXISTING SURGE TANK "B" AND SURGE TANK "C"
(BACKFILL NOT SHOWN)
PAINT DETAIL OBSTRUCTION PAINTING
AIR VENT DETAIL
ELEVATION
NOT TO SCALE
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK "C"
GENERAL LAYOUT & DETAILS
F-206-C-2
20 Oct '67
2-15
FINAL


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC
PENSTOCK No.3 CONDUIT "C"
& SURGE TANK No.3 EXCAVATION &
CONCRETE
SHEET 1 OF 2
F-2106-C-3
REF. DWGS.
F-2106-C-4 SURGE TANK OVERBURDEN & EXCAVATION (SH.2)
F-4106-C-3 CONCRETE DETAILS SURGE TANK FOUNDATION, PENSTOCK & CONDUIT JUNCTION AND REINFORCING
F-2020-C-68 PENSTOCK CONDUIT PLAN, PROFILE AND DETAILS
NOTES:
1. CONDUIT THROUGH DAM TO SURGE TANK PIPELINE TO BE ERECTED DOWNHILL.
2. SURGE TANK TO STA. 39+08.80 PENSTOCK TO BE ERECTED UPHILL.
3. APPROXIMATELY 400 FT. OF PENSTOCK INCLUDING BIFURCATION AND BRANCH PIPE WILL BE ERECTED ON THE SURGE TANK FOUNDATIONS AND TEE 1986 BALANCE 1939.
4. THE CIVIL WORKS CONTRACTOR SHALL KEEP THE EXCAVATION FOR THE SURGE TANK FOUNDATIONS IN THE AREA SECURE AGAINST THE DESTRUCTIVE EFFECTS OF THE MAXIMUM EXPECTED STORM WATER.
PLAN
SCALE 1"=100'-0"
SECTION F-F
SECTION D-D
SECTION E-E
SECTION B-B
PLAN OF BIFURCATION
ELEVATION ALONG AXIS OF BIFURCATION
EXISTING CONTOUR DITCH No.2
EXISTING DIKE
EXISTING ROAD
EXISTING BRIDGE
EXISTING DRAINAGE PIPES
CONSTRUCTION DRAINAGE DITCH (OR DIKE)
EXISTING SURGE TANK No.3
PENSTOCK No.3
CONDUIT "C"
EXISTING CUT IN ROCK
EXISTING DRAINAGE PIPE
EXISTING SLOPE
SHEET PILING
APPROX. ROCK LINE
EARTH
BELOW ROCK SIX INCHES TO ONE FOOT BELOW PRESENT GROUND
ORIGINAL GROUND
LIMIT OF CONTRACT
EXISTING CUT
SWITCHYARD
FUTURE
STAGE II
STAGE I
EXISTING FOOTING
FENCE
EXISTING SLOPE
EXISTING STORAGE SITE PIPELINE ASSEMBLY
EXISTING CONTOUR DITCH No.2
EXISTING DITCH
EXISTING CROSS DRAIN
10' WIDE BULLDOZER CONTROL DITCHES
24'ø CULVERT
18'ø DRAINAGE PIPES (EXISTING)
18'ø DRAIN PIPE
48"ø CMP CULVERT
EXISTING DIVERSION DITCH
EXISTING DIVERSION DIKE
EXISTING CONTOUR DITCH No.1
8'ø WELCORE CONNECTED TO INTAKE DRAIN & 8'ø PLASTIC PIPE.
2-6'ø PERFORATED NO-CO-RODE PIPES
8'ø WELCORE PIPE CONNECTED TO INTAKE DRAIN & 8'ø PLASTIC PIPE.
EXISTING 6'ø WELCORE PIPE EXTENDED AS REQ'D. TO BE MADE IN FIELD
EXISTING DRAINAGE PIPE
6'ø PERFORATED NO-CO-RODE PIPE
6'ø PERFORATED NO-CO-RODE PIPES
EXISTING CONCRETE PIPELINE
EXISTING CONCRETE PIPELINE
FACE OF INTAKE NO.8
STA. 7+36.00
U/S END FIRST PIPELINE
1-28'-2.0
NOTE!
ROCK MAY BE BUILT AS SHOWN ON NORTH SIDE OF CONDUIT C OR WHEN MORE CONVENIENT ON SITE ON NORTH SIDE AS SHOWN. DRAINAGE TRENCH REMAINS
NOTE!
DURING CONSTRUCTION, RAINWATER FALLING WITHIN THE EXCAVATION SHALL BE DRAINED BY GRAVITY TO A SUMP AND PUMPED OUT.
REMOVE EXISTING CONCRETE
EXISTING CUT IN ROCK
EXISTING DIKE
EXISTING DRAINAGE PIPES
EXISTING BRIDGE
EXISTING DIKE
EXISTING DIKE
EXISTING DIK


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
PRESSURE CONDUIT "C"
EXCAVATION DETAILS - LOCAL TO SWITCHYARD EMBANKMENT
F-2106-C-3
SH.2 OF 2
APPROVED FOR CONSTRUCTION
PLAN
PROFILE OF CONDUIT "C"
SECTION 1-1
SECTION 2-2
SECTION 3-3
SECTION 4-4
SECTION 5-5
SECTION 6-6


SECTION E-E
SECTION D-D
SECTION C-C
SECTION F-F
SECTION G-G
SECTION HH
SECTION A-A
SECTION B-B
PLAN
EXCAVATION TO ROCK
SCALE 1"=20'-0"
SURGE TANK 'C'
℄ CONDUIT 'C'
℄ CONDUIT 'B'
EXISTING PIER No.1
EXISTING PIER No.4
CATCH-BASIN
CONSTRUCTION DRAINAGE DITCH
NOTES:
1) SURFACE & FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.
2) ENDS OF 6" ø PERFORATED PIPES TO BE BLANKED OFF WITH A MASS CONCRETE PLUG OR BLANKED OFF.
3) FIRST STAGE BACKFILL SHOULD BE PLACED AROUND EXISTING PIERS TO FINAL ELEVATION AS SOON AS POSSIBLE
4) BACKFILL SHALL FOLLOW CONCRETE PLUGS AND CONDUIT INSTALLATION AS CLOSELY AS PRACTICAL
5) EXCAVATE PIER BASES AND SURGE TANK TEE FOUNDATION TO SOLID ROCK. IF NECESSARY STEP ROCK RADIALLY FROM CENTRE FOR SURGE TANK AND PIERS.
APPROVED
FOR CONSTRUCTION
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK 'C'
EXCAVATION & BACKFILL (SH 1 OF 2)
F-2106-C-4


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC
SURGE TANK
OVERBURDEN EXCAVATION
F-2106-C-4
SECTION E-E
SECTION D-D
SECTION C-C
SECTION F-F
DETAIL OF CATCH-BASIN
SECTION B-B
SECTION G-G
PLAN
EXCAVATION TO ROCK
SECTION A-A
NOTE:
SURFACE AND FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.
REF. DWGS.
F-2106-C-3 PRESSURE CONDUIT "C" & SURGE TANK No.3 & EXCAVATION & DRAINAGE (SHEET 1).
F-2106-C-5 CONCRETE DETAILS SURGE TANK FOUNDATION PRESSURE CONDUIT ANCHORS & BRIDGE.

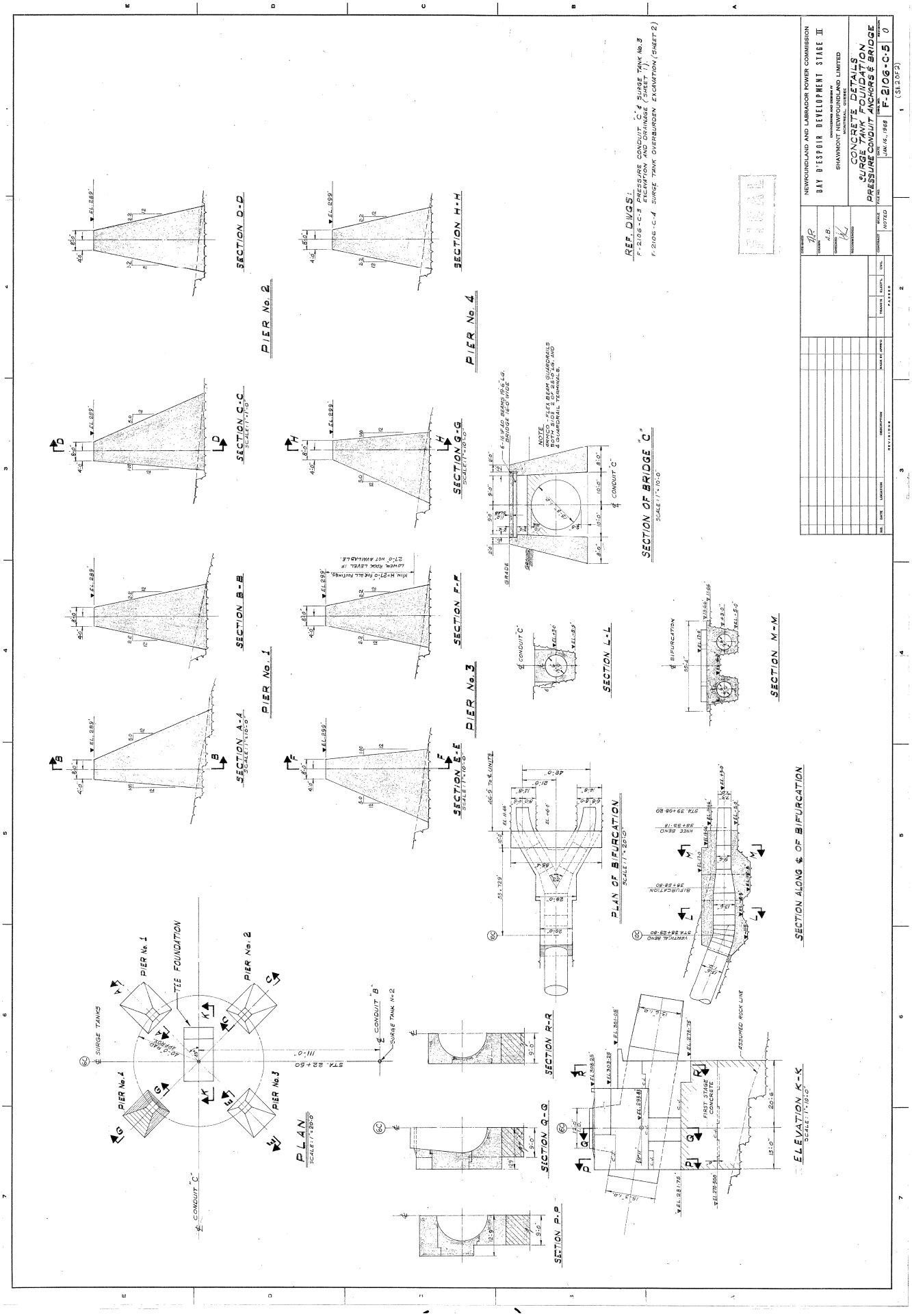


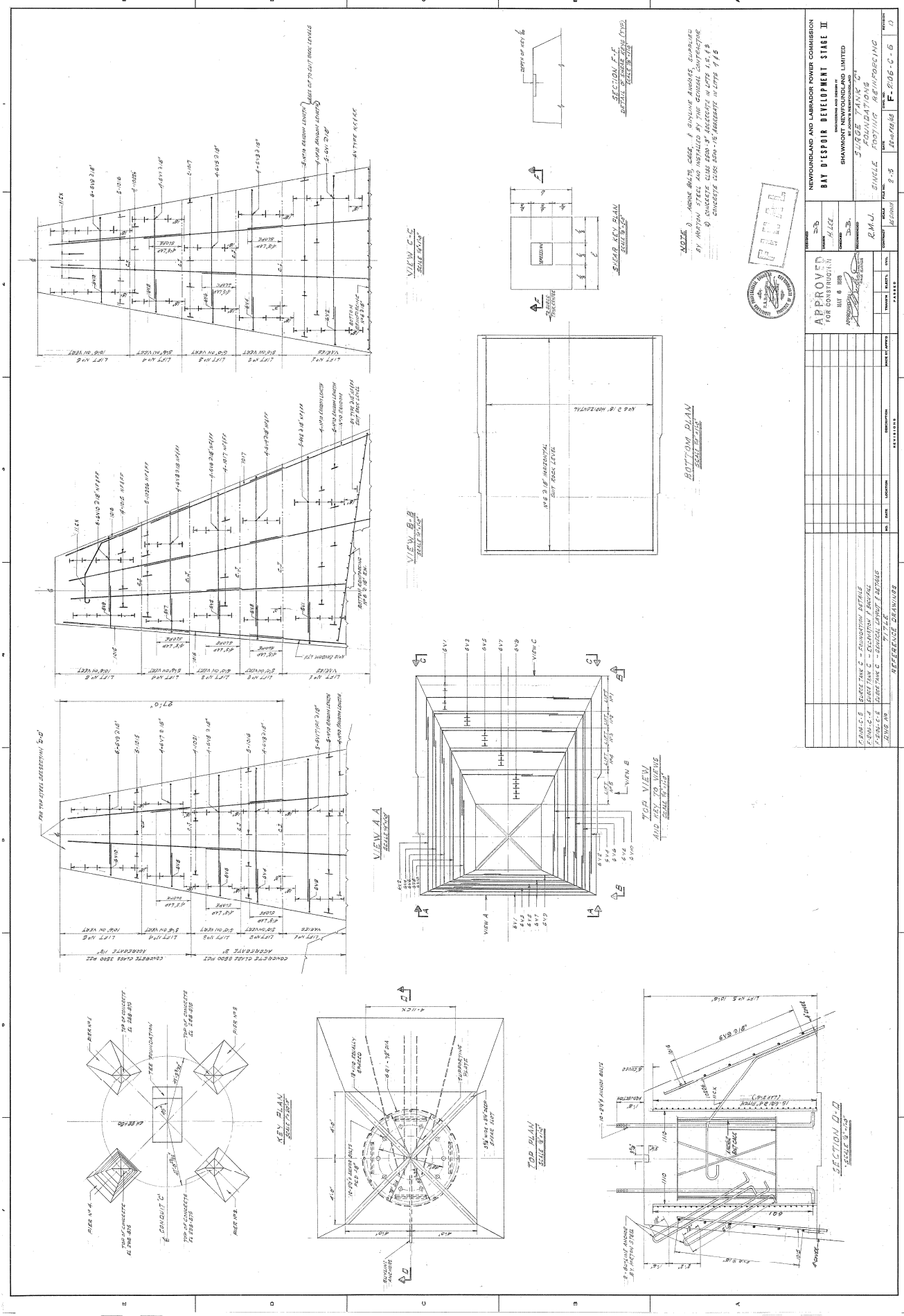
F-2106-C-4	SURGE TANK 'C' - EXCAVATION & BACKFILL												
F-2106-C-3	PRESSURE CONDUIT 'C', SURGE TANK 'C' EXCAVATION & BACKFILL												
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS												
F-2106-C-1	PRESSURE CONDUIT 'C' - PLAN, PROFILE & DETAILS.	1	98-5-08	A.B.	℄ & ℄	RADII OF PIERS CORRECTED.	T.D.	D.D.					
DRG Nº	TITLE	NO.	DATE	LOCATION		DESCRIPTION	MADE BY	APPR'D					
EL-2106-C-5	BAR LIST	REVISIONS											
DWG Nº	TITLE	PASSED											
REFERENCE DRAWINGS	REFERENCE DRAWINGS												

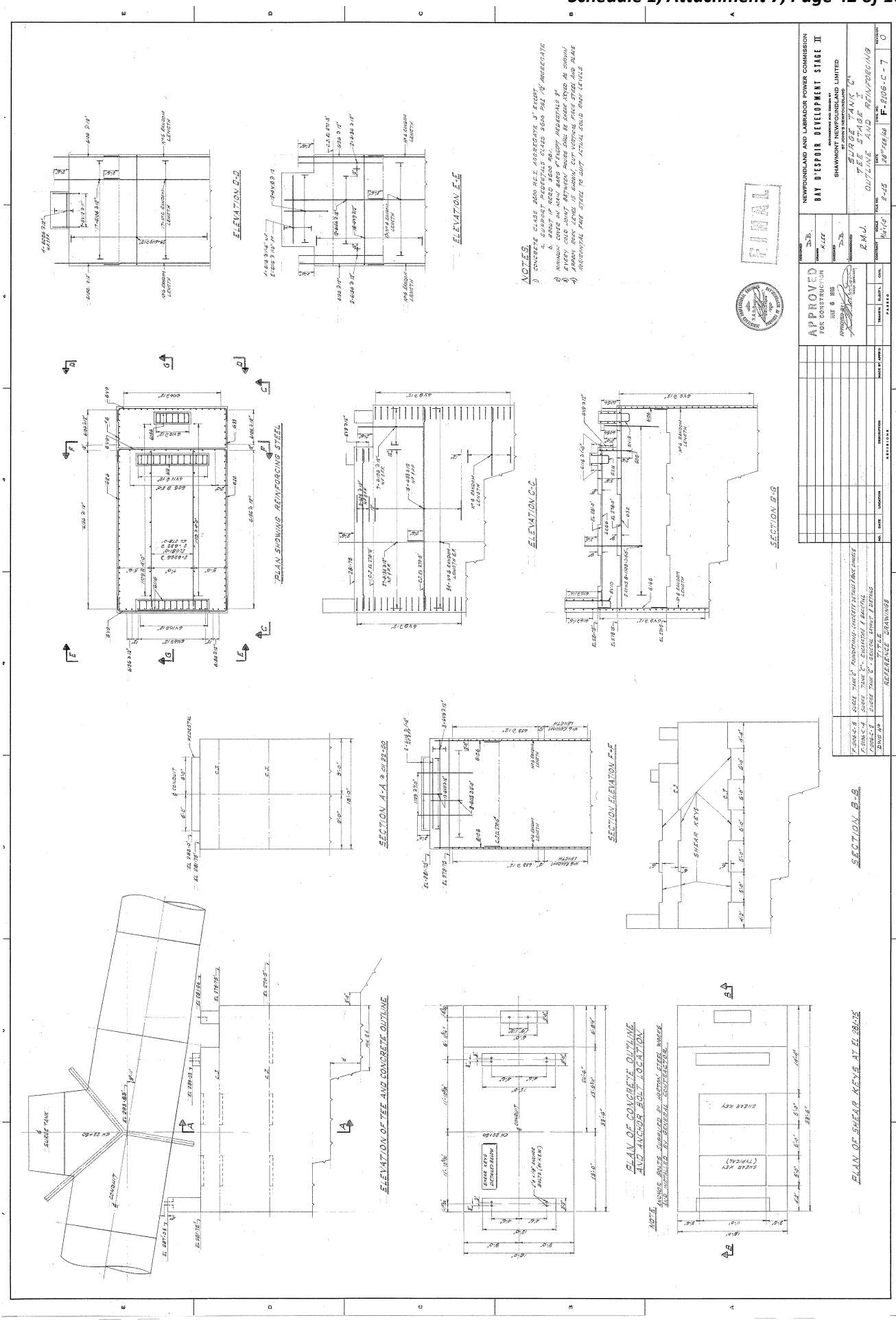
APPROVED FOR CONSTRUCTION
MAY 6 1968
APPROVED BY: [illegible]
HANS GARDISER

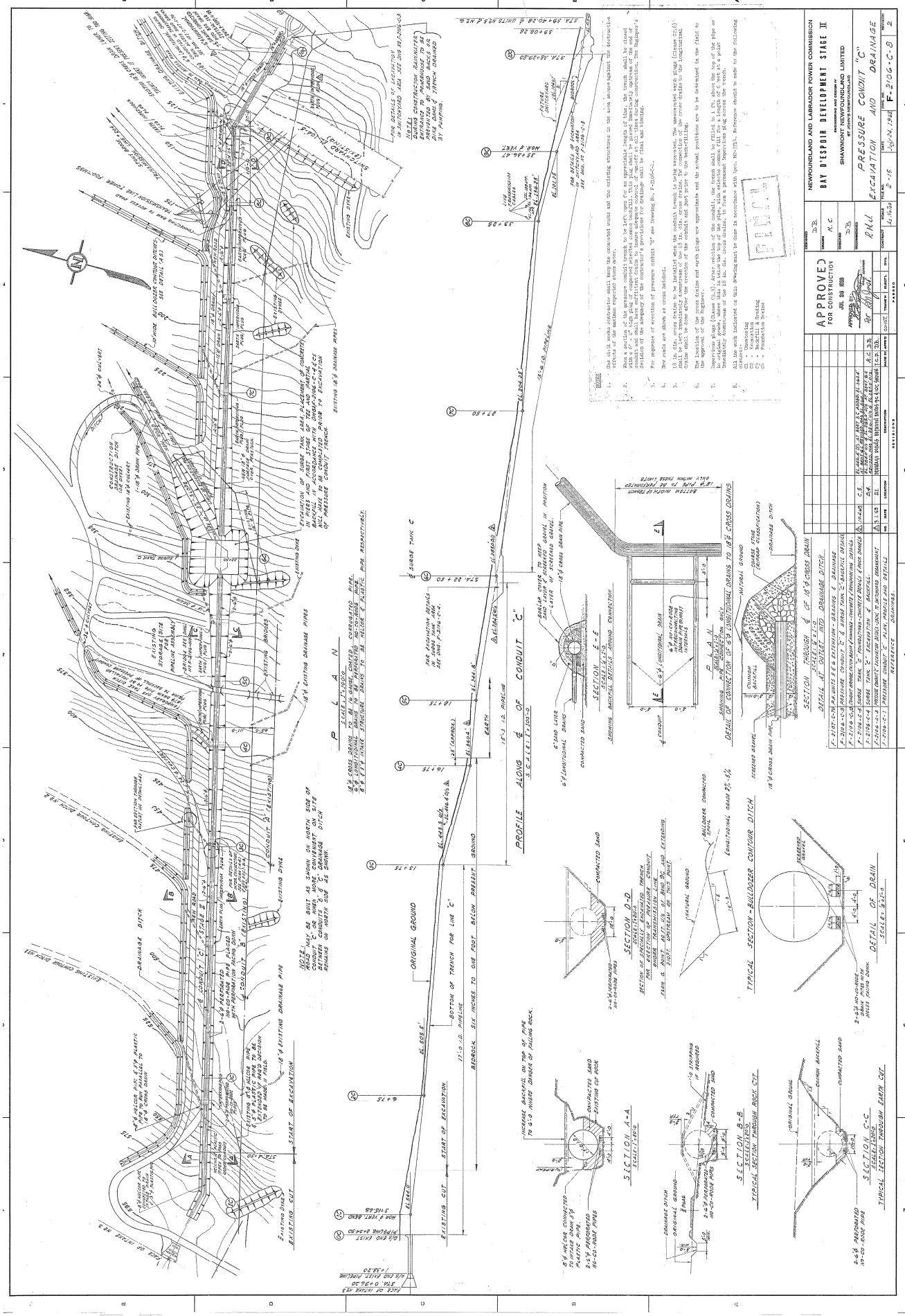
DESIGNED	DRAWN	CHECKED	RECOMMENDED	CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
N.P.	A.B.	[illegible]	[illegible]		NOTED	2-15	FEB 1968	F-2106-C-5.	1

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC
SURGE TANK 'C'
FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS
(SHEET 1 OF 2)


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
CONCRETE DETAILS
SURGE TANK FOUNDATION
PRESSURE CONDUIT ANCHORS & BRIDGE
F-2106-C-5
REF. DWGS:
F-2106-C-3 PRESSURE CONDUIT "C" & SURGE TANK No. 3 EXCAVATION AND DRAINAGE (SHEET 1)
F-2106-C-4 SURGE TANK OVERBURDEN EXCAVATION (SHEET 2)
PIER No. 1
PIER No. 2
PIER No. 3
PIER No. 4
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
SECTION OF BRIDGE "C"
SECTION L-L
SECTION M-M
PLAN OF BIFURCATION
SECTION ALONG ℄ OF BIFURCATION
PLAN
SECTION R-R
SECTION Q-Q
SECTION P-P
ELEVATION K-K
TEE FOUNDATION
SURGE TANKS
CONDUIT "C"
CONDUIT "B"
SURGE TANK No. 2
FIRST STAGE CONCRETE
ASSUMED ROCK LINE


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK "C"
FOUNDATIONS
SINGLE FOOTING REINFORCING
APPROVED FOR CONSTRUCTION
VIEW C-C
VIEW B-B
VIEW A-A
SECTION F-F
SHEAR KEY PLAN
BOTTOM PLAN
TOP VIEW AND KEY TO VIEWS
KEY PLAN
TOP PLAN
SECTION D-D
REFERENCE DRAWINGS


NOTES
ELEVATION C-D
ELEVATION E-F
PLAN SHOWING REINFORCING STEEL
ELEVATION C-C
SECTION G-G
SECTION A-A @ EL 82.00
SECTION ELEVATION F-F
SECTION B-B
ELEVATION OF TEE AND CONCRETE OUTLINE
PLAN OF CONCRETE OUTLINE AND ANCHOR BOLT LOCATION
PLAN OF SHEAR KEYS AT EL 28.15
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
PENSTOCK No. 3
TEE
OUTLINE AND REINFORCING
APPROVED FOR CONSTRUCTION
F-8106-C-7
REFERENCE DRAWINGS


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
PRESSURE CONDUIT "C"
EXCAVATION AND DRAINAGE
APPROVED FOR CONSTRUCTION
JUL 23 1968
PROFILE ALONG ℄ OF CONDUIT "C"
PLAN
SECTION THROUGH ℄ OF 18'ø CROSS DRAIN
DETAIL AT OUTLET INTO DRAINAGE DITCH
TYPICAL SECTION - BULLDOZER CONTOUR DITCH
DETAIL OF DRAIN
SECTION A-A
SECTION B-B
SECTION C-C
TYPICAL SECTION THROUGH EARTH CUT
TYPICAL SECTION THROUGH ROCK CUT
DETAIL OF CONNECTION OF 6'ø LONGITUDINAL DRAINS TO 18'ø CROSS DRAINS
SECTION D-D
SECTION E-E
SECTION OF SPECIAL EXCAVATION FOR PROTECTION OF PRESSURE CONDUIT
EXISTING ROAD
EXISTING DYKE
EXISTING DRAINAGE DITCH
EXISTING CULVERT
EXISTING BRIDGE
EXISTING STORAGE SITE
EXISTING SURGE TANK "C"
EXISTING 18'ø DRAINAGE PIPE
EXISTING 6'ø CONDUIT
EXISTING 8'ø CONDUIT
EXISTING 12'ø CONDUIT
EXISTING 18'ø CONDUIT
EXISTING 24'ø CULVERT
EXISTING 36'ø CULVERT
EXISTING 48'ø CULVERT
EXISTING 60'ø CULVERT
EXISTING 72'ø CULVERT
EXISTING 84'ø CULVERT
EXISTING 96'ø CULVERT
EXISTING 108'ø CULVERT
EXISTING 120'ø CULVERT
EXISTING 132'ø CULVERT
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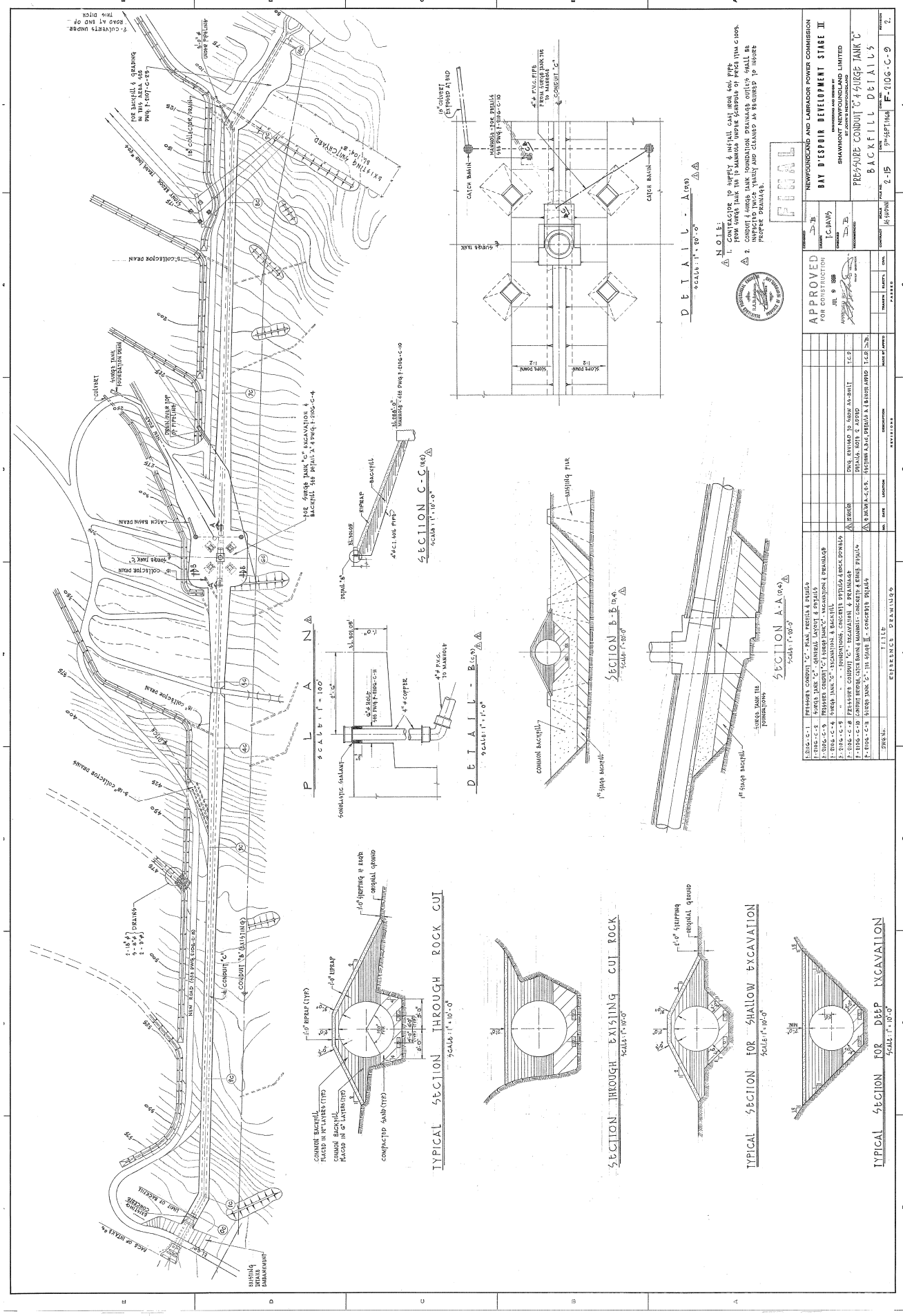
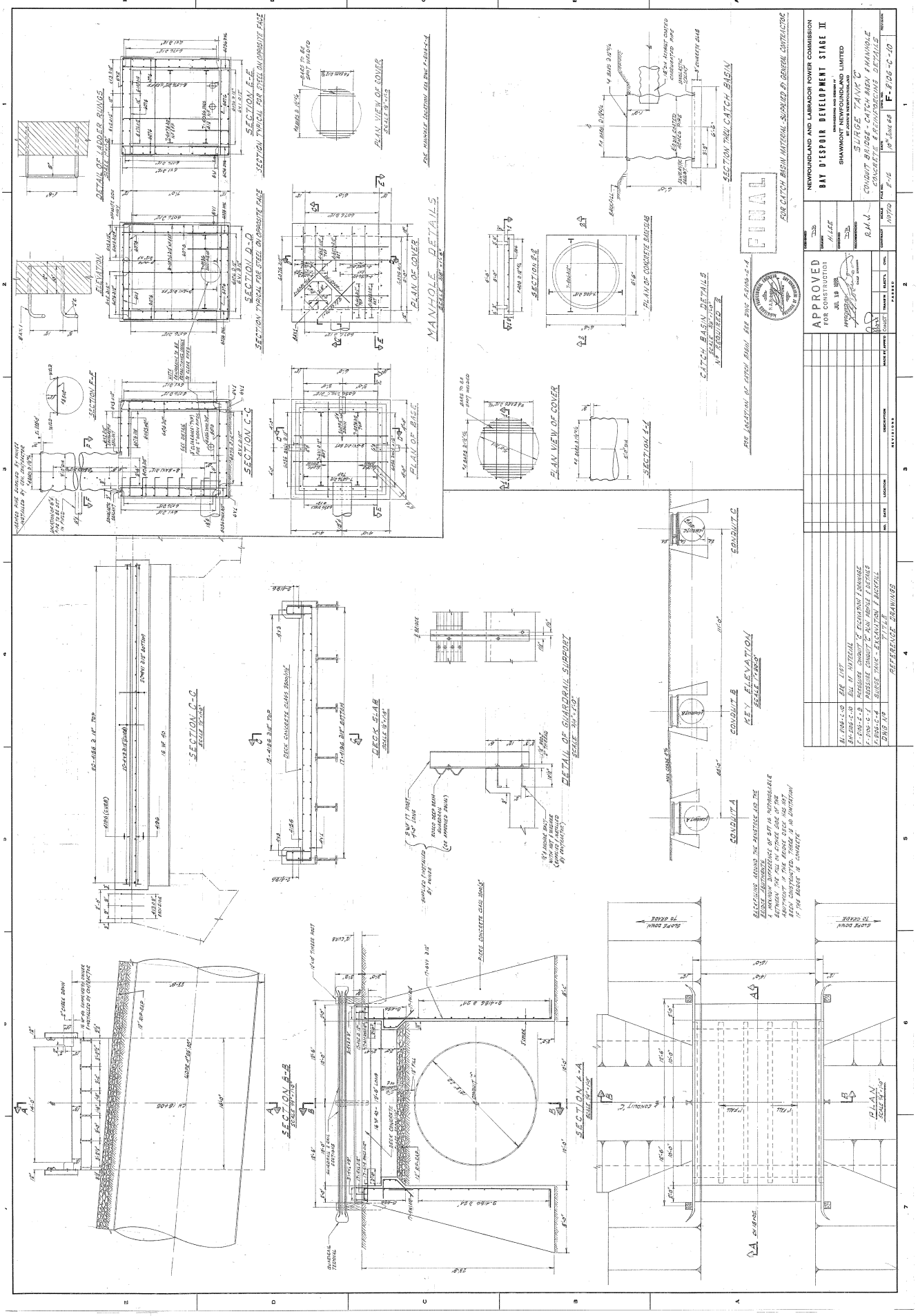
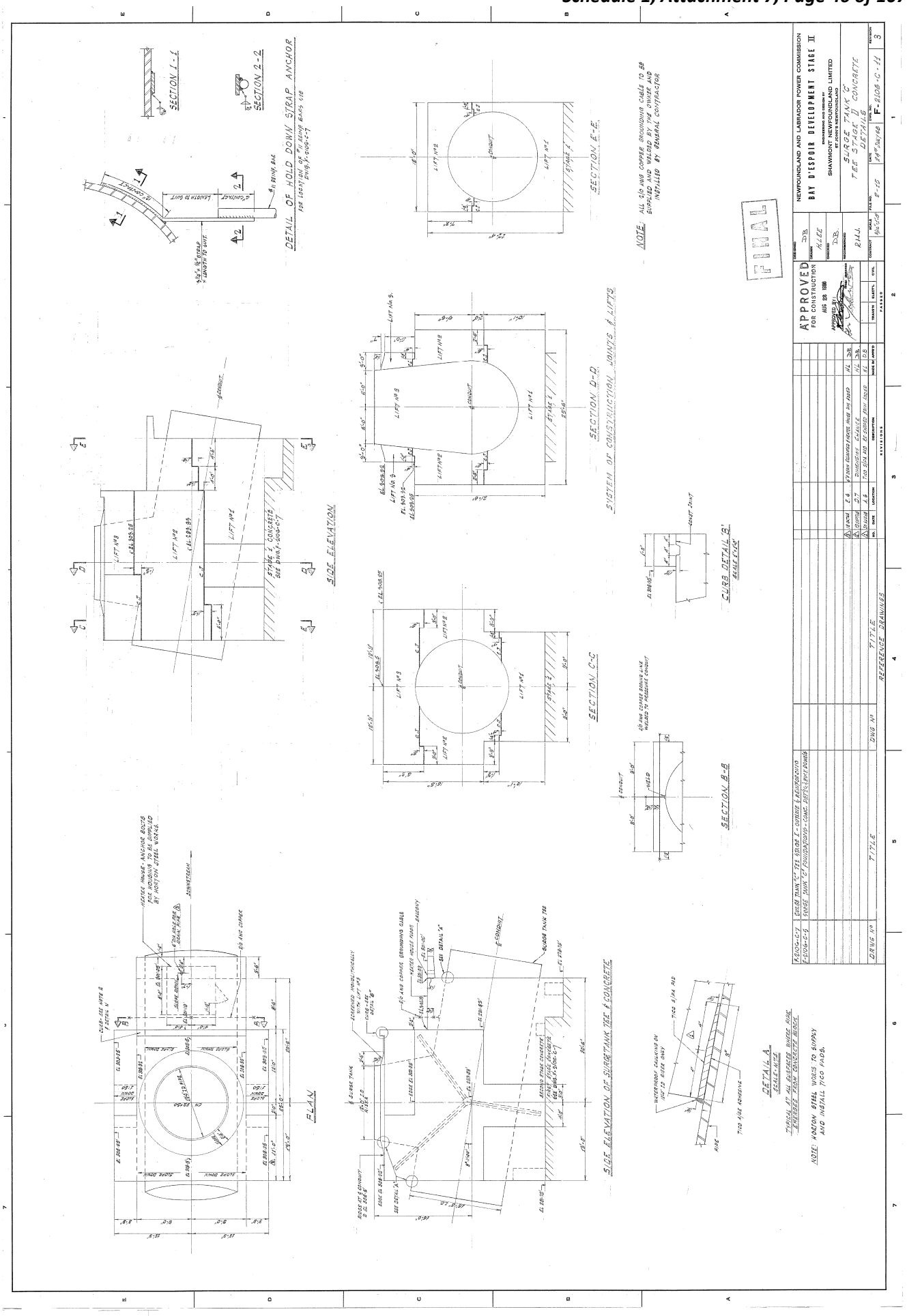
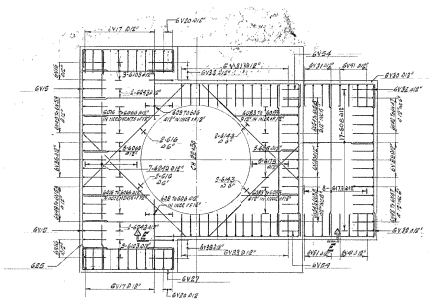
EXISTING 156'ø CULVERT
EXISTING 168'ø CULVERT
EXISTING

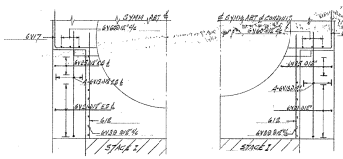

PLAN
SECTION C-C
DETAIL - A
DETAIL - B
SECTION A-A
SECTION B-B
TYPICAL SECTION THROUGH ROCK CUT
SECTION THROUGH EXISTING CUT ROCK
TYPICAL SECTION FOR SHALLOW EXCAVATION
TYPICAL SECTION FOR DEEP EXCAVATION
NOTE:
1. CONTRACTOR TO SUPPLY & INSTALL CAST IRON SOIL PIPE FROM SURGE TANK TIE TO MANHOLE UNDER SIDEWALK OF PRICE ITEM C-1005.
2. CONDUIT & SURGE TANK FOUNDATION DRAINAGE OUTLETS SHALL BE INSPECTED TWICE YEARLY AND CLEANED AS REQUIRED TO INSURE PROPER DRAINAGE.
APPROVED FOR CONSTRUCTION
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
PRESSURE CONDUIT & SURGE TANK "C"
BACKFILL DETAILS
F-106-C-9


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK "C"
CONDUIT BRIDGE - CATCH BASIN & MANHOLE
CONCRETE & REINFORCING DETAILS
F-2106-C-10
APPROVED FOR CONSTRUCTION
FINAL
MANHOLE DETAILS
CATCH BASIN DETAILS
SECTION C-C
SECTION B-B
SECTION A-A
DETAIL OF GUARDRAIL SUPPORT
KEY ELEVATION
DECK SLAB
PLAN
REFERENCE DRAWINGS


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK 'C'
TEE STAGE II CONCRETE
DETAILS
APPROVED
FOR CONSTRUCTION
FINAL
SECTION 1-1
SECTION 2-2
DETAIL OF HOLD DOWN STRAP ANCHOR
SECTION E-E
SECTION D-D
SYSTEM OF CONSTRUCTION JOINTS & LIFTS
SIDE ELEVATION
SECTION C-C
CURB DETAIL 'B'
SECTION B-B
PLAN
SIDE ELEVATION OF SURGETANK TEE & CONCRETE
DETAIL A
REFERENCE DRAWINGS

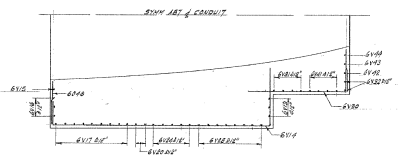


PLAN

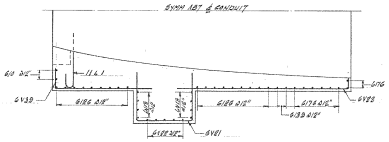


SECTION G-G

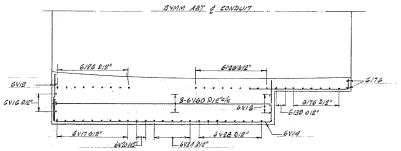
SECTION H-H



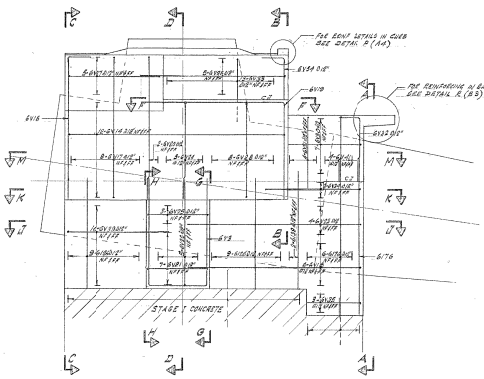
SECTION M-M



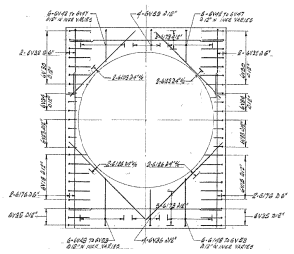
SECTION J-J



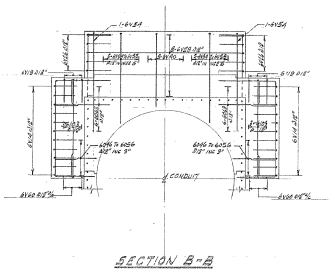
SECTION K-K



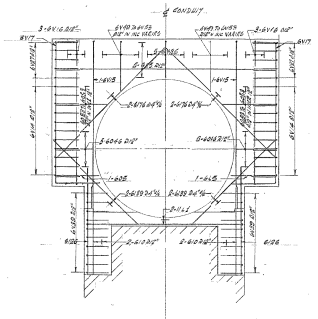
SIDE ELEVATION



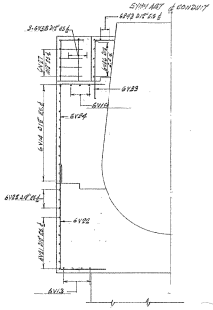
END VIEW A-A



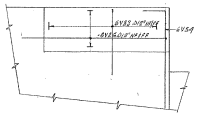
SECTION B-B



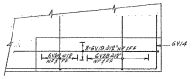
END VIEW C-C



SECTION D-D



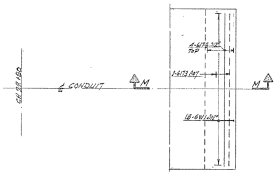
SECTION E-E



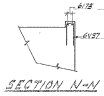
SECTION F-F



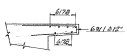
DETAIL P-PLAN OF CURB



DETAIL R-PLAN OF BALCONY



SECTION N-N



SECTION M-M

NOTE
COVER TO REINFORCEMENT TO BE 4" EXCEPT UNLESS NOTED

FINAL

| | | |

APPENDIX B

PHOTOGRAPHS



Photo 1 Leakage from the Temporary Stoplogs



Photo 2 Sandbag Berm Downstream of Stoplog



Photo 3 Leakage Around the Temporary Stoplogs



Photo 4 Leakage Around the Temporary Stoplogs

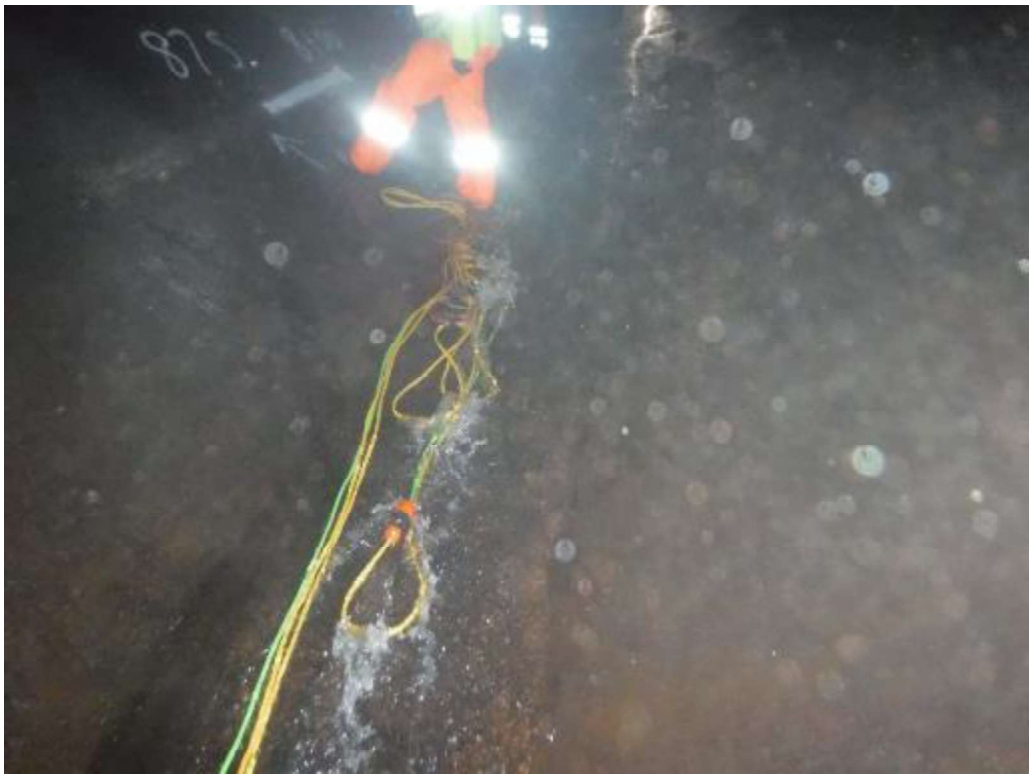


Photo 5 Water in Penstock due to Leakage Around Stoplogs



Photo 6 Water in Penstock due to Leakage Around Stoplogs



Photo 7 Sandbag Berm and Water Pumps at Manhole No.1



Photo 8 Typical Condition of an Original Weld



Photo 9 Typical Access Hatch from Previous Repairs and Maintenance

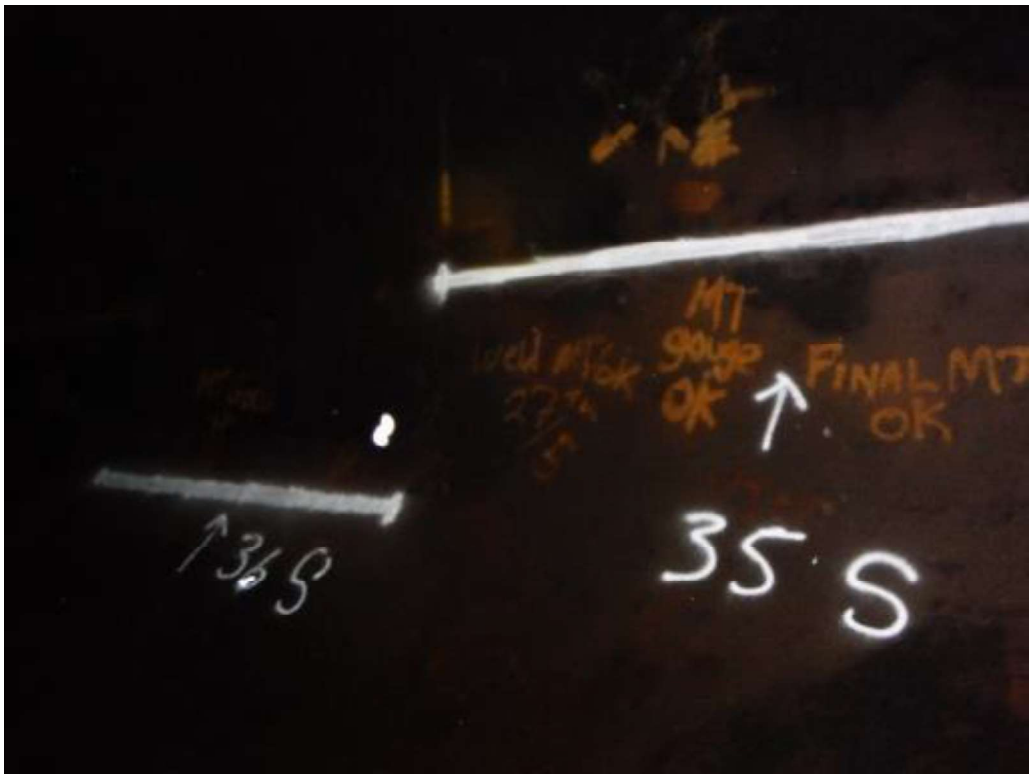


Photo 10 Longitudinal Welds Tested on Southside of Can 35

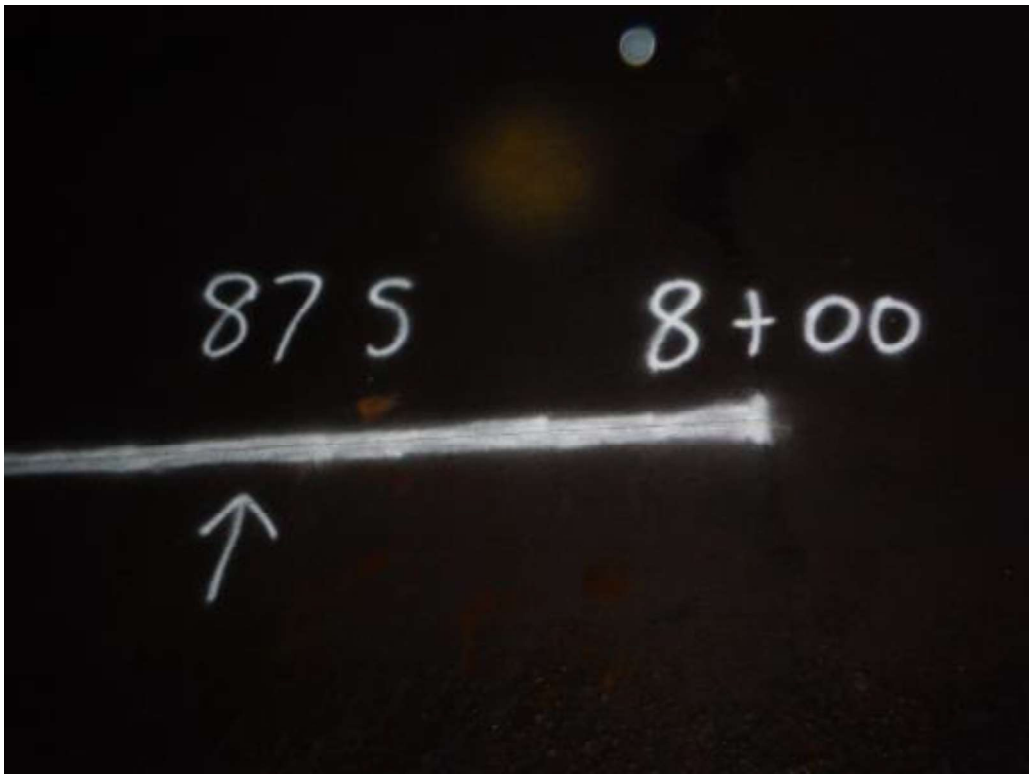


Photo 11 Longitudinal Weld Tested on Southside of Can 87



Photo 12 Northside of Circumferential Weld Between Cans 192 and 193



Photo 13 South Side of Circumferential Weld Between Cans 192 and 193



Photo 14 Indication on South Circumferential Weld Between Cans 192 and 193 With Contrast Paint



Photo 15 Indication on South Circumferential Weld Between Cans 192 and 193

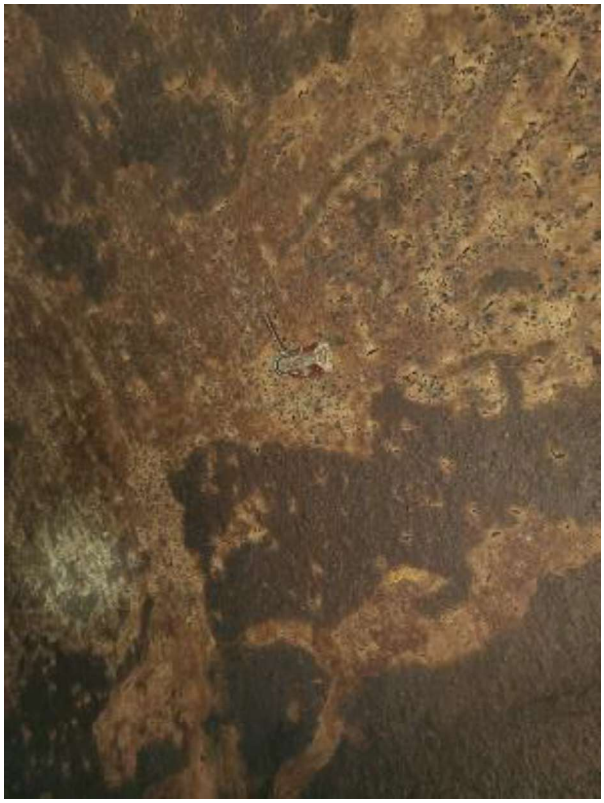


Photo 16 Magnetic Scaffold Hanger from Previous Repairs



Photo 17 Manhole No. 2



Photo 18 Leakage and Efflorescence on Top of the Downstream Surge Tank Transition



Photo 19 Penstock 3 Intake Structure



Photo 20 Looking Downstream from Intake



Photo 21 Looking Downstream Between Penstock 2 and 3



Photo 22 Looking Upstream over Penstock 3



Photo 23 Manhole No.1 with Access to Penstock



Photo 24 Manhole No.1 Cover – Note missing Bottom Plate



Photo 25 Wooden Shack Covering Weir N-1



Photo 26 Culvert Upstream of Wooden Shack



Photo 27 Weir N-1 with Some Water Flow



Photo 28 Looking Upstream from Access Road, Upstream of Surge Towers



Photo 29 Looking Upstream to Access Road Bridge



Photo 30 Looking Left of Surge Towers



Photo 31 Piezometer Immediately Upstream from Surge Towers



Photo 32 Top of Concrete Encasing Surge Tower Transition



Photo 33 Manhole No.2 Immediately Upstream of Surge Tower



Photo 34 Monitoring Well on Left Side of Penstock Downstream of Surge Tower



Photo 35 Location Where Sinkhole was Discovered During the 2019 Inspection



Photo 36 Exposed Crest of Penstock Downstream of Concrete Transition Encasement



Photo 37 Vegetation Growth over Penstock No.3



Photo 38 Typical Pressure Transducer Covering



Photo 39 Manhole No.3



Photo 40 Looking Downstream to Switchyard on Right Side of Penstock



Photo 41 Looking Downstream to Switchyard



Photo 42 Monitoring Well on Left Side of Penstock Before Switchyard



Photo 43 Looking Upstream on Left Side of Penstock



Photo 44 Looking Upstream to Surge Towers



Photo 45 Monitoring Well on Left Side of Penstock



Photo 46 Looking Downstream on Left Side of Penstock 3 Surge Towers



Photo 47 Wier N-2 With Minor Water Flow

APPENDIX C

WELD TEST

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Have Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
1	R	R	I	I	I	
2	R	R	I	I	I	
3	R	R	I	I	I	
4	R	R	I	I	I	
5	R	R	I	I	I	
6	R	R	I	I	I	
7	R	R	I	I	I	
8	R	R	I	I	I	
9	R	R	I	I	I	
10	R	R	I	I	I	
11	R	R	I	I	I	
12	R	R	I	I	I	
13	R	R	I	I	I	
14	R	R	I	I	I	
15	R	R	I	I	I	
16	R	R	I	I	I	
17	R	R	I	I	I	
18	R	R	I	I	I	
19	R	R	I	I	I	
20	R	R	I	I	I	
21	R	R	I	I	I	
22	R	R	I	I	I	
23	R	R	I	I	I	
24	R	R	I	I	I	
25	R	R	I	I	I	
26	R	R	I	I	I	
27	R	R	I	I	I	
28	R	R	I	I	I	
29	R	R	I	I	I	
30	R	R	I	I	I	
31	R	R	I	I	I	
32	R	R	I	I	I	
33	R	R	I	I	I	
34	R	R	I	I	I	
35	R	R	I	I	I	
36	R	R	I	I	I	
37	R	R	I	I	I	
38	R	R	I	I	I	
39	R	R	I	I	I	
40	R	R	I	I	I	
41	R	R	I	I	I	
42	R	R	I	I	I	
43	R	R	I	I	I	
44	R	R	I	I	I	
45	R	R	I	I	I	
46	R	R	I	I	I	
47	R	R	I	I	I	
48	R	R	I	I	I	
49	R	R	I	I	I	
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59	R	R	I	I	I	
60	R	R	I	I	I	
61	R	R	I	I	I	
62	R	R	I	I	I	
63	R	R	I	I	I	
64	R	R	I	I	I	
65	R	O	I	I	I	
66	R	R	I	I	I	
67	R	R	I	I	I	

Legend:	
R =	Weld seam has been Refurbished
O =	Original Weld
P =	Weld seam has been partially refurbished
I =	Weld seam has been inspected
N =	Weld seam has not been inspected

Both Longitudinal Welds Have Been Inspection
One Longitudinal Weld Have Been Inspected
No Longitudinal Welds Have Been Inspected

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
68	R	R	I	I	I	
69	R	R	I	I	I	
70	R	P	I	I	I	
71	R	R	I	I	I	
72	R	R	I	I	I	
73	R	R	I	I	I	
74	R	R	I	I	I	
75	R	R	I	I	I	
76	R	R	I	I	I	
77	R	R	I	I	I	
78	R	R	I	I	I	
79	R	R	I	I	I	
80	R	R	I	I	I	
81	R	R	I	I	I	
82	R	P	I	I	I	
83	R	R	I	I	I	
84	R	R	I	I	I	
85	R	R	I	I	I	
86	R	R	I	I	I	
87	R	R	I	I	I	
88	R	R	I	I	I	
89	R	R	I	I	I	Welded hatch on North Side
90	R	R	I	I	I	
91	R	R	I	I	I	
92	R	R	I	I	I	
93	R	R	I	I	I	
94	R	R	I	I	I	
95	R	R	I	I	I	
96	R	R	I	I	I	
97	R	P	I	I	I	
98	R	R	I	I	I	
99	R	R	I	I	I	
100	R	R	I	I	I	
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102	R	R	I	I	I	
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106	R	R	I	I	I	
107	R	R	I	I	I	
108	R	P	I	I	I	
109	R	R	I	I	I	
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115	R	R	I	I	I	
116	R	R	I	I	I	
117	R	R	I	I	I	
118	R	R	I	I	I	
119	R	R	I	I	I	
120	R	R	I	I	I	
121	R	R	I	I	I	
122	R	P	I	I	I	Manhole #1
123	R	R	I	I	I	
124	R	P	I	I	I	
125	R	P	I	I	I	
126	R	R	I	I	I	
127	R	R	I	I	I	
128	R	R	I	I	I	
129	R	P	I	I	I	
130	R	R	I	I	I	
131	R	R	I	I	I	
132	R	R	I	I	I	
133	R	R	I	I	I	
134	R	R	I	I	I	

Legend:	
R =	Weld seam has been Refurbished
O =	Original Weld
P =	Weld seam has been partially refurbished
I =	Weld seam has been inspected
N =	Weld seam has not been inspected

Both Longitudinal Welds Have Been Inspection
One Longitudinal Weld Have Been Inspected
No Longitudinal Welds Have Been Inspected

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
135	R	P	I	I	I	
136	R	O	I	I	I	
137	R	R	I	I	I	
138	R	R	I	I	I	
139	R	P	I	I	I	
140						
141						
142	O	O	I	I	I	
143	O	O	I	I	I	
144	R	O	I	I	I	
145	P	P	I	I	I	
146	O	O	I	I	I	
147	O	O	I	I	I	
148	P	O	I	I	I	
149	P	P	I	I	I	
150	P	O	I	I	I	
151	O	O	I	I	I	
152	P	O	I	I	I	
153	P	O	I	I	I	
154	P	O	I	I	I	
155	O	P	I	I	I	
156	P	P	I	I	I	3 welds on north side
157	P	O	I	I	I	3 welds on north side.
158	P	P	I	I	I	3 welds on north side. 2 are original, 1 is partialll refurbished
159	O	P	I	I	I	
160	P	P	I	I	I	2 welds on north - both are partialll refurbished
161	R	R	I	I	I	
162	R	O	I	I	I	2 welds on north - both are refurbished
163	R	R	I	I	I	
164	R	O	I	I	I	2 welds on north side.
165	R	O	I	I	I	2 welds on south side - both are partially repaired
166	R	R	I	I	I	2 welds on south side - both are refurbished
167	O	P	I	I	I	
168	O	P	I	I	I	
169	O	O	I	I	I	Welds are on top and bottom
170	O	O	I	I	I	
171	O	O	I	I	I	Welds are on top and bottom
172	R	O	I	I	I	
173	O	O	I	I	I	
174	O	O	I	I	I	
175	R	R	I	I	I	
176	R	O	I	I	I	Hatch on south side
177	O	O	I	I	I	
178	O	O	I	I	I	
179	O	O	I	I	I	
180	O	O	I	I	I	
181	O	O	I	I	I	
182	O	O	I	N	P	
183	O	O	I	N	P	
184	O	O	I	I	I	
185	O	O	I	I	I	
186	O	O	I	N	P	
187	O	O	I	N	P	
188	O	O	N	N	N	
189	O	O	N	N	N	
190	O	O	N	N	N	
191	O	O	N	N	N	
192	O	O	N	N	N	
193	O	O	I	I	I	
194	O	O	I	I	I	
195	O	O	N	N	N	
196	O	O	N	N	N	
197	O	O	N	N	N	
198	O	O	N	N	N	
199	O	O	N	N	N	
200	O	O	N	N	N	
201	O	O	I	I	I	

Legend:	
R =	Weld seam has been Refurbished
O =	Original Weld
P =	Weld seam has been partially refurbished
I =	Weld seam has been inspected
N =	Weld seam has not been inspected

Both Longitudinal Welds Have Been Inspection
One Longitudinal Weld Have Been Inspected
No Longitudinal Welds Have Been Inspected

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
202	O	O	I	I	I	
203	O	O	I	I	I	
204	O	O	I	I	I	
205	O	O	I	I	I	
206	O	O	I	I	I	
207	O	R	I	I	I	
208	O	O	I	I	I	
209	O	R	I	I	I	
210	R	P	I	I	I	
211	R	P	I	I	I	
212	R	P	I	I	I	
213	R	P	I	I	I	
214	R	O	I	I	I	
215	R	R	I	I	I	
216	R	R	I	I	I	
217	R	O	I	I	I	
218	R	R	I	I	I	
219	R	O	I	I	I	
220	R	R	I	I	I	
221	O	R	I	I	I	
222	R	O	I	I	I	
223	R	R	I	I	I	Small hatch on northside
224	O	P	I	I	I	
225	O	R	I	I	I	
226	O	R	I	I	I	
227	O	O	I	I	I	
228	O	O	I	I	I	
229	O	O	I	I	I	
230	O	O	I	I	I	
231	O	O	I	I	I	
232	O	O	N	I	P	Manhole #2
233	O	O	I	I	I	
234	O	O	N	N	N	
235	O	O	I	N	P	Start of Surge Tower
236	O	O	N	N	N	
237	O	O	N	N	N	
238	O	O	N	I	P	End of Surge Tower
239	O	O	N	N	N	
240	O	O	I	I	I	
241	O	O	I	I	I	
242	P	O	I	N	P	
243	O	O	I	N	P	
244	O	O	N	N	N	
245	O	O	N	N	N	
246	O	O	N	N	N	
247	O	O	N	N	N	
248	O	O	N	N	N	
249	O	O	N	I	P	
250	O	O	I	N	P	
251	O	O	N	N	N	
252	O	O	I	I	I	
253	O	O	N	N	N	
254	O	O	N	N	N	
255	O	O	N	N	N	
256	O	O	N	N	N	
257	O	O	N	N	N	
258	O	O	I	N	P	
259	O	O	N	I	P	
260	O	O	N	N	N	
261	O	O	I	I	I	
262	O	O	N	N	N	
263	O	O	N	N	N	
264	O	O	N	N	N	
265	O	O	N	N	N	
266	O	O	N	N	N	
267	O	O	N	N	N	
268	O	O	I	N	P	

Legend:	
R =	Weld seam has been Refurbished
O =	Original Weld
P =	Weld seam has been partially refurbished
I =	Weld seam has been inspected
N =	Weld seam has not been inspected

Both Longitudinal Welds Have Been Inspection
One Longitudinal Weld Have Been Inspected
No Longitudinal Welds Have Been Inspected

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
269	O	O	N	I	P	
270	O	O	N	N	N	
271	O	O	I	N	P	
272	O	O	I	N	P	
273	O	O	I	N	P	
274	O	O	N	N	N	
275	O	O	N	N	N	
276	O	O	N	N	N	
277	O	O	N	N	N	
278	O	O	N	I	P	
279	O	O	I	N	P	
280	O	O	N	N	N	
281	O	O	I	I	I	
282	O	O	N	N	N	
283	O	O	N	N	N	
284	O	O	I	N	P	
285	O	O	N	N	N	
286	O	O	N	N	N	
287	O	O	N	N	N	
288	O	O	N	N	N	
289	O	O	I	I	I	
290	O	O	N	N	N	
291	O	O	I	I	I	
292	O	O	N	N	N	
293	O	O	N	N	N	
294	O	O	I	N	P	
295	O	O	I	N	P	
296	O	O	I	N	P	
297	O	O	I	N	P	
298	O	O	I	I	I	
299	O	O	I	N	P	
300	O	O	I	I	I	
301	O	O	I	N	P	
302	O	O	I	I	I	
303	O	O	I	I	I	
304	O	O	I	I	I	
305	O	P	I	I	I	
306	R	O	I	I	I	
307	R	O	I	I	I	
308	R	O	I	I	I	
309	R	O	I	I	I	
310	O	R	I	I	I	Hatch on northside
311	O	R	I	I	I	
312	O	R	I	I	I	
313	R	R	I	I	I	
314	O	O	I	I	I	
315	R	O	I	I	I	
316	R	R	I	I	I	
317	R	R	I	I	I	
318	R	R	I	I	I	
319	R	R	I	I	I	
320	R	R	I	I	I	
321	O	R	I	I	I	
322	R	P	I	I	I	
323	R	R	I	I	I	
324	R	R	I	I	I	
325	O	O	I	I	I	
326	R	O	I	I	I	
327	O	O	I	I	I	
328	O	O	I	I	I	
329	R	R	I	I	I	
330	P	R	I	I	I	
331	O	R	I	I	I	
332	R	P	I	I	I	
333	R	R	I	I	I	
334	R	O	I	I	I	
335	R	P	I	I	I	

Legend:	
R =	Weld seam has been Refurbished
O =	Original Weld
P =	Weld seam has been partially refurbished
I =	Weld seam has been inspected
N =	Weld seam has not been inspected

Both Longitudinal Welds Have Been Inspection
One Longitudinal Weld Have Been Inspected
No Longitudinal Welds Have Been Inspected

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
336	R	O	I	I	I	
337	O	R	I	I	I	
338	R	R	I	I	I	
339	O	R	I	I	I	
340	O	R	I	I	I	
341	R	O	I	I	I	
342	O	O	I	I	I	Manhole #3
343	R	R	I	I	I	
344	O	O	I	I	I	
345	R	R	I	I	I	
346	O	O	I	I	I	
347	O	O	I	I	I	
348	O	O	I	I	I	
349	O	O	I	I	I	
350	O	O	I	I	I	
351	O	O	I	I	I	
352	O	O	I	I	I	
353	O	O	I	I	I	
354	O	O	N	N	N	
355	O	O	P	I	P	
356	O	O	I	I	I	
357	O	O	N	N	N	
358	O	O	N	N	N	
359	O	O	I	I	I	
360	O	O	I	N	P	
361	O	O	I	N	P	
362	O	O	N	I	P	
363	O	O	N	N	N	
364	O	O	N	N	N	
365	O	O	I	I?	I	
366	O	O	N	N	N	
367	O	O	N	N	N	
368	O	O	N	N	N	
369	O	O	N	I	P	
370						
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400						

Longitudinal Seams

Legend:		
R =	Weld seam has been Refurbished	Both Longitudinal Welds Have Been Inspection
O =	Original Weld	One Longitudinal Weld Have Been Inspected
P =	Weld seam has been partially refurbished	No Longitudinal Welds Have Been Inspected
I =	Weld seam has been inspected	
N =	Weld seam has not been inspected	

Can	Reburbished or Original		Inspected Status			Notes:
	North	South	North	South	Can	
			Qty		%	
Number of Repaired Seams			349		44%	
Number of Partially Repaired Seams			42		5%	
Number of Original Seams			338		42%	
Number of Cans Fully Inspected			279		70%	
Number of Cans Partially Inspected			32		8%	
Number of Cans Not Inspected			56		14%	
Total Number of Seams			**800**			

APPENDIX D

THICKNESS MEASUREMENTS DATA AND STRESS CALCULATIONS

TABLE D-1 THICKNESS MEASUREMENTS AND STRESSES (FSL)

TABLE D-2 WATER HAMMER (DYNAMIC) STRESSES

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	21-594-1	Copy:	
Date:	August 20, 2021	Date Received:	August 15, 2021
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin LeGrow		
P.O. No.	2021-0268		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3		
Testing Required:	Magnetic Particle Inspection	Signed:	Conor Murphy NDT Inspector

Remarks

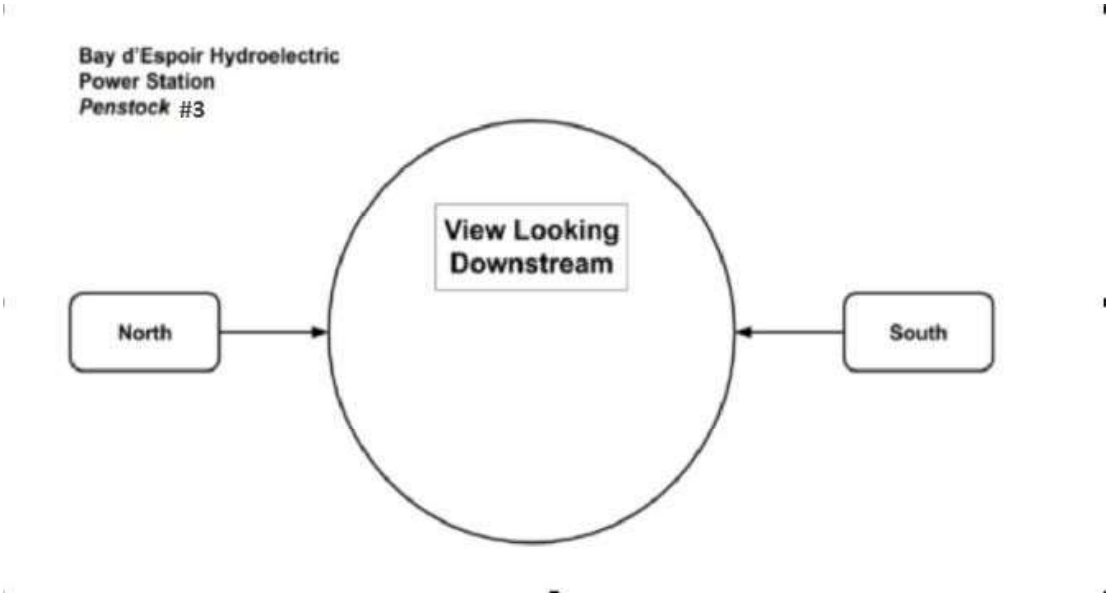
As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds for the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

An indication was noted on can #193 and shown to the engineer on site, Chris Vella. All other above areas mentioned above were found to be acceptable as per the noted criteria.

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
1	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
6	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
14	- Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
17	- Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
18	- Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
20	- Longitudinal right (south) weld - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
24	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
26	- Longitudinal right (south) weld - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
29	- Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
31	- Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
35	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
36	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
40	- Longitudinal right (south) weld - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
45	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
46	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
50	- Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
51	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
56	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
60	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
65	- Longitudinal right (south) weld - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
66	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
70	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
74	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
76	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
81	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
83	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
85	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
87	- Longitudinal right (south) weld. - 6" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 6" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
91	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
92	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
95	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
97	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
100	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
101	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
105	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
107	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
111	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
112	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
117	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
122	- Longitudinal right (south) weld.. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
125	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
129	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
130	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
136	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
143	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
144	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
153	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
162	- Longitudinal right (south) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
163	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
172	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
174	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
183	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
193	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Indication Noted on Circumferential weld	**Figures 1,2,3,4**
211	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
222	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
223	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
233	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
240	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
252	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
260	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
271	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
273	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
281	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
290	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
300	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
311	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and rightlongitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
321	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
322	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
331	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
341	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
342	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
351	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
352	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
360	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
361	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
369	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

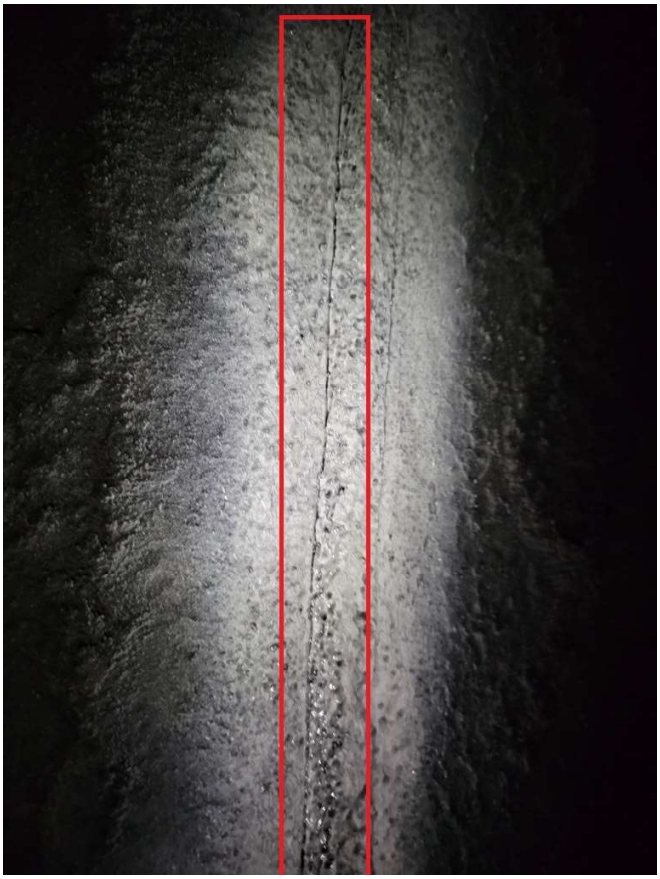


Figure 1 - Can #193 north side circumferential weld example of indication - indication is on the down stream side of the weld



Figure 1 - Can #193 north side circumferential weld indication size - indication goes from longitudinal weld to bottom centre line in way of water

ETS No.: 21-594-1 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

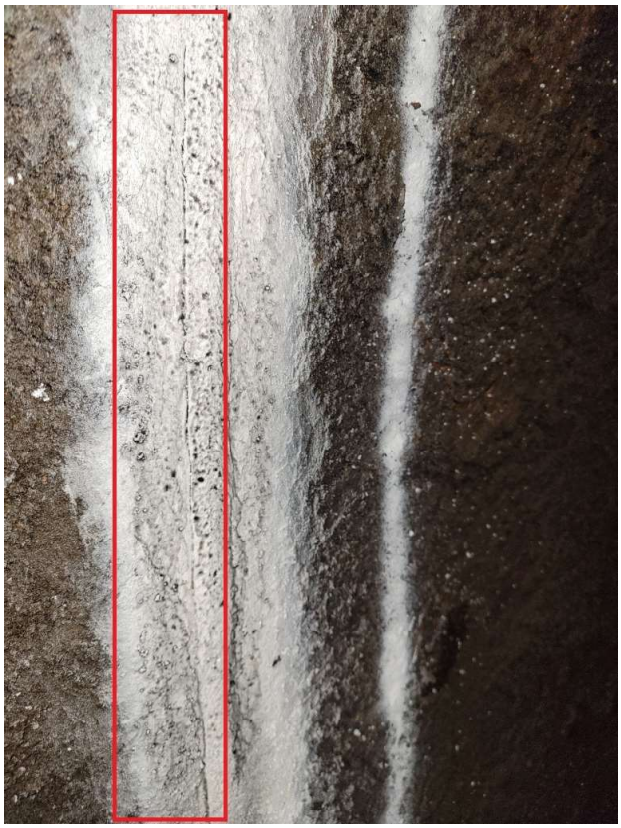


Figure 3 - Can #193 south side circumferential weld example of indication - indication is on the down stream side of the weld

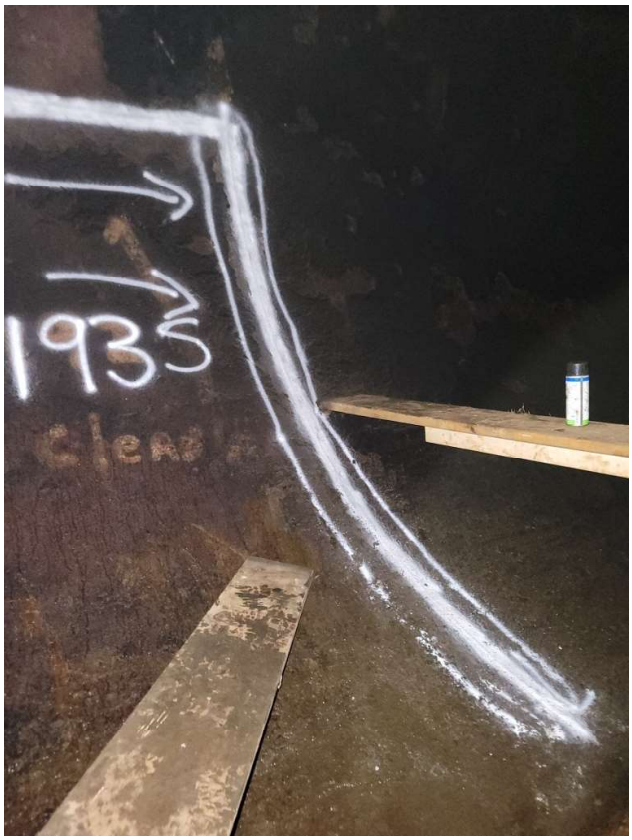


Figure 4 - Can #193 south side circumferential weld indication size - indication goes from longitudinal weld to bottom centre line in way of water

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

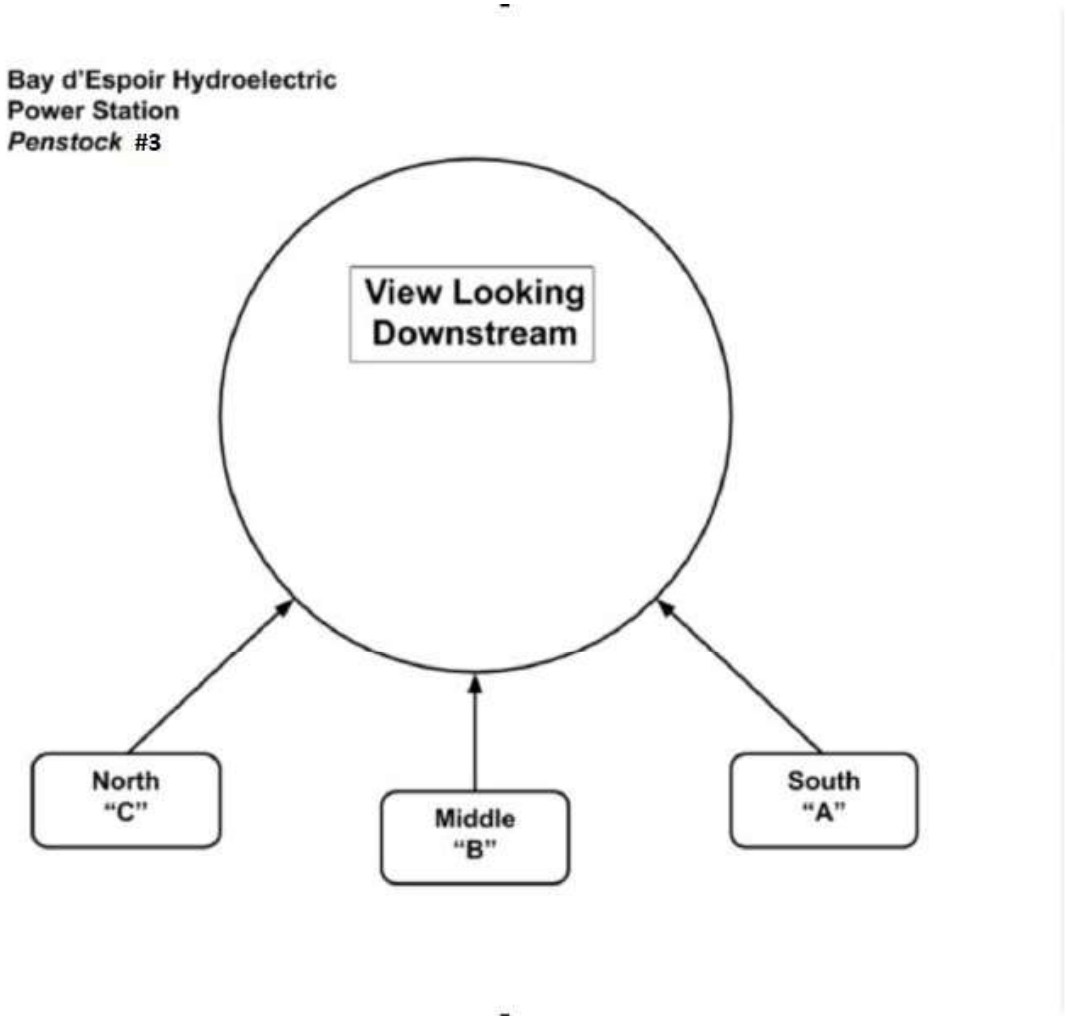
ETS No.:	21-594-2	Copy:	
Date:	August 20, 2021	Date Received:	August 15, 2021
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin LeGrow		
P.O. No.	2021-0268		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	 NDT Inspector

Remarks
As directed, ultrasonic thickness measurements were taken on Penstock #3. 3 Readings were taken at each location as requested. Readings are shown in mm's on the attached tables.

Equipment Used
Krautkramer DMS 2 digital thickness gauge (S/N 01YL2P).
Krautkramer TC560 probe (S/N 14A01G28).
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 21-594-2 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Ultrasonic Thickness Measurements

Location Of Readings



ETS No.: 21-594-2 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Ultrasonic Thickness Measurements

Can Number	Location A			Location B			Location C		
1	11.3	11.4	11.5	11.3	11.4	11.5	11.6	11.3	11.4
6	12.7	12.6	12.8	12.4	12.5	12.5	12.7	12.8	12.6
16	10.6	10.8	10.9	10.8	10.9	10.6	10.5	10.6	10.5
26	10.2	10.3	10.4	10.4	10.2	10.1	10.2	10.3	10.1
35	10.5	10.4	10.3	10.2	10.1	10.2	10.4	10.5	10.4
45	10.4	10.4	10.4	10.3	10.3	10.3	10.4	10.4	10.4
55	10.4	10.4	10.4	10.6	10.6	10.6	10.5	10.5	10.5
65	10.6	10.6	10.5	10.4	10.3	10.4	10.5	10.4	10.5
74	10.2	10.4	10.3	10.3	10.3	10.3	10.3	10.3	10.3
81	10.4	10.4	10.4	10.3	10.3	10.3	10.2	10.2	10.2
91	10.4	10.4	10.4	10.3	10.3	10.3	10.2	10.2	10.2
101	10.3	10.3	10.3	10.5	10.5	10.5	10.8	10.8	10.8
112	10.4	10.4	10.4	10.5	10.5	10.5	10.8	10.8	10.8
122	10.4	10.4	10.4	10.3	10.3	10.3	10.6	10.6	10.6
132	13.8	13.1	13.2	13.6	13.3	13.2	3.9	13.2	13.6
143	13.8	13.1	13.2	13.1	13.3	13.4	13.5	13.6	13.1
153	13.1	13.2	13.3	13.1	13.2	13.3	12.9	13.2	13.3
163	13.6	13.9	14.0	14.1	14.2	13.7	13.9	14.0	14.1
172	13.5	13.4	13.8	13.6	13.6	13.6	13.5	13.5	13.5
183	15.5	15.5	15.5	15.4	15.6	15.9	15.4	15.5	15.9
193	16.8	16.9	16.4	16.5	16.5	16.9	16.9	16.9	17.0
203	16.0	16.5	16.6	15.4	15.5	15.6	16.4	16.2	16.3
211	15.4	15.5	16.0	15.6	15.8	15.4	16.1	16.0	15.8
223	15.4	15.5	16	15.6	15.8	15.4	16.0	15.9	15.8
233	18.9	18.6	18.5	18.9	18.4	18.5	18.9	18.8	18.5

ETS No.: 21-594-2 Date: 20 August 2021
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Ultrasonic Thickness Measurements

Can Number	Location A			Location B			Location C		
240	20.2	20.4	20.6	20.6	20.4	20.6	20.4	20.6	20.4
250	16.8	16.8	16.8	16.8	16.8	16.8	16.7	16.6	16.8
261	17.3	17.4	17.4	17.6	17.4	17.4	17.0	17.0	17.0
271	17.5	17.6	17.8	17.0	17.0	17.0	16.9	16.9	16.9
281	19.9	19.8	19.7	19.0	19.0	19.0	19.4	19.4	19.4
291	19.0	19.0	19.0	18.9	18.9	18.9	19.0	19.0	19.0
300	21.3	21.2	21.3	21.1	21.2	21.2	21.3	21.3	21.3
310	22.7	22.7	22.7	22.5	22.5	22.5	22.4	22.4	22.4
321	23.3	22.6	22.7	22.4	23.0	23.4	23.2	22.4	23.6
331	24.6	24.2	24.9	24.0	24.3	24.6	25.1	25.2	25.4
340	25.6	25.5	25.5	25.3	25.4	26.0	25.3	25.4	25.3
351	25.4	25.4	25.1	26.0	26.0	26.0	25.4	25.4	25.4
360	27.0	27.1	27.2	26.8	26.2	26.3	26.9	26.8	26.7
369	28.0	28.0	28.0	27.1	27.1	27.1	27.5	27.5	27.5

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

TABLE 1 - Full Supply Level (FSL)
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water= 62.4 pcf
Normal pond EL= 597 feet
Joint Efficiency= 0.7
D_1 ID= 17.00 feet
D_2 ID= 15.25 feet
D_3 ID= 13.50 feet

Can #	Distance From Intake (Fwd Edge of Can 1 ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
Penstock Interior From Upstream End of Conduit																
			1	11.3000	0.4449	0.5000	-11.0%				17,000					A285
1A			2	11.4000	0.4488	0.5000	-10.2%	0.4411			17,000					Assume plate thickness 0.5 inch
			3	11.5000	0.4528	0.5000	-9.4%				17,000					
			4	11.3000	0.4449	0.5000	-11.0%				17,000					
1B	42.0	8.50	5	11.4000	0.4488	0.5000	-10.2%	0.4411	0.4449	555.19	17,000	4,154.20	0.24	5,934.58	0.35	
			6	11.5000	0.4528	0.5000	-9.4%				17,000					
			7	11.6000	0.4567	0.5000	-8.7%				17,000					
1C			8	11.3000	0.4449	0.5000	-11.0%	0.4383			17,000					
			9	11.4000	0.4488	0.5000	-10.2%				17,000					
			10	12.7000	0.5000	0.5000	0.0%				17,000					
6A			11	12.6000	0.4961	0.5000	-0.8%	0.4923			17,000					
			12	12.8000	0.5039	0.5000	0.8%				17,000					
			13	12.4000	0.4882	0.5000	-2.4%				17,000					
6B	86.0	8.50	14	12.5000	0.4921	0.5000	-1.6%	0.4864	0.4882	555.05	17,000	3,798.29	0.22	5,426.13	0.32	
			15	12.5000	0.4921	0.5000	-1.6%				17,000					
			16	12.7000	0.5000	0.5000	0.0%				17,000					
6C			17	12.8000	0.5039	0.5000	0.8%	0.4923			17,000					
			18	12.6000	0.4961	0.5000	-0.8%				17,000					
			19	10.6000	0.4173	0.4375	-4.6%				17,000					
16A			20	10.8000	0.4252	0.4375	-2.8%	0.4121			17,000					
			21	10.9000	0.4291	0.4375	-1.9%				17,000					
			22	10.8000	0.4252	0.4375	-2.8%				17,000					
16B	185.3	8.50	23	10.9000	0.4291	0.4375	-1.9%	0.4121	0.4134	554.70	17,000	4,522.68	0.27	6,460.97	0.38	
			24	10.6000	0.4173	0.4375	-4.6%				17,000					
			25	10.5000	0.4134	0.4375	-5.5%				17,000					
16C			26	10.6000	0.4173	0.4375	-4.6%	0.4102			17,000					
			27	10.5000	0.4134	0.4375	-5.5%				17,000					
			28	10.2000	0.4016	0.4375	-8.2%				17,000					
26A			29	10.3000	0.4055	0.4375	-7.3%	0.3978			17,000					
			30	10.4000	0.4094	0.4375	-6.4%				17,000					
			31	10.4000	0.4094	0.4375	-6.4%				17,000					
26B	236.3	8.50	32	10.2000	0.4016	0.4375	-8.2%	0.3911	0.3976	552.75	17,000	4,918.36	0.29	7,026.23	0.41	
			33	10.1000	0.3976	0.4375	-9.1%				17,000					
			34	10.2000	0.4016	0.4375	-8.2%				17,000					
26C			35	10.3000	0.4055	0.4375	-7.3%	0.3939			17,000					
			36	10.1000	0.3976	0.4375	-9.1%				17,000					
			37	10.5000	0.4134	0.4375	-5.5%				17,000					
35A			38	10.4000	0.4094	0.4375	-6.4%	0.4017			17,000					
			39	10.3000	0.4055	0.4375	-7.3%				17,000					
			40	10.2000	0.4016	0.4375	-8.2%				17,000					
35B	323.5	8.50	41	10.1000	0.3976	0.4375	-9.1%	0.3958	0.3976	543.45	17,000	5,951.98	0.35	8,502.83	0.50	
			42	10.2000	0.4016	0.4375	-8.2%				17,000					
			43	10.4000	0.4094	0.4375	-6.4%				17,000					
35C			44	10.5000	0.4134	0.4375	-5.5%	0.4063			17,000					
			45	10.4000	0.4094	0.4375	-6.4%				17,000					
			46	10.4000	0.4094	0.4375	-6.4%				17,000					
45A			47	10.4000	0.4094	0.4375	-6.4%	0.4094			17,000					
			48	10.4000	0.4094	0.4375	-6.4%				17,000					
			49	10.3000	0.4055	0.4375	-7.3%				17,000					
45B	423.0	8.50	50	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4055	532.84	17,000	6,993.32	0.41	9,990.45	0.59	
			51	10.3000	0.4055	0.4375	-7.3%				17,000					
			52	10.4000	0.4094	0.4375	-6.4%				17,000					
45C			53	10.4000	0.4094	0.4375	-6.4%	0.4094			17,000					
			54	10.4000	0.4094	0.4375	-6.4%				17,000					
			55	10.4000	0.4094	0.4375	-6.4%				17,000					
55A			56	10.4000	0.4094	0.4375	-6.4%	0.4094			17,000					
			57	10.4000	0.4094	0.4375	-6.4%				17,000					
			58	10.6000	0.4173	0.4375	-4.6%				17,000					
55B	532.7	8.50	59	10.6000	0.4173	0.4375	-4.6%	0.4173	0.4094	521.14	17,000	8,188.86	0.48	11,698.37	0.69	
			60	10.6000	0.4173	0.4375	-4.6%				17,000					
			61	10.5000	0.4134	0.4375	-5.5%				17,000					
55C			62	10.5000	0.4134	0.4375	-5.5%	0.4134			17,000					
			63	10.5000	0.4134	0.4375	-5.5%				17,000					
			64	10.6000	0.4173	0.4375	-4.6%				17,000					
65A			65	10.6000	0.4173	0.4375	-4.6%	0.4116			17,000					
			66	10.5000	0.4134	0.4375	-5.5%				17,000					
			67	10.4000	0.4094	0.4375	-6.4%				17,000					
65B	622.4	8.50	68	10.3000	0.4055	0.4375	-7.3%	0.4037	0.4055	512.45	17,000	9,215.63	0.54	13,165.18	0.77	
			69	10.4000	0.4094	0.4375	-6.4%				17,000					
			70	10.5000	0.4134	0.4375	-5.5%				17,000					
65C			71	10.4000	0.4094	0.4375	-6.4%	0.4076			17,000					
			72	10.5000	0.4134	0.4375	-5.5%				17,000					
			73	10.2000	0.4016	0.4375	-8.2%				17,000					
74A			74	10.4000	0.4094	0.4375	-6.4%	0.3978			17,000					
			75	10.3000	0.4055	0.4375	-7.3%				17,000					
			76	10.3000	0.4055	0.4375	-7.3%				17,000					
74B	712.0	8.50	77	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4016	504.80	17,000	10,148.06	0.60	14,497.23	0.85	
			78	10.3000	0.4055	0.4375	-7.3%				17,000					
			79	10.3000	0.4055	0.4375	-7.3%				17,000					
74C			80	10.3000	0.4055	0.4375	-7.3%	0.4055			17,000					
			81	10.3000	0.4055	0.4375	-7.3%				17,000					
			82	10.4000	0.4094	0.4375	-6.4%				17,000					
81A			83	10.4000	0.4094	0.4375	-6.4%	0.4094			17,000					
			84	10.4000	0.4094	0.4375	-6.4%				17,000					
			85	10.3000	0.4055	0.4375	-7.3%				17,000					
81B	782.0	8.50	86	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4016	498.82	17,000	10,806.06	0.64	15,437.23	0.91	
			87	10.3000	0.4055	0.4375	-7.3%				17,000					
			88	10.2000	0.4016	0.4375	-8.2%				17,000					
81C			89	10.2000	0.4016	0.4375	-8.2%	0.4016			17,000					
			90	10.2000	0.4016	0.4375	-8.2%				17,000					

Can #	Distance From Intake (Fwd Edge of Can 1 ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			91	10.4000	0.4094	0.4375	-6.4%				17,000					
91A			92	10.4000	0.4094	0.4375	-6.4%	0.4094			17,000					
			93	10.4000	0.4094	0.4375	-6.4%				17,000					
			94	10.3000	0.4055	0.4375	-7.3%				17,000					
91B	882.0	8.50	95	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4016	490.28	17,000	11,746.05	0.69	16,780.08	0.99	
			96	10.3000	0.4055	0.4375	-7.3%				17,000					
			97	10.2000	0.4016	0.4375	-8.2%				17,000					
91C			98	10.2000	0.4016	0.4375	-8.2%	0.4016			17,000					
			99	10.2000	0.4016	0.4375	-8.2%				17,000					
			100	10.3000	0.4055	0.4375	-7.3%				24,000					G40.8 B - 40 ksi
101A			101	10.3000	0.4055	0.4375	-7.3%	0.4055			24,000					
			102	10.3000	0.4055	0.4375	-7.3%				24,000					
			103	10.5000	0.4134	0.4375	-5.5%				24,000					
101B	981.9	8.50	104	10.5000	0.4134	0.4375	-5.5%	0.4134	0.4055	481.75	24,000	12,562.10	0.52	17,945.86	0.75	
			105	10.5000	0.4134	0.4375	-5.5%				24,000					
			106	10.8000	0.4252	0.4375	-2.8%				24,000					
101C			107	10.8000	0.4252	0.4375	-2.8%	0.4252			24,000					
			108	10.8000	0.4252	0.4375	-2.8%				24,000					
			109	10.4000	0.4094	0.4375	-6.4%				24,000					G40.8 B - 40 ksi
112A			110	10.4000	0.4094	0.4375	-6.4%	0.4094			24,000					
			111	10.4000	0.4094	0.4375	-6.4%				24,000					
			112	10.5000	0.4134	0.4375	-5.5%				24,000					
112B	1,091.5	8.50	113	10.5000	0.4134	0.4375	-5.5%	0.4134	0.4094	472.39	24,000	13,451.59	0.56	19,216.56	0.80	
			114	10.5000	0.4134	0.4375	-5.5%				24,000					
			115	10.8000	0.4252	0.4375	-2.8%				24,000					
112C			116	10.8000	0.4252	0.4375	-2.8%	0.4252			24,000					
			117	10.8000	0.4252	0.4375	-2.8%				24,000					
			118	10.4000	0.4094	0.4375	-6.4%				24,000					G40.8 B - 40 ksi
122A			119	10.4000	0.4094	0.4375	-6.4%	0.4094			24,000					
			120	10.4000	0.4094	0.4375	-6.4%				24,000					
			121	10.3000	0.4055	0.4375	-7.3%				24,000					
122B	1,191.0	8.50	122	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4055	463.89	24,000	14,508.40	0.60	20,726.29	0.86	
			123	10.3000	0.4055	0.4375	-7.3%				24,000					
			124	10.6000	0.4173	0.4375	-4.6%				24,000					
122C			125	10.6000	0.4173	0.4375	-4.6%	0.4173			24,000					
			126	10.6000	0.4173	0.4375	-4.6%				24,000					
			127	13.8000	0.5433	0.5625	-3.4%				24,000					G40.8 B - 40 ksi
132A			128	13.1000	0.5157	0.5625	-8.3%	0.4970			24,000					
			129	13.2000	0.5197	0.5625	-7.6%				24,000					
			130	13.6000	0.5354	0.5625	-4.8%				24,000					
132B	1,289.0	8.50	131	13.3000	0.5236	0.5625	-6.9%	0.5102	0.5157	454.47	24,000	12,215.27	0.51	17,450.39	0.73	
			132	13.2000	0.5197	0.5625	-7.6%				24,000					
			133	13.9000	0.5472	0.5625	-2.7%				24,000					
132C			134	13.2000	0.5197	0.5625	-7.6%	0.5070			24,000					
			135	13.6000	0.5354	0.5625	-4.8%				24,000					
			136	13.8000	0.5433	0.5625	-3.4%				24,000					assume 0.5625
143A			137	13.1000	0.5157	0.5625	-8.3%	0.4970			24,000					G40.8 B - 40 ksi
			138	13.2000	0.5197	0.5625	-7.6%				24,000					
			139	13.1000	0.5157	0.5625	-8.3%				24,000					
143B	1,373.3	7.63	140	13.3000	0.5236	0.5625	-6.9%	0.5105	0.5157	431.25	24,000	12,742.67	0.53	18,203.82	0.76	
			141	13.4000	0.5276	0.5625	-6.2%				24,000					
			142	13.5000	0.5315	0.5625	-5.5%				24,000					
143C			143	13.6000	0.5354	0.5625	-4.8%	0.5071			24,000					
			144	13.1000	0.5157	0.5625	-8.3%				24,000					
			145	13.1000	0.5157	0.5625	-8.3%				24,000					G40.8 B - 40 ksi
153A			146	13.2000	0.5197	0.5625	-7.6%	0.5120			24,000					
			147	13.3000	0.5236	0.5625	-6.9%				24,000					
			148	13.1000	0.5157	0.5625	-8.3%				24,000					
153B	1,464.3	7.63	149	13.2000	0.5197	0.5625	-7.6%	0.5120	0.5079	406.17	24,000	14,897.98	0.62	21,282.83	0.89	
			150	13.3000	0.5236	0.5625	-6.9%				24,000					
			151	12.9000	0.5079	0.5625	-9.7%				24,000					
153C			152	13.2000	0.5197	0.5625	-7.6%	0.5010			24,000					
			153	13.3000	0.5236	0.5625	-6.9%				24,000					
			154	13.6000	0.5354	0.5625	-4.8%				24,000					G40.8 B - 40 ksi
163A			155	13.9000	0.5472	0.5625	-2.7%	0.5286			24,000					
			156	14.0000	0.5512	0.5625	-2.0%				24,000					
			157	14.1000	0.5551	0.5625	-1.3%				24,000					
163B	1,552.3	7.63	158	14.2000	0.5591	0.5625	-0.6%	0.5308	0.5354	381.92	24,000	15,926.93	0.66	22,752.76	0.95	
			159	13.7000	0.5394	0.5625	-4.1%				24,000					
			160	13.9000	0.5472	0.5625	-2.7%				24,000					
163C			161	14.0000	0.5512	0.5625	-2.0%	0.5435			24,000					
			162	14.1000	0.5551	0.5625	-1.3%				24,000					
			163	13.5000	0.5315	0.5625	-5.5%				24,000					G40.8 B - 40 ksi
172A			164	13.4000	0.5276	0.5625	-6.2%	0.5181			24,000					
			165	13.8000	0.5433	0.5625	-3.4%				24,000					
			166	13.6000	0.5354	0.5625	-4.8%				24,000					
172B	1,617.5	7.63	167	13.6000	0.5354	0.5625	-4.8%	0.5354	0.5276	368.30	24,000	17,188.74	0.72	24,555.34	1.02	
			168	13.6000	0.5354	0.5625	-4.8%				24,000					
			169	13.5000	0.5315	0.5625	-5.5%				24,000					
172C			170	13.5000	0.5315	0.5625	-5.5%	0.5315			24,000					
			171	13.5000	0.5315	0.5625	-5.5%				24,000					
			172	15.5000	0.6102	0.6250	-2.4%				24,000					G40.8 B - 40 ksi
183A			173	15.5000	0.6102	0.6250	-2.4%	0.6102			24,000					
			174	15.5000	0.6102	0.6250	-2.4%				24,000					
			175	15.4000	0.6063	0.6250	-3.0%				24,000					
183B	1,724.8	7.63	176	15.6000	0.6142	0.6250	-1.7%	0.5961	0.6063	359.99	24,000	15,499.78	0.65	22,142.55	0.92	
			177	15.9000	0.6260	0.6250	0.2%				24,000					
			178	15.4000	0.6063	0.6250	-3.0%				24,000					
183C			179	15.5000	0.6102	0.6250	-2.4%	0.5938			24,000					
			180	15.9000	0.6260	0.6250	0.2%				24,000					
			181	16.8000	0.6614	0.7500	-11.8%				24,000					G40.8 B - 38 ksi
193A			182	16.9000	0.6654	0.7500	-11.3%	0.6371			24,000					
			183	16.4000	0.6457	0.7500	-13.9%				24,000					
			184	16.5000	0.6496	0.7500	-13.4%				24,000					
193B	1,807.5	7.63	185	16.5000	0.6496	0.7500	-13.4%	0.6370	0.6457	352.64	24,000	15,005.72	0.63	21,436.74	0.89	
			186	16.9000	0.6654	0.7500	-11.3%				24,000					
			187	16.9000	0.6654	0.7500	-11.3%				24,000					
193C			188	16.9000	0.6654	0.7500	-11.3%	0.6622			24,000					
			189	17.0000	0.6693	0.7500	-10.8%				24,000					
			190	16.0000	0.6299	0.6875	-8.4%				24,000					G40.8 B - 38 ksi
203A			191	16.5000	0.6496	0.6875	-5.5%	0.6196			24,000					
			192	16.6000	0.6535	0.6875	-4.9%				24,000					
			193	15.4000	0.6063	0.6875	-11.8%				24,000					
203B	1,876.6	7.63	194	15.5000	0.6102	0.6875	-11.2%	0.6025	0.6063	341.62	24,000	16,701.13	0.70	23,858.76	0.99	
			195	15.6000	0.6142	0.6875	-10.7%				24,000					
			196	16.4000	0.6457	0.6875	-6.1%				24,000					
203C			197	16.2000	0.6378	0.6875	-7.2%	0.6340			24,000					
			198	16.3000	0.6417	0.6875	-6.7%				24,000					

Can #	Distance From Intake (Fwd Edge of Can 1 ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
			199	15.4000	0.6063	0.5990	1.2%				33,333					HSB 50 Steel
211A			200	15.5000	0.6102	0.5990	1.9%	0.5907			33,333					
			201	16.0000	0.6299	0.5990	5.2%				33,333					
			202	15.6000	0.6142	0.5990	2.5%				33,333					
211B	1,952.4	7.63	203	15.8000	0.6220	0.5990	3.8%	0.5987	0.6063	329.52	33,333	17,492.60	0.52	24,989.42	0.75	
			204	15.4000	0.6063	0.5990	1.2%				33,333					
			205	16.1000	0.6339	0.5990	5.8%				33,333					
211C			206	16.0000	0.6299	0.5990	5.2%	0.6168			33,333					
			207	15.8000	0.6220	0.5990	3.8%				33,333					
			208	15.4000	0.6063	0.6250	-3.0%				33,333					HSB 50 Steel
223A			209	15.5000	0.6102	0.6250	-2.4%	0.5907			33,333					
			210	16.0000	0.6299	0.6250	0.8%				33,333					
			211	15.6000	0.6142	0.6250	-1.7%				33,333					
223B	2,071.8	7.63	212	15.8000	0.6220	0.6250	-0.5%	0.5987	0.6063	310.47	33,333	18,738.08	0.56	26,768.68	0.80	
			213	15.4000	0.6063	0.6250	-3.0%				33,333					
			214	16.0000	0.6299	0.6250	0.8%				33,333					
223C			215	15.9000	0.6260	0.6250	0.2%	0.6183			33,333					
			216	15.8000	0.6220	0.6250	-0.5%				33,333					
			217	18.9000	0.7441	0.7500	-0.8%				24,000					G 40.8 B - 38 ksi
233A			218	18.6000	0.7323	0.7500	-2.4%	0.7188			24,000					
			219	18.5000	0.7283	0.7500	-2.9%				24,000					
			220	18.9000	0.7441	0.7500	-0.8%				24,000					
233B	2,165.7	7.63	221	18.4000	0.7244	0.7500	-3.4%	0.7119	0.7244	295.48	24,000	16,503.34	0.69	23,576.19	0.98	
			222	18.5000	0.7283	0.7500	-2.9%				24,000					
			223	18.9000	0.7441	0.7500	-0.8%				24,000					
233C			224	18.8000	0.7402	0.7500	-1.3%	0.7215			24,000					
			225	18.5000	0.7283	0.7500	-2.9%				24,000					
			226	20.2000	0.7953	0.8125	-2.1%				24,000					G 40.8 B - 38 ksi
240A			227	20.4000	0.8031	0.8125	-1.2%	0.7877			24,000					
			228	20.6000	0.8110	0.8125	-0.2%				24,000					
			229	20.6000	0.8110	0.8125	-0.2%				24,000					
240B	2,215.0	7.63	230	20.4000	0.8031	0.8125	-1.2%	0.7995	0.7953	287.60	24,000	15,425.54	0.64	22,036.48	0.92	
			231	20.6000	0.8110	0.8125	-0.2%				24,000					
			232	20.4000	0.8031	0.8125	-1.2%				24,000					
240C			233	20.6000	0.8110	0.8125	-0.2%	0.7969			24,000					
			234	20.4000	0.8031	0.8125	-1.2%				24,000					
			235	16.8000	0.6614	0.6720	-1.6%				33,333					HSB 50 Steel
250A			236	16.8000	0.6614	0.6720	-1.6%	0.6614			33,333					
			237	16.8000	0.6614	0.6720	-1.6%				33,333					
			238	16.8000	0.6614	0.6720	-1.6%				33,333					
250B	2,333.3	6.75	239	16.8000	0.6614	0.6720	-1.6%	0.6614	0.6535	268.72	33,333	17,631.08	0.53	25,187.25	0.76	
			240	16.8000	0.6614	0.6720	-1.6%				33,333					
			241	16.7000	0.6575	0.6720	-2.2%				33,333					
250C			242	16.6000	0.6535	0.6720	-2.7%	0.6498			33,333					
			243	16.8000	0.6614	0.6720	-1.6%				33,333					
			244	17.3000	0.6811	0.7060	-3.5%				33,333					
261A			245	17.4000	0.6850	0.7060	-3.0%	0.6793			33,333					
			246	17.4000	0.6850	0.7060	-3.0%				33,333					
			247	17.6000	0.6929	0.7060	-1.9%				33,333					
261B	2,423.5	6.75	248	17.4000	0.6850	0.7060	-3.0%	0.6788	0.6693	254.33	33,333	17,970.90	0.54	25,672.71	0.77	
			249	17.4000	0.6850	0.7060	-3.0%				33,333					
			250	17.0000	0.6693	0.7060	-5.2%				33,333					
261C			251	17.0000	0.6693	0.7060	-5.2%	0.6693			33,333					
			252	17.0000	0.6693	0.7060	-5.2%				33,333					
			253	17.5000	0.6890	0.7390	-6.8%				33,333					
271A			254	17.6000	0.6929	0.7390	-6.2%	0.6824			33,333					
			255	17.8000	0.7008	0.7390	-5.2%				33,333					
			256	17.0000	0.6693	0.7390	-9.4%				33,333					
271B	2,543.7	6.75	257	17.0000	0.6693	0.7390	-9.4%	0.6693	0.6654	235.15	33,333	19,088.93	0.57	27,269.91	0.82	
			258	17.0000	0.6693	0.7390	-9.4%				33,333					
			259	16.9000	0.6654	0.7390	-10.0%				33,333					
271C			260	16.9000	0.6654	0.7390	-10.0%	0.6654			33,333					
			261	16.9000	0.6654	0.7390	-10.0%				33,333					
			262	19.9000	0.7835	0.7980	-1.8%				33,333					
281A			263	19.8000	0.7795	0.7980	-2.3%	0.7718			33,333					
			264	19.7000	0.7756	0.7980	-2.8%				33,333					
			265	19.0000	0.7480	0.7980	-6.3%				33,333					
281B	2,624.0	6.75	266	19.0000	0.7480	0.7980	-6.3%	0.7480	0.7480	222.33	33,333	17,580.70	0.53	25,115.28	0.75	
			267	19.0000	0.7480	0.7980	-6.3%				33,333					
			268	19.4000	0.7638	0.7980	-4.3%				33,333					
281C			269	19.4000	0.7638	0.7980	-4.3%	0.7638			33,333					
			270	19.4000	0.7638	0.7980	-4.3%				33,333					
			271	19.0000	0.7480	0.8290	-9.8%				33,333					
291A			272	19.0000	0.7480	0.8290	-9.8%	0.7480			33,333					
			273	19.0000	0.7480	0.8290	-9.8%				33,333					
			274	18.9000	0.7441	0.8290	-10.2%				33,333					
291B	2,720.5	6.75	275	18.9000	0.7441	0.8290	-10.2%	0.7441	0.7441	209.84	33,333	18,263.02	0.55	26,090.03	0.78	
			276	18.9000	0.7441	0.8290	-10.2%				33,333					
			277	19.0000	0.7480	0.8290	-9.8%				33,333					
291C			278	19.0000	0.7480	0.8290	-9.8%	0.7480			33,333					
			279	19.0000	0.7480	0.8290	-9.8%				33,333					
			280	21.3000	0.8386	0.8540	-1.8%				33,333					
300A			281	21.2000	0.8346	0.8540	-2.3%	0.8328			33,333					
			282	21.3000	0.8386	0.8540	-1.8%				33,333					
			283	21.1000	0.8307	0.8540	-2.7%				33,333					
300B	2,811.7	6.75	284	21.2000	0.8346	0.8540	-2.3%	0.8289	0.8307	202.25	33,333	16,679.27	0.50	23,827.53	0.71	
			285	21.2000	0.8346	0.8540	-2.3%				33,333					
			286	21.3000	0.8386	0.8540	-1.8%				33,333					
300C			287	21.3000	0.8386	0.8540	-1.8%	0.8386			33,333					
			288	21.3000	0.8386	0.8540	-1.8%				33,333					
			289	22.7000	0.8937	0.9040	-1.1%				33,333					
310A			290	22.7000	0.8937	0.9040	-1.1%	0.8937			33,333					
			291	22.7000	0.8937	0.9040	-1.1%				33,333					
			292	22.5000	0.8858	0.9040	-2.0%				33,333					
310B	2,923.5	6.75	293	22.5000	0.8858	0.9040	-2.0%	0.8858	0.8819	192.95	33,333	16,081.57	0.48	22,973.67	0.69	
			294	22.5000	0.8858	0.9040	-2.0%				33,333					
			295	22.4000	0.8819	0.9040	-2.4%				33,333					
310C			296	22.4000	0.8819	0.9040	-2.4%	0.8819			33,333					
			297	22.4000	0.8819	0.9040	-2.4%				33,333					
			298	23.3000	0.9173	0.9290	-1.3%				33,333					
321A			299	22.6000	0.8898	0.9290	-4.2%	0.8710			33,333					
			300	22.7000	0.8937	0.9290	-3.8%				33,333					
			301	22.4000	0.8819	0.9290	-5.1%				33,333					
321B	3,039.5	6.75	302	23.0000	0.9055	0.9290	-2.5%	0.8640	0.8819	183.30	33,333	16,465.65	0.49	23,522.35	0.71	
			303	23.4000	0.9213	0.9290	-0.8%				33,333					
			304	23.2000	0.9134	0.9290	-1.7%				33,333					
321C			305	22.4000	0.8819	0.9290	-5.1%	0.8610			33,333					
			306	23.6000	0.9291	0.9290	0.0%				33,333					

Can #	Distance From Intake (Fwd Edge of Can 1 ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
331A			307	24.6000	0.9685	0.9540	1.5%	0.9401			33,333					
			308	24.2000	0.9528	0.9540	-0.1%				33,333					
			309	24.9000	0.9803	0.9540	2.8%				33,333					
331B	3,125.2	6.75	310	24.0000	0.9449	0.9540	-1.0%	0.9335	0.9449	176.17	33,333	15,632.67	0.47	22,332.38	0.67	
			311	24.3000	0.9567	0.9540	0.3%				33,333					
			312	24.6000	0.9685	0.9540	1.5%				33,333					
331C			313	25.1000	0.9882	0.9540	3.6%	0.9817			33,333					
			314	25.2000	0.9921	0.9540	4.0%				33,333					
			315	25.4000	1.0000	0.9540	4.8%				33,333					
340A			316	25.6000	1.0079	0.9790	2.9%	1.0008			33,333					
			317	25.5000	1.0039	0.9790	2.5%				33,333					
			318	25.5000	1.0039	0.9790	2.5%				33,333					
340B	3,226.3	6.75	319	25.3000	0.9961	0.9790	1.7%	0.9773	0.9961	167.76	33,333	15,125.98	0.45	21,608.54	0.65	
			320	25.4000	1.0000	0.9790	2.1%				33,333					
			321	26.0000	1.0236	0.9790	4.6%				33,333					
340C			322	25.3000	0.9961	0.9790	1.7%	0.9929			33,333					
			323	25.4000	1.0000	0.9790	2.1%				33,333					
			324	25.3000	0.9961	0.9790	1.7%				33,333					
351A			316	25.4000	1.0000	1.0250	-2.4%	0.9827			33,333					
			317	25.4000	1.0000	1.0250	-2.4%				33,333					
			318	25.1000	0.9882	1.0250	-3.6%				33,333					
351B	3,320.5	6.75	319	26.0000	1.0236	1.0250	-0.1%	1.0236	0.9882	149.64	33,333	15,889.98	0.48	22,699.98	0.68	
			320	26.0000	1.0236	1.0250	-0.1%				33,333					
			321	26.0000	1.0236	1.0250	-0.1%				33,333					
351C			322	25.4000	1.0000	1.0250	-2.4%	1.0000			33,333					
			323	25.4000	1.0000	1.0250	-2.4%				33,333					
			324	25.4000	1.0000	1.0250	-2.4%				33,333					
360A			325	27.0000	1.0630	1.0610	0.2%	1.0592			33,333					
			326	27.1000	1.0669	1.0610	0.6%				33,333					
			327	27.2000	1.0709	1.0610	0.9%				33,333					
360B	3,409.4	6.75	328	26.8000	1.0551	1.0610	-0.6%	1.0159	1.0315	127.26	33,333	15,984.43	0.48	22,834.90	0.69	
			329	26.2000	1.0315	1.0610	-2.8%				33,333					
			330	26.3000	1.0354	1.0610	-2.4%				33,333					
360C			331	26.9000	1.0591	1.0610	-0.2%	1.0474			33,333					
			332	26.8000	1.0551	1.0610	-0.6%				33,333					
			333	26.7000	1.0512	1.0610	-0.9%				33,333					
369A			334	28.0000	1.1024	1.0950	0.7%	1.1024			33,333					
			335	28.0000	1.1024	1.0950	0.7%				33,333					
			336	28.0000	1.1024	1.0950	0.7%				33,333					
369B	3,477.8	6.75	337	27.1000	1.0669	1.0950	-2.6%	1.0669	1.0669	110.06	33,333	16,019.43	0.48	22,884.91	0.69	
			338	27.1000	1.0669	1.0950	-2.6%				33,333					
			339	27.1000	1.0669	1.0950	-2.6%				33,333					
369C			340	27.5000	1.0827	1.0950	-1.1%	1.0827			33,333					
			341	27.5000	1.0827	1.0950	-1.1%				33,333					
			342	27.5000	1.0827	1.0950	-1.1%				33,333					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$

[2] Hoop stress / S_A

[3] Hoop stress / 0.7 $_{\text{joint efficiency}}$

[4] Joint stress / S_A

Minimum Wall Thickness	
All	0.3976
17dia	0.3976
15.25dia	0.5079
13.5dia	0.6535

TABLE 2 - Transient (30% surge)
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf
Normal pond EL=	597	feet
Joint Efficiency=	0.7	
D_1 ID=	17.00	feet
D_2 ID=	15.25	feet
D_3 ID=	13.50	feet

Can #	Distance From Intake (Fwd Edge of Can 1 ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4]	
Penstock Interior From Upstream End of Conduit																
			1	11.3000	0.4449	0.5000	-11.0%				17000					A285
1A			2	11.4000	0.4488	0.5000	-10.2%	0.4411			17000					Assume plate thickness 0.5 inch
			3	11.5000	0.4528	0.5000	-9.4%				17000					
			4	11.3000	0.4449	0.5000	-11.0%				17000					
1B	42	8.50	5	11.4000	0.4488	0.5000	-10.2%	0.4411	0.4449	555.1871	17000	5400.5	0.32	7715.0	0.45	
			6	11.5000	0.4528	0.5000	-9.4%				17000					
			7	11.6000	0.4567	0.5000	-8.7%				17000					
1C			8	11.3000	0.4449	0.5000	-11.0%	0.4383			17000					
			9	11.4000	0.4488	0.5000	-10.2%				17000					
			10	12.7000	0.5000	0.5000	0.0%				17000					
6A			11	12.6000	0.4961	0.5000	-0.8%	0.4923			17000					
			12	12.8000	0.5039	0.5000	0.8%				17000					
			13	12.4000	0.4882	0.5000	-2.4%				17000					
6B	86	8.50	14	12.5000	0.4921	0.5000	-1.6%	0.4864	0.4882	555.0479	17000	4937.8	0.29	7054.0	0.41	
			15	12.5000	0.4921	0.5000	-1.6%				17000					
			16	12.7000	0.5000	0.5000	0.0%				17000					
6C			17	12.8000	0.5039	0.5000	0.8%	0.4923			17000					
			18	12.6000	0.4961	0.5000	-0.8%				17000					
			19	10.6000	0.4173	0.4375	-4.6%				17000					
16A			20	10.8000	0.4252	0.4375	-2.8%	0.4121			17000					
			21	10.9000	0.4291	0.4375	-1.9%				17000					
			22	10.8000	0.4252	0.4375	-2.8%				17000					
16B	185.25	8.50	23	10.9000	0.4291	0.4375	-1.9%	0.4121	0.4134	554.7011	17000	5879.5	0.35	8399.3	0.49	
			24	10.6000	0.4173	0.4375	-4.6%				17000					
			25	10.5000	0.4134	0.4375	-5.5%				17000					
16C			26	10.6000	0.4173	0.4375	-4.6%	0.4102			17000					
			27	10.5000	0.4134	0.4375	-5.5%				17000					
			28	10.2000	0.4016	0.4375	-8.2%				17000					
26A			29	10.3000	0.4055	0.4375	-7.3%	0.3978			17000					
			30	10.4000	0.4094	0.4375	-6.4%				17000					
			31	10.4000	0.4094	0.4375	-6.4%				17000					
26B	236.333	8.50	32	10.2000	0.4016	0.4375	-8.2%	0.3911	0.3976	552.7528	17000	6393.9	0.38	9134.1	0.54	
			33	10.1000	0.3976	0.4375	-9.1%				17000					
			34	10.2000	0.4016	0.4375	-8.2%				17000					
26C			35	10.3000	0.4055	0.4375	-7.3%	0.3939			17000					
			36	10.1000	0.3976	0.4375	-9.1%				17000					
			37	10.5000	0.4134	0.4375	-5.5%				17000					
35A			38	10.4000	0.4094	0.4375	-6.4%	0.4017			17000					
			39	10.3000	0.4055	0.4375	-7.3%				17000					
			40	10.2000	0.4016	0.4375	-8.2%				17000					
35B	323.5	8.50	41	10.1000	0.3976	0.4375	-9.1%	0.3958	0.3976	543.4540	17000	7737.6	0.46	11053.7	0.65	
			42	10.2000	0.4016	0.4375	-8.2%				17000					
			43	10.4000	0.4094	0.4375	-6.4%				17000					
35C			44	10.5000	0.4134	0.4375	-5.5%	0.4063			17000					
			45	10.4000	0.4094	0.4375	-6.4%				17000					
			46	10.4000	0.4094	0.4375	-6.4%				17000					
45A			47	10.4000	0.4094	0.4375	-6.4%	0.4094			17000					
			48	10.4000	0.4094	0.4375	-6.4%				17000					
			49	10.3000	0.4055	0.4375	-7.3%				17000					
45B	423	8.50	50	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4055	532.8400	17000	9091.3	0.53	12987.6	0.76	
			51	10.3000	0.4055	0.4375	-7.3%				17000					
			52	10.4000	0.4094	0.4375	-6.4%				17000					
45C			53	10.4000	0.4094	0.4375	-6.4%	0.4094			17000					
			54	10.4000	0.4094	0.4375	-6.4%				17000					
			55	10.4000	0.4094	0.4375	-6.4%				17000					
55A			56	10.4000	0.4094	0.4375	-6.4%	0.4094			17000					
			57	10.4000	0.4094	0.4375	-6.4%				17000					
			58	10.6000	0.4173	0.4375	-4.6%				17000					
55B	532.666	8.50	59	10.6000	0.4173	0.4375	-4.6%	0.4173	0.4094	521.1421	17000	10645.5	0.63	15207.9	0.89	
			60	10.6000	0.4173	0.4375	-4.6%				17000					
			61	10.5000	0.4134	0.4375	-5.5%				17000					
55C			62	10.5000	0.4134	0.4375	-5.5%	0.4134			17000					
			63	10.5000	0.4134	0.4375	-5.5%				17000					
			64	10.6000	0.4173	0.4375	-4.6%				17000					
65A			65	10.6000	0.4173	0.4375	-4.6%	0.4116			17000					
			66	10.5000	0.4134	0.4375	-5.5%				17000					
			67	10.4000	0.4094	0.4375	-6.4%				17000					
65B	622.416	8.50	68	10.3000	0.4055	0.4375	-7.3%	0.4037	0.4055	512.4515	17000	11980.3	0.70	17114.7	1.01	
			69	10.4000	0.4094	0.4375	-6.4%				17000					
			70	10.5000	0.4134	0.4375	-5.5%				17000					
65C			71	10.4000	0.4094	0.4375	-6.4%	0.4076			17000					
			72	10.5000	0.4134	0.4375	-5.5%				17000					
			73	10.2000	0.4016	0.4375	-8.2%				17000					
74A			74	10.4000	0.4094	0.4375	-6.4%	0.3978			17000					
			75	10.3000	0.4055	0.4375	-7.3%				17000					
			76	10.3000	0.4055	0.4375	-7.3%				17000					
74B	712	8.50	77	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4016	504.8008	17000	13192.5	0.78	18846.4	1.11	
			78	10.3000	0.4055	0.4375	-7.3%				17000					
			79	10.3000	0.4055	0.4375	-7.3%				17000					
74C			80	10.3000	0.4055	0.4375	-7.3%	0.4055			17000					
			81	10.3000	0.4055	0.4375	-7.3%				17000					
			82	10.4000	0.4094	0.4375	-6.4%				17000					
81A			83	10.4000	0.4094	0.4375	-6.4%	0.4094			17000					
			84	10.4000	0.4094	0.4375	-6.4%				17000					
			85	10.3000	0.4055	0.4375	-7.3%				17000					
81B	782	8.50	86	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4016	498.8226	17000	14047.9	0.83	20068.4	1.18	
			87	10.3000	0.4055	0.4375	-7.3%				17000					
			88	10.2000	0.4016	0.4375	-8.2%				17000					
81C			89	10.2000	0.4016	0.4375	-8.2%	0.4016			17000					
			90	10.2000	0.4016	0.4375	-8.2%				17000					
			91	10.4000	0.4094	0.4375	-6.4%				17000					
91A			92	10.4000	0.4094	0.4375	-6.4%	0.4094			17000					
			93	10.4000	0.4094	0.4375	-6.4%				17000					
			94	10.3000	0.4055	0.4375	-7.3%				17000					
91B	882	8.50	95	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4016	490.2824	17000	15269.9	0.90	21814.1	1.28	
			96	10.3000	0.4055	0.4375	-7.3%				17000					
			97	10.2000	0.4016	0.4375	-8.2%				17000					
91C			98	10.2000	0.4016	0.4375	-8.2%	0.4016			17000					
			99	10.2000	0.4016	0.4375	-8.2%				17000					
			100	10.3000	0.4055	0.4375	-7.3%				24000					G40.8 B
101A			101	10.3000	0.4055	0.4375	-7.3%	0.4055			24000					
			102	10.3000	0.4055	0.4375	-7.3%				24000					
			103	10.5000	0.4134	0.4375	-5.5%				24000					
101B	981.916	8.50	104	10.5000	0.4134	0.4375	-5.5%	0.4134	0.4055	481.7493	24000	16330.7	0.68	23329.6	0.97	
			105	10.5000	0.4134	0.4375	-5.5%				24000					
			106	10.8000	0.4252	0.4375	-2.8%				24000					
101C			107	10.8000	0.4252	0.4375	-2.8%	0.4252			24000					
			108	10.8000	0.4252	0.4375	-2.8%				24000					

112A			109	10.4000	0.4094	0.4375	-6.4%	0.4094			24000					
			110	10.4000	0.4094	0.4375	-6.4%				24000					
			111	10.4000	0.4094	0.4375	-6.4%				24000					
			112	10.5000	0.4134	0.4375	-5.5%				24000					
112B	1091.5	8.50	113	10.5000	0.4134	0.4375	-5.5%	0.4134	0.4094	472.3906	24000	17487.1	0.73	24981.5	1.04	
			114	10.5000	0.4134	0.4375	-5.5%				24000					
			115	10.8000	0.4252	0.4375	-2.8%				24000					
112C			116	10.8000	0.4252	0.4375	-2.8%	0.4252			24000					
			117	10.8000	0.4252	0.4375	-2.8%				24000					
122A			118	10.4000	0.4094	0.4375	-6.4%	0.4094			24000					
			119	10.4000	0.4094	0.4375	-6.4%				24000					
			120	10.4000	0.4094	0.4375	-6.4%				24000					
			121	10.3000	0.4055	0.4375	-7.3%				24000					
122B	1191	8.50	122	10.3000	0.4055	0.4375	-7.3%	0.4055	0.4055	463.8930	24000	18860.9	0.79	26944.2	1.12	
			123	10.3000	0.4055	0.4375	-7.3%				24000					
			124	10.6000	0.4173	0.4375	-4.6%				24000					
122C			125	10.6000	0.4173	0.4375	-4.6%	0.4173			24000					
			126	10.6000	0.4173	0.4375	-4.6%				24000					
			127	13.8000	0.5433	0.5625	-3.4%				24000					
132A			128	13.1000	0.5157	0.5625	-8.3%	0.4970			24000					
			129	13.2000	0.5197	0.5625	-7.6%				24000					
			130	13.6000	0.5354	0.5625	-4.8%				24000					
132B	1289	8.50	131	13.3000	0.5236	0.5625	-6.9%	0.5102	0.5157	454.4660	24000	15879.9	0.66	22685.5	0.95	
			132	13.2000	0.5197	0.5625	-7.6%				24000					
			133	13.9000	0.5472	0.5625	-2.7%				24000					
132C			134	13.2000	0.5197	0.5625	-7.6%	0.5070			24000					
			135	13.6000	0.5354	0.5625	-4.8%				24000					
			136	13.8000	0.5433	0.5625	-3.4%				24000					assume 0.5625
143A			137	13.1000	0.5157	0.5625	-8.3%	0.4970			24000					
			138	13.2000	0.5197	0.5625	-7.6%				24000					
			139	13.1000	0.5157	0.5625	-8.3%				24000					
143B	1373.25	7.63	140	13.3000	0.5236	0.5625	-6.9%	0.5105	0.5157	431.2495	24000	16565.5	0.69	23665.0	0.99	
			141	13.4000	0.5276	0.5625	-6.2%				24000					
			142	13.5000	0.5315	0.5625	-5.5%				24000					
143C			143	13.6000	0.5354	0.5625	-4.8%	0.5071			24000					
			144	13.1000	0.5157	0.5625	-8.3%				24000					
			145	13.1000	0.5157	0.5625	-8.3%				24000					
153A			146	13.2000	0.5197	0.5625	-7.6%	0.5120			24000					
			147	13.3000	0.5236	0.5625	-6.9%				24000					
			148	13.1000	0.5157	0.5625	-8.3%				24000					
153B	1464.25	7.63	149	13.2000	0.5197	0.5625	-7.6%	0.5120	0.5079	406.1728	24000	19367.4	0.81	27667.7	1.15	
			150	13.3000	0.5236	0.5625	-6.9%				24000					
			151	12.9000	0.5079	0.5625	-9.7%				24000					
153C			152	13.2000	0.5197	0.5625	-7.6%	0.5010			24000					
			153	13.3000	0.5236	0.5625	-6.9%				24000					
			154	13.6000	0.5354	0.5625	-4.8%				24000					
163A			155	13.9000	0.5472	0.5625	-2.7%	0.5286			24000					
			156	14.0000	0.5512	0.5625	-2.0%				24000					
			157	14.1000	0.5551	0.5625	-1.3%				24000					
163B	1552.25	7.63	158	14.2000	0.5591	0.5625	-0.6%	0.5308	0.5354	381.9229	24000	20705.0	0.86	29578.6	1.23	
			159	13.7000	0.5394	0.5625	-4.1%				24000					
			160	13.9000	0.5472	0.5625	-2.7%				24000					
163C			161	14.0000	0.5512	0.5625	-2.0%	0.5435			24000					
			162	14.1000	0.5551	0.5625	-1.3%				24000					
			163	13.5000	0.5315	0.5625	-5.5%				24000					
172A			164	13.4000	0.5276	0.5625	-6.2%	0.5181			24000					
			165	13.8000	0.5433	0.5625	-3.4%				24000					
			166	13.6000	0.5354	0.5625	-4.8%				24000					
172B	1617.5	7.63	167	13.6000	0.5354	0.5625	-4.8%	0.5354	0.5276	368.2970	24000	22345.4	0.93	31921.9	1.33	
			168	13.6000	0.5354	0.5625	-4.8%				24000					
			169	13.5000	0.5315	0.5625	-5.5%				24000					
172C			170	13.5000	0.5315	0.5625	-5.5%	0.5315			24000					
			171	13.5000	0.5315	0.5625	-5.5%				24000					
			172	15.5000	0.6102	0.6250	-2.4%				24000					
183A			173	15.5000	0.6102	0.6250	-2.4%	0.6102			24000					
			174	15.5000	0.6102	0.6250	-2.4%				24000					
			175	15.4000	0.6063	0.6250	-3.0%				24000					
183B	1724.75	7.63	176	15.6000	0.6142	0.6250	-1.7%	0.5961	0.6063	359.9885	24000	20149.7	0.84	28785.3	1.20	
			177	15.9000	0.6260	0.6250	0.2%				24000					
			178	15.4000	0.6063	0.6250	-3.0%				24000					
183C			179	15.5000	0.6102	0.6250	-2.4%	0.5938			24000					
			180	15.9000	0.6260	0.6250	0.2%				24000					
			181	16.8000	0.6614	0.7500	-11.8%				24000					
193A			182	16.9000	0.6654	0.7500	-11.3%	0.6371			24000					
			183	16.4000	0.6457	0.7500	-13.9%				24000					
			184	16.5000	0.6496	0.7500	-13.4%				24000					
193B	1807.5	7.63	185	16.5000	0.6496	0.7500	-13.4%	0.6370	0.6457	352.6436	24000	19507.4	0.81	27867.8	1.16	
			186	16.9000	0.6654	0.7500	-11.3%				24000					
			187	16.9000	0.6654	0.7500	-11.3%				24000					
193C			188	16.9000	0.6654	0.7500	-11.3%	0.6622			24000					
			189	17.0000	0.6693	0.7500	-10.8%				24000					
			190	16.0000	0.6299	0.6875	-8.4%				24000					
203A			191	16.5000	0.6496	0.6875	-5.5%	0.6196			24000					
			192	16.6000	0.6535	0.6875	-4.9%				24000					
			193	15.4000	0.6063	0.6875	-11.8%				24000					
203B	1876.583	7.63	194	15.5000	0.6102	0.6875	-11.2%	0.6025	0.6063	341.6183	24000	21711.5	0.90	31016.4	1.29	
			195	15.6000	0.6142	0.6875	-10.7%				24000					
			196	16.4000	0.6457	0.6875	-6.1%				24000					
203C			197	16.2000	0.6378	0.6875	-7.2%	0.6340			24000					
			198	16.3000	0.6417	0.6875	-6.7%				24000					
			199	15.4000	0.6063	0.5990	1.2%				33333					HSB 50 Steel
211A			200	15.5000	0.6102	0.5990	1.9%	0.5907			33333					
			201	16.0000	0.6299	0.5990	5.2%				33333					
			202	15.6000	0.6142	0.5990	2.5%				33333					
211B	1952.416	7.63	203	15.8000	0.6220	0.5990	3.8%	0.5987	0.6063	329.5158	33333	22740.4	0.68	32486.3	0.97	
			204	15.4000	0.6063	0.5990	1.2%				33333					
			205	16.1000	0.6339	0.5990	5.8%				33333					
211C			206	16.0000	0.6299	0.5990	5.2%	0.6168			33333					
			207	15.8000	0.6220	0.5990	3.8%				33333					
			208	15.4000	0.6063	0.6250	-3.0%				33333					HSB 50 Steel
223A			209	15.5000	0.6102	0.6250	-2.4%	0.5907			33333					
			210	16.0000	0.6299	0.6250	0.8%				33333					
			211	15.6000	0.6142	0.6250	-1.7%				33333					
223B	2071.75	7.63	212	15.8000	0.6220	0.6250	-0.5%	0.5987	0.6063	310.4708	33333	24359.5	0.73	34799.3	1.04	
			213	15.4000	0.6063	0.6250	-3.0%				33333					
			214	16.0000	0.6299	0.6250	0.8%				33333					
223C			215	15.9000	0.6260	0.6250	0.2%	0.6183			33333					
			216	15.8000	0.6220	0.6250	-0.5%				33333					
			217	18.9000	0.7441	0.7500	-0.8%				24000					G 40.8 B
233A			218	18.6000	0.7323	0.7500	-2.4%	0.7188			24000					
			219	18.5000	0.7283	0.7500	-2.9%				24000					
			220	18.9000	0.7441	0.7500	-0.8%				24000					
233B	2165.666	7.63	221	18.4000	0.7244	0.7500	-3.4%	0.7119	0.7244	295.4824	24000	21454.3	0.89	30649.1	1.28	
			222	18.5000	0.7283	0.7500	-2.9%				24000					
			223	18.9000	0.7441	0.7500	-0.8%				24000					
233C			224	18.8000	0.7402	0.7500	-1.3%	0.7215			24000					
			225	18.5000	0.7283	0.7500	-2.9%				24000					
			226	20.2000	0.7953	0.8125	-2.1%				24000					
240A			227	20.4000	0.8031	0.8125	-1.2%	0.7877			24000					
			228	20.6000	0.8110	0.8125	-0.2%				24000					
			229	20.6000	0.8110	0.8125	-0.2%				24000					
240B	2215	7.63	230	20.4000	0.8031	0.8125	-1.2%	0.7995	0.7953	287.6040	24000	20053.2	0.84	28647.4	1.19	
			231	20.6000	0.8110	0.8125	-0.2%				24000					
			232	20.4000	0.8031	0.8125	-1.2%				24000					
240C			233	20.6000	0.8110	0.8125	-0.2%	0.7969			24000					
			234	20.4000	0.8031	0.8125	-1.2%				24000					
			235	16.8000	0.6614	0.6720	-1.6%				33333					HSB 50 Steel
250A			236	16.8000	0.6614	0.6720	-1.6%	0.6614			33333					
			237	16.8000	0.6614	0.6720	-1.6%				33333					
			238	16.8000	0.6614	0.6720	-1.6%				33333					
250B	2333.333	6.75	239	16.8000	0.6614	0.6720	-1.6%	0.6614	0.6535	268.7187	33333	22920.4	0.69	32743.4	0.98	
			240	16.8000	0.6614	0.6720	-1.6%				33333					
			241	16.7000	0.6575	0.6720	-2.2%				33333					
250C			242	16.6000	0.6535	0.6720	-2.7%	0.6498			33333					
			243	16.8000	0.6614	0.6720	-1.6%				33333					

			244	17.3000	0.6811	0.7060	-3.5%				33333					
261A			245	17.4000	0.6850	0.7060	-3.0%	0.6793			33333					
			246	17.4000	0.6850	0.7060	-3.0%				33333					
			247	17.6000	0.6929	0.7060	-1.9%				33333					
261B	2423.5	6.75	248	17.4000	0.6850	0.7060	-3.0%	0.6788	0.6693	254.3286	33333	23362.2	0.70	33374.5	1.00	
			249	17.4000	0.6850	0.7060	-3.0%				33333					
			250	17.0000	0.6693	0.7060	-5.2%				33333					
261C			251	17.0000	0.6693	0.7060	-5.2%	0.6693			33333					
			252	17.0000	0.6693	0.7060	-5.2%				33333					
			253	17.5000	0.6890	0.7390	-6.8%				33333					
271A			254	17.6000	0.6929	0.7390	-6.2%	0.6824			33333					
			255	17.8000	0.7008	0.7390	-5.2%				33333					
			256	17.0000	0.6693	0.7390	-9.4%				33333					
271B	2543.666	6.75	257	17.0000	0.6693	0.7390	-9.4%	0.6693	0.6654	235.1508	33333	24815.6	0.74	35450.9	1.06	
			258	17.0000	0.6693	0.7390	-9.4%				33333					
			259	16.9000	0.6654	0.7390	-10.0%				33333					
271C			260	16.9000	0.6654	0.7390	-10.0%	0.6654			33333					
			261	16.9000	0.6654	0.7390	-10.0%				33333					
			262	19.9000	0.7835	0.7980	-1.8%				33333					
281A			263	19.8000	0.7795	0.7980	-2.3%	0.7718			33333					
			264	19.7000	0.7756	0.7980	-2.8%				33333					
			265	19.0000	0.7480	0.7980	-6.3%				33333					
281B	2624	6.75	266	19.0000	0.7480	0.7980	-6.3%	0.7480	0.7480	222.3300	33333	22854.9	0.69	32649.9	0.98	
			267	19.0000	0.7480	0.7980	-6.3%				33333					
			268	19.4000	0.7638	0.7980	-4.3%				33333					
281C			269	19.4000	0.7638	0.7980	-4.3%	0.7638			33333					
			270	19.4000	0.7638	0.7980	-4.3%				33333					
			271	19.0000	0.7480	0.8290	-9.8%				33333					
291A			272	19.0000	0.7480	0.8290	-9.8%	0.7480			33333					
			273	19.0000	0.7480	0.8290	-9.8%				33333					
			274	18.9000	0.7441	0.8290	-10.2%				33333					
291B	2720.5	6.75	275	18.9000	0.7441	0.8290	-10.2%	0.7441	0.7441	209.8372	33333	23741.9	0.71	33917.0	1.02	
			276	18.9000	0.7441	0.8290	-10.2%				33333					
			277	19.0000	0.7480	0.8290	-9.8%				33333					
291C			278	19.0000	0.7480	0.8290	-9.8%	0.7480			33333					
			279	19.0000	0.7480	0.8290	-9.8%				33333					
			280	21.3000	0.8386	0.8540	-1.8%				33333					
300A			281	21.2000	0.8346	0.8540	-2.3%	0.8328			33333					
			282	21.3000	0.8386	0.8540	-1.8%				33333					
			283	21.1000	0.8307	0.8540	-2.7%				33333					
300B	2811.666	6.75	284	21.2000	0.8346	0.8540	-2.3%	0.8289	0.8307	202.2531	33333	21683.1	0.65	30975.8	0.93	
			285	21.2000	0.8346	0.8540	-2.3%				33333					
			286	21.3000	0.8386	0.8540	-1.8%				33333					
300C			287	21.3000	0.8386	0.8540	-1.8%	0.8386			33333					
			288	21.3000	0.8386	0.8540	-1.8%				33333					
			289	22.7000	0.8937	0.9040	-1.1%				33333					
310A			290	22.7000	0.8937	0.9040	-1.1%	0.8937			33333					
			291	22.7000	0.8937	0.9040	-1.1%				33333					
			292	22.5000	0.8858	0.9040	-2.0%				33333					
310B	2923.5	6.75	293	22.5000	0.8858	0.9040	-2.0%	0.8858	0.8819	192.9496	33333	20906.0	0.63	29865.8	0.90	
			294	22.5000	0.8858	0.9040	-2.0%				33333					
			295	22.4000	0.8819	0.9040	-2.4%				33333					
310C			296	22.4000	0.8819	0.9040	-2.4%	0.8819			33333					
			297	22.4000	0.8819	0.9040	-2.4%				33333					
			298	23.3000	0.9173	0.9290	-1.3%				33333					
321A			299	22.6000	0.8898	0.9290	-4.2%	0.8710			33333					
			300	22.7000	0.8937	0.9290	-3.8%				33333					
			301	22.4000	0.8819	0.9290	-5.1%				33333					
321B	3039.5	6.75	302	23.0000	0.9055	0.9290	-2.5%	0.8640	0.8819	183.2996	33333	21405.3	0.64	30579.1	0.92	
			303	23.4000	0.9213	0.9290	-0.8%				33333					
			304	23.2000	0.9134	0.9290	-1.7%				33333					
321C			305	22.4000	0.8819	0.9290	-5.1%	0.8610			33333					
			306	23.6000	0.9291	0.9290	0.0%				33333					
			307	24.6000	0.9685	0.9540	1.5%				33333					
331A			308	24.2000	0.9528	0.9540	-0.1%	0.9401			33333					
			309	24.9000	0.9803	0.9540	2.8%				33333					
			310	24.0000	0.9449	0.9540	-1.0%				33333					
331B	3125.166	6.75	311	24.3000	0.9567	0.9540	0.3%	0.9335	0.9449	176.1730	33333	20322.5	0.61	29032.1	0.87	
			312	24.6000	0.9685	0.9540	1.5%				33333					
			313	25.1000	0.9882	0.9540	3.6%				33333					
331C			314	25.2000	0.9921	0.9540	4.0%	0.9817			33333					
			315	25.4000	1.0000	0.9540	4.8%				33333					
			316	25.6000	1.0079	0.9790	2.9%				33333					
340A			317	25.5000	1.0039	0.9790	2.5%	1.0008			33333					
			318	25.5000	1.0039	0.9790	2.5%				33333					
			319	25.3000	0.9961	0.9790	1.7%				33333					
340B	3226.333	6.75	320	25.4000	1.0000	0.9790	2.1%	0.9773	0.9961	167.7570	33333	19663.8	0.59	28091.1	0.84	
			321	26.0000	1.0236	0.9790	4.6%				33333					
			322	25.3000	0.9961	0.9790	1.7%				33333					
340C			323	25.4000	1.0000	0.9790	2.1%	0.9929			33333					
			324	25.3000	0.9961	0.9790	1.7%				33333					
			316	25.4000	1.0000	1.0250	-2.4%				33333					
351A			317	25.4000	1.0000	1.0250	-2.4%	0.9827			33333					
			318	25.1000	0.9882	1.0250	-3.6%				33333					
			319	26.0000	1.0236	1.0250	-0.1%				33333					
351B	3320.5	6.75	320	26.0000	1.0236	1.0250	-0.1%	1.0236	0.9882	149.6409	33333	20657.0	0.62	29510.0	0.89	
			321	26.0000	1.0236	1.0250	-0.1%				33333					
			322	25.4000	1.0000	1.0250	-2.4%				33333					
351C			323	25.4000	1.0000	1.0250	-2.4%	1.0000			33333					
			324	25.4000	1.0000	1.0250	-2.4%				33333					
			325	27.0000	1.0630	1.0610	0.2%				33333					
360A			326	27.1000	1.0669	1.0610	0.6%	1.0592			33333					
			327	27.2000	1.0709	1.0610	0.9%				33333					
			328	26.8000	1.0551	1.0610	-0.6%				33333					
360B	3409.416	6.75	329	26.2000	1.0315	1.0610	-2.8%	1.0159	1.0315	127.2600	33333	20779.8	0.62	29685.4	0.89	
			330	26.3000	1.0354	1.0610	-2.4%				33333					
			331	26.9000	1.0591	1.0610	-0.2%				33333					
360C			332	26.8000	1.0551	1.0610	-0.6%	1.0474			33333					
			333	26.7000	1.0512	1.0610	-0.9%				33333					
			334	28.0000	1.1024	1.0950	0.7%				33333					
369A			335	28.0000	1.1024	1.0950	0.7%	1.1024			33333					
			336	28.0000	1.1024	1.0950	0.7%				33333					
			337	27.1000	1.0669	1.0950	-2.6%				33333					
369B	3477.75	6.75	338	27.1000	1.0669	1.0950	-2.6%	1.0669	1.0669	110.0598	33333	20825.3	0.62	29750.4	0.89	
			339	27.1000	1.0669	1.0950	-2.6%				33333					
			340	27.5000	1.0827	1.0950	-1.1%				33333					
369C			341	27.5000	1.0827	1.0950	-1.1%	1.0827			33333					
			342	27.5000	1.0827	1.0950	-1.1%				33333					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$

[2] Hoop stress / S_A

[3] Hoop stress / 0.7 $_{\text{joint efficiency}}$

[4] Joint stress / S_A

Minimum Wall Thickness	
All	0.3976
17dia	0.3976
15.25dia	0.5079
13.5dia	0.6535

EXTERNAL PRESSURES EVALUATION- PENSTOCK 2 BAY D'ESPOIR

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 17 feet								
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_i=	0	
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	Fill Unit Weight=	120	lb/ft^3
OD Conduit Diameter=	17.06626667	feet	ID:	17.00	feet	(soil load) W_c=	6655.8	lb/ft
		Assume well				(live load) W_l=	1706.6	lb/ft
Buoyancy Factor R_w=	1	drained = 1				W_c=	351.7	lb/ft
B_prime=	0.23302752					W_{steel}=	957.8	lb/ft
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf
E=	30000000	psi						
b=	1					External pressure with vacuum=	**3.10**	psi
(Minimum measured wall thickness) t_{MIN}=	0.3976	inches				[1]External pressure with snow load=	**3.24**	psi
I=	0.0052	inches^4				[1]External pressure with snow and live=	**3.72**	psi
[1,2]FS=	2							
[2]Allowable pressure q_a=	**4.11**	psi						

Ratio Q/q_a=	0.754129
Ratio Q/q_a=	0.788968
Ratio Q/q_a=	0.907038

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 15.25 feet								
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_i=	0	
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3
Total Height of Soil=	3	feet	(for DL calc) t=	1.19	inches	Fill Unit Weight=	120	lb/ft^3
OD Conduit Diameter=	15.33465	feet	ID:	15.25	feet	(soil load) W_c=	5980.5	lb/ft
		Assume well				(live load) W_l=	1533.5	lb/ft
Buoyancy Factor R_w=	1	drained = 1				W_c=	316	lb/ft
B_prime=	0.2330					W_{steel}=	2336	lb/ft
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf
E=	30000000	psi						
b=	1					External pressure with vacuum=	**3.76**	psi
(Minimum measured wall thickness) t_{MIN}=	0.5079	inches				[1]External pressure with snow load=	**3.91**	psi
I=	0.0109	inches^4				[1]External pressure with snow and live=	**4.39**	psi
[1,2]FS=	2							
[2]Allowable pressure q_a=	**6.94**	psi						

100 psf per foot section

Ratio Q/q_a=	0.542156
Ratio Q/q_a=	0.56276
Ratio Q/q_a=	0.632584

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 13.5 feet								
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_i=	0	
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	Fill Unit Weight=	120	lb/ft^3
OD Conduit Diameter=	13.60891667	feet	ID:	13.50	feet	(soil load) W_c=	5307.5	lb/ft
		Assume well				(live load) W_l=	1360.9	lb/ft
Buoyancy Factor R_w=	1	drained = 1				W_c=	280.5	lb/ft
B_prime=	0.23302752					W_{steel}=	2836.9	lb/ft
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf
E=	30000000	psi						
b=	1					External pressure with vacuum=	**4.15**	psi
(Minimum measured wall thickness) t_{MIN}=	0.6535	inches				[1]External pressure with snow load=	**4.30**	psi
I=	0.0233	inches^4				[1]External pressure with snow and live=	**4.78**	psi
[1,2]FS=	2							
[2]Allowable pressure q_a=	**12.07**	psi						

Ratio Q/q_a=	0.34397
Ratio Q/q_a=	0.355816
Ratio Q/q_a=	0.395962

References:

[1]ASCE No. 79, Steel Penstocks, 2nd Edition, 2012

[2]AWWA M11, Steel Pipe - A Guide for Design and Installation, current version.

Can	Max Joint Stress (psi)	Dynamic Hoop Stress Increase (psi)	Total Water Hammer Stress (psi)	Allowable Stress (psi)	Stress Ratio (Joints)	Yield Stress (psi)	Factor of Safety Against Yield (Joints)	Base Material Stress (Surge)	Stress Ratio (Base Material - Surge)	Factor of Safety (Base Material)
1	5,934.6	1,780.4	7,715.0	17,000	0.45	26,000	3.37	5,400.5	0.32	4.81
6	5,426.1	1,627.8	7,054.0	17,000	0.41	26,000	3.69	4,937.8	0.29	5.27
16	6,461.0	1,938.3	8,399.3	17,000	0.49	26,000	3.10	5,879.5	0.35	4.42
26	7,026.2	2,107.9	9,134.1	17,000	0.54	26,000	2.85	6,393.9	0.38	4.07
35	8,502.8	2,550.8	11,053.7	17,000	0.65	26,000	2.35	7,737.6	0.46	3.36
45	9,990.5	2,997.1	12,987.6	17,000	0.76	26,000	2.00	9,091.3	0.53	2.86
55	11,698.4	3,509.5	15,207.9	17,000	0.89	26,000	1.71	10,645.5	0.63	2.44
65	13,165.2	3,949.6	17,114.7	17,000	1.01	26,000	1.52	11,980.3	0.70	2.17
74	14,497.2	4,349.2	18,846.4	17,000	1.11	26,000	1.38	13,192.5	0.78	1.97
81	15,437.2	4,631.2	20,068.4	17,000	1.18	26,000	1.30	14,047.9	0.83	1.85
91	16,780.1	5,034.0	21,814.1	17,000	1.28	26,000	1.19	15,269.9	0.90	1.70
101	17,945.9	5,383.8	23,329.6	24,000	0.97	40,000	1.71	16,330.7	0.68	2.45
112	19,216.6	5,765.0	24,981.5	24,000	1.04	40,000	1.60	17,487.1	0.73	2.29
122	20,726.3	6,217.9	26,944.2	24,000	1.12	40,000	1.48	18,860.9	0.79	2.12
132	17,450.4	5,235.1	22,685.5	24,000	0.95	40,000	1.76	15,879.9	0.66	2.52
143	18,203.8	5,461.1	23,665.0	24,000	0.99	40,000	1.69	16,565.5	0.69	2.41
153	21,282.8	6,384.8	27,667.7	24,000	1.15	40,000	1.45	19,367.4	0.81	2.07
163	22,752.8	6,825.8	29,578.6	24,000	1.23	40,000	1.35	20,705.0	0.86	1.93
172	24,555.3	7,366.6	31,921.9	24,000	1.33	40,000	1.25	22,345.4	0.93	1.79
183	22,142.5	6,642.8	28,785.3	24,000	1.20	40,000	1.39	20,149.7	0.84	1.99
193	21,436.7	6,431.0	27,867.8	24,000	1.16	38,000	1.36	19,507.4	0.81	1.95
203	23,858.8	7,157.6	31,016.4	24,000	1.29	38,000	1.23	21,711.5	0.90	1.75
211	24,989.4	7,496.8	32,486.3	33,333	0.97	50,000	1.54	22,740.4	0.68	2.20
223	26,768.7	8,030.6	34,799.3	33,333	1.04	50,000	1.44	24,359.5	0.73	2.05
233	23,576.2	7,072.9	30,649.1	24,000	1.28	38,000	1.24	21,454.3	0.89	1.77
240	22,036.5	6,610.9	28,647.4	24,000	1.19	38,000	1.33	20,053.2	0.84	1.89
250	25,187.3	7,556.2	32,743.4	33,333	0.98	50,000	1.53	22,920.4	0.69	2.18
261	25,672.7	7,701.8	33,374.5	33,333	1.00	50,000	1.50	23,362.2	0.70	2.14
271	27,269.9	8,181.0	35,450.9	33,333	1.06	50,000	1.41	24,815.6	0.74	2.01
281	25,115.3	7,534.6	32,649.9	33,333	0.98	50,000	1.53	22,854.9	0.69	2.19
291	26,090.0	7,827.0	33,917.0	33,333	1.02	50,000	1.47	23,741.9	0.71	2.11
300	23,827.5	7,148.3	30,975.8	33,333	0.93	50,000	1.61	21,683.1	0.65	2.31
310	22,973.7	6,892.1	29,865.8	33,333	0.90	50,000	1.67	20,906.0	0.63	2.39
321	23,522.4	7,056.7	30,579.1	33,333	0.92	50,000	1.64	21,405.3	0.64	2.34
331	22,332.4	6,699.7	29,032.1	33,333	0.87	50,000	1.72	20,322.5	0.61	2.46
340	21,608.5	6,482.6	28,091.1	33,333	0.84	50,000	1.78	19,663.8	0.59	2.54
351	22,700.0	6,810.0	29,510.0	33,333	0.89	50,000	1.69	20,657.0	0.62	2.42
360	22,834.9	6,850.5	29,685.4	33,333	0.89	50,000	1.68	20,779.8	0.62	2.41
369	22,884.9	6,865.5	29,750.4	33,333	0.89	50,000	1.68	20,825.3	0.62	2.40

Schedule 1, Attachment 8

Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project

Kleinschmidt Associates

September 2022

newfoundland labrador hydro

PENSTOCK 3 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
Kleinschmidt Associates

Kleinschmidt

September 2022

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in December of 2021 to inspect and evaluate the condition of Penstocks No. 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development in 2022.

In 2016, cracking was identified in Penstock 1 and Kleinschmidt assisted NLH with the inspection and weld repair design. Penstock 1 was repaired the same year as the inspection. Kleinschmidt inspected Penstock 2 later in 2016 and discovered similar weld deterioration of Penstock 2, which was repaired in 2017. Subsequent to the previous inspections of Penstock 1 and 2, deteriorated welds were repaired in Penstock 3 after inspection in 2018. This is not the full history of issues and repairs for the penstocks but is intended to show a pattern of weld related issues.

As indicated in the record drawings, Penstock 3 was installed in 1968, a year after the Penstock 1 and 2, using similar plate materials, thicknesses, and weld procedures. Due to the three penstocks being of similar age and design and because of the identified weld deterioration and corrosion, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock 3 inspection was to assess the integrity of the welds and complete steel thickness measurements to evaluate metal loss and corrosion to determine if the penstock condition is acceptable to operate through another calendar year.

An inspection of Penstock 3 was conducted by Kleinschmidt in May 2022, which consisted of a visual walk-over of the penstock exterior, and a detailed evaluation of the condition of the interior of the penstock. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which consisted of cleaning and visually inspecting a percentage of the steel shell and the longitudinal and circumferential welds. Non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell were performed during the inspection.

The 2022 inspection revealed some loss of material thickness of the penstock shell. The plate thickness was comparable to the record drawings, and the interior of the shell displayed a layer of rust with moderate corrosion and pitting common for a 50-year-old

penstock. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3.

Active but slight seepage was identified coming through the welded joints at the penstock to surge tank transition again this year. Efflorescence and water were observed coming into the penstock from the exterior. This indicates the presence of cracks at the weld locations. This is not a cause for immediate repair as the area is fully encased in concrete mitigating the possibility of a significant breach, but it does further indicate the need for weld refurbishment.

The sinkhole discovered in 2019 downstream of the surge tank on the left side of the penstock has been filled in previous years and appears to have stabilized. The area should continue to be monitored for further erosion.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.52. This indicates that the penstock in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.05, which is not acceptable for late 1960 steel pipe. The calculated stresses at the joints assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used for the analysis, as discussed in Section 4, if RT weld testing is performed to verify the integrity of the welds. A higher joint efficiency would result in favourable factors of safety; however, considering the known weld deterioration, a higher joint efficiency is not justified at this time.

The base plate material away from the joints has a maximum stress ratio of 1.07 and a safety factor of 1.47, which is acceptable and could tolerate 3 mm (1/8 inches) of material loss from design thickness in most cases.

This approximately 50-year-old penstock has shown some loss of thickness from the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has approximately an additional 50 years of useful service life (est. 2070) with a new coating. However, because of the condition of the existing welds, the 17-ft section of penstock will need to be replaced, the remaining penstock welds refurbished, and the interior re-coated before the steel deteriorates further.

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ACRONYMS

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
CI	confidence interval
CH	Chainage (in metres)
cms	Cubic Metres per Second
ETS	EasternTechnical Services Ltd.
Fu	Ultimate Tensile Stress
Fy	Yield Stress
GWh	Gigawatt Hours
kPa	Kilo-Pascals
Kleinschmidt	Kleinschmidt Associates
MW	Megawatts
NDT	non-destructive testing
NLH	Newfoundland and Labrador Hydro
SPRAT	Society of Professional Rope Access Technicians
STA	Station (in feet)
TRR	Technical Rope and Rescue
UT	Ultrasonic Thickness

1.0 INTRODUCTION

In 2016, cracking was identified by Newfoundland and Labrador Hydro (NLH) in Penstock 1 due to weld degradation and Kleinschmidt assisted with inspection and a weld repair design. However, the discovery of an additional indication in Penstock 1 prompted a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods.

NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished. The focus of the Penstock 3 inspection in 2022 was to assess the integrity of the welds and to complete steel plate thickness measurements to evaluate the current condition of the steel. The 2022 inspection concentrated on welds that have never been inspected downstream of the surge tank and welds not inspected during the previous year in the upper end of the penstock. Approximately 10 percent of the longitudinal welds were tested along the penstock.

The May 2022 inspection of Penstock 3 consisted of weld inspections and steel plate thickness measurements completed by Eastern Technical Services (ETS) and Technical Rope and Rescue (TRR). Kleinschmidt engineer Chris Vella travelled to the Bay d'Espoir Hydro Site to complete an interior and exterior condition assessment of the penstock and assist with the weld inspection.

This report presents our evaluation of the capacity of the penstock in its current condition, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 ft (176 metres [m]) and seven generating units with a total capacity of 604 megawatts (MW). The hydro development is comprised of four intake structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks Nos. 1, 2, and 3 have surge towers approximately 2,400 ft (727 m) upstream of the powerhouse. The first phase of the initial project construction included installation of two intake structures and a four-unit powerhouse with Penstocks 1 and 2 connecting the two intakes to the powerhouse. The second phase of the project consisted of installing Penstock 3 with a third intake and two additional units in the powerhouse. A separate intake structure and powerhouse for Unit No. 7, connected by Penstock 4 was built in 1970. Penstock 3 supplies Units No. 5 and No. 6. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock 3 is a 1,100-m-long buried steel penstock, tapering from 5.2 m in diameter (at the intake) to 4.1 m in diameter at the powerhouse bifurcation. At the flattest point, the penstock has a 0.0% slope and has a 20% slope at the steepest. There are at least three areas to access the interior of Penstock 3, one at the well in the intake structure, three manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Appendix A includes the original 1968 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 7/16 inches at the intake to 1 5/8 inches at the bifurcation upstream of the powerhouse (plate thicknesses in this report are expressed in inches to match the drawings provided). The penstock is constructed of A285, G40.88 and HSB 50 steel. The penstock is 17.0 ft (5.2 m) in diameter until STA 12+41 (CH 376.2), 15.25 ft (4.6 m) in diameter between STA 12+41 (CH 376.2) and STA 27+50 (CH 833.3) where it then reduces to 13.5 ft (4.1 m) in diameter for the remaining 1,581 ft (479.1 m) to the bifurcation. The welds are double V groove full penetration welds.

A majority of the penstock has a cover of 2 ft (0.61 m) of clayey soil and 1 ft (0.30 m) minimum thick layer of riprap. The penstock crosses underneath the switchyard and terminates at the powerhouse. Several weirs are located where the drainage daylights to the ditches and wells for inspection and monitoring purposes.

3.0 INSPECTION

Christopher Vella, P.Eng., inspected the interior and exterior of Penstock 3 on May 23 and 24, 2022, with the assistance of personnel from TRR, ETS, and NLH. Ray Buffett of NLH participated in safety talks and assisted with site access and communication. NLH were present to answer questions about the history, operation, and maintenance of the station. ETS assisted with the ultrasonic thickness (UT) and MT testing of the penstock steel and welds. TRR rope access personnel assisted with safe access, confined space entry protocols, communication, and provided standby at the penstock entry for rescue.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying any pitting or cracking, and an overall general condition assessment of the interior of the shell. ETS personnel performed MT weld tests on approximately 10% of the longitudinal welds overall. ETS also took UT measurements from approximately 10% of the Cans[1].

The exterior of the buried penstock was examined for signs of leakage. For this inspection, all references to penstock left and right are oriented looking downstream.

Table 3-1 Definitions for Condition Assessment

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required.
Good	General or light deterioration where performance is not affected, and remedial action is not expected to be required in the next 10 years.
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years.
Poor	Significant deterioration is visible, and remediation is required in the next 1 to 5 years.
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year.

[1] A Can, referred to in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used in this report to reference location within the penstock during the inspection, with Can No. 1 located at the upstream end of the penstock at the intake.

References to right and left are from the perspective of someone looking downstream unless noted otherwise.

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on the morning of Monday, May 23, 2022. The inspection team entered the penstock on the same day at the upstream most manhole (manhole #1) of Penstock 3. TRR assisted with confined space entrance and rigging for fall protection. The internal inspection finished on Tuesday May 24, 2022. The exterior inspection commenced on Tuesday May 24, 2022 and was completed by Kleinschmidt the same day. Kleinschmidt pre-marked welds to be inspected inside of the penstock so TRR and ETS could proceed with the internal inspection and weld testing while Kleinschmidt performed the external inspection. Air quality in the penstock remained good for the duration of the inspection.

The internal penstock inspection commenced at the headgate location. The headgate was replaced in 2021 and had very little leakage. The water running along the invert of the penstock was the lowest amount observed by Mr. Vella in any of the penstocks since this program of inspections began (Photo 1, Appendix B). Leakage was observed through some of the bolted connections on the gate as seen in Photos 2 and 3, Appendix B. There was spray leakage from the 9th and 16th bolts on the bottom seal counted from the north side. The interior surface of the penstock was mostly damp with dry areas around the access holes. Much of the organics upstream of the surge tank has been removed during previous penstock weld inspections and repairs, which facilitated the current inspection. More effort was required downstream of the surge tank to remove organics and clean welds as there were a greater quantity of existing welds not previously inspected. The penstock was completely dewatered and was inspected to the bifurcation at the downstream end of the penstock.

The exterior inspection was completed in sunny and warm weather conditions. The ground surface was rocky with steep slopes with short vegetation. Some areas were noted to have alder bush growth and taller vegetation that was impeding inspection and sight of the ground surface (Photo 32). The ground was reasonably dry reducing slip potential. There were areas of saturated soil on the left-hand side of the penstock located adjacent of the surge tank, which was previously noted in previous inspections. The grade followed

the penstock slope between the intake and the switchyard. The deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 Interior Inspection

The interior of the penstock was inspected from May 23 to 24. The penstock consists of approximately 435 "Cans" into the powerhouse scroll case. A Can, referred to in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used in this report to reference location within the penstock during the inspection, with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded at the interior surface at approximately 10 Can intervals. Shell thickness measurements were taken by ETS with a Krautkramer DMS 2 digital Ultrasonic thickness gauge (S/N 01YL2P). A dual element Krautkramer TC560 transducer (S/N 14A01G28) was used. The gauge was calibrated before the field measurements to an accuracy of 0.001 inch using a calibrated steel bar. Improved thickness reading confidence may be achieved by calibrating the UT gauge with the same material as the penstock; A285 and G40.88 steel. A sample of each penstock steel material can be machined to various thicknesses for the purpose of steel thickness calibration of the UT gauge. Kleinschmidt recommends calibration improvements moving forward for the 2023 penstock inspections. Due to the fact that both the field measurements and Appendix A drawings give shell thicknesses in inches, the evaluation and analysis was completed in Imperial units. Metric equivalents are provided in parenthesis where required.

Thickness readings were recorded from the interior of the penstock typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the penstock. Throughout the inspection, Kleinschmidt took UT thickness readings for the purpose of quality control and to compare results to the ETS readings. All recorded readings by Kleinschmidt were on average 0.5 mm (1/64 inch) greater than the readings recorded by ETS. This difference is not ideal and is likely caused by the different transducers, calibration steel, and UT units. However, this is not detrimental to the analysis and the thinner ETS values are used in the analysis. Appendix D provides the ETS report of shell thickness readings and Table D-1 and Table D-2 in Appendix D summarizes the

average shell thickness readings and stresses respectively for each section of penstock. A summary of this data is provided in Table 4-1.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

Penstock 3 is fabricated from 30 different plate sizes ranging from 7/16 to 1 5/8 inches with 21 of these plate sizes occurring downstream of the surge tank. Inspection thickness readings were taken of 7 different plate sizes upstream of the surge tank, ranging from 7/16-inch (11 mm) to 3/4-inch (19 mm). The average change in material thickness upstream of the surge tank was found to be approximately 4.9% thinner than design. The steel plate thicknesses below the surge tank range from 0.638 inches (16 mm) to 1.625 inches (41 mm). The average change in material thickness below the surge tank was found to be approximately 8.1% thinner than design. Appendix D provides the ETS report of the MP and UT testing.

The interior of the penstock is generally in fair condition with consistent moderate corrosion and pitting with tubercles and growth (Photos 4 to 6). Pitting was moderate, relative to the plate thickness, and detailed pit measurements were not taken. A significant number of weld repairs were observed, and the previous weld repair work made this inspection a little easier as much of the organic build-up had been previously removed. Organic build-up downstream of Can 195 was fairly heavy making it more difficult to find some of the original welds.

The repaired welds were in good condition and the original welded joints were in fair condition and did not have any apparent indications or excessive deterioration (Photos 8 to 17). One original circumferential weld located between Cans 192 and 193 on the south side had some undercutting identified as an indication noted in the weld test report in Appendix C (Photo 18). A steel geologists hammer was used to impact the weld to determine if the weld cap would separate from the weld or penstock steel. The weld did not separate after several strikes of the hammer.

The repaired welds from 2018 were in good condition and relatively clean with some surface rust and organic buildup. The repaired welds were all marked showing that they had been tested, marked "MT OK" with a date, and retested, marked "Final MT OK" before Penstock 3 was returned to service. The 2022 inspection of the welds was concentrated

on the unrepaired welds but also included several of the repaired welds. The welds in Penstock 3 were cleaned using a grinder with a wire brush wheel attachment then wiped clean and painted with a white contrast paint to facilitate the MP weld test. MP testing included 73 full length longitudinal welds and a few feet of 146 circumferential welds. An initial visual inspection of the weld was conducted concentrating on condition of the bead in regard to pitting, corrosion or cracking, and undermining or washout. The welds were also impacted with a geologists hammer to assess the integrity of the weld joints. Corrosion of the original welds was fair for all welds inspected with light to moderate pitting. The new or repaired welds were in good condition with only insignificant surface rust just starting and no degradation. No indications or significant issues were identified.

3.2.2 Surge Tank Transition

During the 2021 inspection of Penstock 3, the surge tank transition welds were observed to be leaking. The current inspection of the welds on the downstream section of the transition showed the welds were leaking (Photo 19 to 22). Efflorescence was observed surrounding the area of the welds that were leaking water suggesting the water is coming through or along the concrete block at the base of the surge tank. It is recommended that these welds be repaired in the next 3 to 5 years. Due to the surge tower transition piece being encased in concrete, it is unlikely that a rupture will occur; however, leakage between the steel and the concrete encasement may result in erosion of the concrete, deterioration of the rebar in the concrete, and eventually propagate to the surrounding soil if not repaired.

3.2.3 Appurtenances

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock 3 has three large manholes and a bifurcation at the powerhouse.

Manholes 1, 2, and 3 were moderately corroded and were in fair condition. Manhole 1 was missing the bottom plate.

The penstock drainage pipes and culverts were noted to be in fair condition. Drainage weir N-1 located in a wooden shack, was in fair condition and had clear water running at about 6 gallons per minute (gpm) (Photos 23 and 24). Vegetation overgrowth surrounding the shack last year had been cleared making the inspection this year easier. The culverts

in the drainage ditch immediately upstream of weir N-1 were noted to be clean and flowing well.

Drainage weir N-2 was in fair condition and had about 8 gpm of flowing through the weir (Photos 25 and 26). It should be noted that it rained lightly the previous day. Light moss growth was noted within the drainage pipe but not enough to impede the weir. The drainage layout is depicted along the length of the penstock in Drawing F2106-C-1 (Appendix A); however, the termination of the drainage plumbing, and weirs are not shown.

A drainage culvert was found along the left side of the penstock just upstream of the surge tank access road (Photo 27). The culvert was mostly buried in dirt, leafy debris, and moss. The culvert is hard to find as it is hidden in the alders and bushes. The culvert should be cleaned out and ditched to drain.

The unlabeled weir at about Station 0+710 is full of sediment, small gravel, and sand (Photo 28). Flow from the culvert is partially bypassing the weir box at the upstream right end where the box is not seal. The weir box should be emptied and repaired.

The culvert at about Station 0+900 has had the swale recently ditched and cleaned out (Photo 29); however, the end of the pipe is partially blocked by mud left by excavator (Photo 30). The end of the pipe should be cleaned to flow free.

3.3 Exterior Inspection

Kleinschmidt began the exterior inspection on May 24th at the intake and proceeded to move downstream. The inspection was completed the same day and terminated at the switchyard. The interior weld testing and UT measurements performed by ETS continued inside the penstock while Mr. Vella walked the exterior. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 31 to 35. Kleinschmidt observed the exterior ground surface for evidence of signs of leakage such as sloughing of the soil or depressions while walking the length of the penstock. No obvious indications were observed during the 2022 exterior inspection of the penstock. There is a wet area to the left of the surge tank that was wet this year exacerbated by rain the previous day (Photo 34). The wet area has been noted in the previous inspections. It is believed the water is rain runoff and ground water from the adjacent hill.

During the 2019 exterior inspection of the penstock, a sink hole was discovered 9 ft downstream of the surge tank concrete encasement, located on the left side of the penstock. The hole was about 4 ft in diameter and 4 ft deep and was filled following the finding and according to Ray Buffet was refilled the next year following further settlement. The area was reviewed this year and was observed to have stabilized with no further settlement or material loss. The alders surrounding the area had been trimmed back per last year's recommendation allowing for easier inspection.

There is an observation well about 20 ft downstream of the surge tank on the left side. No flow was observed; however, there was stagnant water in the bottom of the well. The recent sink hole discovered in 2019 and visual evidence of previous settlement in the area suggest that the drainage system in the area is not functioning properly. It was recommended that the drainage system be inspected. It was noted by Ray Buffet that some of the drainage system was inspected, and no issues were found.

The ditching on the left side of Penstock 3 should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage.

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No.79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix D. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 and 24,000 psi was used for CSA G40.8 Grade B. The yield strength of HSB 50 was assumed to be 50,000 psi; however, no reference was located for this value. No ultimate tensile strength was assumed so that allowable stresses in the evaluation were based on the yield strength criteria for HSB 50 steel (33,333 psi).

The strength of the welded seams are reduced compared to the base material. The strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used for the analysis if weld testing is performed to verify the integrity of the welds. As per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds requiring higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- stresses in the penstock under flood conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the analysis of steel shell thickness data and internal pressure steel stress analysis results. See Appendix C for detailed thickness data and stress calculations.

The minimum thickness measurement for each penstock Can was used to calculate the allowable stresses within each penstock section. To calculate the allowable stresses, the minimum thickness measurement was used in contrast to the 97.5% confidence interval (CI) used in previous years. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

Three thickness measurements were taken at each location, A, B, and C, for each Can that was inspected with a UT gauge, with nine thickness measurements in total for each Can. When analyzing the thickness measurements using the 97.5% CI method, the calculated thickness was significantly less when compared to the minimum measured thicknesses. When the 97.5% CI is applied to a small data group, such as three to nine thickness measurements, it results in wide confidence intervals. Using the minimum steel-shell thickness measurement for the purpose of analysis in lieu of the 97.5% CI thickness, we feel is representative of the remaining penstock plate thickness.

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 ft (182 m) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 ft (271 m) at the powerhouse and linearly reducing to 660 (201 m) ft at the surge tower and then matching the FSL of 597 ft (182 m) at the intake. The maximum joint stress ratio is 1.52 for increased surge, is greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.05, unacceptable for late 1960 steel pipe. However, an increase in the joint efficiency through weld testing that would verify the joints integrity could potentially improve these values. For the plate steel away from the joints, the material has a maximum stress ratio of 1.07 and a minimum safety factor of 1.47, which is acceptable for present day design.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Max Joint Stress (psi)	Base Material Stress[1,3] (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress [1,3] (psi)	Allowable Stress (psi)	Joint Stress Ratio[1,2,3]	Base Material Stress Ratio[2,3]	Factor of Safety Against Yield[4] (Joints)	Factor of Safety Against Yield[4] (Base Material)
4	6,003	5,463	1,801	7,804	17,000	0.46	0.32	3.33	4.76
15	7,687	6,995	2,306	9,993	17,000	0.59	0.41	2.60	3.72
25	8,775	7,986	2,633	11,408	17,000	0.67	0.47	2.28	3.26
33	9,953	9,057	2,986	12,938	17,000	0.76	0.53	2.01	2.87
44	11,330	10,310	3,399	14,729	17,000	0.87	0.61	1.77	2.52
54	13,135	11,953	3,940	17,075	17,000	1.00	0.70	1.52	2.18
63	14,328	13,038	4,298	18,626	17,000	1.10	0.77	1.40	1.99
72	15,220	13,851	4,566	19,787	17,000	1.16	0.81	1.31	1.88
84	17,254	15,701	5,176	22,430	17,000	0.93	0.65	1.16	1.66
93	18,443	16,783	5,533	23,976	17,000	1.00	0.70	1.08	1.55
102	19,449	17,698	5,835	25,284	17,000	1.05	0.74	1.03	1.47
113	19,480	17,727	5,844	25,324	17,000	1.06	0.74	1.58	2.26
123	20,797	18,925	6,239	27,036	17,000	1.13	0.79	1.48	2.11
135	20,152	18,339	6,046	26,198	24,000	1.09	0.76	1.53	2.18
145	22,972	20,905	6,892	29,864	24,000	1.24	0.87	1.34	1.91
155	23,866	21,718	7,160	31,026	24,000	1.29	0.90	1.29	1.84
164	23,804	21,662	7,141	30,946	24,000	1.29	0.90	1.29	1.85
176	23,216	21,127	6,965	30,181	24,000	1.26	0.88	1.33	1.89
188	23,105	21,025	6,931	30,036	24,000	1.25	0.88	1.33	1.90
198	25,608	23,303	7,682	33,291	24,000	1.39	0.97	1.20	1.72
206	25,639	23,331	7,692	33,331	24,000	1.39	0.97	1.14	1.63
213	26,839	24,423	8,052	34,890	24,000	1.45	1.02	1.09	1.56
225	22,174	20,179	6,652	28,827	24,000	1.20	0.84	1.73	2.48
235	18,578	16,906	5,573	24,152	24,000	1.01	0.70	2.07	2.96
245	26,411	24,034	7,923	34,334	24,000	1.43	1.00	1.11	1.58
255	26,962	24,535	8,089	35,051	24,000	1.46	1.02	1.08	1.55
263	28,111	25,581	8,433	36,544	24,000	1.52	1.07	1.37	1.95
275	24,668	22,448	7,400	32,068	24,000	1.34	0.94	1.56	2.23
283	25,762	23,444	7,729	33,491	24,000	1.40	0.98	1.49	2.13
293	24,161	21,987	7,248	31,410	24,000	1.31	0.92	1.59	2.27
304	24,373	22,179	7,312	31,685	24,000	1.32	0.92	1.58	2.25
313	24,251	22,069	7,275	31,527	24,000	1.31	0.92	1.59	2.27
323	24,080	21,912	7,224	31,303	24,000	1.30	0.91	1.60	2.28
333	22,448	20,428	6,734	29,183	24,000	1.22	0.85	1.71	2.45
344	21,728	19,772	6,518	28,246	24,000	1.18	0.82	1.77	2.53
355	22,266	20,262	6,680	28,946	24,000	1.21	0.84	1.73	2.47
363	21,013	19,121	6,304	27,316	24,000	1.14	0.80	1.83	2.61
376	21,398	19,472	6,419	27,817	24,000	1.16	0.81	1.80	2.57
384	22,517	20,490	6,755	29,272	24,000	1.22	0.85	1.71	2.44
398	23,023	20,951	6,907	29,929	24,000	1.25	0.87	1.67	2.39

[1] Joint efficiency of 0.7 included
[2] Total stress / Allowable stress
[3] Uses minimum Can thickness
[4] SF = F_y/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 103 psf and the depth of soil cover on the penstock was assumed to be 3 ft. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment. The snow and live load combination uses a reduced snow and live load of 75 percent of each.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

Notes:

- No vehicular loading was used in the analysis where the penstock does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake are not used in the analysis.
- Similar to Penstocks 1 and 2, the penstock appears to be located in cohesive fine-grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as we assumed there is adequate drainage.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest measured steel thickness values were used.

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	4.11	3.24	3.72
15.25	6.94	3.91	4.39
13.50	12.07	4.30	4.78

There was no vehicular surcharge analysis conducted for the shallow buried penstock as there is no location for traffic to cross the penstock. Where vehicular traffic can cross the penstock, additional analyses were not completed due to the depth of the buried penstock at these locations (intake and switchyard).

4.3.2 Sub-atmospheric Internal Penstock Pressure Analysis

Sub-atmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and a detailed hydrodynamic model was not created for this report, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according to the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 m^2 (3.07 ft^2), which is well below the area provided by the approximately 5.1 m^2 (55 ft^2) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits and becomes permanently deformed. No deformations were observed by inspection. The penstock is continuously supported by the soil therefore excessive local buckling stresses in the penstock are unlikely.

4.5 Local Weld Conditions

ETS performed MT tests on the full length of 73 longitudinal welds and a few feet of 146 circumferential welds for this August 2021 inspection. No indications were discovered from the MT tests. The circumferential weld between Cans 192 and 193 and the leaking welds at the surge tank transition were identified from visual inspection and will require repair within the next 3 to 5 years.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life. However, due to repeated indications in the 17 ft section of Penstock 1 including in previously repaired welds, and due to the similarities in design and known issues, it is recommended that the 17-ft section of the three penstocks be replaced, the remaining welds refurbished, and the interior of the penstock re-coated to prevent further corrosion. Replacing the welds from the inside of the penstock only may not fully mitigate the issues in the 17 ft section of penstock and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. This has been highlighted again this year with two indications discovered in Penstock 1 in previously repaired welds, and multiple indications found the year before. Indications found in relatively new welds indicates that the weld repairs may have a limited life expectancy. All indications were found in the 17-ft diameter section the last two years indicating again that this section of penstock is particularly prone to weld indications. This section of penstock has the largest diameter and the thinnest plate, is made of a different steel grade than the rest of the penstock and has peaking induced residual stresses at the joints. The 17-ft diameter section of Penstock 3 should be replaced to remove the risk of future failures during operation and to provide confidence in the 17 ft section that will not be gained by repairing the welds. The remainder of the penstock should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively within 7 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate some small loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior penstock surface. Assuming similar rates of material loss, the penstock should have 50 to 80 years of service life remaining if recoated. For the most part the base plate material away from the joints can tolerate up to 2 mm further material loss and maintain a stress ratio below 1.0.

5.2 Internal Pressure Strength

Stress ratios for a combined static and dynamic internal pressures peak at 1.52 at the joints (Table 4-1). This indicates that the penstock does not meet present day design criteria for new penstock design. The thickness of this plate and other plates with high

stress ratios should be measured next year and the adjacent plates should be measured to confirm thickness and deterioration in the area. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.03, which is not acceptable for late 1960 steel pipe. As noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor. The penstock should have at least 50 years of service life if the 17 ft section is replaced and the remaining penstock is recoated, and the welds are test and refurbished.

6.0 RECOMMENDATIONS

Penstock 3 17-ft diameter section should be replaced within 7 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- radiographic testing of the welds if possible;
- surge Analysis to verify peak pressure and resulting stresses;
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage;
- continued inspections of the interior including MP weld testing;
- repair of circumferential weld between Cans 192 and 193; and
- repair of surge tank transition section welds.

The Surge Analysis should be completed before refurbishment to confirm stresses that may be used in weld sizing. Monitoring for leakage is something that should be done for every penstock regardless of age, construction, or condition. It is an early indicator of issues. Leakage for buried penstocks is most effectively done by monitoring drainage pipes and looking for wet areas and sink holes along the penstock alignment. MP weld testing after coating is applied may not be possible without removing the coating but not unheard of and will be dependent on coating system used. Other forms of weld testing are available that can test through paint such as the MagnaFORM Probe from Olympus. Considering indications were found at previously repaired welds this is something that will require further investigation and consideration.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 7 years. At this stage, Kleinschmidt is unable to estimate the rate of corrosion of the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. The estimated rate of corrosion can be better estimated

over a period of 5 years or more if thicknesses are taken in the same locations with similar methods. Until then, stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of the penstock. A quality field applied penstock coating can last 20-40 years or more. If the penstock is recoated prior to significant steel deterioration every 20-40 years, NLH can anticipate extending the life of the penstock nominally another 80 years. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated, but it is difficult to tell its condition.

6.2 Exterior Inspection

The repaired sinkhole downstream of the surge tank should continue to be monitored.

It is recommended that the observation well downstream, and to the left of the surge tank, be inspected from the bottom. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage.

The ditching on the left side of Penstock 3 adjacent the surge tank should be improved to collect snow and rain runoff such that it does not collect near the penstock where it can obscure or be confused for penstock leakage.

Kleinschmidt recommends repairing culvert damage described previously as well as continuing to monitor the exterior of the penstocks for signs of leakage. Drainpipes should also be monitored at times with consistent weather conditions.

The drainage culvert found along the left side of the penstock just upstream of the surge tank access road was mostly buried in dirt, leafy debris, and moss. The culvert is hard to find as it is hidden in the alders and bushes. The culvert should be cleaned out, alder bushes cut back, and ditched to drain.

The unlabeled weir at about Station 0+710 is full of sediment, small gravel, and sand (Photo 28). Flow from the culvert is partially bypassing the weir box at the upstream right end where the box is not seal. The weir box should be emptied and repaired.

The culvert at about Station 0+900 has had the swale recently ditched and cleaned out (Photo 29); however, the end of the pipe is partially blocked by mud left by excavator (Photo 30). The end of the pipe should be cleaned to flow free.

6.3 Interior Inspections

6.3.1 General Evaluation

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. The Level II inspections should take thickness readings and vertical diameters at each location noted in Kleinschmidt's inspection report. The yearly inspections should provide a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending deterioration, regardless if the coating has been replaced or not, the detailed inspections can be extended to a 5 to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval. Extensive weld testing and repairs have appeared to have adequately addressed weld issues, except that the transition into the surge tank was not repaired. Repairs to this area should be made during the next dewatering.

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SIGNATURE PAGE

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Senior Hydro Engineer

CMV:NSS:SCB

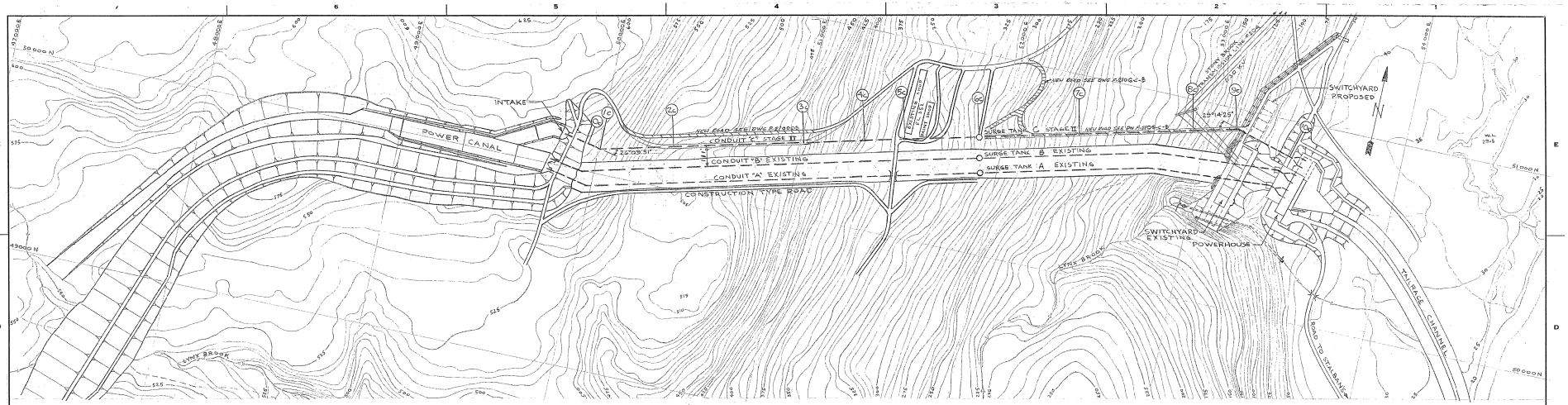




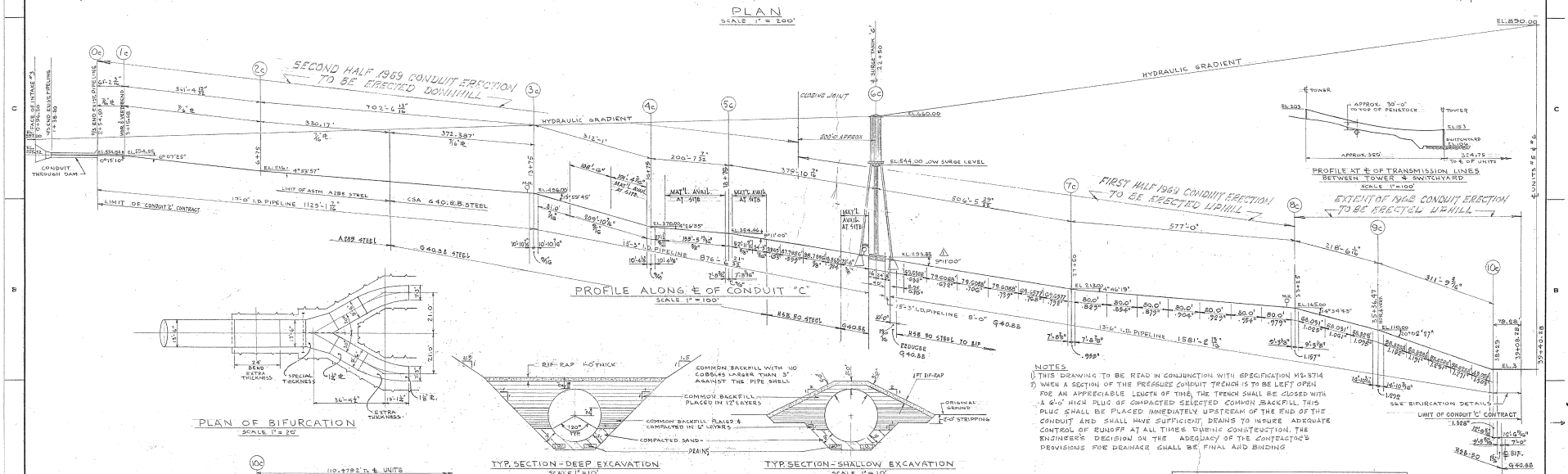
\\kleinschmidtusa.com\Condor\Jobs\2670\030\Docs\2670030.04 2022\2022 Inspections and Reports\Penstock 3\2670030.04_Bay d'Espoir Penstock 3 Inspection Report FINAL.docx

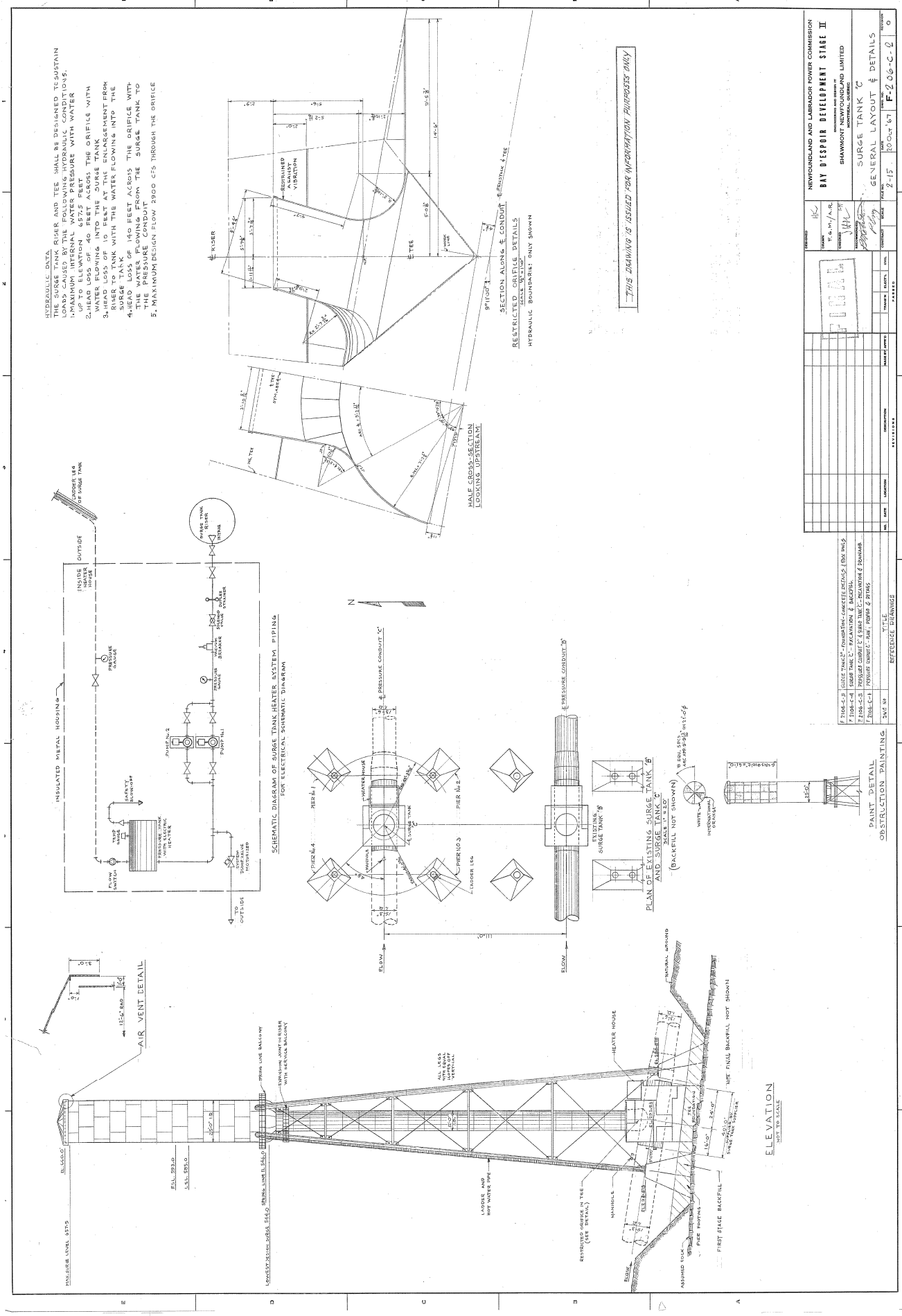
APPENDIX A

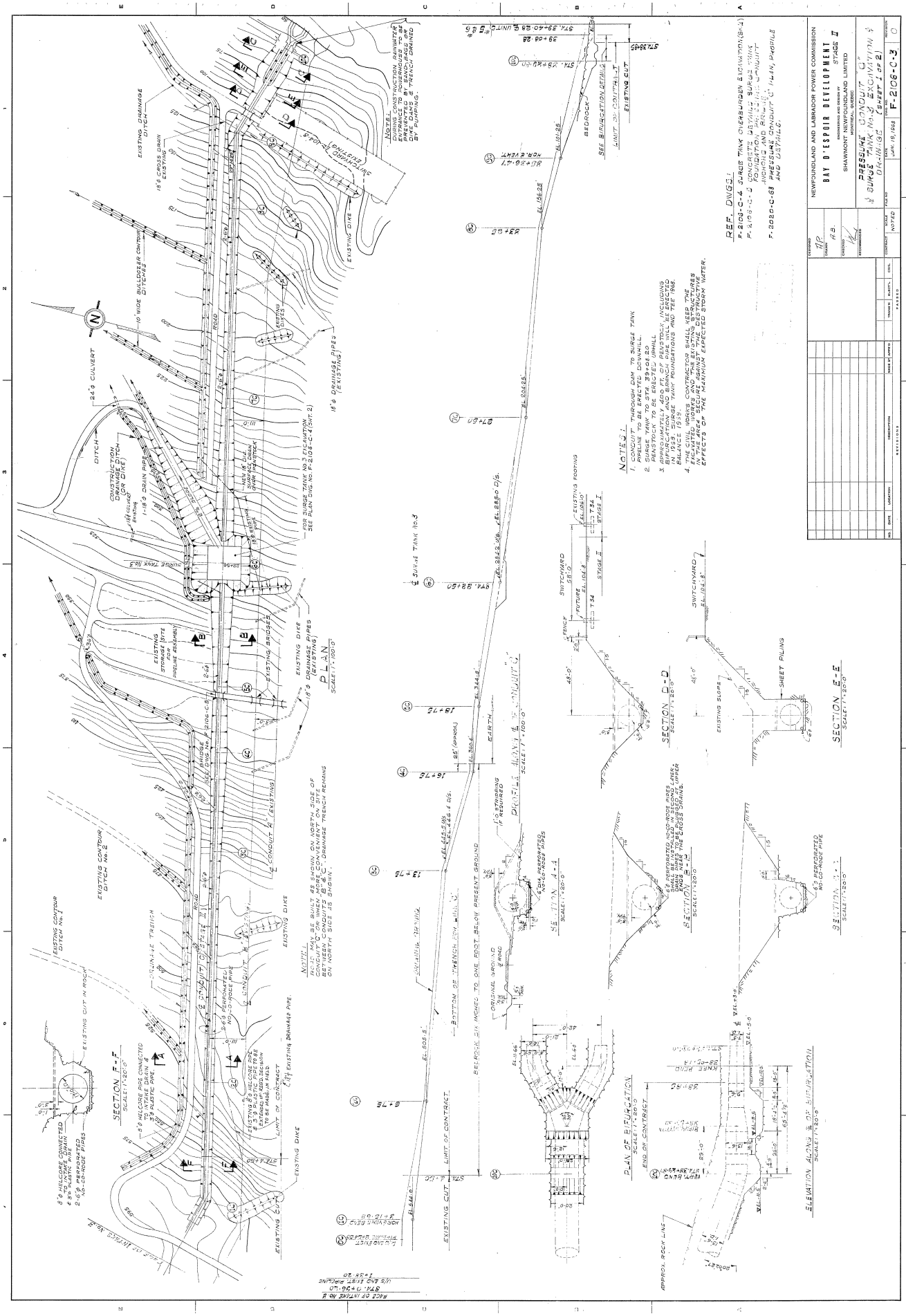
PENSTOCK LAYOUT DRAWINGS



PLAN
SCALE 1" = 200'




HYDRAULIC DATA
THE SURGE TANK RISER AND TEE SHALL BE DESIGNED TO SUSTAIN LOADS CAUSED BY THE FOLLOWING HYDRAULIC CONDITIONS.
1. MAXIMUM INTERNAL WATER PRESSURE WITH WATER UP TO ELEVATION 657.5 FEET
2. HEAD LOSS OF 40 FEET ACROSS THE ORIFICE WITH WATER FLOWING INTO THE SURGE TANK
3. HEAD LOSS OF 10 FEET AT THE ENLARGEMENT FROM RISER TO TANK WITH THE WATER FLOWING INTO THE SURGE TANK
4. HEAD LOSS OF 140 FEET ACROSS THE ORIFICE WITH THE WATER FLOWING FROM THE SURGE TANK TO THE PRESSURE CONDUIT
5. MAXIMUM DESIGN FLOW 2900 CFS THROUGH THE ORIFICE
THIS DRAWING IS ISSUED FOR INFORMATION PURPOSES ONLY
SECTION ALONG ℄ CONDUIT
RESTRICTED ORIFICE DETAILS
SCALE 1"=1'-0"
HYDRAULIC BOUNDARIES ONLY SHOWN
HALF CROSS-SECTION LOOKING UPSTREAM
SCHEMATIC DIAGRAM OF SURGE TANK HEATER SYSTEM PIPING
FOR ELECTRICAL SCHEMATIC DIAGRAM
INSULATED METAL HOUSING
INSIDE HEATER HOUSE
OUTSIDE
PRESSURE GAUGE
VACUUM BREAKER
SURGE TANK WATER INTAKE
SURGE TANK DRAIN VALVE
PUMP No.2
PUMP No.1
SAFETY BLOWOFF
FLOW SWITCH
STEAM VALVE
THROUGH TANK WITH ELECTRIC HEATER
TEMPERATURE MOTIONTROL
TO OUTSIDE
PLAN OF EXISTING SURGE TANK "B" AND SURGE TANK "C"
SCALE 1"=20'
(BACKFILL NOT SHOWN)
EXISTING SURGE TANK "B"
PIER No.1
PIER No.2
PIER No.3
PIER No.4
HEATER HOUSE
LADDER LEG
FLOW
WHITE-INTERNATIONAL ORANGE
AIR VENT DETAIL
ELEVATION
NOT TO SCALE
PAINT DETAIL
OBSTRUCTION PAINTING
MAX SURGE LEVEL 657.5
EL 660.0
EL 593.0
LWL 595.0
LOWEST RESID. SURGE 544.0
SPRING LINE EL 546.0
SPRING LINE BALCONY
EXPANSION JOINT IN RISER WITH SERVICE BALCONY
ALL LEGS WITH EQUAL BATTER EXCEPT VERTICAL
HEATER HOUSE
NATURAL GROUND
NOT FINAL BACKFILL NOT SHOWN
SURGE TANK SUMP
FIRST STAGE BACKFILL
LOOSE AND HOT WATER PIPE
RESTRICTED ORIFICE IN TEE (SEE DETAIL)
MANHOLE
PIER FOOTING
ASSUMED ROCK
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK 'C'
GENERAL LAYOUT & DETAILS
DRAWING NO. F-2 06-C-2
DATE 20 Oct '67
SCALE 2-15
CONTRACT
DESIGNED
DRAWN W.G. M/A.R.
CHECKED
TECHNICALLY APPROVED
F 2106-C-2 SURGE TANK 'C' - FOUNDATION - CONCRETE DETAILS & BOX SHTS.
F 2106-C-4 SURGE TANK 'C' - EXCAVATION & BACKFILL
F 2106-C-3 PRESSURE CONDUIT & SURGE TANK 'C' - REINFORCING & DOWNAGE
F 2106-C-1 PRESSURE CONDUIT - PLAN, PROFILE & DETAILS
SHT. NO.
REFERENCE DRAWINGS
TITLE
REVISIONS
NO. DATE DESCRIPTION MADE BY APPD.
TRACED BY CHKD. PASSED
SHT. CONTRACT SCALE PROJ. NO. REVISION


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC
PRESSURE CONDUIT "C"
SURGE TANK No.3 EXCAVATION & CONCRETE
GENERAL ARRANGEMENT
SHEET 1 OF 2
F-2106-C-3
REF. DWGS.
F-2106-C-4 SURGE TANK OVERBURDEN & EXCAVATION (SHT 2)
F-4106-C-3 CONCRETE DETAILS SURGE TANK FOUNDATION, PRESSURE CONDUIT JUNCTION AND REINFORCING
F-2020-C-68 PRESSURE CONDUIT PLAN, PROFILE AND DETAILS
NOTES:
1. CONDUIT THROUGH DAM TO SURGE TANK PIPELINE TO BE ERECTED DOWNHILL.
2. SURGE TANK TO STA. 39+08.80 PIPELINE TO BE ERECTED UPHILL.
3. APPROXIMATELY 400 FT. OF PENSTOCK INCLUDING BIFURCATION AND BRANCH PIPE WILL BE ERECTED ON THE SURGE TANK FOUNDATIONS AND TEE TEST BALANCE 1959.
4. THE CIVIL WORKS CONTRACTOR SHALL KEEP THE EXCAVATION FOR THE SURGE TANK AND PIPELINES IN THE AREA SECURE AGAINST THE DESTRUCTIVE EFFECTS OF THE MAXIMUM EXPECTED STORM WATER.
PLAN
SCALE 1"=100'-0"
SECTION E-E
SECTION F-F
SECTION B-B
SECTION C-C
SECTION D-D
PLAN OF BIFURCATION
ELEVATION ALONG AXIS OF BIFURCATION
EXISTING CONTOUR DITCH No.2
EXISTING DIKE
EXISTING ROAD
EXISTING BRIDGE
EXISTING DRAINAGE PIPES
EXISTING CUT IN ROCK
EXISTING DRAINAGE DITCH
CONSTRUCTION DRAINAGE DITCH (IN DIKE)
10' WIDE BULLDOZER CONTROL DITCHES
24'ø CULVERT
18'ø DRAIN PIPE
SURGE TANK No.3
EXISTING STORAGE SITE
PIPELINE ASSEMBLY
CONDUIT "C" (EXISTING)
CONDUIT "C" (NEW)
EXISTING CONTOUR DITCH No.1
EXISTING SLOPE
SHEET PILING
SWITCHYARD
EXISTING FOOTING
FUTURE
STAGE II
STAGE I
FENCE
EARTH
ROCK
ORIGINAL GROUND
LIMIT OF CONTRACT
EXISTING CUT
BELOW ROCK SIX INCHES TO ONE FOOT BELOW PRESENT GROUND
BOTTOM OF TRENCH
TRENCH REMAINING
CONDUIT "C" EXISTING
CONDUIT "C" NEW
8'ø PERFORATED NO-CO-RODE PIPE
8'ø WELCORE PIPE CONNECTED TO INTAKE DRAIN & PLASTIC PIPE
2-6'ø PERFORATED NO-CO-RODE PIPES
EXISTING 8'ø WELCORE PIPE EXTENDED WITH REQ. SECTION TO BE MADE IN FIELD
LIMIT OF CONTRACT
EXISTING DRAINAGE PIPE
EXISTING DIKE
EXISTING INTAKE No.2
FACE OF INTAKE No.2
STA. 7+36.00
U/S END FIRST PIPELINE
1-28'-2.0
APPROX. ROCK LINE
CONCRETE
PIPELINE
SHOTCRETE
2"±
0.09
0.18
0.36
0.72
1.44
2.88
5.76
11.52
23.04
46.08
92.16
184.32
368.64
737.28
1474.56
2949.12
5898.24
11796.48
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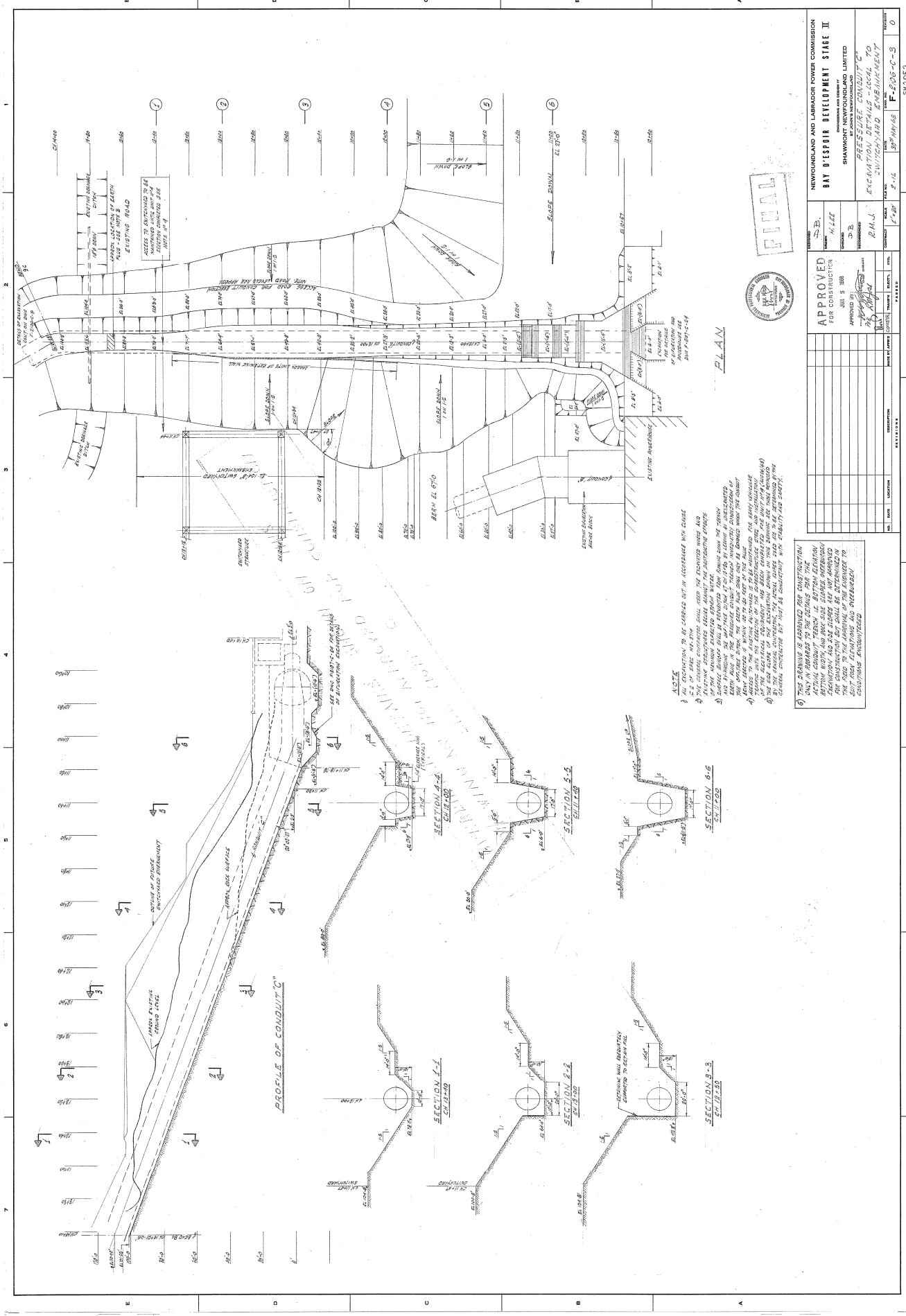
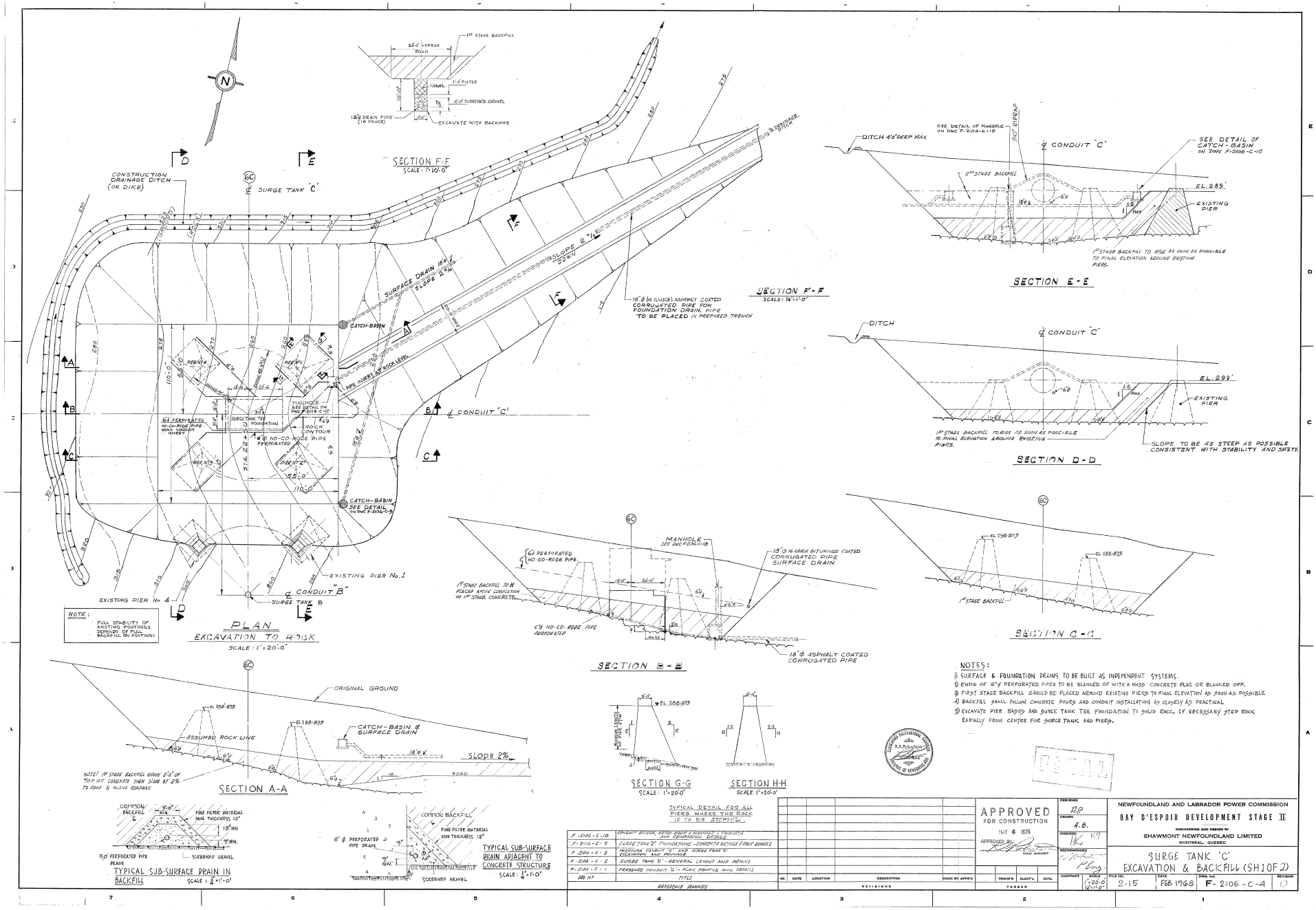
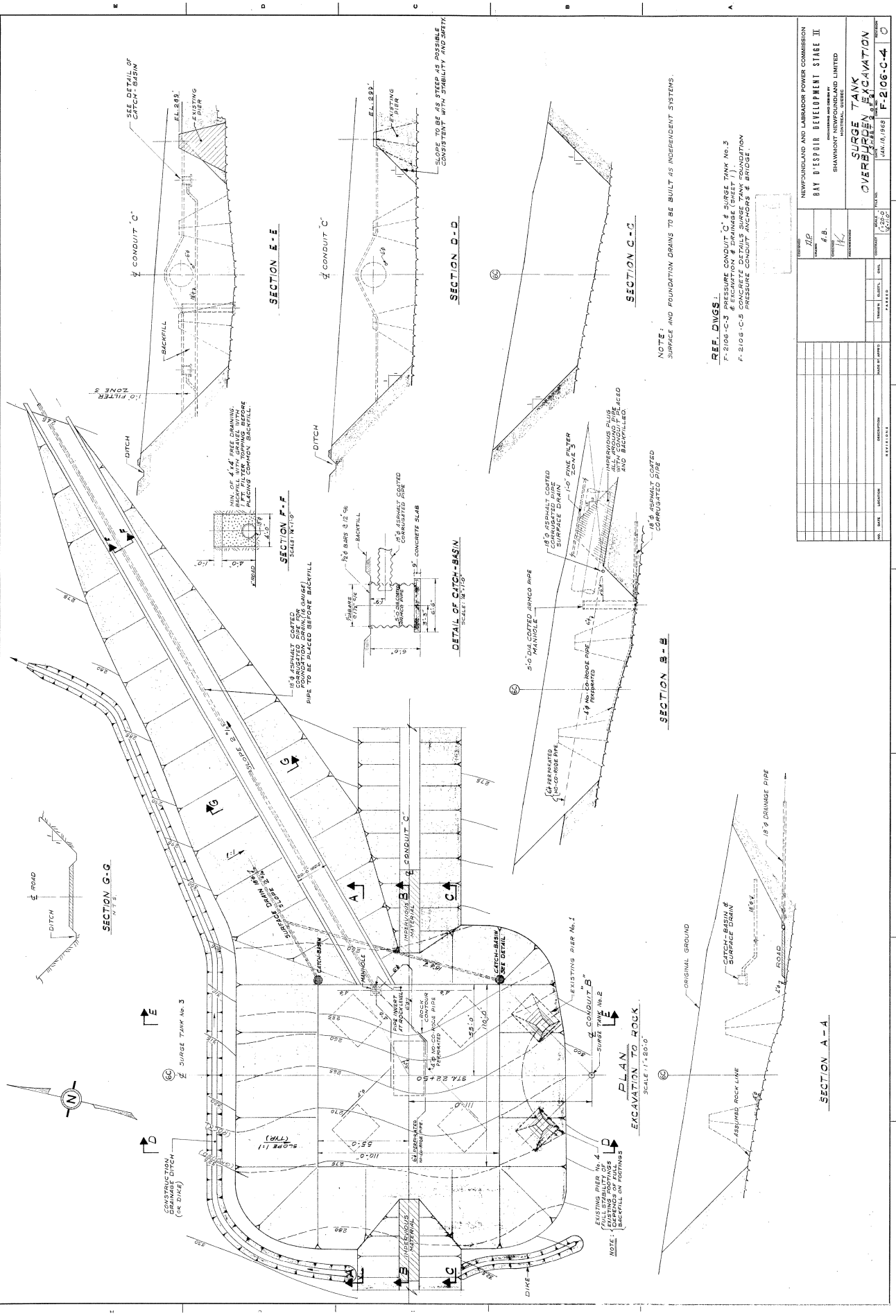
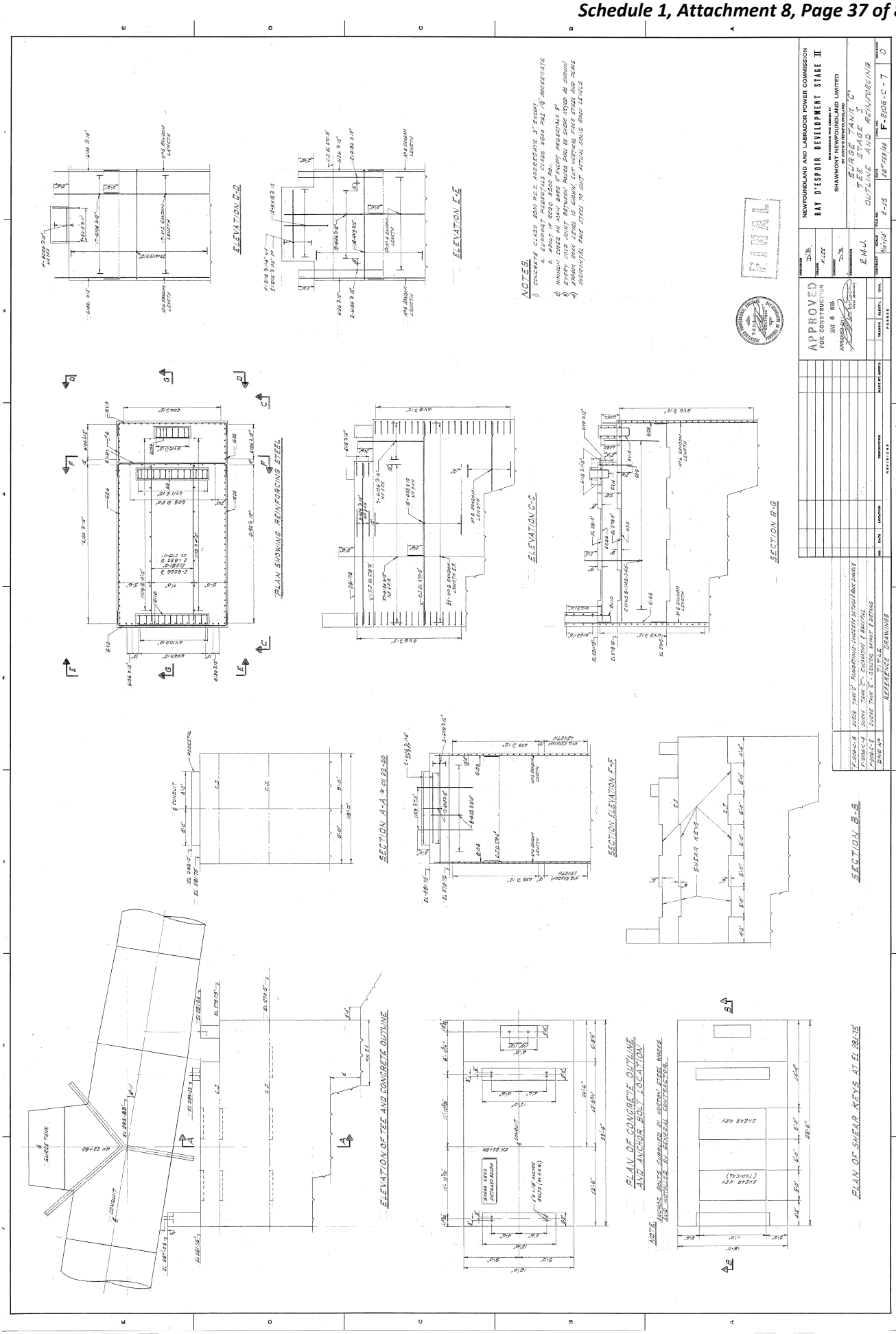
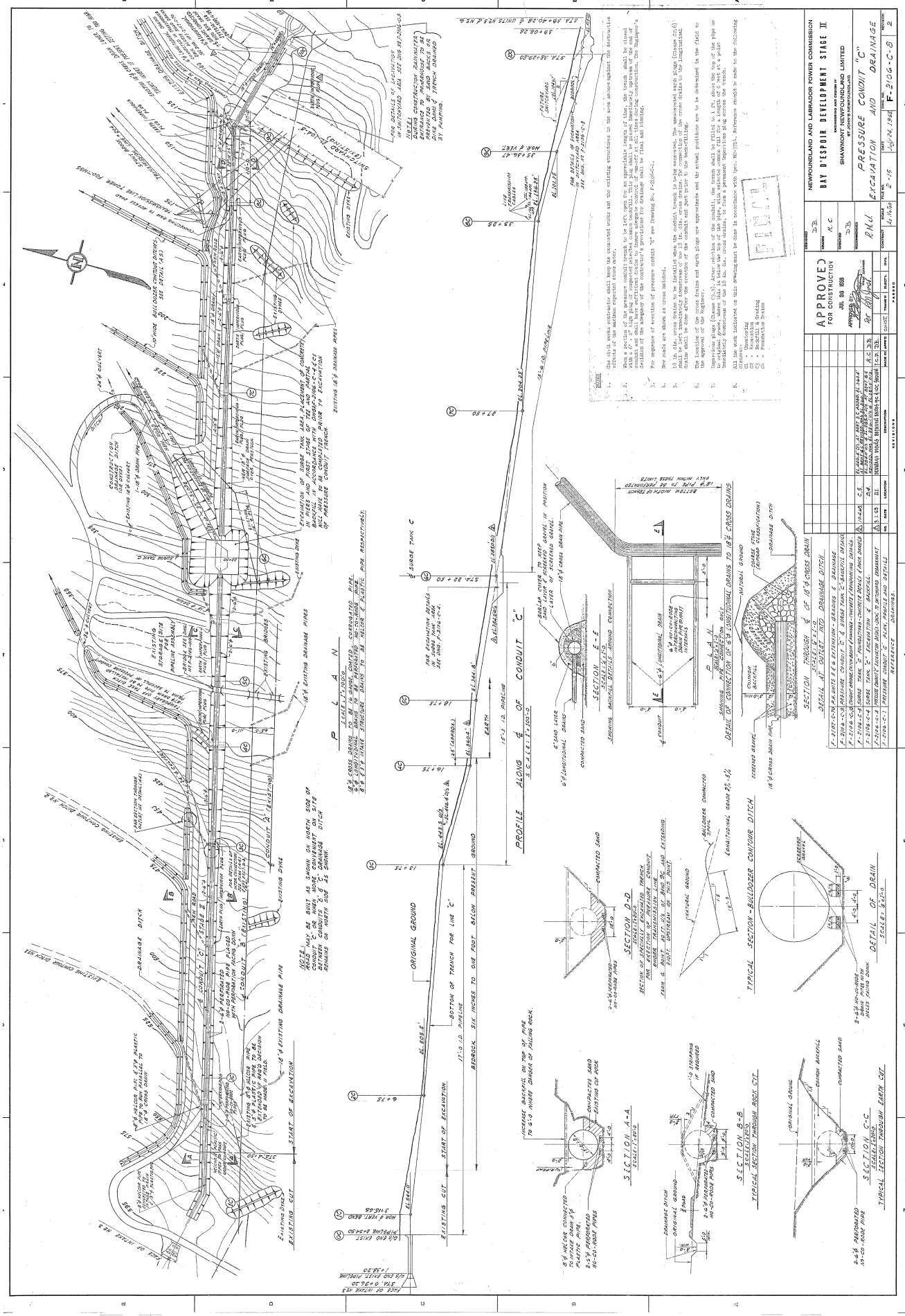

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
PRESSURE CONDUIT "C"
EXCAVATION DETAILS - LOCAL TO SWITCHYARD EMBANKMENT
APPROVED FOR CONSTRUCTION
PLAN
PROFILE OF CONDUIT "C"
SECTION 1-1
SECTION 2-2
SECTION 3-3
SECTION 4-4
SECTION 5-5
SECTION 6-6

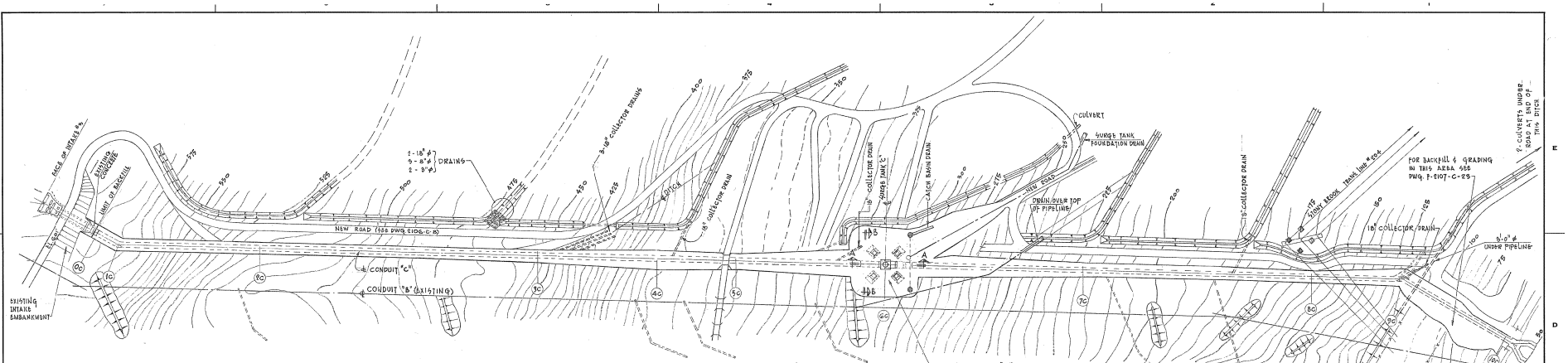


Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 8, Page 35 of 86


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC
SURGE TANK OVERBURDEN EXCAVATION
F-2106-C-4
SECTION E-E
SECTION F-F
SECTION D-D
SECTION C-C
SECTION B-B
SECTION A-A
SECTION G-G
DETAIL OF CATCH-BASIN
PLAN EXCAVATION TO ROCK
NOTE: SURFACE AND FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.
REF. DWGS:
F-2106-C-3 PRESSURE CONDUIT "C" & SURGE TANK No.3
& EXCAVATION & DRAINAGE (SHEET 1)
F-2106-C-5 PRESSURE CONDUIT "C" & SURGE TANK No.3
EXCAVATION & DRAINAGE (SHEET 2)
PRESSURE CONDUIT ANCHORS & BRIDGE.
CONDUIT "C"
SURGE TANK No. 3
SURGE TANK No. 2
EXISTING PIER No. 1
EXISTING PIER No. 4
CATCH-BASIN
MANHOLE
DITCH
ROAD
BACKFILL
CONSTRUCTION DRAINAGE DITCH (OR DIKE)
DIKE
ORIGINAL GROUND
ASSUMED ROCK LINE
18'ø ASPHALT COATED CORRUGATED PIPE
18'ø DRAINAGE PIPE
5'-0" DIA COATED ARMCO PIPE MANHOLE
1'-0 FINE FILTER SURFACE DRAIN
INTERWOOD PLUG WITH CONDUIT PLACED AND BACKFILLED
CONCRETE SLAB
BACKFILL
1'-0 FILTER ZONE 3
SLOPE TO BE AS STEEP AS POSSIBLE CONSISTENT WITH STABILITY AND SAFETY.
SEE DETAIL OF CATCH-BASIN
EXISTING PIER
EL. 289'
MIN. OF 4'x4' FREE DRAINING, GRANULAR MATERIAL BEFORE PLACING COMMON BACKFILL
SLOPE 1:1 (TYP.)
SLOPE 2:1
INTERWOOD MATERIAL
CATCH-BASIN SURFACE DRAIN
CATCH-BASIN SEE DETAIL
FIRE HYDRANT
CONTOUR
NOTE: EXISTING FOOTINGS TO BE EXCAVATED BACKFILL ON FOOTINGS

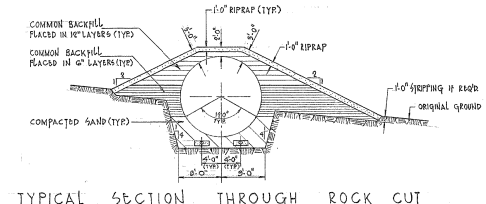

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK "C"
TEE STAGE I
OUTLINE AND REINFORCING
F-2106-C-7
APPROVED FOR CONSTRUCTION
NOTES
ELEVATION D-D
ELEVATION E-E
PLAN SHOWING REINFORCING STEEL
ELEVATION C-C
SECTION G-G
SECTION A-A
SECTION ELEVATION F-F
SECTION B-B
ELEVATION OF TEE AND CONCRETE OUTLINE
PLAN OF CONCRETE OUTLINE AND ANCHOR BOLT LOCATION
PLAN OF SHEAR KEYS AT EL 281.75
SHEAR KEYS
REFERENCE DRAWINGS


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
PRESSURE CONDUIT "C"
EXCAVATION AND DRAINAGE
APPROVED FOR CONSTRUCTION
JUL 23 1969
F-2106-C-8
PROFILE ALONG ℄ OF CONDUIT "C"
PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION THROUGH ℄ OF 18'ø CROSS DRAIN
DETAIL AT OUTLET INTO DRAINAGE DITCH
DETAIL OF DRAIN
TYPICAL SECTION-BULLDOZER CONTOUR DITCH
TYPICAL SECTION THROUGH EARTH CUT
TYPICAL SECTION THROUGH ROCK CUT
DETAIL OF CONNECTION OF 6'ø LONGITUDINAL DRAINS TO 18'ø CROSS DRAINS
SECTION OF SPECIAL EXCAVATED TRENCH FOR SECTION OF PRESSURE CONDUIT
EXISTING CULVERT TO BE EXTENDED
EXISTING DITCH
EXISTING ROAD
EXISTING DYKE
EXISTING BRIDGE
EXISTING DRAINAGE PIPE
EXISTING CULVERT
EXISTING STORAGE SITE
EXISTING SURGE TANK "C"
EXISTING 18'ø DRAINAGE PIPE
EXISTING 24'ø CULVERT
EXISTING 12'ø DRAINAGE PIPE
EXISTING 8'ø DRAINAGE PIPE
EXISTING 6'ø DRAINAGE PIPE
EXISTING 4'ø DRAINAGE PIPE
EXISTING 3'ø DRAINAGE PIPE
EXISTING 2'ø DRAINAGE PIPE
EXISTING 1'ø DRAINAGE PIPE
EXISTING 18'ø DRAINAGE PIPE



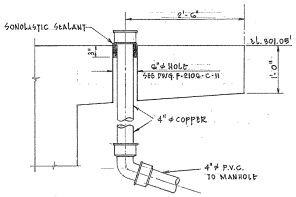
PLAN

SCALE: 1" = 100'



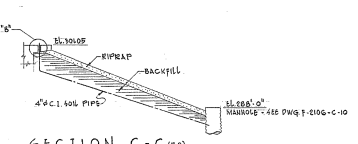
TYPICAL SECTION THROUGH ROCK CUT

SCALE: 1" = 10'-0"



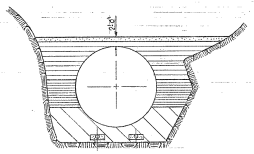
DETAIL - B (C,9)

SCALE: 1" = 1'-0"



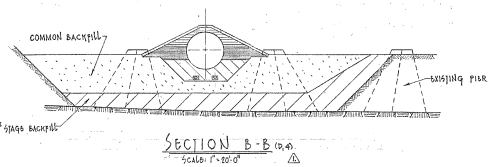
SECTION C-C (B,C)

SCALE: 1" = 10'-0"



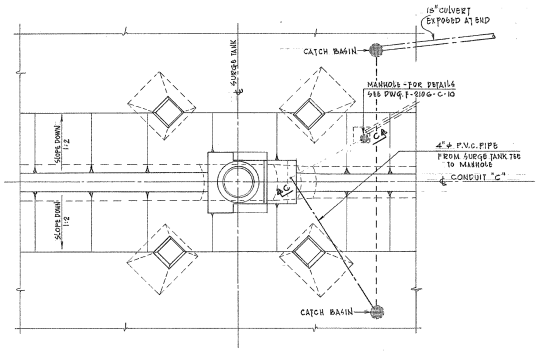
SECTION THROUGH EXISTING CUT ROCK

SCALE: 1" = 10'-0"



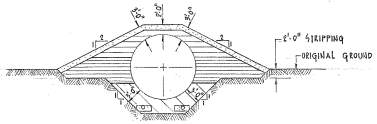
SECTION B-B (D,4)

SCALE: 1" = 20'-0"



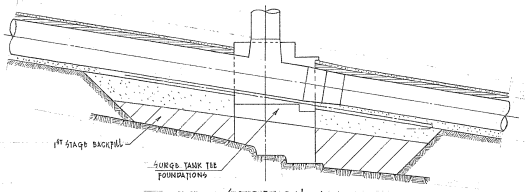
DETAIL - A (D,8)

SCALE: 1" = 20'-0"



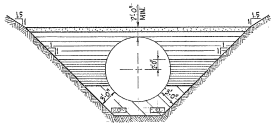
TYPICAL SECTION FOR SHALLOW EXCAVATION

SCALE: 1" = 10'-0"



SECTION A-A (D,4)

SCALE: 1" = 20'-0"



TYPICAL SECTION FOR DEEP EXCAVATION

SCALE: 1" = 10'-0"

NOTE:

1. CONTRACTOR TO SUPPLY & INSTALL CAST IRON 40# PIPE FROM SURGE TANK TEE TO MANHOLE UNDER SCHEDULE OF PRICE ITEM C 1005.
2. CONDUIT & SURGE TANK FOUNDATION DRAINAGE OUTLETS SHALL BE INSPECTED TWICE YEARLY AND CLEANED AS REQUIRED TO INSURE PROPER DRAINAGE.

DWG. No.	TITLE
F-2106-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS
F-2106-C-2	SURGE TANK "C" - GENERAL LAYOUT & DETAILS
F-2106-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F-2106-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F-2106-C-5	" " " - FOUNDATIONS, CONCRETE DETAILS & ROCK DOWELS
F-2106-C-8	PRESSURE CONDUIT "C" - EXCAVATION & DRAINAGE
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLS - CONCRETE & REINF. DETAILS
F-2106-C-11	SURGE TANK "C" - 1ST STAGE II - CONCRETE DETAILS

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
12	88/06/30		DWG. REVISED TO SHOW AS-BUILT	T.C.D.	
9	88/06/A.C./C.S.		SECTIONS A, B & C, DETAILS A & B NOTE ADDED	T.C.D.	D.B.

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 9 1988
APPROVED BY

FINAL

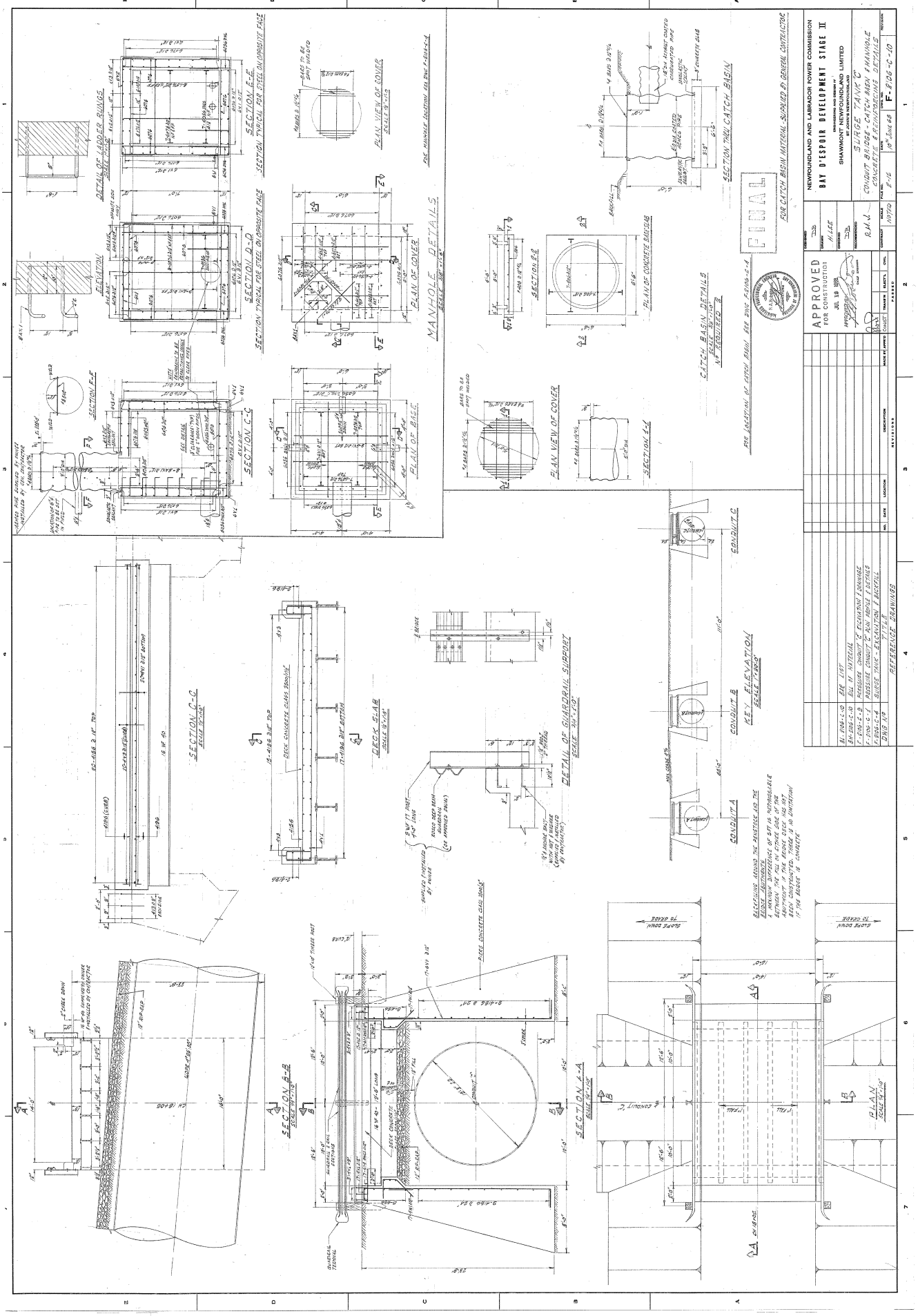
TRANSM.	ELECT'L.	CIVIL

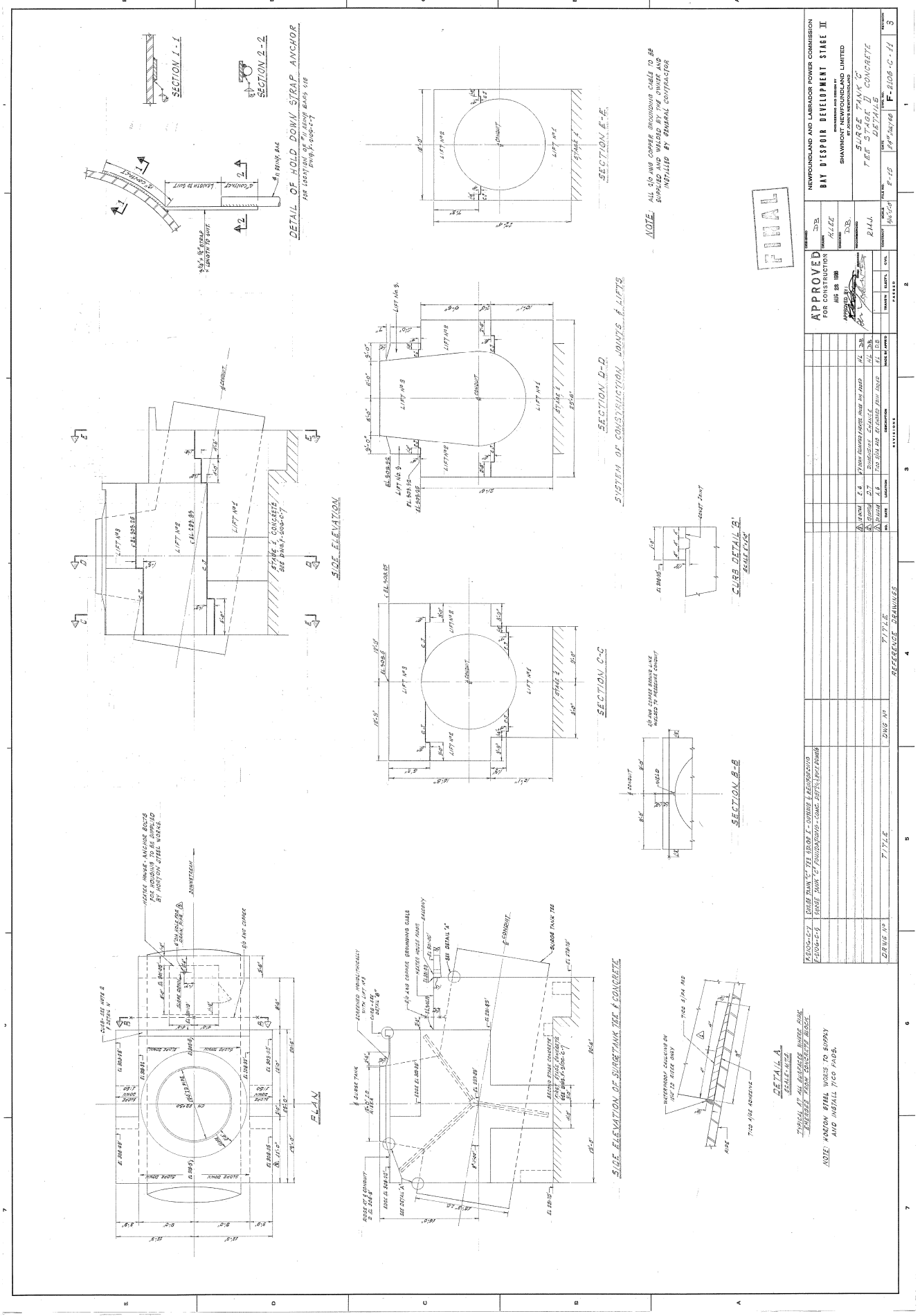
PASSED

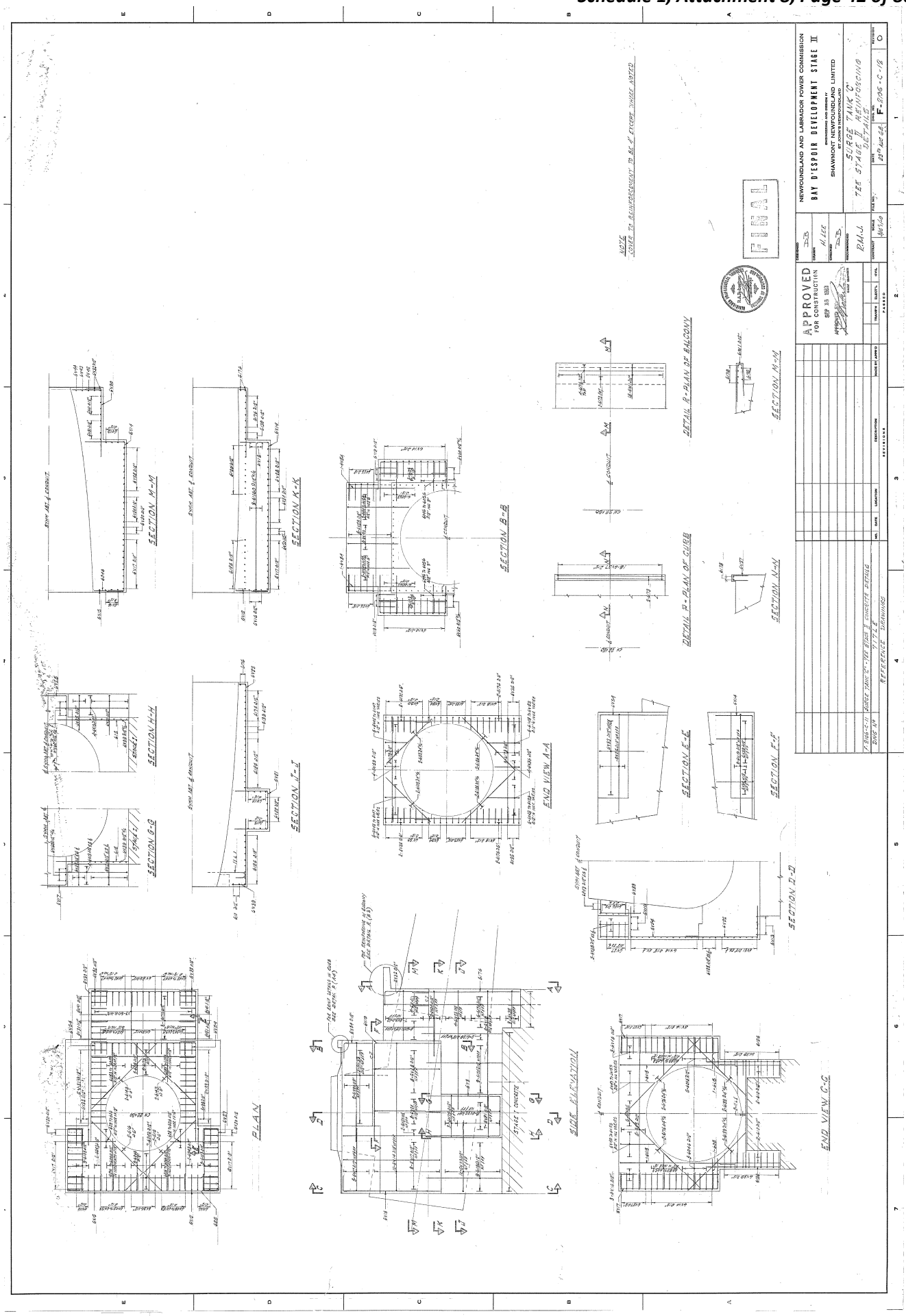
DESIGNED D.B.
DRAWN T.C. DAVIS
CHECKED D.B.
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND
PRESSURE CONDUIT "C" & SURGE TANK "C"
BACKFILL DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	AS SHOWN	2-15	5TH SEPT. 1968	F-2106-C-9	2.


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK "C"
CONDUIT BRIDGE - CATCH BASIN & MANHOLE
CONCRETE & REINFORCING DETAILS
APPROVED FOR CONSTRUCTION
FINAL
MANHOLE DETAILS
CATCH BASIN DETAILS
SECTION C-C
SECTION B-B
SECTION A-A
DETAIL OF GUARDRAIL SUPPORT
KEY ELEVATION
DECK SLAB
PLAN
REFERENCE DRAWINGS


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK 'C'
TEE STAGE II CONCRETE
DETAILS
APPROVED
FOR CONSTRUCTION
FINAL
SECTION 1-1
SECTION 2-2
DETAIL OF HOLD DOWN STRAP ANCHOR
SECTION E-E
SECTION D-D
SYSTEM OF CONSTRUCTION JOINTS & LIFTS
SIDE ELEVATION
SECTION C-C
CURB DETAIL 'B'
SECTION B-B
PLAN
SIDE ELEVATION OF SURGETANK TEE & CONCRETE
DETAIL A
REFERENCE DRAWINGS


NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
SHAWMONT NEWFOUNDLAND LIMITED
SURGE TANK 01
TEE STAGE REINFORCING
DETAILS
APPROVED
FOR CONSTRUCTION
SEP 13 1983
FINAL
SECTION M-M
SECTION K-K
SECTION B-B
DETAIL R-PLAN OF BALCONY
SECTION N-N
SECTION H-H
SECTION J-J
SECTION E-E
SECTION F-F
SECTION G-G
END VIEW A-A
SECTION D-D
PLAN
SIDE ELEVATION
END VIEW C-C

APPENDIX B

PHOTOGRAPHS



Photo 1 Leakage Flow along Penstock Invert



Photo 2 Leak through Clamping Plate at Bottom of Gate

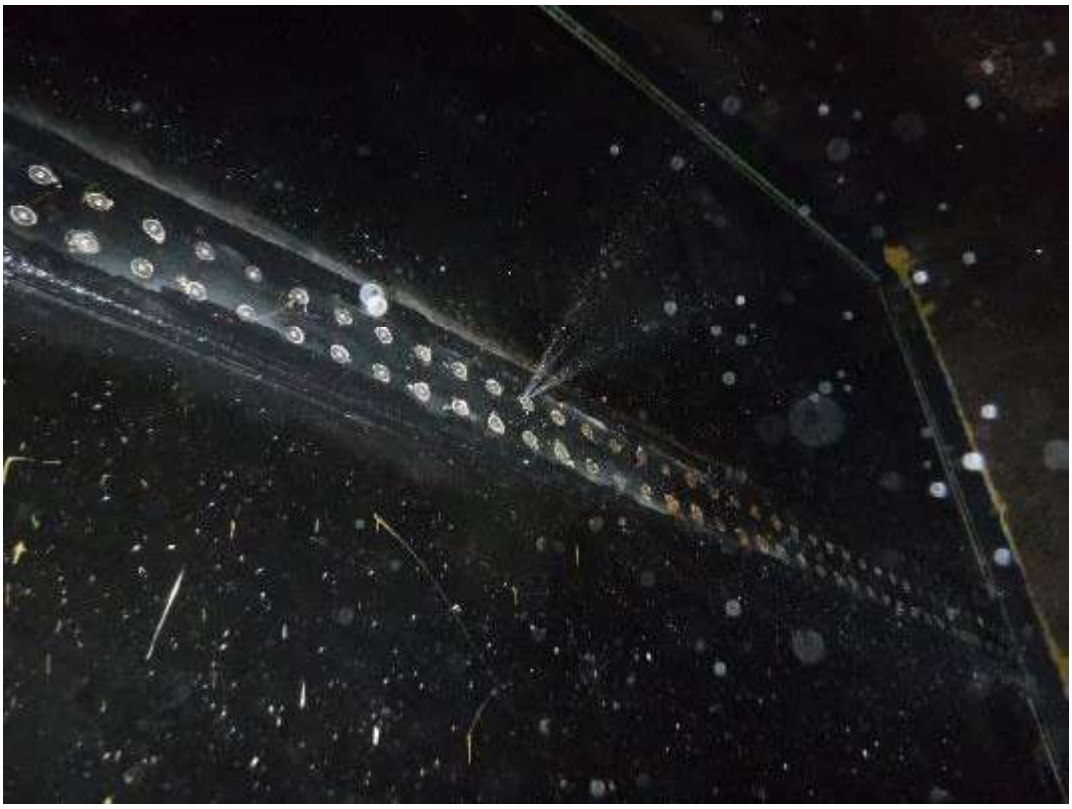


Photo 3 Minor Leakage through Bolt Hole; Top, Side and Corner Seal No Visible Leakage



Photo 4 Typical Surface Condition Near Can 15



Photo 5 Typical Surface Condition Near Can 240



Photo 6: Typical Surface Condition Near Can 300



Photo 7 Typical Surface Condition Near Can 360



Photo 8 Previously Repaired Longitudinal Weld Can 15 South Side



Photo 9 Previously Repaired Longitudinal Weld Can 15 S



Photo 10 Previously Repaired Longitudinal Weld Can 114 South Side



Photo 11 Previously Repaired Longitudinal Weld Can 114 South Side



Photo 12 Original Longitudinal Weld Can 146 South Side



Photo 13 Original Longitudinal Weld Can 146 South Side



Photo 14 Original Longitudinal Weld Can 254 North Side



Photo 15 Original Longitudinal Weld Can 254 North Side



Photo 16 Original Longitudinal Weld Can 344 North Side



Photo 17 Original Longitudinal Weld Can 344 North Side

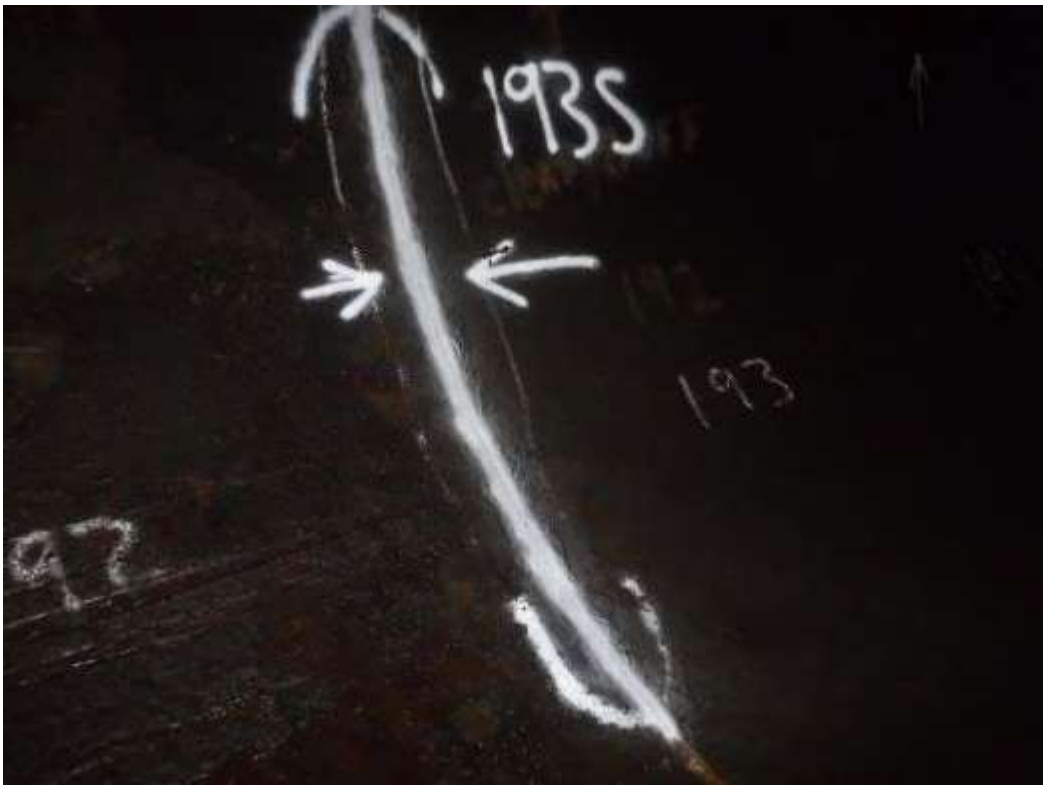


Photo 18 Indication along Circumferential Weld Between Cans 192 and 193.



Photo 19 Leakage Near Crown Of Surge Tank Transition Piece



Photo 20 Leakage and Efflorescence Near Crown of Surge Tank Transition Piece



Photo 21 Leakage Near Crown of Surge Tank Transition Piece



Photo 22 Leakage Near Crown of Surge Tank Transition Piece



Photo 23 Shed Housing Weir N-1



Photo 24 Weir N-1



Photo 25 Weir N-2



Photo 26 Weir N-2



Photo 27 Culvert Located Just Upstream of the Surge Tank Access Road



Photo 28 Culvert at about Station 0+710



Photo 29 Swale Downstream of Culvert at about Station 0+900



Photo 30 Culvert at about Station 0+900



Photo 31 Looking Downstream from Upstream End of penstock 3



Photo 32 Looking Downstream along Penstock 3 from about Station 0+100



Photo 33 Looking Upstream from about Station 0+200



Photo 34 Wet Area to Left of Surge Tank



Photo 35 Looking Upstream Toward Surge Tanks from about Station 700



Photo 36 Looking Downstream Along Penstock 3 Toward Switch Yard at About Station 800

APPENDIX C

WELD TEST

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	22-384-1	Copy:	
Date:	25 May, 2022	Date Received:	22 May, 2022
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy, SNT TC-1A: UT, ET, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I
Attn:	Colin LeGrow		
P.O. No.			
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3		
Testing Required:	Magnetic Particle Inspection	Signed:	NDT Inspector

Remarks

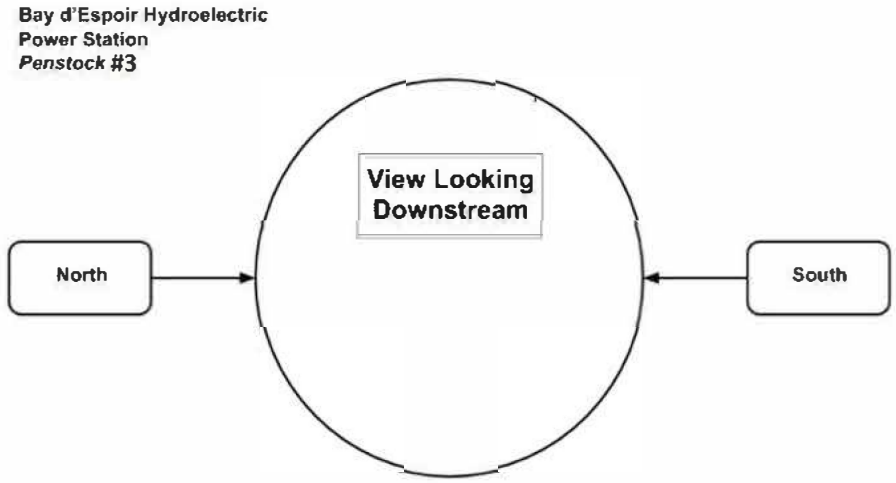
As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E-1444 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

The above noted areas were found to be acceptable as per the above noted criteria.

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
4	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
5	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
15	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
16	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
25	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
33	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
42	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
44	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
54	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
63	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
72	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
84	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
86	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
93	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
94	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
102	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
103	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
113	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
114	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
121	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
123	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
135	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
145	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
146	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
155	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
156	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
164	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
176	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
177	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
188	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
189	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
193	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. Indication still noted like previous year inspection. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	Indication noted on circumferential weld	**Figure 1 and 1.1**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
196	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
197	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/205**
205	- Longitudinal left (north) - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
206	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
212	- Longitudinal left (north) - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
213	- Longitudinal left (north) - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
224	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
225	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
235	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
244	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
254	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
255	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
263	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
264	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

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ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
274	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
275	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
283	- Longitudinal right (south) weld. - Longitudinal left (north) weld - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
292	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
293	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
303	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
304	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
313	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
323	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
333	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
343	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right longitudinal welds.	MT Acceptable	**N/A**
344	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
354	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
355	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
363	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
376	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
384	- Longitudinal right (south) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**
398	- Longitudinal left (north) weld. - 12" Section of upstream circumferential weld adjacent to left and right longitudinal welds. - 12" Section of downstream circumferential weld adjacent to left and right	MT Acceptable	**N/A**

ETS No.: 22-384 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 1 - Can #193 south side circumferential weld indication size - indication goes from longitudinal weld to bottom centre line in way of water



Figure 1.1 - Can #193 south side circumferential weld example of indication - indication is on the down stream side of the weld

APPENDIX D

THICKNESS MEASUREMENTS DATA AND STRESS CALCULATIONS

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
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Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	22-384-2	Copy:	
Date:	25 May 2022	Date Received:	22 May 2022
Client:	Technical Rope & Rescue 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Colin Legrow		
P.O. No.			
Project:	Penstock Inspection - Penstock #3		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	Conor Murphy NDT Inspector

Remarks

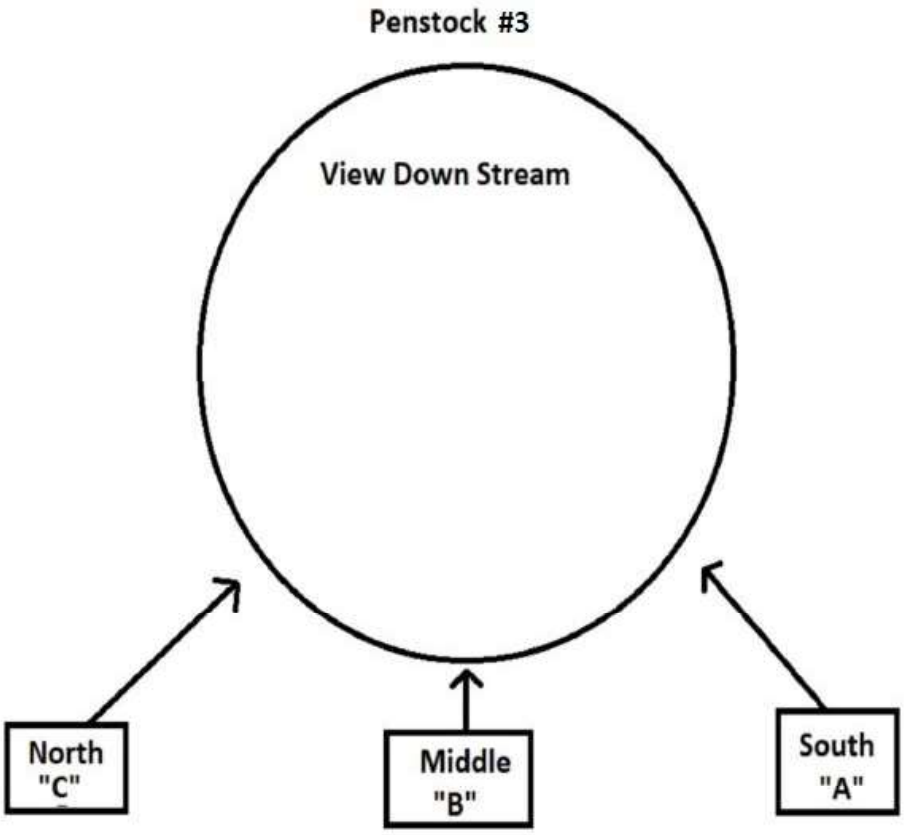
As directed, ultrasonic thickness measurements were taken on Penstock #3 in Areas as requested. 3 readings were taken at each location and averaged, readings are shown in mm's on the attached tables.

Equipment Used

Krautkramer DMS 2 digital thickness gauge (S/N 01YL2P).
Krautkramer TC560 probe (S/N 14A01G28).
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 22-384-2 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Penstock #3
Ultrasonic Thickness Measurements

Location Of Readings Taken On Penstock #3



ETS No.: 22-384-2 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Penstock #3
Ultrasonic Thickness Measurements

Can Number	Location A	Location B	Location C
4	11.3	12.5	12.1
15	10.8	10.4	10.3
25	10.3	10.8	10.2
33	10.3	10.5	10.4
44	10.7	10.8	10.8
54	10.5	10.9	10.4
63	10.9	10.4	10.6
72	10.6	10.9	10.9
84	10.3	10.6	10.8
93	10.6	10.4	10.3
102	10.4	10.9	11.0
113	10.9	10.4	10
123	10.4	10.5	10.4
135	12.7	13.1	13
145	12.7	14.4	13.2
155	14.5	13.7	13.9
164	14.3	14.5	14.1
176	15.5	15.7	14.9
188	16.0	16.4	15.9
198	15.0	15.0	15.3
206	15.6	16.5	16.6
213	15.5	15.7	16.0
225	19.0	18.6	17.7
235	22.2	22.4	22.1
245	16.5	16.1	16.2
255	16.6	17.7	16.9
263	16.5	16.5	17.0

ETS No.: 22-384-2 Date: 25 May 2022
Client: Technical Rope & Rescue
Location: Penstock #3
Ultrasonic Thickness Measurements

Can Number	Location A	Location B	Location C
275	19.9	20.1	19.8
283	20.5	19.3	20.4
293	21.0	21.3	21.2
304	21.3	22.3	21.8
313	22.5	21.8	22.4
323	23.9	24.2	22.4
333	24.9	24.5	24.6
344	24.9	24.9	24.1
355	24.9	25.5	26.0
363	27.5	27.8	27.6
376	28.9	29.9	28.8
384	28.9	29.9	30.8
398	31.2	30.9	31.2

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

2022 Analysis Summary									
Can	Joint Stress (FSL) (psi)	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase (psi)	Total Water Hammer Stress (Surge at Joints) (psi)	Allowable Stress (psi)	Max Joint Stress Ratio	Max Base Material Stress Ratio	Factor of Safety Against Yield (Joints)	Factor of Safety Against Yield (Base)
4	6003	5463	1801	7804	17000	0.46	0.32	3.33	4.76
15	7687	6995	2306	9993	17000	0.59	0.41	2.60	3.72
25	8775	7986	2633	11408	17000	0.67	0.47	2.28	3.26
33	9953	9057	2986	12938	17000	0.76	0.53	2.01	2.87
44	11330	10310	3399	14729	17000	0.87	0.61	1.77	2.52
54	13135	11953	3940	17075	17000	1.00	0.70	1.52	2.18
63	14328	13038	4298	18626	17000	1.10	0.77	1.40	1.99
72	15220	13851	4566	19787	17000	1.16	0.81	1.31	1.88
84	17254	15701	5176	22430	17000	0.93	0.65	1.16	1.66
93	18443	16783	5533	23976	17000	1.00	0.70	1.08	1.55
102	19449	17698	5835	25284	17000	1.05	0.74	1.03	1.47
113	19480	17727	5844	25324	17000	1.06	0.74	1.58	2.26
123	20797	18925	6239	27036	17000	1.13	0.79	1.48	2.11
135	20152	18339	6046	26198	24000	1.09	0.76	1.53	2.18
145	22972	20905	6892	29864	24000	1.24	0.87	1.34	1.91
155	23866	21718	7160	31026	24000	1.29	0.90	1.29	1.84
164	23804	21662	7141	30946	24000	1.29	0.90	1.29	1.85
176	23216	21127	6965	30181	24000	1.26	0.88	1.33	1.89
188	23105	21025	6931	30036	24000	1.25	0.88	1.33	1.90
198	25608	23303	7682	33291	24000	1.39	0.97	1.20	1.72
206	25639	23331	7692	33331	24000	1.39	0.97	1.14	1.63
213	26839	24423	8052	34890	24000	1.45	1.02	1.09	1.56
225	22174	20179	6652	28827	24000	1.20	0.84	1.73	2.48
235	18578	16906	5573	24152	24000	1.01	0.70	2.07	2.96
245	26411	24034	7923	34334	24000	1.43	1.00	1.11	1.58
255	26962	24535	8089	35051	24000	1.46	1.02	1.08	1.55
263	28111	25581	8433	36544	24000	1.52	1.07	1.37	1.95
275	24668	22448	7400	32068	24000	1.34	0.94	1.56	2.23
283	25762	23444	7729	33491	24000	1.40	0.98	1.49	2.13
293	24161	21987	7248	31410	24000	1.31	0.92	1.59	2.27
304	24373	22179	7312	31685	24000	1.32	0.92	1.58	2.25
313	24251	22069	7275	31527	24000	1.31	0.92	1.59	2.27
323	24080	21912	7224	31303	24000	1.30	0.91	1.60	2.28
333	22448	20428	6734	29183	24000	1.22	0.85	1.71	2.45
344	21728	19772	6518	28246	24000	1.18	0.82	1.77	2.53
355	22266	20262	6680	28946	24000	1.21	0.84	1.73	2.47
363	21013	19121	6304	27316	24000	1.14	0.80	1.83	2.61
376	21398	19472	6419	27817	24000	1.16	0.81	1.80	2.57
384	22517	20490	6755	29272	24000	1.22	0.85	1.71	2.44
398	23023	20951	6907	29929	24000	1.25	0.87	1.67	2.39

TABLE 1 - Full Supply Level (FSL)
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water= 62.4 pcf
Normal pond EL= 597 feet
Joint Efficiency= 0.7
1.0
D_1 ID= 17.00 feet
D_2 ID= 15.25 feet
D_3 ID= 13.50 feet
Note: Starting point is 42ft D/S of the face of the Intake

Project No: 2670030
Date: 6/14/2022
By: NPT
Checked CMV

Can #	Distance From Intake (Fwd Edge of Can 1) (ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints			Notes
												Stress (psi)[3]	Stress Ratio[2]	Stress (psi)[4]	Stress Ratio[4] (0.7)	Stress Ratio[5] (1.0)	
Penstock Interior From Upstream End of Conduit																	
4	26.3	8.50	A	11.3000	0.4449	0.4375	1.7%	0.4240	0.4449	554.70	17,000	4,202.26	0.25	6,003.22	0.35	0.25	A285 STEEL GRADE UNKNOWN 17 FT DIA.
			B	12.5000	0.4921	0.4375	12.5%				17,000						
			C	12.1000	0.4764	0.4375	8.9%				17,000						
15	126.0	8.50	A	10.8000	0.4252	0.4375	-2.8%	0.3930	0.4055	547.64	17,000	5,380.65	0.32	7,686.64	0.45	0.32	
			B	10.4000	0.4094	0.4375	-6.4%				17,000						
			C	10.3000	0.4055	0.4375	-7.3%				17,000						
25	186.5	8.50	A	10.3000	0.4055	0.4375	-7.3%	0.3860	0.4016	541.19	17,000	6,142.76	0.36	8,775.38	0.52	0.36	
			B	10.8000	0.4252	0.4375	-2.8%				17,000						
			C	10.2000	0.4016	0.4375	-8.2%				17,000						
33	262.5	8.50	A	10.3000	0.4055	0.4375	-7.3%	0.4017	0.4055	533.08	17,000	6,966.79	0.41	9,952.56	0.59	0.41	
			B	10.5000	0.4134	0.4375	-5.5%				17,000						
			C	10.4000	0.4094	0.4375	-6.4%				17,000						
44	371.1	8.50	A	10.7000	0.4213	0.4375	-3.7%	0.4194	0.4213	521.41	17,000	7,931.01	0.47	11,330.01	0.67	0.47	
			B	10.8000	0.4252	0.4375	-2.8%				17,000						
			C	10.8000	0.4252	0.4375	-2.8%				17,000						
54	471.5	8.50	A	10.5000	0.4134	0.4375	-5.5%	0.3969	0.4094	511.83	17,000	9,194.37	0.54	13,134.81	0.77	0.54	
			B	10.9000	0.4291	0.4375	-1.9%				17,000						
			C	10.4000	0.4094	0.4375	-6.4%				17,000						
63	562.0	8.50	A	10.9000	0.4291	0.4375	-1.9%	0.3992	0.4094	504.09	17,000	10,029.47	0.59	14,327.82	0.84	0.59	
			B	10.4000	0.4094	0.4375	-6.4%				17,000						
			C	10.6000	0.4173	0.4375	-4.6%				17,000						
72	652.0	8.50	A	10.6000	0.4173	0.4375	-4.6%	0.4118	0.4173	496.41	17,000	10,654.31	0.63	15,220.44	0.90	0.63	
			B	10.9000	0.4291	0.4375	-1.9%				17,000						
			C	10.9000	0.4291	0.4375	-1.9%				17,000						
84	771.7	8.50	A	10.3000	0.4055	0.4375	-7.3%	0.3966	0.4055	486.19	24,000	12,077.80	0.50	17,253.99	0.72	0.50	CSA G40.8 GR.B STEEL
			B	10.6000	0.4173	0.4375	-4.6%				24,000						
			C	10.8000	0.4252	0.4375	-2.8%				24,000						
93	861.0	8.50	A	10.6000	0.4173	0.4375	-4.6%	0.3990	0.4055	478.56	24,000	12,910.15	0.54	18,443.07	0.77	0.54	
			B	10.4000	0.4094	0.4375	-6.4%				24,000						
			C	10.3000	0.4055	0.4375	-7.3%				24,000						
102	950.1	8.50	A	10.4000	0.4094	0.4375	-6.4%	0.3991	0.4094	470.88	24,000	13,614.20	0.57	19,448.86	0.81	0.57	
			B	10.9000	0.4291	0.4375	-1.9%				24,000						
			C	11.0000	0.4331	0.4375	-1.0%				24,000						
113	1,059.6	7.63	A	10.9000	0.4291	0.4375	-1.9%	0.3760	0.3937	461.60	24,000	13,635.89	0.57	19,479.84	0.81	0.57	15.25 FT DIA.
			B	10.4000	0.4094	0.4375	-6.4%				24,000						
			C	10.0000	0.3937	0.4375	-10.0%				24,000						
123	1,159.0	7.63	A	10.4000	0.4094	0.4375	-6.4%	0.4063	0.4094	446.67	24,000	14,557.92	0.61	20,797.02	0.87	0.61	
			B	10.5000	0.4134	0.4375	-5.5%				24,000						
			C	10.4000	0.4094	0.4375	-6.4%				24,000						
135	1,259.0	7.63	A	12.7000	0.5000	0.5625	-11.1%	0.4931	0.5000	419.11	24,000	14,106.69	0.59	20,152.42	0.84	0.59	
			B	13.1000	0.5157	0.5625	-8.3%				24,000						
			C	13.0000	0.5118	0.5625	-9.0%				24,000						
145	1,349.4	7.63	A	12.7000	0.5000	0.5625	-11.1%	0.4615	0.5000	394.22	24,000	16,080.70	0.67	22,972.43	0.96	0.67	
			B	14.4000	0.5669	0.5625	0.8%				24,000						
			C	13.2000	0.5197	0.5625	-7.6%				24,000						
155	1,440.7	7.63	A	14.5000	0.5709	0.5625	1.5%	0.5204	0.5394	369.74	24,000	16,706.36	0.70	23,866.23	0.99	0.70	
			B	13.7000	0.5394	0.5625	-4.1%				24,000						
			C	13.9000	0.5472	0.5625	-2.7%				24,000						
164	1,518.5	7.63	A	14.3000	0.5630	0.6250	-9.9%	0.5476	0.5551	363.71	24,000	16,663.09	0.69	23,804.42	0.99	0.69	
			B	14.5000	0.5709	0.6250	-8.7%				24,000						
			C	14.1000	0.5551	0.6250	-11.2%				24,000						
176	1,610.8	7.63	A	15.5000	0.6102	0.6250	-2.4%	0.5729	0.5866	356.56	24,000	16,251.47	0.68	23,216.38	0.97	0.68	
			B	15.7000	0.6181	0.6250	-1.1%				24,000						
			C	14.9000	0.5866	0.6250	-6.1%				24,000						
188	1,718.0	7.63	A	16.0000	0.6299	0.6875	-8.4%	0.6134	0.6260	341.66	24,000	16,173.16	0.67	23,104.52	0.96	0.67	
			B	16.4000	0.6457	0.6875	-6.1%				24,000						
			C	15.9000	0.6260	0.6875	-8.9%				24,000						
198	1,791.0	7.63	A	15.0000	0.5906	0.5990	-1.4%	0.5811	0.5906	330.01	24,000	17,925.77	0.75	25,608.24	1.07	0.75	HSB 50 STEEL
			B	15.0000	0.5906	0.5990	-1.4%				24,000						
			C	15.3000	0.6024	0.5990	0.6%				24,000						
206	1,860.0	7.63	A	15.6000	0.6142	0.6250	-1.7%	0.5966	0.6142	319.00	24,000	17,947.23	0.75	25,638.90	1.07	0.75	
			B	16.5000	0.6496	0.6250	3.9%				24,000						
			C	16.6000	0.6535	0.6250	4.6%				24,000						
213	1,929.1	7.63	A	15.5000	0.6102	0.7240	-13.7%	0.6000	0.6102	307.85	24,000	18,787.16	0.78	26,838.80	1.12	0.78	
			B	15.7000	0.6181	0.7240	-14.6%				24,000						
			C	16.0000	0.6299	0.7240	-13.0%				24,000						
225	2,049.0	6.75	A	19.0000	0.7480	0.8125	-7.9%	0.6743	0.6969	288.84	24,000	15,522.04	0.65	22,174.34	0.92	0.65	CSA G40.8 GR.B STEEL, 13.5 FT DIA. REDUCER
			B	18.6000	0.7323	0.8125	-9.9%				24,000						
			C	17.7000	0.6969	0.8125	-14.2%				24,000						
235	2,138.0	6.75	A	22.2000	0.8740	0.6720	30.1%	0.8635	0.8701	274.63	24,000	13,004.68	0.54	18,578.11	0.77	0.54	HSB 50 STEEL
			B	22.4000	0.8819	0.6720	31.2%				24,000						
			C	22.1000	0.8701	0.6720	29.5%				24,000						
245	2,220.0	6.75	A	16.5000	0.6496	0.7060	-8.0%	0.6244	0.6339	263.14	24,000	18,487.44	0.77	26,410.63	1.10	0.77	
			B	16.1000	0.6339	0.7060	-10.2%				24,000						
			C	16.2000	0.6378	0.7060	-9.7%				24,000						
255	2,320.0	6.75	A	16.6000	0.6535	0.7390	-11.6%	0.6280	0.6535	245.59	24,000	18,873.44	0.79	26,962.06	1.12	0.79	
			B	17.7000	0.6969	0.7390	-5.7%				24,000						
			C	16.9000	0.6654	0.7390	-10.0%				24,000						
263	2,400.0	6.75	A	16.5000	0.6496	0.7680	-15.4%	0.6339	0.6496	232.82	24,000	19,677.69	0.82	28,110.99	1.17	0.82	
			B	16.5000	0.6496	0.7680	-15.4%				24,000						
			C	17.0000	0.6693	0.7680	-12.9%				24,000						
275	2,521.0	6.75	A	19.9000	0.7835	0.9550	-18.0%	0.7730	0.7795	213.51	24,000	17,267.59	0.72	24,667.99	1.03	0.72	
			B	20.1000	0.7913	0.9550	-17.1%				24,000						
			C	19.8000	0.7795	0.9550	-18.4%				24,000						
283	2,601.0	6.75	A	20.5000	0.8071	0.8290	-2.6%	0.7386	0.7598	206.61	24,000	18,033.66	0.75	25,762.37	1.07	0.75	
			B	19.3000	0.7598	0.8290	-8.3%				24,000						
			C	20.4000	0.8031	0.8290	-3.1%				24,000						
293	2,697.0	6.75	A	21.0000	0.8268	0.8790	-5.9%	0.8215	0.8268	198.62	24,000	16,912.84	0.70	24,161.20	1.01	0.70	
			B	21.9000	0.8386	0.8790	-4.6%				24,000						
			C	21.7000	0.8346	0.8790	-5.0%				24,000						
304	2,808.0	6.75	A	21.3000	0.8386	0.9040	-7.2%	0.8197	0.8386	189.39	24,000	17,061.14	0.71	24,373.05	1.02	0.71	
			B	22.3000	0.8780	0.9040	-2.9%				24,000						
			C	21.8000	0.8583	0.9040	-5.1%				24,000						

Can #	Distance From Intake (Fwd Edge of Can 1) (ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints		Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4] (0.7)	Stress Ratio[5] (1.0J)	
313	2,898.0	6.75	A	22.5000	0.8858	0.9250	-4.45%	0.8461	0.8583	181.90	24,000	16,976.02	0.71	24,251.46	1.01	0.71	
			B	21.8000	0.8583	0.9250	-7.21%				24,000						
			C	22.4000	0.8819	0.9250	-4.66%				24,000						
323	2,999.0	6.75	A	23.9000	0.9409	0.9540	-1.38%	0.8958	0.8819	173.50	24,000	16,855.72	0.70	24,079.60	1.00	0.70	
			B	24.2000	0.9528	0.9540	-0.11%				24,000						
			C	23.9000	0.9409	0.9540	-1.38%				24,000						
333	3,099.0	6.75	A	24.3000	0.9803	1.1570	-15.27%	0.9551	0.9646	165.18	24,000	15,713.67	0.65	22,448.09	0.94	0.65	
			B	24.5000	0.9646	1.1570	-16.6%				24,000						
			C	24.6000	0.9685	1.1570	-16.27%				24,000						
344	3,209.0	6.75	A	24.3000	0.9803	1.0610	-7.6%	0.9342	0.9488	185.86	24,000	15,209.51	0.63	21,727.87	0.91	0.63	
			B	24.9000	0.9803	1.0610	-7.6%				24,000						
			C	24.1000	0.9488	1.0610	-10.56%				24,000						
355	3,305.0	6.75	A	24.9000	0.9803	1.0610	-7.6%	0.9601	0.9803	161.69	24,000	15,586.04	0.65	22,265.77	0.93	0.65	
			B	25.1000	0.9882	1.0610	-6.84%				24,000						
			C	26.0000	1.0236	1.0610	-3.53%				24,000						
365	3,382.0	6.75	A	27.5000	1.0827	1.1520	-6.01%	1.0761	1.0827	143.30	24,000	14,708.76	0.61	21,012.51	0.88	0.61	
			B	27.2000	1.0709	1.1520	-7.05%				24,000						
			C	27.6000	1.0866	1.1520	-5.7%				24,000						
376	3,471.0	6.75	A	28.9000	1.1378	1.2310	-7.6%	1.1027	1.1359	113.14	24,000	14,978.36	0.62	21,397.66	0.89	0.62	
			B	29.9000	1.1772	1.2310	-4.4%				24,000						
			C	29.1000	1.1457	1.2310	-6.92%				24,000						
384	3,550.0	6.75	A	28.9000	1.1378	1.2710	-10.5%	1.1025	1.1378	86.07	24,000	15,961.70	0.66	22,516.71	0.94	0.66	
			B	29.9000	1.1772	1.2710	-7.4%				24,000						
			C	29.1000	1.1457	1.2710	-9.86%				24,000						
398	3,689.0	6.75	A	31.2000	1.2283	1.3030	-5.73%	1.2110	1.2165	38.44	24,000	16,115.87	0.67	23,022.68	0.96	0.67	
			B	30.9000	1.2165	1.3030	-6.6%				24,000						
			C	31.2000	1.2283	1.3030	-5.73%				24,000						

Notes:

[1] Hoop stress = $Pr/t_{1.2}$

[2] Hoop stress / S_A

[3] Hoop stress / 0.7 $J_{joint\ efficiency}$

[4] Joint stress / S_A

[5] Hoop stress / 1.0 $J_{joint\ efficiency}$

Minimum Wall Thickness	
All	0.3957
1268a	0.4014
15-25Hla	0.3997
13-26Bla	0.8339

TABLE 2 - Transient
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4 pcf	Project No:	2670030
Normal pond EL=	597 feet	Date:	6/14/2022
Joint Efficiency=	0.7	By:	NPT
	1.0	Checked	CMV
D_1 ID=	17.00 feet		
D_2 ID=	15.25 feet		
D_3 ID=	13.50 feet		

Note: Starting point is 42ft D/S of the face of the Intake

Can #	Distance From Intake (Fwd Edge of Can 1) (ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Plate Thickness (in)	%Change in Material	97.5% Confidence Interval	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress (psi)	Base Material		At Joints			Notes
												Stress (psi)[1]	Stress Ratio[2]	Stress (psi)[3]	Stress Ratio[4] (0.7)	Stress Ratio[5] (1.0)	
Penstock Interior From Upstream End of Conduit																	
4	26.3	8.50	A	11.3000	0.4449	0.4375	1.7%	0.4240	0.4449	554.70	17,000	5,462.93	0.32	7,804.19	0.46	0.32	A285 STEEL GRADE UNKNOWN 17 FT DIA.
			B	12.5000	0.4921	0.4375	12.5%				17,000						
			C	12.1000	0.4764	0.4375	8.9%				17,000						
15	126.0	8.50	A	10.8000	0.4252	0.4375	-2.8%	0.3930	0.4055	547.64	17,000	6,994.84	0.41	9,992.63	0.59	0.41	
			B	10.4000	0.4094	0.4375	-6.4%				17,000						
			C	10.3000	0.4055	0.4375	-7.3%				17,000						
25	186.5	8.50	A	10.3000	0.4055	0.4375	-7.3%	0.3860	0.4016	541.19	17,000	7,985.59	0.47	11,407.99	0.67	0.47	
			B	10.8000	0.4252	0.4375	-2.8%				17,000						
			C	10.2000	0.4016	0.4375	-8.2%				17,000						
33	262.5	8.50	A	10.3000	0.4055	0.4375	-7.3%	0.4017	0.4055	533.08	17,000	9,056.83	0.53	12,938.33	0.76	0.53	
			B	10.5000	0.4134	0.4375	-5.5%				17,000						
			C	10.4000	0.4094	0.4375	-6.4%				17,000						
44	371.1	8.50	A	10.7000	0.4213	0.4375	-3.7%	0.4194	0.4213	521.41	17,000	10,310.31	0.61	14,729.01	0.87	0.61	
			B	10.8000	0.4252	0.4375	-2.8%				17,000						
			C	10.8000	0.4252	0.4375	-2.8%				17,000						
54	471.5	8.50	A	10.5000	0.4134	0.4375	-5.5%	0.3969	0.4094	511.83	17,000	11,952.68	0.70	17,075.26	1.00	0.70	
			B	10.9000	0.4291	0.4375	-1.9%				17,000						
			C	10.4000	0.4094	0.4375	-6.4%				17,000						
63	562.0	8.50	A	10.9000	0.4291	0.4375	-1.9%	0.3992	0.4094	504.09	17,000	13,038.32	0.77	18,626.17	1.10	0.77	
			B	10.4000	0.4094	0.4375	-6.4%				17,000						
			C	10.6000	0.4173	0.4375	-4.6%				17,000						
72	652.0	8.50	A	10.6000	0.4173	0.4375	-4.6%	0.4118	0.4173	496.41	17,000	13,850.60	0.81	19,786.58	1.16	0.81	
			B	10.9000	0.4291	0.4375	-1.9%				17,000						
			C	10.9000	0.4291	0.4375	-1.9%				17,000						
84	771.7	8.50	A	10.3000	0.4055	0.4375	-7.3%	0.3966	0.4055	486.19	24,000	15,701.13	0.65	22,430.19	0.93	0.65	CSA G40.8 GR.B STEEL
			B	10.6000	0.4173	0.4375	-4.6%				24,000						
			C	10.8000	0.4252	0.4375	-2.8%				24,000						
93	861.0	8.50	A	10.6000	0.4173	0.4375	-4.6%	0.3990	0.4055	478.56	24,000	16,783.19	0.70	23,975.99	1.00	0.70	
			B	10.4000	0.4094	0.4375	-6.4%				24,000						
			C	10.3000	0.4055	0.4375	-7.3%				24,000						
102	950.1	8.50	A	10.4000	0.4094	0.4375	-6.4%	0.3991	0.4094	470.88	24,000	17,698.46	0.74	25,283.52	1.05	0.74	
			B	10.9000	0.4291	0.4375	-1.9%				24,000						
			C	11.0000	0.4331	0.4375	-1.0%				24,000						
113	1,059.6	7.63	A	10.9000	0.4291	0.4375	-1.9%	0.3760	0.3937	461.60	24,000	17,726.66	0.74	25,323.79	1.06	0.74	15.25 FT DIA.
			B	10.4000	0.4094	0.4375	-6.4%				24,000						
			C	10.0000	0.3937	0.4375	-10.0%				24,000						
123	1,159.0	7.63	A	10.4000	0.4094	0.4375	-6.4%	0.4063	0.4094	446.67	24,000	18,925.29	0.79	27,036.13	1.13	0.79	
			B	10.5000	0.4134	0.4375	-5.5%				24,000						
			C	10.4000	0.4094	0.4375	-6.4%				24,000						
135	1,259.0	7.63	A	12.7000	0.5000	0.5625	-11.1%	0.4931	0.5000	419.11	24,000	18,338.70	0.76	26,198.14	1.09	0.76	
			B	13.1000	0.5157	0.5625	-8.3%				24,000						
			C	13.0000	0.5118	0.5625	-9.0%				24,000						

145	1,349.4	7.63	A	12.7000	0.5000	0.5625	-11.1%	0.4615	0.5000	394.22	24,000	20,904.91	0.87	29,864.16	1.24	0.87	
			B	14.4000	0.5669	0.5625	0.8%				24,000						
			C	13.2000	0.5197	0.5625	-7.6%				24,000						
155	1,440.7	7.63	A	14.5000	0.5709	0.5625	1.5%	0.5204	0.5394	369.74	24,000	21,718.27	0.90	31,026.10	1.29	0.90	
			B	13.7000	0.5394	0.5625	-4.1%				24,000						
			C	13.9000	0.5472	0.5625	-2.7%				24,000						
164	1,518.5	7.63	A	14.3000	0.5630	0.6250	-9.9%	0.5476	0.5551	363.71	24,000	21,662.02	0.90	30,945.75	1.29	0.90	
			B	14.5000	0.5709	0.6250	-8.7%				24,000						
			C	14.1000	0.5551	0.6250	-11.2%				24,000						
176	1,610.8	7.63	A	15.5000	0.6102	0.6250	-2.4%	0.5729	0.5866	356.56	24,000	21,126.91	0.88	30,181.30	1.26	0.88	
			B	15.7000	0.6181	0.6250	-1.1%				24,000						
			C	14.9000	0.5866	0.6250	-6.1%				24,000						
188	1,718.0	7.63	A	16.0000	0.6299	0.6875	-8.4%	0.6134	0.6260	341.66	24,000	21,025.11	0.88	30,035.87	1.25	0.88	
			B	16.4000	0.6457	0.6875	-6.1%				24,000						
			C	15.9000	0.6260	0.6875	-8.9%				24,000						
198	1,791.0	7.63	A	15.0000	0.5906	0.5990	-1.4%	0.5811	0.5906	330.01	24,000	23,303.50	0.97	33,290.71	1.39	0.97	HSB 50 STEEL
			B	15.0000	0.5906	0.5990	-1.4%				24,000						
			C	15.3000	0.6024	0.5990	0.6%				24,000						
206	1,860.0	7.63	A	15.6000	0.6142	0.6250	-1.7%	0.5966	0.6142	319.00	24,000	23,331.40	0.97	33,330.57	1.39	0.97	
			B	16.5000	0.6496	0.6250	3.9%				24,000						
			C	16.6000	0.6535	0.6250	4.6%				24,000						
213	1,929.1	7.63	A	15.5000	0.6102	0.7240	-15.7%	0.6000	0.6102	307.85	24,000	24,423.31	1.02	34,890.44	1.45	1.02	
			B	15.7000	0.6181	0.7240	-14.6%				24,000						
			C	16.0000	0.6299	0.7240	-13.0%				24,000						
225	2,049.0	6.75	A	19.0000	0.7480	0.8125	-7.9%	0.6743	0.6969	288.84	24,000	20,178.65	0.84	28,826.64	1.20	0.84	CSA G40.8 GR.B STEEL, 13.5 FT DIA. REDUCER
			B	18.6000	0.7323	0.8125	-9.9%				24,000						
			C	17.7000	0.6969	0.8125	-14.2%				24,000						
235	2,138.0	6.75	A	22.2000	0.8740	0.6720	30.1%	0.8635	0.8701	274.63	24,000	16,906.08	0.70	24,151.54	1.01	0.70	HSB 50 STEEL
			B	22.4000	0.8819	0.6720	31.2%				24,000						
			C	22.1000	0.8701	0.6720	29.5%				24,000						
245	2,220.0	6.75	A	16.5000	0.6496	0.7060	-8.0%	0.6244	0.6339	263.14	24,000	24,033.68	1.00	34,333.82	1.43	1.00	
			B	16.1000	0.6339	0.7060	-10.2%				24,000						
			C	16.2000	0.6378	0.7060	-9.7%				24,000						
255	2,320.0	6.75	A	16.6000	0.6535	0.7390	-11.6%	0.6280	0.6535	245.59	24,000	24,535.47	1.02	35,050.68	1.46	1.02	
			B	17.7000	0.6969	0.7390	-5.7%				24,000						
			C	16.9000	0.6654	0.7390	-10.0%				24,000						
263	2,400.0	6.75	A	16.5000	0.6496	0.7680	-15.4%	0.6339	0.6496	232.82	24,000	25,581.00	1.07	36,544.28	1.52	1.07	
			B	16.5000	0.6496	0.7680	-15.4%				24,000						
			C	17.0000	0.6693	0.7680	-12.9%				24,000						
275	2,521.0	6.75	A	19.9000	0.7835	0.9550	-18.0%	0.7730	0.7795	213.51	24,000	22,447.87	0.94	32,068.38	1.34	0.94	
			B	20.1000	0.7913	0.9550	-17.1%				24,000						
			C	19.8000	0.7795	0.9550	-18.4%				24,000						
283	2,601.0	6.75	A	20.5000	0.8071	0.8290	-2.6%	0.7386	0.7598	206.61	24,000	23,443.76	0.98	33,491.08	1.40	0.98	
			B	19.3000	0.7598	0.8290	-8.3%				24,000						
			C	20.4000	0.8031	0.8290	-3.1%				24,000						
293	2,697.0	6.75	A	21.0000	0.8268	0.8790	-5.9%	0.8215	0.8268	198.62	24,000	21,986.69	0.92	31,409.56	1.31	0.92	
			B	21.3000	0.8386	0.8790	-4.6%				24,000						
			C	21.2000	0.8346	0.8790	-5.0%				24,000						
304	2,808.0	6.75	A	21.3000	0.8386	0.9040	-7.2%	0.8197	0.8386	189.39	24,000	22,179.48	0.92	31,684.97	1.32	0.92	
			B	22.3000	0.8780	0.9040	-2.9%				24,000						
			C	21.8000	0.8583	0.9040	-5.1%				24,000						
313	2,898.0	6.75	A	22.5000	0.8858	0.9290	-4.6%	0.8461	0.8583	181.90	24,000	22,068.83	0.92	31,526.89	1.31	0.92	
			B	21.8000	0.8583	0.9290	-7.6%				24,000						
			C	22.4000	0.8819	0.9290	-5.1%				24,000						
323	2,999.0	6.75	A	23.9000	0.9409	0.9540	-1.4%	0.8508	0.8819	173.50	24,000	21,912.44	0.91	31,303.48	1.30	0.91	
			B	24.2000	0.9528	0.9540	-0.1%				24,000						
			C	22.4000	0.8819	0.9540	-7.6%				24,000						
333	3,099.0	6.75	A	24.9000	0.9803	1.1570	-15.3%	0.9551	0.9646	165.18	24,000	20,427.77	0.85	29,182.52	1.22	0.85	
			B	24.5000	0.9646	1.1570	-16.6%				24,000						
			C	24.6000	0.9685	1.1570	-16.3%				24,000						
344	3,209.0	6.75	A	24.9000	0.9803	1.0610	-7.6%	0.9342	0.9488	185.86	24,000	19,772.37	0.82	28,246.24	1.18	0.82	
			B	24.9000	0.9803	1.0610	-7.6%				24,000						
			C	24.1000	0.9488	1.0610	-10.6%				24,000						
355	3,305.0	6.75	A	24.9000	0.9803	1.0610	-7.6%	0.9601	0.9803	161.69	24,000	20,261.85	0.84	28,945.50	1.21	0.84	
			B	25.5000	1.0039	1.0610	-5.4%				24,000						

			C	26.0000	1.0236	1.0610	-3.5%				24,000					
			A	27.5000	1.0827	1.1520	-6.0%				24,000					
363	3,383.0	6.75	B	27.8000	1.0945	1.1520	-5.0%	1.0761	1.0827	143.30	24,000	19,121.39	0.80	27,316.27	1.14	0.80
			C	27.6000	1.0866	1.1520	-5.7%				24,000					
			A	28.9000	1.1378	1.2310	-7.6%				24,000					
376	3,471.0	6.75	B	29.9000	1.1772	1.2310	-4.4%	1.1027	1.1339	113.14	24,000	19,471.87	0.81	27,816.96	1.16	0.81
			C	28.8000	1.1339	1.2310	-7.9%				24,000					
			A	28.9000	1.1378	1.2710	-10.5%				24,000					
384	3,550.0	6.75	B	29.9000	1.1772	1.2710	-7.4%	1.1025	1.1378	86.07	24,000	20,490.20	0.85	29,271.72	1.22	0.85
			C	30.8000	1.2126	1.2710	-4.6%				24,000					
			A	31.2000	1.2283	1.3030	-5.7%				24,000					
398	3,689.0	6.75	B	30.9000	1.2165	1.3030	-6.6%	1.2110	1.2165	38.44	24,000	20,950.64	0.87	29,929.48	1.25	0.87
			C	31.2000	1.2283	1.3030	-5.7%				24,000					

Notes:

[1] Hoop stress = $Pr/t_{97.5}$
[2] Hoop stress / S_A
[3] Hoop stress / 0.7 $_{joint\ efficiency}$
[4] Joint stress / S_A
[5] Hoop stress / 1.0 $_{joint\ efficiency}$

Minimum Wall Thickness	
All	0.3937
17dia	0.4016
15.25dia	0.3937
13.5dia	0.6339

SLOPE SUMMARY										
Section	Degrees, Minutes, Seconds	θ	Distance			Elevation			Slope	
			From (ft)	To (ft)	Delta (ft)	Initial Elevation (ft)	Final Elevation (ft)	Change in Elevation (ft)		
0C - 1C	0,15,10	0.253	0	61.18	61.18	554.82	554.55	0.27	0.004413207	
1C - 2C	6,7,25	6.124	61.18	422.56	361.38	554.55	516	38.55	0.106674415	
2C - 3C	4,53,57	4.899	422.56	1125.13	702.57	516	456	60	0.085400743	17ft
3C - 4C	15,59,45	15.996	1125.13	1437.21	312.08	456	370	86	0.275570367	15.25ft
4C - 5C	4,26,35	4.443	1437.21	1637.81	200.6	370	354.46	15.54	0.077467597	
5C - 6C	9,11,00	9.183	1637.81	2017.68	379.87	354.46	293.83	60.63	0.159607234	
6C - 7C	9,11,00	9.183	2017.68	2524.17	506.49	293.83	213	80.83	0.159588541	13.5ft (32ft D/S of 6C)
7C - 8C	4,46,19	4.772	2524.17	3101.17	577	213	165	48	0.083188908	
8C - 9C	14,34,43	14.579	3101.17	3319.68	218.51	165	110	55	0.251704727	
9C - 10C	20,02,27	20.041	3319.68	3631.45	311.77	110	3	107	0.343201719	
10C - PH	0	0.000	3631.45	3710.73	79.28	3	3	0	0	

ELEVATION CALCULATIONS						
Can #	Distance (From Can #1) (ft)	Slope (θ)	Distance from Slope Change (ft)	Change in Elevation (ft)	Final Elevation (ft)	Section
-					554.82	Intake
4	26	0.25	26.42	0.12	554.70	0C-1C
15	126	6.12	64.82	6.91	547.64	1C-2C
25	186	6.12	125.24	13.36	541.19	1C-2C
33	262	6.12	201.24	21.47	533.08	1C-2C
44	372	6.12	310.65	33.14	521.41	1C-2C
54	471	4.90	48.86	4.17	511.83	2C-3C
63	562	4.90	139.44	11.91	504.09	2C-3C
72	652	4.90	229.44	19.59	496.41	2C-3C
84	772	4.90	349.02	29.81	486.19	2C-3C
93	861	4.90	438.44	37.44	478.56	2C-3C
102	951	4.90	528.27	45.12	470.88	2C-3C
113	1060	4.90	636.94	54.40	461.60	2C-3C
123	1159	16.00	33.87	9.33	446.67	3C-4C
135	1259	16.00	133.87	36.89	419.11	3C-4C
145	1349	16.00	224.20	61.78	394.22	3C-4C
155	1441	4.44	3.37	0.26	369.74	4C-5C
164	1518	4.44	81.21	6.29	363.71	4C-5C
176	1611	4.44	173.46	13.44	356.56	4C-5C
188	1718	9.18	80.19	12.80	341.66	5C-6C
198	1791	9.18	153.19	24.45	330.01	5C-6C
206	1860	9.18	222.19	35.46	319.00	5C-6C
213	1930	9.18	292.02	46.61	307.85	5C-6C
225	2049	9.18	411.19	65.62	288.84	6C-7C
235	2138	9.18	500.19	79.83	274.63	6C-7C
245	2210	9.18	572.19	91.32	263.14	6C-7C
255	2320	9.18	682.19	108.87	245.59	6C-7C
263	2400	9.18	762.19	121.64	232.82	6C-7C
275	2521	9.18	883.19	140.95	213.51	6C-7C
283	2601	4.77	76.83	6.39	206.61	7C-8C
293	2697	4.77	172.83	14.38	198.62	7C-8C
304	2808	4.77	283.83	23.61	189.39	7C-8C
313	2898	4.77	373.83	31.10	181.90	7C-8C
323	2999	4.77	474.83	39.50	173.50	7C-8C
333	3099	4.77	574.83	47.82	165.18	7C-8C
344	3209	14.58	107.83	27.14	185.86	8C-9C
355	3305	14.58	203.83	51.31	161.69	8C-9C
363	3383	20.04	63.32	21.70	143.30	9C-10C
376	3471	20.04	151.32	51.86	113.14	9C-10C
384	3550	20.04	230.32	78.93	86.07	9C-10C
398	3689	20.04	369.32	126.56	38.44	9C-10C

PLATE THICKNESS SUMMARY		
From - To (ft)	Thickness (in)	Steel
0 - 61	0.4375	ASTM A285
61 - 753	0.4375	
753 - 1114	0.4375	CSA G40.8 B STEEL
1114.3 - 1136	0.5625	
1136-1217	0.4375	
1217-1427	0.5625	
1427-1448	0.7500	
1448-1475	0.5625	
1475-1630	0.6250	
1630-1646	0.7500	
1646-1699	0.6250	
1699-1733	0.6875	
1733-1743	0.6530	HSB 50 STEEL
1743-1831	0.5990	
1831-1919	0.6250	
1919-1929	0.7240	
1929-2002	0.7500	G40.8B
2002-2042	SURGE TANK	
2042-2050	UNKNOWN	
2050-2060	0.8125	
2060-2069	0.7000	HSB 50 STEEL
2069-2138	0.6380	
2138-2218	0.6720	
2218-2298	0.7060	
2298-2377	0.7390	
2377-2447	0.7680	
2447-2517	0.7980	
2517-2532	0.9550	
2532-2612	0.8290	
2612-2692	0.8540	
2692-2772	0.8790	
2772-2852	0.9040	
2852-2932	0.9290	
2952-3012	0.9540	
3012-3092	0.9790	
3092-3111	1.1570	
3111-3179	1.0250	
3179-3247	1.0610	
3247-3305	1.0950	
3305-3336	1.2920	
3336-3394	1.1520	
3394-3453	1.1910	
3453-3512	1.2310	
3512-3571	1.2710	
3571-3620	1.3030	

EXTERNAL PRESSURES EVALUATION- PENSTOCK 2 BAY D'ESPOIR

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 17 feet								
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_v=	0	
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	Fill Unit Weight=	120	lb/ft^3
OD Conduit Diameter=	17.06626667	feet	ID:	17.00	feet	(soil load) W_c=	6655.8	lb/ft
		Assume well				(live load) W_l=	1706.6	lb/ft
Buoyancy Factor R_w=	1	drained = 1				W_s=	351.7	lb/ft
B_prime=	0.23302752					W_{steel}=	957.8	lb/ft
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf
E=	30000000	psi						
b=	1					External pressure with vacuum=	**3.10**	psi
(Minimum measured wall thickness) t_{MIN}=	0.3976	inches				[1]External pressure with snow load=	**3.24**	psi
I=	0.0052	$inches^4$				[1]External pressure with snow and live=	**3.72**	psi
[1,2]FS=	2							
[2]Allowable pressure q_a=	**4.11**	psi						

								Ratio Q/q_a= 0.754129
								Ratio Q/q_a= 0.788968
								Ratio Q/q_a= 0.907038

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 15.25 feet								
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_v=	0	
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3
Total Height of Soil=	3	feet	(for DL calc) t=	1.19	inches	Fill Unit Weight=	120	lb/ft^3
OD Conduit Diameter=	15.33465	feet	ID:	15.25	feet	(soil load) W_c=	5980.5	lb/ft
		Assume well				(live load) W_l=	1533.5	lb/ft
Buoyancy Factor R_w=	1	drained = 1				W_s=	316	lb/ft
B_prime=	0.2330					W_{steel}=	2336	lb/ft
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf
E=	30000000	psi						
b=	1					External pressure with vacuum=	**3.76**	psi
(Minimum measured wall thickness) t_{MIN}=	0.5079	inches				[1]External pressure with snow load=	**3.91**	psi
I=	0.0109	$inches^4$				[1]External pressure with snow and live=	**4.39**	psi
[1,2]FS=	2							
[2]Allowable pressure q_a=	**6.94**	psi						

								100 psf per foot section
								Ratio Q/q_a= 0.542156
								Ratio Q/q_a= 0.56276
								Ratio Q/q_a= 0.632584

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 13.5 feet								
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_v=	0	
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	Fill Unit Weight=	120	lb/ft^3
OD Conduit Diameter=	13.60891667	feet	ID:	13.50	feet	(soil load) W_c=	5307.5	lb/ft
		Assume well				(live load) W_l=	1360.9	lb/ft
Buoyancy Factor R_w=	1	drained = 1				W_s=	280.5	lb/ft
B_prime=	0.23302752					W_{steel}=	2836.9	lb/ft
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf
E=	30000000	psi						
b=	1					External pressure with vacuum=	**4.15**	psi
(Minimum measured wall thickness) t_{MIN}=	0.6535	inches				[1]External pressure with snow load=	**4.30**	psi
I=	0.0233	$inches^4$				[1]External pressure with snow and live=	**4.78**	psi
[1,2]FS=	2							
[2]Allowable pressure q_a=	**12.07**	psi						

								Ratio Q/q_a= 0.34397
								Ratio Q/q_a= 0.355816
								Ratio Q/q_a= 0.395962

References:

[1]ASCE No. 79, Steel Penstocks, 2nd Edition, 2012

[2]AWWA M11, Steel Pipe - A Guide for Design and Installation, current version.

Schedule 1, Attachment 9

Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project

Kleinschmidt Associates

January 2024



PENSTOCK 3 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
Kleinschmidt Associates

January 2024

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in January 2023 to inspect and evaluate the condition of Penstocks 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

In 2016, cracking was identified in Penstock 1 and Kleinschmidt assisted NLH with the inspection and weld repair design. Penstock 1 was repaired the same year as the inspection. Kleinschmidt inspected Penstock 2 later in 2016 and discovered similar weld deterioration of Penstock 2, which was repaired in 2017. Subsequent to the previous inspections of Penstock 1 and 2, deteriorated welds were repaired in Penstock 3 after inspection in 2018.

As indicated in the record drawings, Penstock 3 was installed in 1968, a year after the Penstock 1 and 2, using similar plate materials, thicknesses, and weld procedures. Due to the three penstocks being of similar age and design and because of the identified weld deterioration and corrosion, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock 3 inspection was to assess the integrity of the welds and complete steel thickness measurements to evaluate metal loss and corrosion to determine if the penstock condition is acceptable to operate through another calendar year

An inspection of Penstock 3 was conducted by Kleinschmidt in May 2023, which consisted of a visual walk-over of the penstock exterior, and a detailed evaluation of the condition of the interior of the penstock. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which consisted of cleaning and visually inspecting the steel shell and the longitudinal and circumferential welds. Non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell were also performed during the inspection.

The 2023 inspection found nine (9) Cans with weld indications as listed in Section 3.2. The indications we repaired by the contractor working on the Surge Tank transition section with repairs complete withing two weeks of this inspection. Eight of the nine cans were in the 17-foot diameter section and were previously repaired welds.

The inspection revealed minimal loss of material thickness of the penstock shell. The plate thickness was comparable to the record drawings, and the interior of the shell displayed a layer of rust with moderate corrosion and pitting common for a 50-year-old penstock. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3.

The welded joints at the penstock to surge tank transition were being repaired during this inspection as recommended in the 2021 inspection report.

The sinkhole discovered in 2019 downstream of the surge tank on the left side of the penstock has been filled in previous years and appears to have stabilized. The area should continue to be monitored for further erosion.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.53 (Can 217). This indicates that the penstock joints in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 0.98, which is not acceptable for late 1960 steel pipe. The calculated stress at the joints assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used for the analysis, as discussed in Section 4, if RT weld testing is performed to verify the integrity of the welds. A higher joint efficiency would result in favourable factors of safety; however, considering the known weld deterioration, a higher joint efficiency is not justified at this time.

The base plate material away from the joints has stress ratios that varies significantly ranging from 0.3 to 1.07. Three of the 36 cans measured had ratios above 1.0.

This approximately 50-year-old penstock has shown minimal loss of thickness from the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070). However, because of the condition of the existing welds, the 17-ft section of penstock will need to be replaced, the remaining penstock welds refurbished, and the interior re-coated before the steel deteriorates further.

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ACRONYMS

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
CH	Chainage (in metres)
cms	Cubic Metres per Second
ETS	EasternTechnical Services Ltd.
Fu	Ultimate Tensile Stress
Fy	Yield Stress
GWh	Gigawatt Hours
kPa	Kilo-Pascals
Kleinschmidt	Kleinschmidt Associates
MW	Megawatts
NLH	Newfoundland and Labrador Hydro
SPRAT	Society of Professional Rope Access Technicians
STA	Station (in feet)
TRR	Technical Rope and Rescue
UT	Ultrasonic Thickness

1.0 INTRODUCTION

In 2016, cracking was identified by Newfoundland and Labrador Hydro (NLH) in Penstock 1 due to weld degradation and Kleinschmidt Associates Canada Inc. (Kleinschmidt) assisted with inspection and a weld repair design. However, the discovery of an additional indication in Penstock 1 prompted a detailed weld inspection of all three penstocks using non-destructive testing (NDT) methods.

NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished. Penstock 3 was not inspected in 2020 due to the Covid-19 pandemic travel restrictions.

The focus of the Penstock 3 inspection in 2023 was to assess the integrity of the welds and to complete steel plate thickness measurements to evaluate the current condition of the steel. The 2023 inspection concentrated on welds that have never been inspected downstream of the surge tank and welds not inspected during the previous year in the upper end of the penstock.

The May 2023 inspection of Penstock 3 consisted of weld inspections and steel plate thickness measurements completed by Technical Rope and Rescue (TRR) and Eastern Technical Services (ETS). Kleinschmidt engineer Chris Vella travelled to the Bay d'Espoir Hydro Site to complete an interior and exterior condition assessment of the penstock and assist with the weld inspection.

This report presents our evaluation of the capacity of the penstock in its current condition, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 ft (176 metres [m]) and seven generating units with a total capacity of 604 megawatts (MW). The hydro development is comprised of four intake structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks Nos. 1, 2, and 3 have surge towers approximately 2,400 ft (727 m) upstream of the powerhouse. The first phase of the initial project construction included installation of two intake structures and a four-unit powerhouse with Penstocks 1 and 2 connecting the two intakes to the powerhouse. The second phase of the project consisted of installing Penstock 3 with a third intake and two additional units in the powerhouse. A separate intake structure and powerhouse for Unit 7, connected by Penstock 4 was built in 1970. Penstock 3 supplies Units 5 and 6. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock 3 is a 1,100-m-long buried steel penstock, tapering from 5.2 m in diameter (at the intake) to 4.1 m in diameter at the powerhouse bifurcation. At the flattest point, the penstock has a 0.0% slope and has a 20% slope at the steepest. There are at least three areas to access the interior of Penstock 3, one at the well in the intake structure, three manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Appendix A includes the original 1968 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 7/16 inches at the intake to 1 5/8 inches at the bifurcation upstream of the powerhouse (plate thicknesses in this report are expressed in inches to match the drawings provided). The penstock is constructed of A285, G40.88 and HSB 50 steel. The penstock is 17.0 ft in diameter until STA 12+41 (CH 376.2), 15.25 ft in diameter between STA 12+41 (CH 376.2) and STA 27+50 (CH 833.3) where it then reduces to 13.5 ft in diameter for the remaining 1,581 ft (479.1 m) to the bifurcation. The welds are double V groove full penetration welds.

A majority of the penstock has a cover of 2 ft (0.61 m) of clayey soil and 1 ft (0.30 m) minimum thick layer of riprap. The penstock crosses underneath the switchyard and terminates at the powerhouse. Several weirs are located where the drainage daylights to the ditches and wells for inspection and monitoring purposes.

3.0 INSPECTION

Christopher Vella, P.Eng. of Kleinschmidt, inspected the interior and exterior of Penstock 3 on May 30 to June 1, 2023, with the assistance of personnel from Technical Rope and Rescue (TRR), Eastern Technical Services (ETS), and NLH. NLH were present to participate in morning safe talks and to answer questions about the history, operation, and maintenance of the station. ETS assisted with the ultrasonic thickness (UT) and MT testing of the penstock steel and welds. TRR rope access personnel assisted with safe access, confined space entry protocols, communication, and provided standby at the penstock entry for rescue.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying pitting or cracking, and an overall general condition assessment of the interior of the shell. ETS personnel performed MT weld tests on approximately 28% of the longitudinal welds from inside the 17-ft diameter section of penstock and 13% of the longitudinal welds overall. ETS took UT measurements from approximately 10% of the cans for the portion of penstock inspected.

The exterior of the buried penstock was examined for signs of leakage. For this inspection, all references to penstock left and right are oriented looking downstream.

Table 3-1 Definitions for Condition Assessment

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected, and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible, and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year

References to right and left are from the perspective of someone looking downstream unless noted otherwise.

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on the morning of Tuesday May 30, 2023. The inspection team entered the penstock on the same day at manhole 2 of Penstock 3. TRR assisted with confined space entrance and rigging for fall protection. The internal inspection finished on June 1, 2023. The exterior inspection commenced on May 31 and was completed by Kleinschmidt the same day. Kleinschmidt pre-marked welds to be inspected inside of the penstock so TRR and ETS could proceed with the internal inspection and weld testing while Kleinschmidt performed the external inspection. Air quality in the penstock remained good for the duration of the inspection.

The internal penstock inspection commenced at the headgate location. At the time of the inspection leakage around the gate was very low as expected from the new gate (Photo 1, Appendix B). There were just a few spots of leakage including the left side seal, and two bolts as shown in Photos 2 thru 4 in Appendix B. The limited leakage allowed for easier and drier travel inside the penstock. The organics upstream of the surge tank had been removed during previous penstock weld repairs, which facilitated the current inspection. More effort was required downstream of the surge tank to remove organics and clean welds as there were a greater quantity of existing welds not previously inspected.

The exterior inspection was completed in cloudy but warm and dry weather conditions. The ground surface was rocky with steep slopes with short vegetation (Photo 36). Some areas were noted to have significant alder bush growth and taller vegetation that was impeding inspection and sight of the ground surface (Photos 34 and 41). The ground was reasonably dry reducing slip potential. There were areas of saturated soil on the left-hand side of the penstock located adjacent and downstream of the surge tank, which has been noted in previous inspections as an area that is typically wet with runoff from the adjacent hill. The grade followed the penstock slope between the intake and the switchyard. The deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 Interior Inspection

The interior of the penstock was inspected from May 30 to June 1, 2023. The penstock consists of approximately 435 "Cans" into the powerhouse scroll case. A can, referred to in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used in this report to reference location within the penstock during the inspection, with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded at the interior surface at various locations. Shell thickness measurements were taken by ETS with a GE DMS Go+ digital thickness gauge (S/N GOPLS20050054) with a KBA 560 Probe (S/N F08945). The gauge was calibrated before the field measurements to an accuracy of 0.01 mm. The field measurements and Appendix A drawings were measured in inches, while the UT shell thicknesses were provided in millimeters.

Thickness readings were recorded from the interior of the penstock generally near the invert of the penstock, typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the penstock. Appendix D provides the ETS report of shell thickness readings.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

Penstock 3 is fabricated from 30 different plate sizes ranging from 7/16 to 1 5/8 inches with 21 of these plate sizes occurring downstream of the surge tank. Inspection thickness readings were taken of 7 plate sizes upstream of the surge tank, ranging from 7/16-inch (11 mm) to 3/4-inch (19 mm). The average change in material thickness upstream of the surge tank was found to be approximately 6.7%. The steel plate thicknesses below the surge tank range from 0.638 inches (16 mm) to 1.625 inches (41 mm). The average change in material thickness below the surge tank was found to be approximately 5.6%. Appendix D provides the ETS report of the UT testing.

The interior of the penstock is generally in fair condition with consistent moderate corrosion and pitting with tubercles and growth. Pitting was moderate, relative to the plate thickness, and gets more significant and deeper further downstream. Detailed pit measurements were not taken at this time. A significant number of weld repairs were observed, and the previous weld repair work made this inspection a little easier as much of the organic build-up had been previously removed.

Welds in Penstock 3 were cleaned with a wire wheel on a grinder, then wiped clean and painted with a white contrast paint to facilitate the MT weld test. MT testing included 104 full-length longitudinal welds and approximately 2 ft of each of the 208 circumferential welds adjacent to the tested longitudinal welds. An initial visual inspection of the weld was conducted, concentrating on the condition of the bead with regard to pitting, corrosion, cracking, undermining or washout. Particular attention was paid to welds not previously tested or repaired as part of Kleinschmidt's annual inspections. The welded joints inspected included original joints and previously repaired joints. The condition of the welded joints varied. On average welds were in fair condition (Photos 11 thru 13) and most did not exhibit excessive deterioration. Some undercutting and pitting was observed in the welds inspected this year.

Nine weld indications were identified during the 2023 weld inspection during the first pass. Following discussions with Hydro the decision was made to test an addition 10 percent of welds in the 17-diameter section where most of the indications were found. This resulted in finding an additional two indications. A complete list of indications are as follows:

- Can 11 South - Indication noted toe of longitudinal weld, approximately 210 mm in length (Photos 16 and 17). Appeared to be cap separation. Repair noted as nice but not required.
- Can 32 North - Indication noted toe of longitudinal weld, approximately 220 mm in length (Photo 18). Repair recommended.
- Can 59 North - Cap washing was noted on longitudinal weld, was approximately 950 mm In length (Photos 19 and 20). Repair recommended.
- Can 69 South- Indication noted toe of upstream circular weld, approximately 620 mm in length (Photo 21). Indication continued up and down on the circular weld. Repair recommended.
- Can 127 South - Centre of weld indication was noted on longitudinal weld, approximately 5mm in length (Photos 22 and 23). Repair recommended.

- Can 138 South – Two indications at toe of longitudinal weld, approximately 50 mm in length and 45 mm in length (Photos 24 to 26). Repair recommended.
- Can 217 South - Two indications toe of longitudinal weld, approximately 430 mm in length and 200 mm (Photos 27 and 28). This is an original weld. Repair recommended.

As part of secondary testing when we tested another 10 percent of welds in the 17-foot diameter section we also found the following:

- Can 77 South - Toe of longitudinal weld, multiple short indications approximately full length of can. Repair recommended.
- Can 140 South - Toe of longitudinal weld, approximately 215 mm in length. Repair recommended.

The Cahill surge tank transition weld repair crew was used to repair all of the indications listed above. During the 2023 inspection, the surge tank transition welds were being repaired and staging in place (Photos 31 and 32). The 2021 inspection identified areas where water appeared to be seeping through the welds, giving evidence to cracks being present. It was recommended that the transition be repaired, and those repairs were taking place during this inspection. With staging in place, the repair crew was able to confirm the presence of a number of weld indications.

3.2.2 Appurtenances

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock 3 has three large manholes and a bifurcation at the powerhouse.

The penstock drainage pipes and culverts were noted to be in fair condition. Kleinschmidt identified and inspected two monitoring weirs, labelled N–1 and N-2. Drainage weir N-1, located in a wooden shack, was in fair condition and had a small amount of drainage flowing through the weir (Photos 42 and 43). Vegetation surrounding the shack has been cut back allowing for easier inspection and rock and debris has been cleaned from the intake.

Drainage weir N-2 was in fair condition and also had a small amount of drainage flowing through the weir (Photo 44). Light moss growth was noted within the drainage pipe but was less than previous years. Moss should continue to be kept clear. The drainage layout is depicted along the length of the penstock in Drawing F2106-C-1 (Appendix A); however, the termination of the drainage plumbing, and weirs are not shown.

3.3 Exterior Inspection

Kleinschmidt began the exterior inspection on May 31 at the intake and proceeded to move downstream. The inspection was completed the same day and terminated at the switchyard. The interior weld testing and UT measurements performed by ETS continued inside the penstock while Mr. Vella walked the exterior. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 33 and 40. Kleinschmidt observed the exterior ground surface for evidence of signs of leakage such as sloughing of the soil or depressions while walking the length of the penstock. No obvious indications were observed during the 2023 exterior inspection of the penstock.

During the 2019 exterior inspection of the penstock, a sink hole was discovered 9 ft downstream of the surge tank concrete encasement, located on the left side of the penstock. The hole was about 4 ft in diameter and 4 ft deep and was repaired and maintained in following years. The 2023 inspection found the repair of the sink hole holding with no further settlement observed. Vegetation in the area had been cleaned out as recommended in the 2022 report making observation of the area easier.

There is an observation well about 20 ft downstream of the surge tank on the left side. No flow was observed, however, there was stagnant water in the bottom of the well. The recent sink hole discovered in 2019 and visual evidence of previous settlement in the area suggest that the drainage system in the area is not functioning properly. It is recommended that the well be inspected from the bottom, which will require fall protection and confined space access procedures. It is recommended that the drainage system be scoped with a camera from the bottom of the well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage. Any inspection findings should be documented and shared with the penstock inspection team.

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in Appendix D. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for ASTM A285 and 24,000 psi was used for CSA G40.8 Grade B. The yield strength of HSB 50 steel was assumed to be 50,000 psi; however, no reference was located for this value. No ultimate tensile strength was assumed so that allowable stresses in the evaluation were based on the yield strength criteria for the HSB 50 steel (33,333 psi).

The strength of the welded seams are reduced compared to the base material. The strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70% was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used for the analysis if weld testing is performed to verify the integrity of the welds. As per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds requiring higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- stresses in the penstock under flood conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the analysis of steel shell thickness data and internal pressure steel stress analysis results. See Appendix C for detailed thickness data and stress calculations.

The minimum thickness measurement was determined for each penstock can and was used to calculate the allowable stresses within each penstock section. To calculate the allowable stresses, the minimum thickness measurement was used in contrast to the 97.5% confidence interval (CI) used in previous years. The 97.5% CI is the average thickness minus 1.96 times the standard deviation of the thickness readings; it is considered the minimum thickness likely in the penstock and conservatively accounts for thicknesses less than the average thickness (ASCE 1995).

Three thickness measurements were taken at each location, A, B, and C, for each can that was inspected with a UT gauge, with nine thickness measurements in total for each can. When analyzing the thickness measurements using the 97.5% CI method, the calculated thickness was significantly less when compared to the minimum measured thicknesses. When the 97.5% CI is applied to a small data group, such as three to nine thickness measurements, it results in wide confidence intervals. Using the minimum steel-shell thickness measurement for the purpose of analysis in lieu of the 97.5% CI thickness, we feel is representative of the remaining penstock plate thickness.

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 597 ft (182 m) at the intake. Transient pressures were taken with a peak dynamic or transient head elevation of 890 ft (271 m) at the powerhouse and linearly reducing to 660 ft (201 m) at the surge tower and then matching the FSL of 597 ft (182 m) at the intake. The maximum stress ratio was determined to be 1.53 at can, 217 for increased surge and is greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 0.98, which unacceptable for late 1960 steel pipe. However, an increase in the joint efficiency through weld testing that would verify the joints integrity could potentially improve these values. For the plate steel away from the joints, the material has a maximum stress ratio of 1.07 and a safety factor against yielding of 1.40.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Max Joint Stress[1,2] (psi)	Max Base Material Stress[2] (psi)	Dynamic Hoop Stress Increase[3] (psi)	Allowable Stress (psi)	Yield Stress (psi)	Stress Ratio (Base)[4]	Factor of Safety (Base)[5]	Stress Ratio (Joints)[4]	Factor of Safety (Joints)[5]
2	7,335.0	5,134.5	1,692.7	17,000	26,000	0.30	5.06	0.43	3.54
10	8,071.6	5,650.1	1,862.7	17,000	26,000	0.33	4.60	0.47	3.22
21	11,106.4	7,774.5	2,563.0	17,000	26,000	0.46	3.34	0.65	2.34
31	12,380.9	8,666.6	2,857.1	17,000	26,000	0.51	3.00	0.73	2.10
38	14,277.3	9,994.1	3,294.8	17,000	26,000	0.59	2.60	0.84	1.82
49	16,849.9	11,794.9	3,888.4	17,000	26,000	0.69	2.20	0.99	1.54
58	18,089.5	12,662.6	4,174.5	17,000	26,000	0.74	2.05	1.06	1.44
68	19,822.1	13,875.5	4,574.3	17,000	26,000	0.82	1.87	1.17	1.31
78	21,988.8	15,392.2	5,074.3	17,000	26,000	0.91	1.69	1.29	1.18
88	23,759.0	16,631.3	5,482.9	24,000	36,000	0.69	2.16	0.99	1.52
96	24,928.3	17,449.8	5,752.7	24,000	36,000	0.73	2.06	1.04	1.44
108	26,504.4	18,553.1	6,116.4	24,000	36,000	0.77	1.94	1.10	1.36
119	28,956.8	20,269.7	6,682.3	24,000	36,000	0.84	1.78	1.21	1.24
127	30,037.6	21,026.3	6,931.7	24,000	36,000	0.88	1.71	1.25	1.20
137	33,381.5	23,367.1	7,703.4	24,000	36,000	0.97	1.54	1.39	1.08
147	28,248.7	19,774.1	6,518.9	24,000	36,000	0.82	1.82	1.18	1.27
158	31,961.4	22,373.0	7,375.7	24,000	36,000	0.93	1.61	1.33	1.13
170	24,306.2	17,014.4	5,609.1	24,000	36,000	0.71	2.12	1.01	1.48
178	29,533.6	20,673.5	6,815.4	24,000	36,000	0.86	1.74	1.23	1.22
186	31,411.9	21,988.4	7,248.9	24,000	36,000	0.92	1.64	1.31	1.15
197	32,958.3	23,070.8	7,605.8	24,000	36,000	0.96	1.56	1.37	1.09
207	34,576.0	24,203.2	7,979.1	24,000	36,000	1.01	1.49	1.44	1.04
217	36,783.2	25,748.3	8,488.4	24,000	36,000	1.07	1.40	1.53	0.98
227	28,108.3	19,675.8	6,486.5	24,000	36,000	0.82	1.83	1.17	1.28
241	27,622.0	19,335.4	6,374.3	24,000	36,000	0.81	1.86	1.15	1.30
248	36,541.4	25,579.0	8,432.6	24,000	36,000	1.07	1.41	1.52	0.99
258	34,056.9	23,839.8	7,859.3	24,000	36,000	0.99	1.51	1.42	1.06
267	33,315.8	23,321.0	7,688.3	24,000	36,000	0.97	1.54	1.39	1.08
276	31,192.4	21,834.7	7,198.2	24,000	36,000	0.91	1.65	1.30	1.15
285	33,612.5	23,528.8	7,756.7	24,000	36,000	0.98	1.53	1.40	1.07
297	32,586.1	22,810.3	7,519.9	24,000	36,000	0.95	1.58	1.36	1.10
308	31,050.7	21,735.5	7,165.6	24,000	36,000	0.91	1.66	1.29	1.16
317	31,052.2	21,736.6	7,165.9	24,000	36,000	0.91	1.66	1.29	1.16
328	30,636.7	21,445.7	7,070.0	24,000	36000	0.89	1.68	1.28	1.18
337	31,069.6	21,748.7	7,169.9	24,000	36,000	0.91	1.66	1.29	1.16
347	26,752.0	18,726.4	6,173.5	24,000	36,000	0.78	1.92	1.11	1.35
357	30,819.2	21,573.5	7,112.1	24,000	36,000	0.90	1.67	1.28	1.17
366	31,880.5	22,316.3	7,357.0	24,000	36,000	0.93	1.61	1.33	1.13

[1] Joint efficiency of 0.7 included

[2] Stress determined from transient analysis

[3] Stress Increase = Transient Stress – FSL Stress

[4] Stress Ratio = Maximum/ Allowable

[5] FS = Yield Stress/ Maximum Stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 103 psf and the depth of soil cover on the penstock was assumed to be 3 ft. Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment. The snow and live load combination uses a reduced snow and live load of 75 percent of each.

Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

Notes:

- No vehicular loading was used in the analysis where the penstock does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake are not used in the analysis.
- Similar to Penstocks 1 and 2, the penstock appears to be located in cohesive fine grained soil above the local ground water table with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as we assumed there is adequate drainage.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest measured steel thickness values were used. See Table 4-2.

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	4.05	3.24	3.72
15.25	4.76	3.91	4.39
13.50	10.81	4.30	4.78

There was no vehicular surcharge analysis conducted for the shallow buried penstock as there is no location for traffic to cross the penstock. Where vehicular traffic can cross the penstock, additional analyses were not completed due to the depth of the buried penstock at these locations (intake and switchyard).

4.3.2 Subatmospheric Internal Penstock Pressure Analysis

Subatmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and a detailed hydrodynamic model was not created for this report, but the likelihood of occurrence of subatmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according to the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 m^2 (3.07 ft^2), which is well below the area provided by the approximately 5.1-m^2 (55-ft^2) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits and becomes permanently deformed. No deformations were observed by inspection. The penstock is continuously supported by the soil therefore excessive local buckling stresses in the penstock are unlikely.

4.5 Local Weld Conditions

ETS performed MT tests on the full length of 96 longitudinal welds and a few feet of 192 circumferential welds for this August 2021 inspection. No indications were discovered.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life. However, the 17 ft section of the penstock should be replaced, the remaining welds refurbished, and the interior of the penstock re-coated to prevent further corrosion. Replacing the welds from the inside of the penstock only may not fully mitigate the issues in the 17 ft section of penstock and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. This has been highlighted this year with multiple indications discovered in Penstocks 2 and 3 in previously repaired welds. Indications found in 5-year-old welds indicates that the weld repairs may have a limited life expectancy. Most indications were found in the 17-ft diameter section this year indicating again that this section of penstock is particularly prone to weld indications. This section of penstock has the largest diameter and the thinnest plate, is made of a different steel grade than the rest of the penstock and has peaking induced residual stresses at the joints. The 17-ft diameter section of Penstock 3 should be replaced to remove the risk of future failures during operation and to provide confidence in the 17 ft section that will not be gained by repairing the welds. The remainder of the penstock should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively within 8 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate minimal loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior penstock surface. Assuming similar rates of material loss, the penstock should have 50 to 70 years of service life remaining if recoated. The base plate material away from the joints can tolerate up to 3 mm (1/8 inch) further material loss in many locations and maintain a stress ratio below 1.0, but some cans may require reinforcement depending on further analysis.

5.2 Internal Pressure Strength

Stress ratios for a combined static and dynamic internal pressures peak at 1.53 (Table 4-1). This indicates that the penstock does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 0.98. As noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step

should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor.

6.0 RECOMMENDATIONS

Penstock 3 17-ft diameter section should be replaced within 8 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- Radiographic testing of the welds if possible;
- Surge Analysis to verify peak pressure and resulting stresses;
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage; and
- continued inspections of the interior including MP weld testing. An increase in testing in the 17-ft diameter section is recommended as noted in Section 6.3 below.

The Surge Analysis should be completed before refurbishment to confirm stresses that may be used in weld sizing. Monitoring for leakage is something that should be done for every penstock regardless of age, construction, or condition. It is an early indicator of issues. Leakage for buried penstocks is most effectively done by monitoring drainage pipes and looking for wet areas and sink holes along the penstock alignment. MP weld testing after coating is applied may not be possible without removing the coating but not unheard of and will be dependent on coating system used. Other forms of weld testing are available that can test through paint such as the MagnaFORM Probe from Olympus. Considering indications were found at previously repaired welds this is something that will require further investigation and consideration.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 8 years. At this stage, Kleinschmidt is unable to estimate the rate of corrosion of the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. Stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of

the penstock. A quality field applied penstock coating can last 20-40 years. If the penstock is recoated prior to significant steel deterioration every 20-40 years, NLH can anticipate extending the life of the penstock potentially another 80 years depending on the section loss realized when cleaning the penstock. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated, but it is difficult to tell its condition.

6.2 Exterior Inspection

The repaired sinkhole downstream of the surge tank should continue to be monitored.

It is recommended that the observation well downstream, and to the left of the surge tank, be inspected from the bottom. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage. It would be good to have a better understanding of the drainage system prior to penstock refurbishment to scope modifications if required.

Kleinschmidt recommends continuing to monitor the exterior of the penstocks for signs of leakage. Drain pipes should also be monitored at times with consistent weather conditions.

6.3 Interior Inspections

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. Weld indications continue to be found and yearly testing is warranted. Based on 2023 findings in penstock 3 and subsequent repairs, and the significant number of weld indications found in Penstock 1 it is recommended that the quantity of welds tested be doubled to a minimum of 20 percent in the 7/16-inch-thick plated section. It is also recommended that effort be made to test a portion of crown welds and welds that are normally too high for the testing crews platform. This will require the use of staging, addition planning, and may take more time than is typical of these inspections. The Level II inspections should take thickness readings at each location noted in Kleinschmidt's inspection report. The yearly inspections should provide a good indication as to the rate of shell deterioration. As for the detailed inspection of thicknesses and vertical diameters, after 5 years of detailed inspections have established the trending

deterioration, regardless if the coating has been replaced or not, the detailed inspections can be extended to a 5 to 10-year interval which is more typical of industry standard for penstock inspections unless changing conditions warrant returning to a 1-year interval.

7.0 REFERENCES

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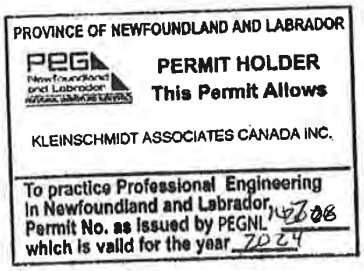
SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.



Chris M. Vella, P.Eng.
Senior Hydro Engineer

CMV:NSS:SCB



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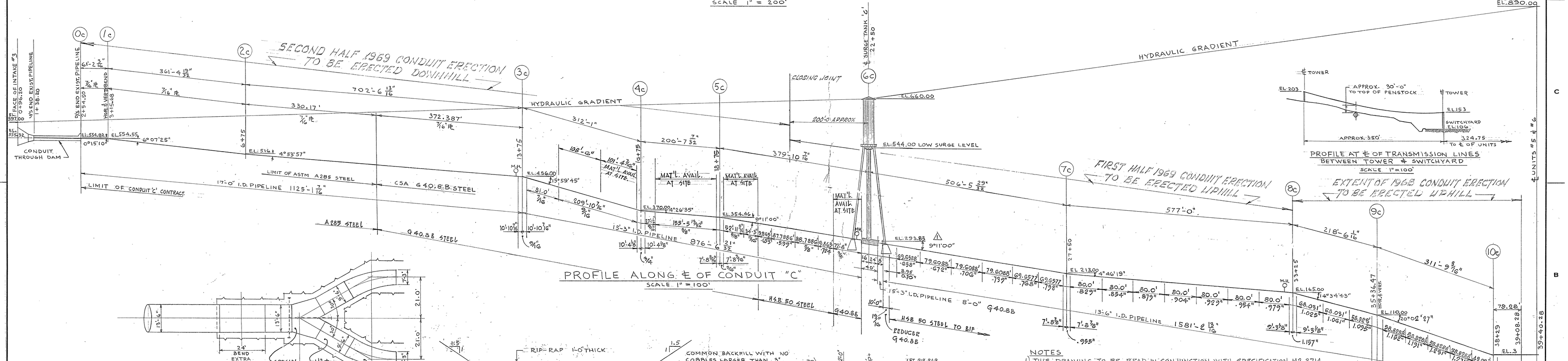
APPENDIX A

PENSTOCK LAYOUT DRAWINGS

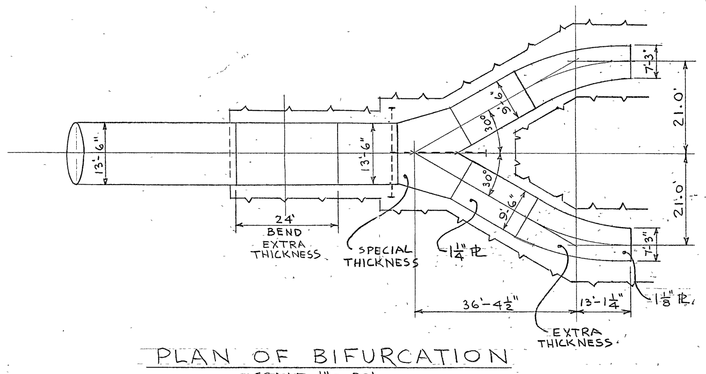


PLAN
SCALE 1" = 200'

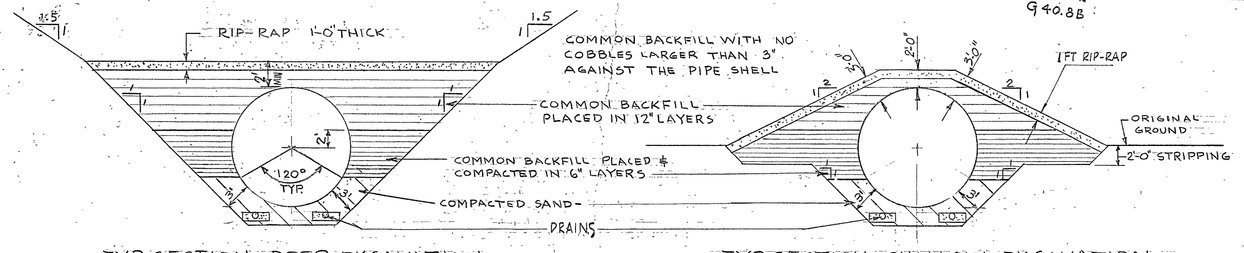


PROFILE ALONG ℄ OF CONDUIT "C"
SCALE 1" = 100'

PROFILE AT ℄ OF TRANSMISSION LINES BETWEEN TOWER & SWITCHYARD
SCALE 1" = 100'

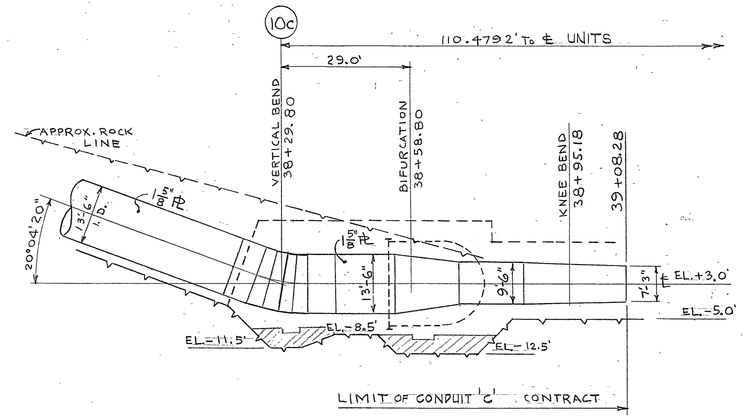


PLAN OF BIFURCATION
SCALE 1" = 20'

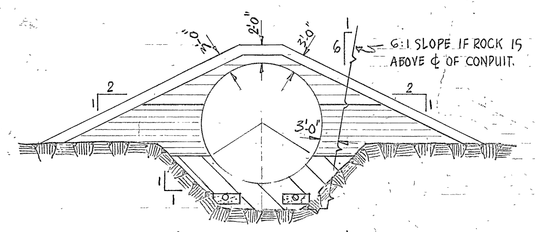


TYP. SECTION - DEEP EXCAVATION
SCALE 1" = 10'

TYP. SECTION - SHALLOW EXCAVATION
SCALE 1" = 10'



ELEVATION ALONG ℄ OF BIFURCATION
SCALE 1" = 20'



TYP. SECTION THRU' ROCK
SCALE: 1" = 10'

NOTES
1) THIS DRAWING TO BE READ IN CONJUNCTION WITH SPECIFICATION M2-3714
2) WHEN A SECTION OF THE PRESSURE CONDUIT TRENCH IS TO BE LEFT OPEN FOR AN APPRECIABLE LENGTH OF TIME, THE TRENCH SHALL BE CLOSED WITH A 6'-0" HIGH PLUG OF COMPACTED SELECTED COMMON BACKFILL. THIS PLUG SHALL BE PLACED IMMEDIATELY UPSTREAM OF THE END OF THE CONDUIT AND SHALL HAVE SUFFICIENT DRAINS TO INSURE ADEQUATE CONTROL OF RUNOFF AT ALL TIMES DURING CONSTRUCTION. THE ENGINEER'S DECISION ON THE ADEQUACY OF THE CONTRACTOR'S PROVISIONS FOR DRAINAGE SHALL BE FINAL AND BINDING

FOR INFORMATION PURPOSES ONLY

NOTE
FOR DETAIL OF DRAINS
SEE DRAWING No F-2020-C-109

DRG No	TITLE
F-2106-C-5	SURGE TANK 'C' - FOUNDATIONS - CONCRETE DETAILS
F-2106-C-4	SURGE TANK 'C' - EXCAVATION & BACKFILL
F-2106-C-3	PRESSURE CONDUIT 'C' & SURGE TANK 'C', EXCAVATION & DRAINAGE
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS.

REFERENCE DRAWINGS.

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
1	4th NOV 68		EL. AT SURGE TANK TEE WAS 293.84	HL	DB

REVISIONS

FINAL

TRANS'N | ELECT'L | CIVIL
PASSED

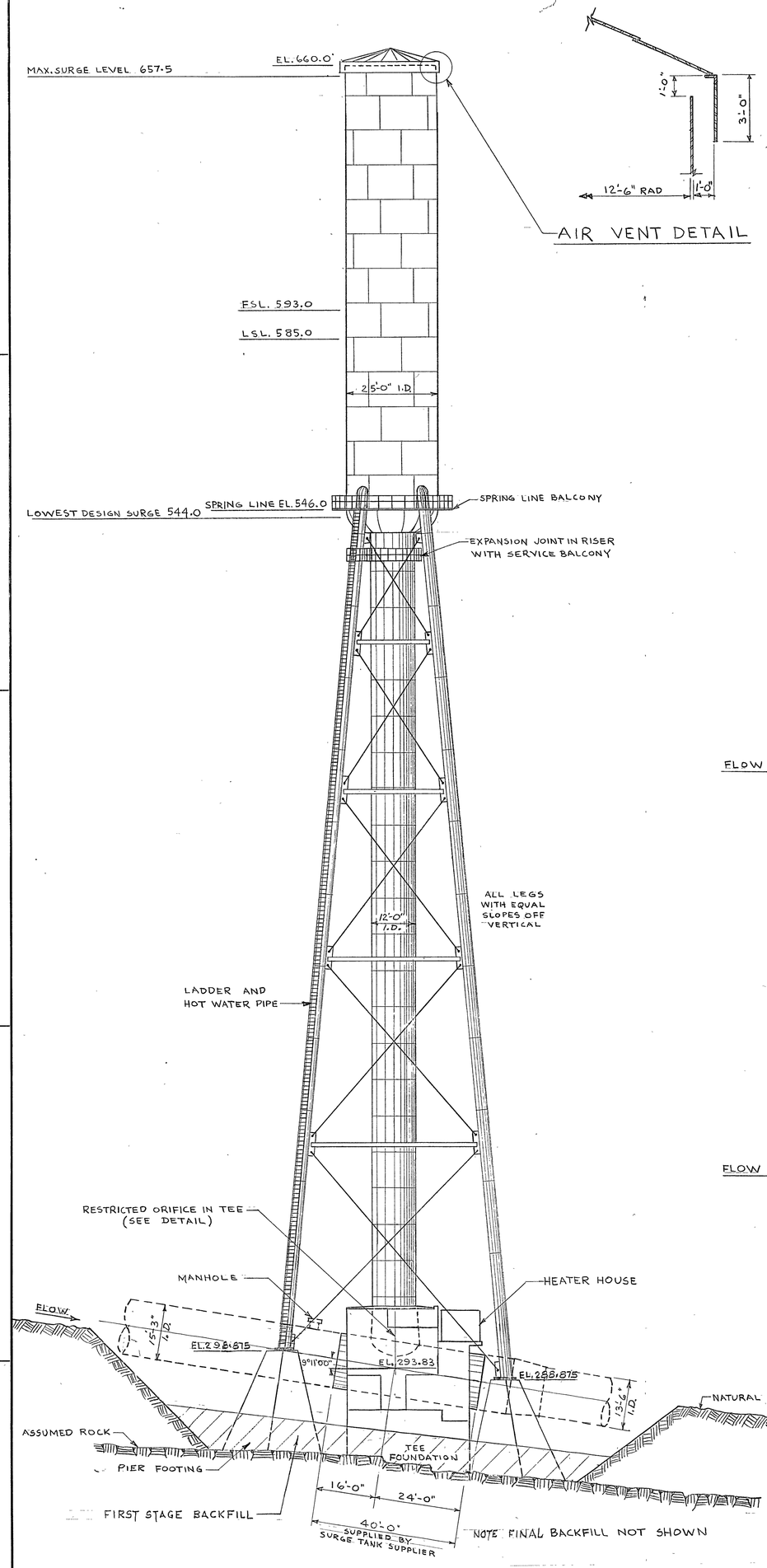
DESIGNED
DRAWN T.D. AR
CHECKED
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUIT "C"
PLAN, PROFILE, & DETAILS.

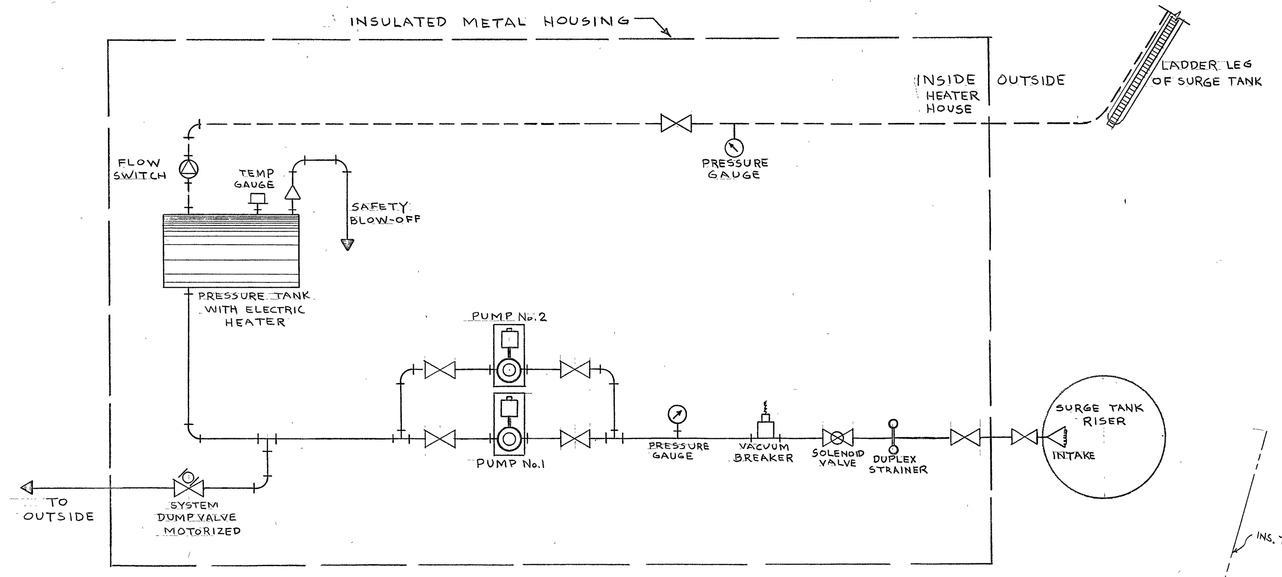
CONTRACT	SCALE	FILE NO	DATE	DWG NO	REVISION
	NOTED	2-15	APR-18-68	F-2106-C-1	1

Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 9, Page 30 of 111

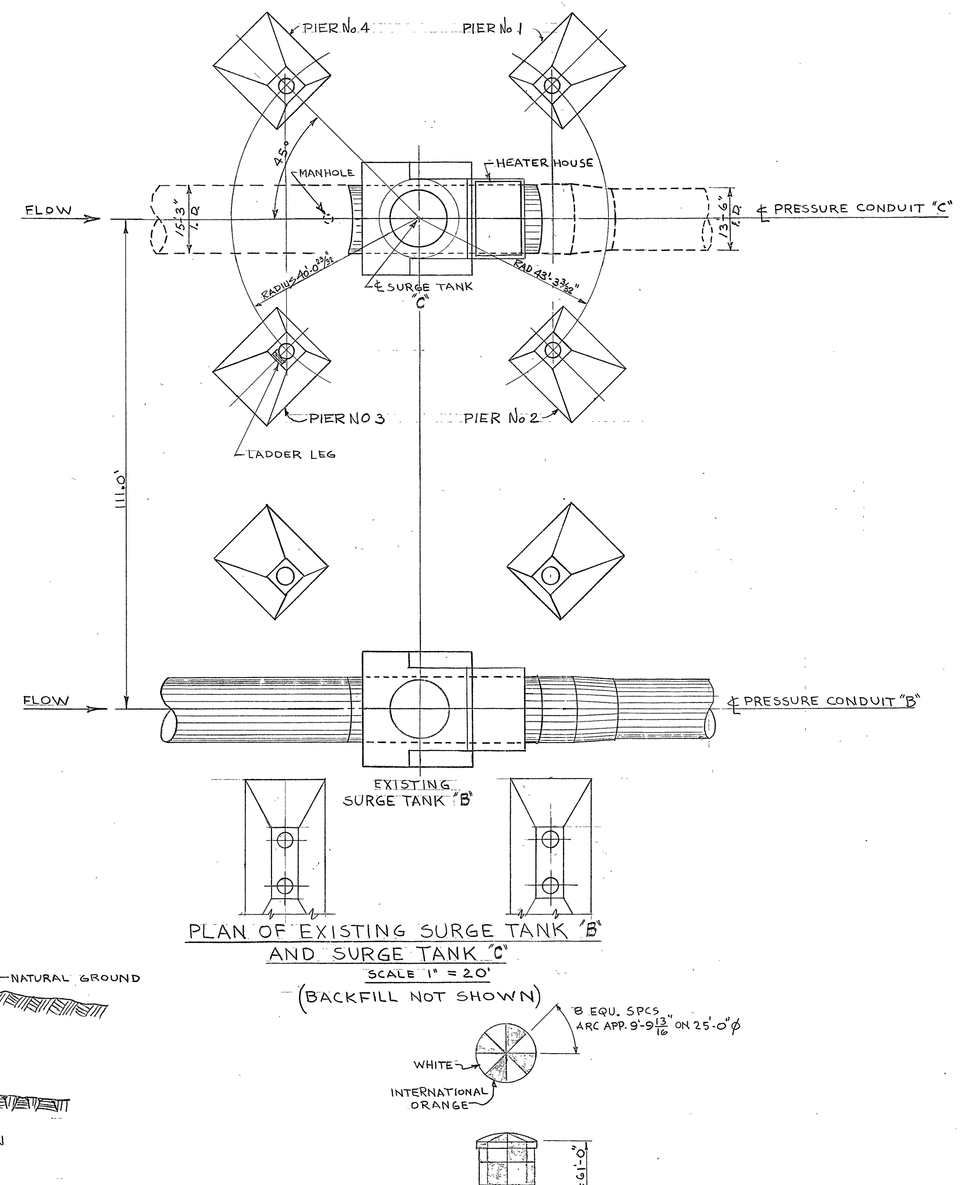


ELEVATION
NOT TO SCALE

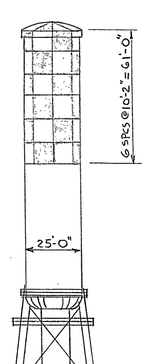
AIR VENT DETAIL



SCHEMATIC DIAGRAM OF SURGE TANK HEATER SYSTEM PIPING
FOR ELECTRICAL SCHEMATIC DIAGRAM



PLAN OF EXISTING SURGE TANK 'B'
AND SURGE TANK 'C'
SCALE 1" = 20'
(BACKFILL NOT SHOWN)

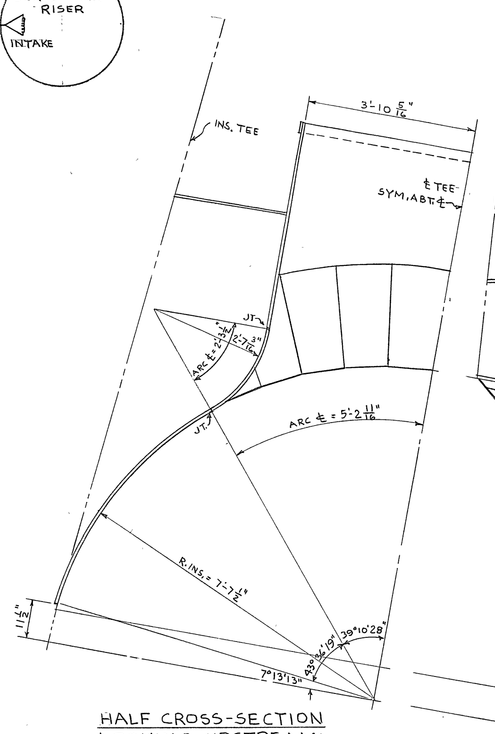


PAINT DETAIL
OBSTRUCTION PAINTING

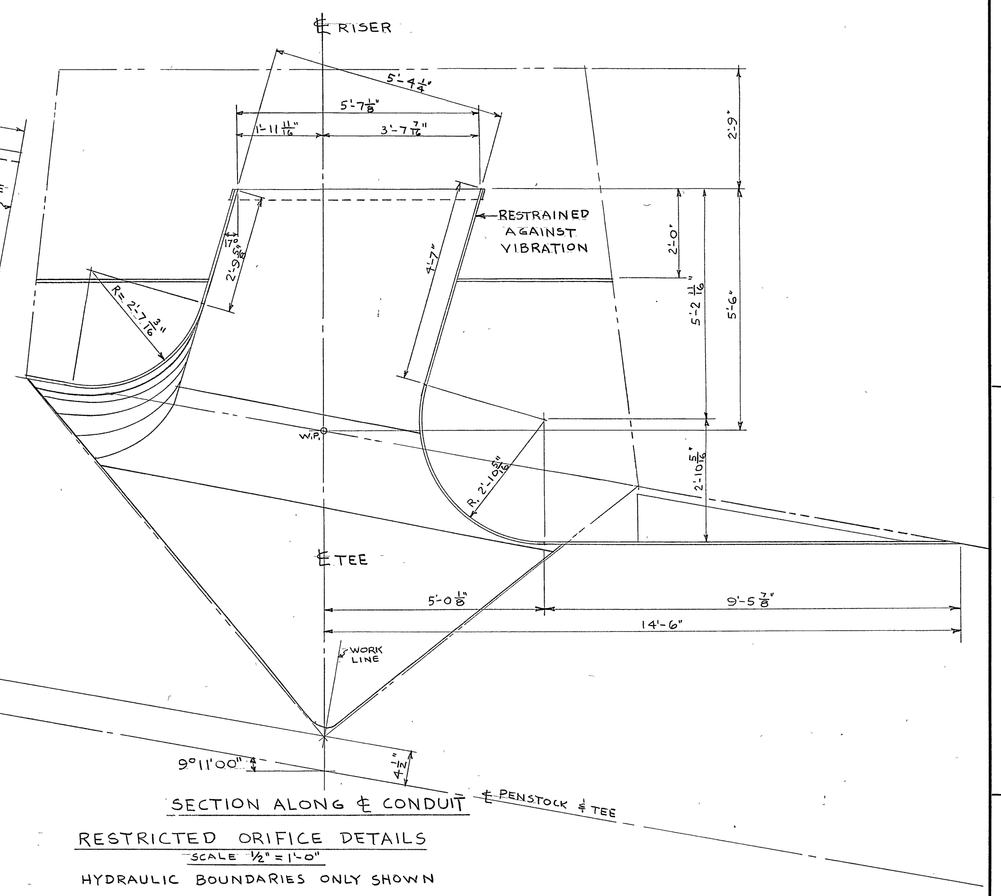
HYDRAULIC DATA

THE SURGE TANK RISER AND TEE SHALL BE DESIGNED TO SUSTAIN LOADS CAUSED BY THE FOLLOWING HYDRAULIC CONDITIONS.

1. MAXIMUM INTERNAL WATER PRESSURE WITH WATER UP TO ELEVATION 657.5 FEET
2. HEAD LOSS OF 40 FEET ACROSS THE ORIFICE WITH WATER FLOWING INTO THE SURGE TANK
3. HEAD LOSS OF 10 FEET AT THE ENLARGEMENT FROM RISER TO TANK WITH THE WATER FLOWING INTO THE SURGE TANK
4. HEAD LOSS OF 140 FEET ACROSS THE ORIFICE WITH THE WATER FLOWING FROM THE SURGE TANK TO THE PRESSURE CONDUIT
5. MAXIMUM DESIGN FLOW 2900 CFS THROUGH THE ORIFICE



HALF CROSS-SECTION
LOOKING UPSTREAM



SECTION ALONG ℄ CONDUIT

RESTRICTED ORIFICE DETAILS
SCALE 1/2" = 1'-0"
HYDRAULIC BOUNDARIES ONLY SHOWN

THIS DRAWING IS ISSUED FOR INFORMATION PURPOSES ONLY

DWG No	TITLE
F 2106-C-2	SURGE TANK "C" - FOUNDATION - CONCRETE DETAILS & ROCK DWLS
F 2106-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F 2106-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F 2106-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D

REVISIONS

FINAL

	TRANS'N	ELECT'L	CIVIL
PASSED			

DESIGNED HK
DRAWN F.G.M./A.R.
CHECKED JHM
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

SURGE TANK "C"
GENERAL LAYOUT & DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
		2-15	20 Oct '67	F-2106-C-2	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 2, Attachment 2, Page 31 of 111

8"ϕ HELCORE CONNECTED TO INTAKE DRAIN & 3"ϕ PLASTIC PIPE
2-6"ϕ PERFORATED NO-CO-RODE PIPES
EXISTING CUT IN ROCK

SECTION F-F
SCALE: 1"=20'-0"

EXISTING CONTOUR DITCH No. 1
EXISTING CONTOUR DITCH No. 2
FACE OF INTAKE No. 3
8"ϕ HELCORE PIPE CONNECTED TO INTAKE DRAIN & 3"ϕ PLASTIC PIPE.
DRAINAGE TRENCH
ROAD
2-6"ϕ
BRIDGE SEE DWG. No. F 2106-C-5
EXISTING STORAGE SITE FOR PIPELINE ASSEMBLY
SURGE TANK No. 3
DITCH
24"ϕ CULVERT
CONSTRUCTION DRAINAGE DITCH (OR DIKE)
18"ϕ CULVERT EXISTING
1-18"ϕ DRAIN PIPE
10' WIDE BULLDOZER CONTOUR DITCHES
EXISTING DRAINAGE DITCH
18"ϕ CROSS DRAIN EXISTING
5% SLOPE
2-6"ϕ PERFORATED NO-CO-RODE PIPE
CONDUIT "B" (EXISTING)
EXISTING 8"ϕ HELCORE PIPE & 3"ϕ PLASTIC PIPE TO BE EXTENDED IF REQD. DECISION TO BE MADE IN FIELD.
EXISTING CUT
LIMIT OF CONTRACT
18"ϕ EXISTING DRAINAGE PIPE.
EXISTING DIKE
CONDUIT "A" (EXISTING)
EXISTING BRIDGE
18"ϕ EXISTING PIPE
NEW 18" DIA. SURFACE DRAIN OVER PENSTOCK
EXISTING DIKES
18"ϕ DRAINAGE PIPES (EXISTING)
EXISTING DIKE
SWITCHYARD EL. 104.8' (EXISTING)
FOR SURGE TANK No. 3 EXCAVATION SEE PLAN DWG. No. F-2106-C-4 (SHT. 2)

NOTE:
ROAD MAY BE BUILT AS SHOWN ON NORTH SIDE OF CONDUIT "C" OR WHEN MORE CONVENIENT ON SITE BETWEEN CONDUITS "B" & "C". DRAINAGE TRENCH REMAINS ON NORTH SIDE AS SHOWN.

PLAN
SCALE: 1"=100'-0"

NOTE:
DURING CONSTRUCTION RAINWATER ENTRANCE TO POWERHOUSE TO BE PREVENTED BY SAND BAGS OR DIKE DAMS & TRENCH DRAINED BY PUMPING.

FACE OF INTAKE No. 3
STA. 0+96.40
U/S END EXIST. PIPELINE
1+34.20

EXISTING CUT
LIMIT OF CONTRACT
STA. 1+30
ORIGINAL GROUND
BOTTOM OF TRENCH FOR LINE "C"
BEDROCK SIX INCHES TO ONE FOOT BELOW PRESENT GROUND
EARTH
EL. 544.0'
EL. 505.5'
EL. 445.5 U/S EL. 446.4 D/S.
25' (APPROX.)
EL. 360.4'
EL. 344.8'
EL. 264.2' U/S. EL. 285.0' D/S.
EL. 204.25'
EL. 156.25'
EL. 101.25'
BEDROCK
SEE BIFURCATION DETAILS
LIMIT OF CONTRACT
EXISTING CUT
STA. 39+65
STA. 39+40.28 C. UNITS
STA. 39+06.28
STA. 38+42.60
STA. 37+56.47 HOR. EVENT
33+00
27+50
22+50
13+75
9+75
6+75
#5 #6

SURGE TANK No. 3

ORIGINAL GROUND
ROAD
1'-0 STRIPPING IF REQUIRED
5'-0" MIN.
6"DIA. PERFORATED NO-CO-RODE PIPES

SECTION A-A
SCALE: 1"=20'-0"

PROFILE ALONG ℄ OF CONDUIT "C"
SCALE: 1"=100'-0"

EL. 11.66'
EL. 6.0'
PLAN OF BIFURCATION
SCALE: 1"=20'-0"

FENCE
SWITCHYARD 58'-0"
EXISTING FOOTING EL. 106'-0"
FUTURE EL. 104'-8"
T 34
STAGE II
STAGE I

SECTION D-D
SCALE: 1"=20'-0"

6'ϕ PERFORATED NO-CO-RODE PIPES SHALL BE INSTALLED IN SECOND LAYER. DRAIN PIPES TO BE PLUGGED AT UPPER ENDS NEAR THE CROSS DRAINS.

SECTION B-B
SCALE: 1"=20'-0"

END OF CONTRACT
APPROX. ROCK LINE
VERT. BEND STA. 38+42.60
BEND STA. 38+65.13
KNEE BEND STA. 38+65.13
29'-0"
38'-9.5"
20°02'27"
EL. +3.0'
EL. -5.0'
EL. -8.5'
EL. -11.5'
EL. -12.5'
26'-0"
18'-4½"
8'-0"
13'-0"
65'-4½"

ELEVATION ALONG ℄ OF BIFURCATION
SCALE: 1"=20'-0"

6'ϕ PERFORATED NO-CO-RODE PIPE

SECTION C-C
SCALE: 1"=20'-0"

48'-0"
SWITCHYARD EL. 104'-8"
EXISTING SLOPE
SHEET PILING

SECTION E-E
SCALE: 1"=20'-0"

NOTES:
1. CONDUIT THROUGH DAM TO SURGE TANK PIPELINE TO BE ERECTED DOWNHILL.
2. SURGE TANK TO STA. 39+08.20 PENSTOCK TO BE ERECTED UPHILL
3. APPROXIMATELY 400 FT. OF PENSTOCK, INCLUDING BIFURCATION AND BRANCH PIPE WILL BE ERECTED IN 1963. SURGE TANK FOUNDATIONS AND TEE 1968. BALANCE 1969.
4. THE CIVIL WORKS CONTRACTOR SHALL KEEP THE EXCAVATED WORKS AND THE EXISTING STRUCTURES IN THE AREA SECURE AGAINST THE DESTRUCTIVE EFFECTS OF THE MAXIMUM EXPECTED STORM WATER.

REF. DWGS:
F-2106-C-4 SURGE TANK OVERBURDEN EXCAVATION (SH. 2)
F-2106-C-5 CONCRETE DETAILS SURGE TANK FOUNDATION PRESSURE CONDUIT ANCHORS AND BRIDGE.
F-2020-C-63 PRESSURE CONDUIT "C" PLAN, PROFILE AND DETAILS.

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
			REVISIONS		

PASSED: TRANS'N | ELECT'L | CIVIL

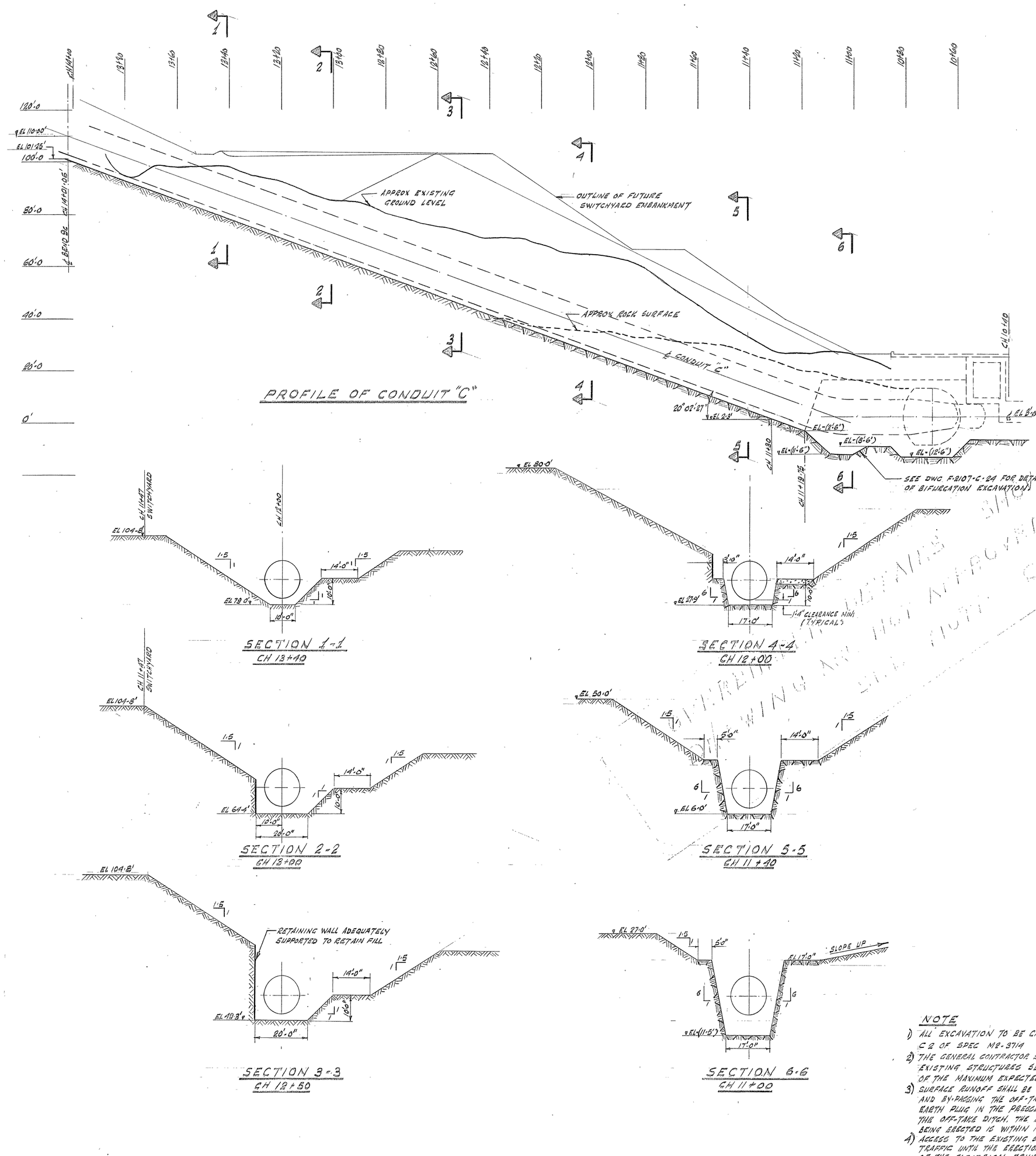
DESIGNED N.P.
DRAWN A.B.
CHECKED
RECOMMENDED

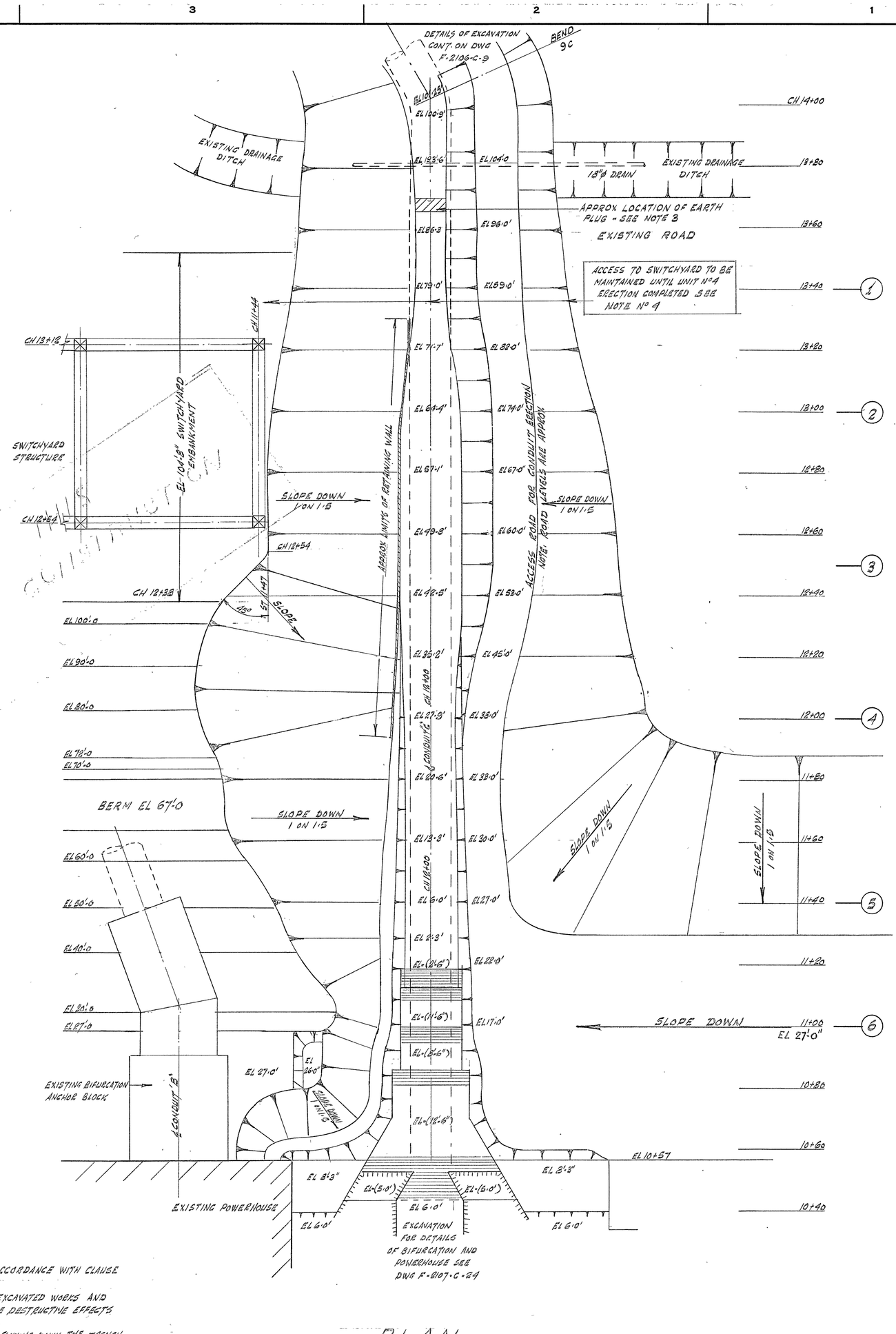
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY SHAWMONT NEWFOUNDLAND LIMITED MONTREAL, QUEBEC

PRESSURE CONDUIT "C" & SURGE TANK No. 3 EXCAVATION & DRAINAGE (SHEET 1 OF 2)

CONTRACT	SCALE	FILE NO	DATE	DWG NO.	REVISION
	NOTED		JAN. 19, 1968	F-2106-C-3	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 5, Page 32 of 111





PLAN

NOTE

1) ALL EXCAVATION TO BE CARRIED OUT IN ACCORDANCE WITH CLAUSE C 2 OF SPEC Nº2-371A
2) THE GENERAL CONTRACTOR SHALL KEEP THE EXCAVATED WORKS AND EXISTING STRUCTURES SECURE AGAINST THE DESTRUCTIVE EFFECTS OF THE MAXIMUM EXPECTED STORM WATER.
3) SURFACE RUNOFF SHALL BE PREVENTED FROM FLOWING DOWN THE TRENCH AND BY-PASSING THE OFF-TAKE DITCH AT CH 13+30 BY LEAVING AN UNEXCAVATED EARTH PLUG IN THE PRESSURE CONDUIT TRENCH IMMEDIATELY DOWNSTREAM OF THE OFF-TAKE DITCH. THE EARTH PLUG SHALL ONLY BE REMOVED WHEN THE CONDUIT BEING ERECTED IS WITHIN 100 TO 150 FEET OF THE PLUG
4) ACCESS TO THE EXISTING SWITCHYARD IS TO BE MAINTAINED FOR HEAVY VEHICULAR TRAFFIC UNTIL THE ERECTION OF THE SUPERSTRUCTURE STEEL AND INSTALLATION OF THE ELECTRICAL EQUIPMENT HAS BEEN COMPLETED FOR UNIT Nº4 (AUG 26/68)
5) THE SIDE SLOPE OF THE EXCAVATION SHOWN ON THIS DRAWING ARE THOSE PROPOSED BY THE GENERAL CONTRACTOR. THE ACTUAL SLOPES USED ARE TO BE DETERMINED BY THE GENERAL CONTRACTOR BUT MUST BE CONSISTANT WITH STABILITY AND SAFETY.
6) THIS DRAWING IS APPROVED FOR CONSTRUCTION ONLY IN REGARDS TO THE DETAILS FOR THE ACTUAL CONDUIT TRENCH i.e. BOTTOM ELEVATION BOTTOM WIDTH, AND ROCK SIDE SLOPES. OVERBURDEN EXCAVATION AND SIDE SLOPES ARE NOT APPROVED FOR CONSTRUCTION BUT SHALL BE DETERMINED IN THE FIELD TO THE APPROVAL OF THE ENGINEER TO SUIT ROCK ELEVATIONS AND OVERBURDEN CONDITIONS ENCOUNTERED

REGISTERED PROFESSIONAL ENGINEER — P.M.R. PETTEN — SIGNATURE — PROVINCE OF NEWFOUNDLAND

FINAL

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
			REVISIONS		

APPROVED FOR CONSTRUCTION
JUN 5 1968
APPROVED BY:
DIRECTOR OF ENGINEERING
P&E

CONSTR.	TRANS'N	ELECT'L	CIVIL
			PASSED

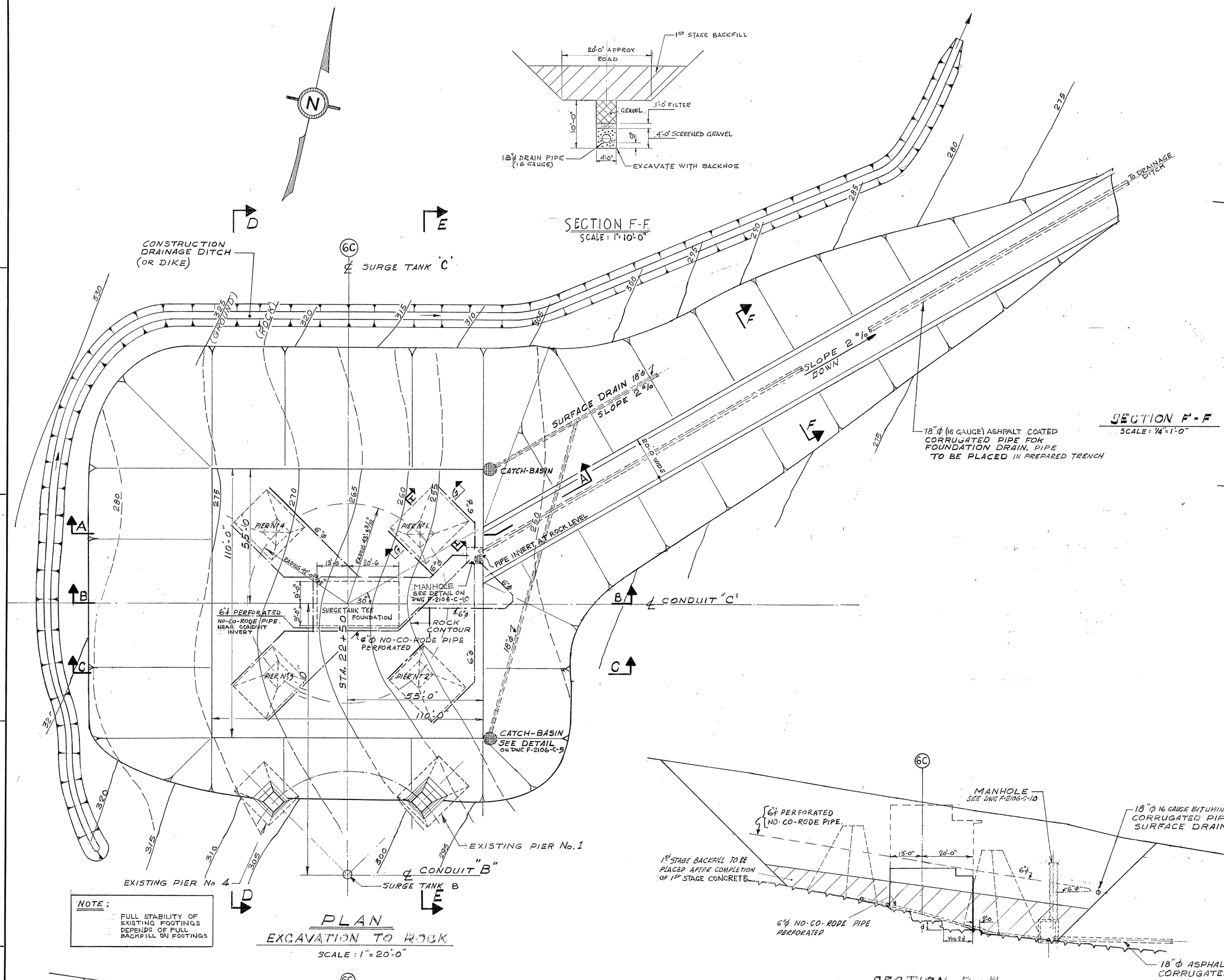
DESIGNED D.B.
DRAWN H. LEE
CHECKED D.B.
RECOMMENDED R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND
PRESSURE CONDUIT "C"
EXCAVATION DETAILS - LOCAL TO SWITCHYARD EMBANKMENT

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1"=80'	2-1E	30TH MAY 68	F-2106-C-3	0

SH.2 OF 2

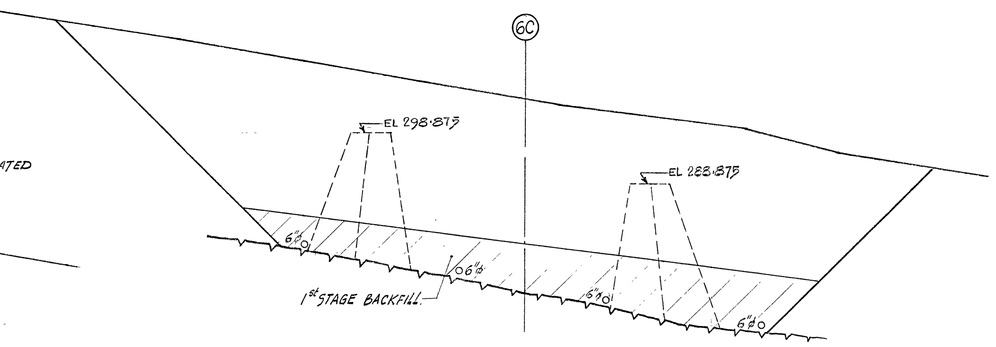
Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 3, Page 33 of 111



NOTE:
FULL STABILITY OF EXISTING FOOTINGS DEPENDS OF FULL BACKFILL ON FOOTINGS

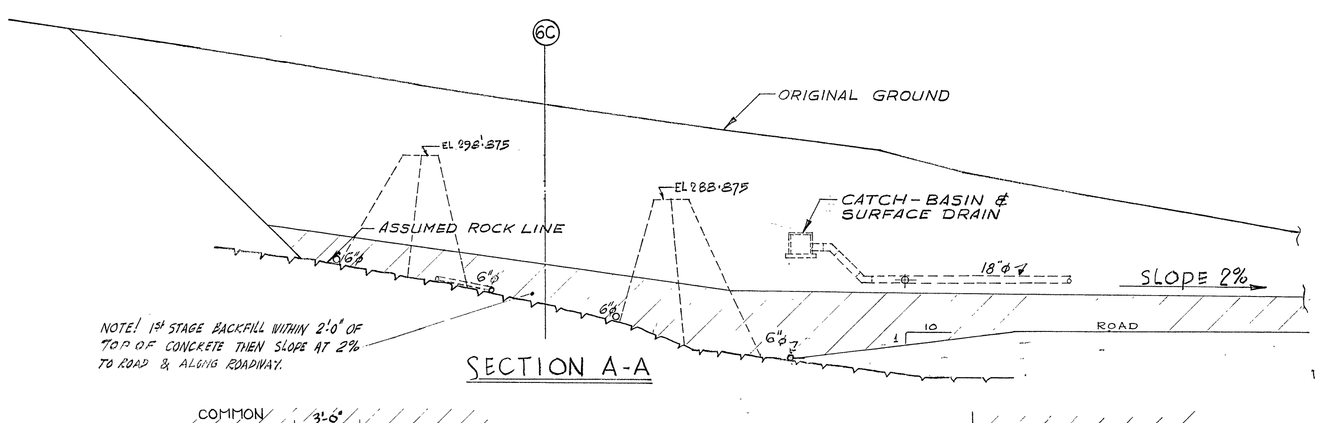
PLAN
EXCAVATION TO ROCK
SCALE: 1"=20'-0"

SECTION B-B

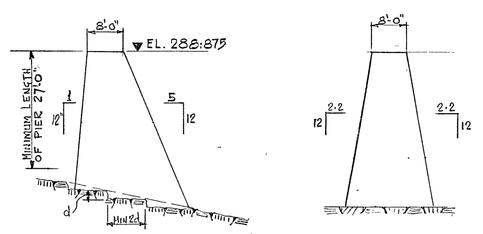


SECTION C-C

NOTES:
1) SURFACE & FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.
2) ENDS OF 6"ϕ PERFORATED PIPES TO BE BLANKED OF WITH A MASS CONCRETE PLUG OR BLANKED OFF.
3) FIRST STAGE BACKFILL SHOULD BE PLACED AROUND EXISTING PIERS TO FINAL ELEVATION AS SOON AS POSSIBLE.
4) BACKFILL SHALL FOLLOW CONCRETE POURS AND CONDUIT INSTALLATION AS CLOSELY AS PRACTICAL
5) EXCAVATE PIER BASES AND SURGE TANK TEE FOUNDATION TO SOLID ROCK. IF NECESSARY STEP ROCK RADIALLY FROM CENTRE FOR SURGE TANK AND PIERS.

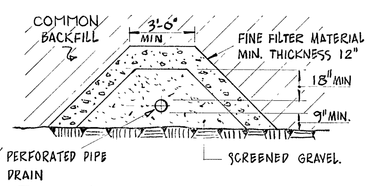


SECTION A-A

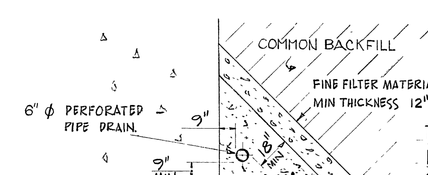


SECTION G-G
SCALE: 1"=20'-0"

SECTION H-H
SCALE 1"=20'-0"



TYPICAL SUB-SURFACE DRAIN IN BACKFILL
SCALE: 1"/4=1'-0"



TYPICAL SUB-SURFACE DRAIN ADJACENT TO CONCRETE STRUCTURE
SCALE: 1/4"=1'-0"

TYPICAL DETAIL FOR ALL PIERS WHERE THE ROCK IS TO BE STEPPED

REFERENCE DRAWINGS

DRG Nº	TITLE
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & DRAINAGE - CONCRETE AND REINFORCING DETAILS
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS
F-2106-C-3	PRESSURE CONDUIT 'C' AND SURGE TANK 'C' EXCAVATION AND DRAINAGE
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT AND DETAILS
F-2106-C-1	PRESSURE CONDUIT 'C' - PLAN, PROFILE AND DETAILS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D

REVISIONS

APPROVED FOR CONSTRUCTION
MAY 6 1968
APPROVED BY: R.A. Robertson
MANAGER, ENGINEERING

TRANS'N	ELECT'L	CIVIL

PASSED

DESIGNED N.P.
DRAWN A.B.
CHECKED [illegible]
RECOMMENDED [illegible]

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

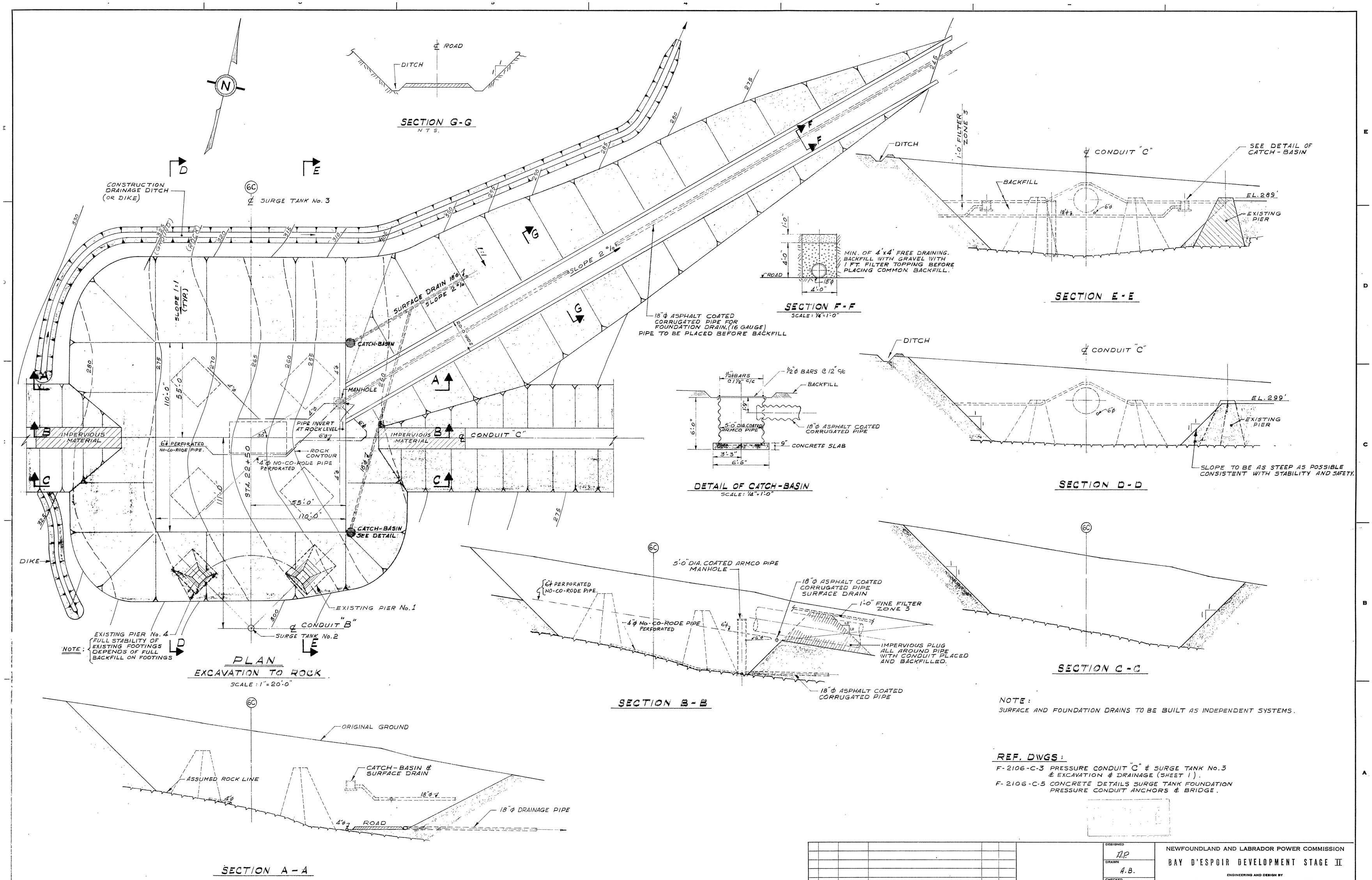
SURGE TANK 'C' EXCAVATION & BACKFILL (SH 1 OF 2)

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1"=20'-0" 1/4"=1'-0"	2-15	FEB 1968	F-2106-C-4	0

RETAIL

Pentstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 2, Attachment 3, Page 34 of 111

7 6 5 4 3 2 1



NOTE:
SURFACE AND FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.

REF. DWGS:
F-2106-C-3 PRESSURE CONDUIT "C" & SURGE TANK No. 3 & EXCAVATION & DRAINAGE (SHEET 1).
F-2106-C-5 CONCRETE DETAILS SURGE TANK FOUNDATION PRESSURE CONDUIT ANCHORS & BRIDGE.

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D	TRANS'N	ELECT'L	CIVIL
REVISIONS						PASSED		

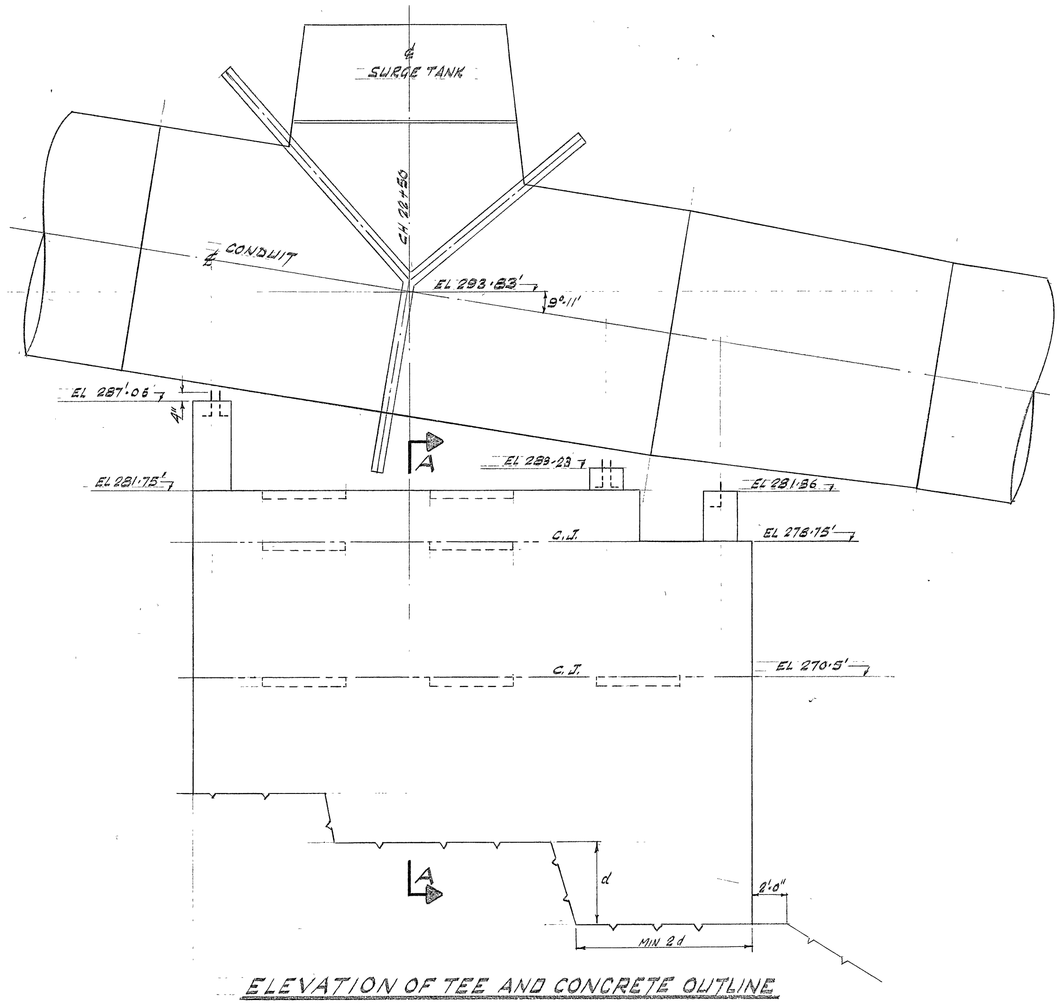
DESIGNED A.P.
DRAWN A.B.
CHECKED
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

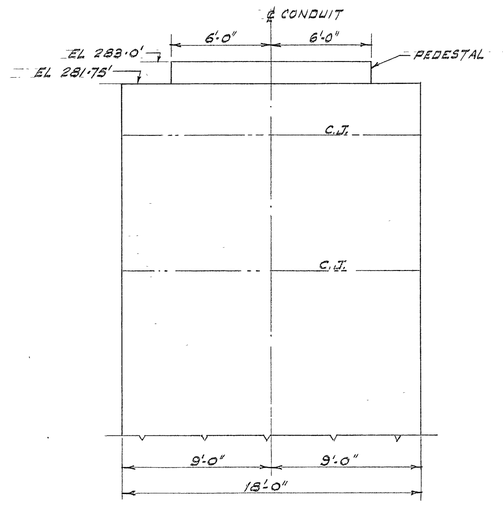
SURGE TANK
OVERBURDEN EXCAVATION
(SHEET 2 OF 2)

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1"=20'-0" 1/4"=1'-0"		JAN. 18, 1968	F-2106-C-4	0

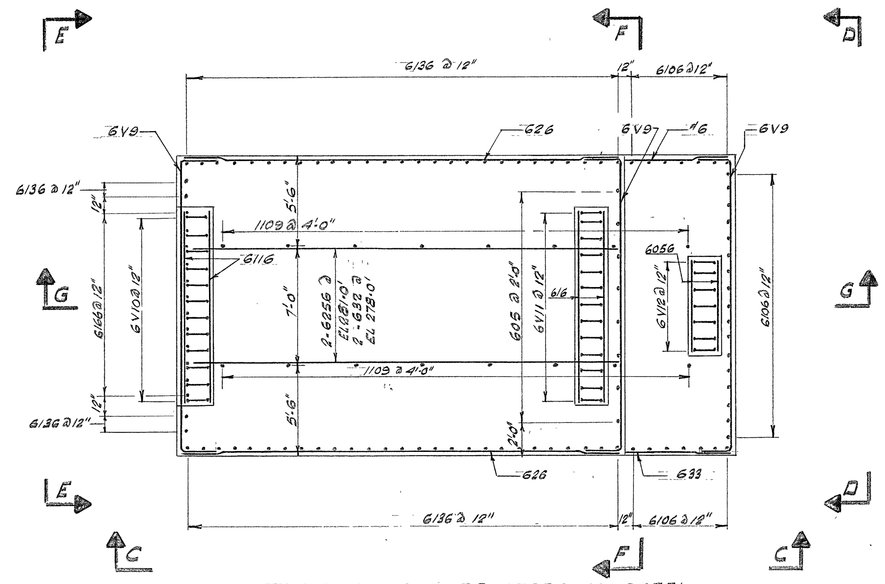
Penstock 3 Section Replacement and Weld Refurbishment – Bay d'Espoir
Schedule 1, Attachment 9, Page 35 of 111



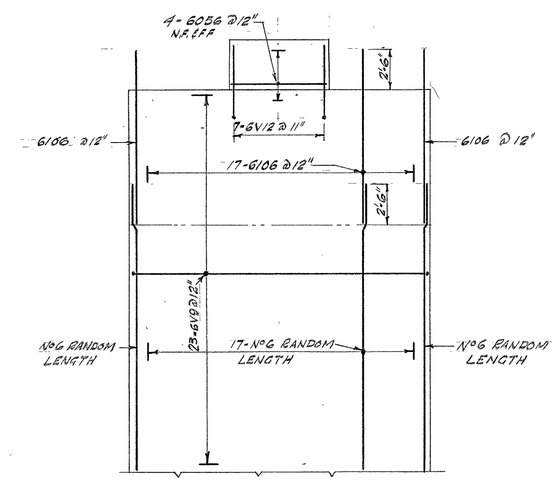
ELEVATION OF TEE AND CONCRETE OUTLINE



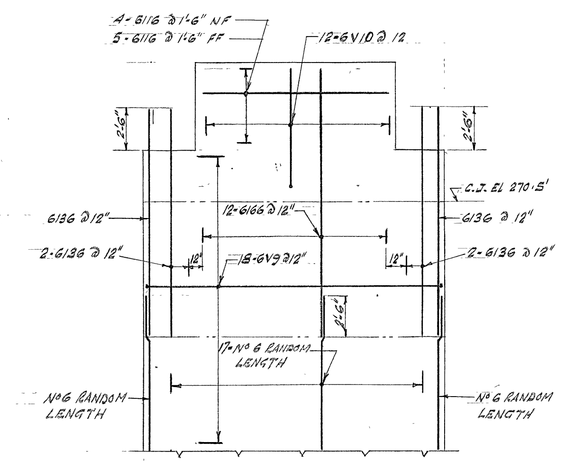
SECTION A-A @ CH 22+50



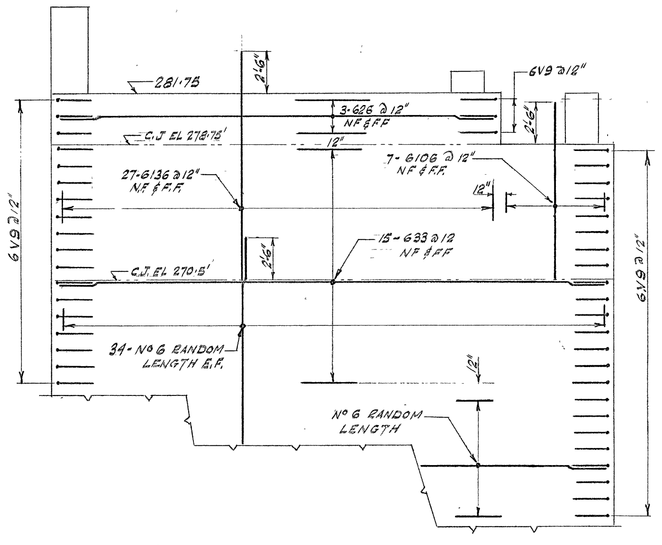
PLAN SHOWING REINFORCING STEEL



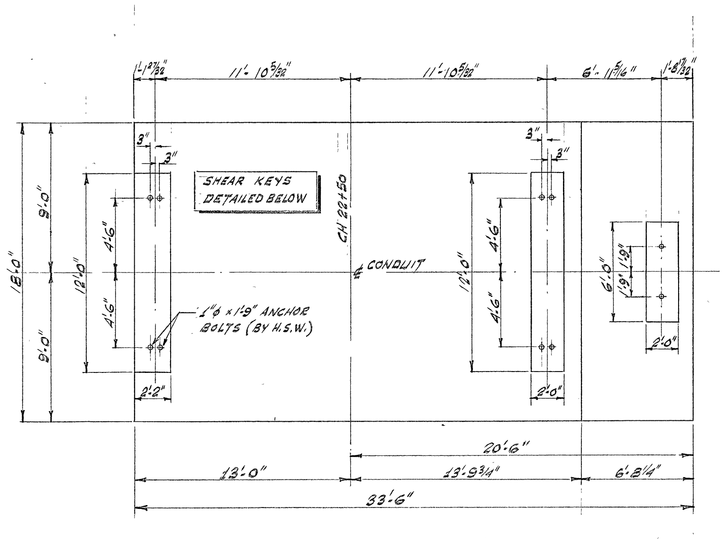
ELEVATION D-D



ELEVATION E-E

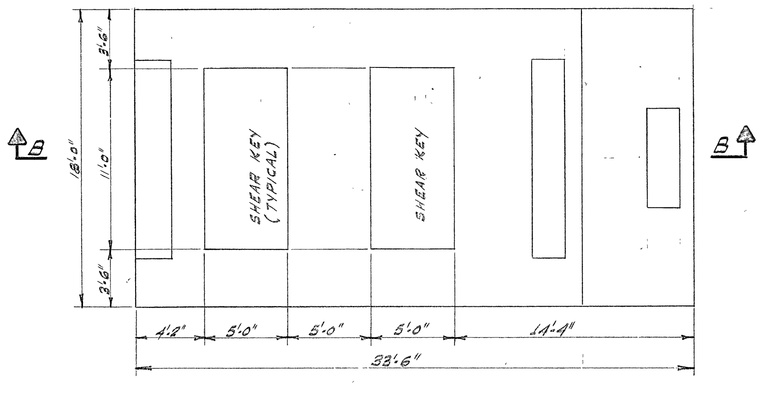


ELEVATION C-C

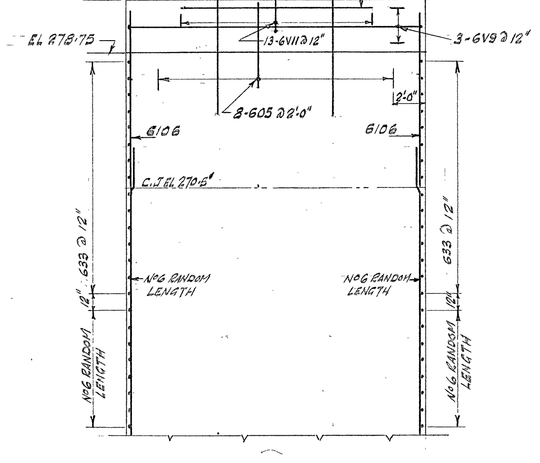


PLAN OF CONCRETE OUTLINE AND ANCHOR BOLT LOCATION

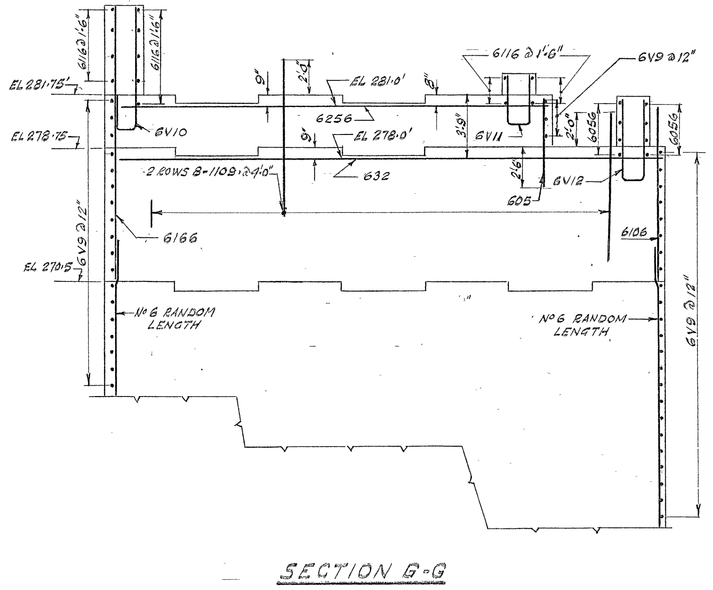
NOTE.
ANCHOR BOLTS SUPPLIED BY HORTON STEEL WORKS AND INSTALLED BY GENERAL CONTRACTOR.



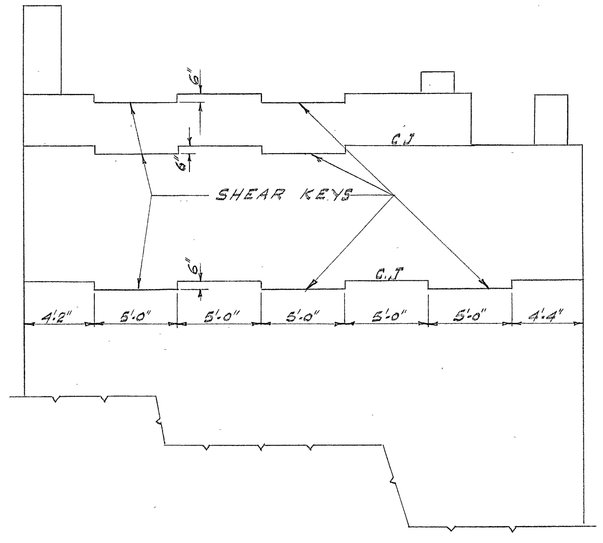
PLAN OF SHEAR KEYS AT EL 281·75'



SECTION ELEVATION F-F



SECTION G-G



SECTION B-B

NOTES.
1) CONCRETE CLASS 2500 H.C.I. AGGREGATE 3" EXCEPT
   a. SUPPORT PEDESTALS CLASS 3500 PSI 1½" AGGREGATE
   b. GROUT IF REQD 3500 PSI.
2) MINIMUM COVER ON MAIN BARS 4" EXCEPT PEDESTALS 3"
3) EVERY COLD JOINT BETWEEN POURS SHALL BE SHEAR KEYED AS SHOWN
4) APPROX ROCK LEVEL IS SHOWN, CUT VERTICAL FACE STEEL AND PLACE HORIZONTAL FACE STEEL TO SUIT ACTUAL SOLID ROCK LEVELS

REGISTERED PROFESSIONAL ENGINEER R.A. Robertson PROVINCE OF NEWFOUNDLAND

FINAL

DWG Nº	TITLE
F-2106-C-5	SURGE TANK 'C' FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS
F-2106-C-4	SURGE TANK 'C' - EXCAVATION & BACKFILL
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D

REVISIONS

APPROVED FOR CONSTRUCTION
MAY 6 1968
APPROVED BY: [signature]
CHIEF ENGINEER

TRANS'N	ELECT'L	CIVIL

PASSED

DESIGNED	D.B.
DRAWN	M.LEE
CHECKED	D.B.
RECOMMENDED	R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

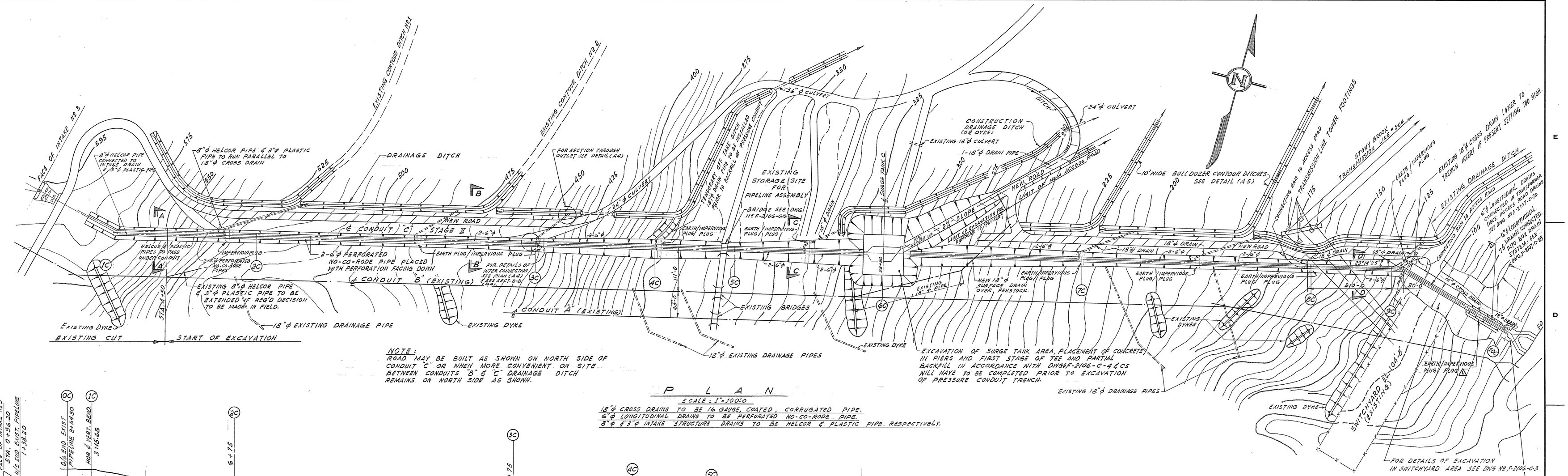
BAY D'ESPOIR DEVELOPMENT STAGE II

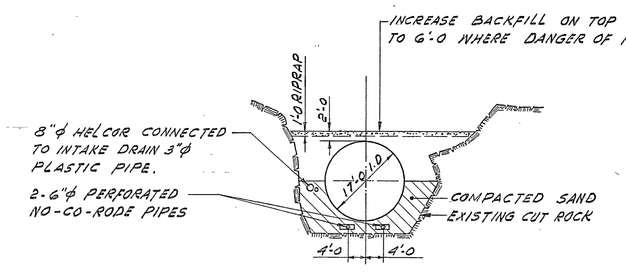
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

SURGE TANK "C"
TEE STAGE I
OUTLINE AND REINFORCING

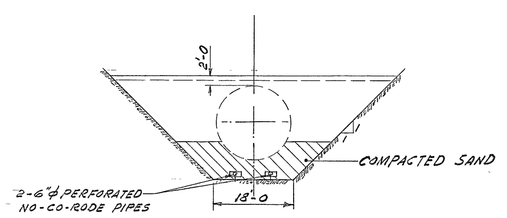
CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	3/16"=1'-0"	2-15	28TH FEB/68	F-2106-C-7	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 5, Page 36 of 111

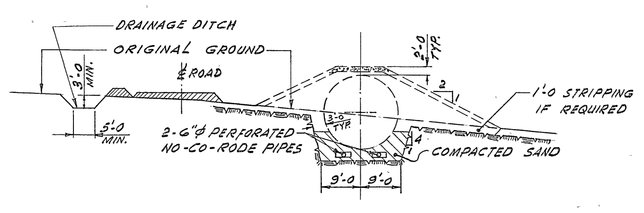




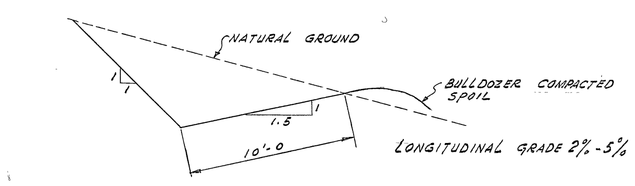
SECTION A-A
SCALE: 1"=20'-0



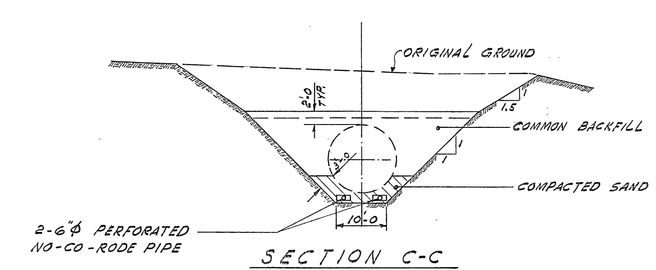
SECTION D-D
SCALE: 1"=20'-0
SECTION OF SPECIALLY EXCAVATED TRENCH FOR ERECTION OF PRESSURE CONDUIT UNDER TRANSMISSION LINE FROM A POINT 30 FT. U/S OF BEND 9C AND EXTENDING 210 FT. UPSTREAM OF THIS POINT.



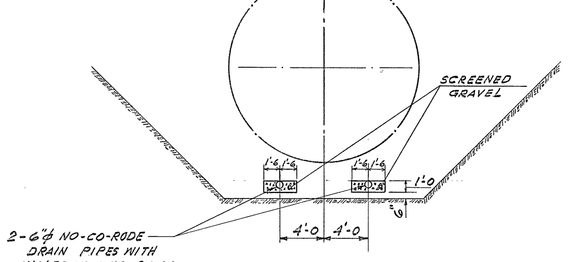
SECTION B-B
SCALE: 1"=20'-0
TYPICAL SECTION THROUGH ROCK CUT



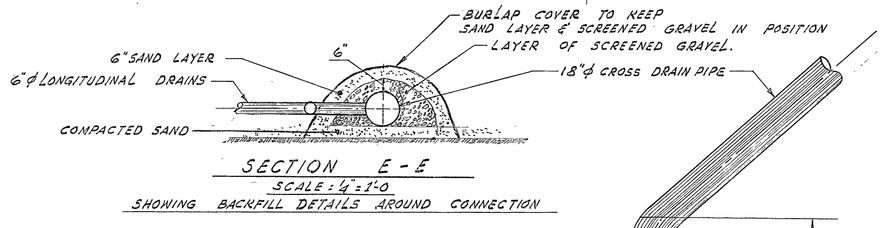
TYPICAL SECTION - BULLDOZER CONTOUR DITCH



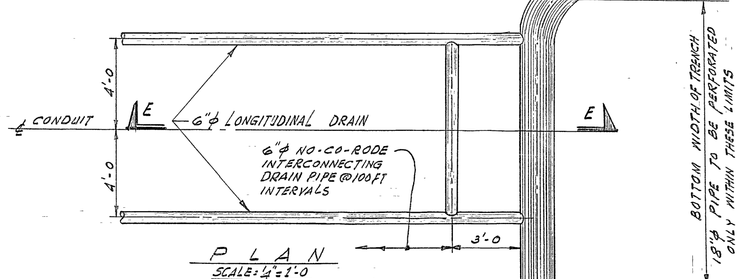
SECTION C-C
SCALE: 1"=20'-0
TYPICAL SECTION THROUGH EARTH CUT



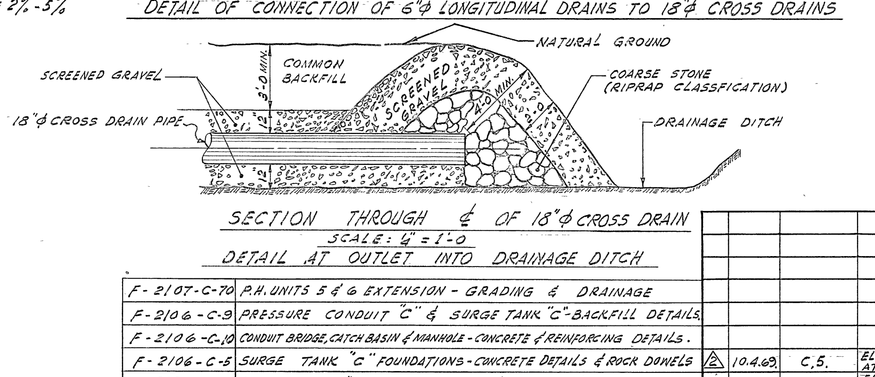
DETAIL OF DRAIN
SCALE: 1"=1'-0



SECTION E-E
SCALE: 1"=1'-0
SHOWING BACKFILL DETAILS AROUND CONNECTION



P L A N
SCALE: 1"=1'-0
SHOWING PIPE CONNECTION ONLY
DETAIL OF CONNECTION OF 6"ϕ LONGITUDINAL DRAINS TO 18"ϕ CROSS DRAINS



SECTION THROUGH ℄ OF 18"ϕ CROSS DRAIN
SCALE: 1"=1'-0
DETAIL AT OUTLET INTO DRAINAGE DITCH

NOTES

1. The civil works contractor shall keep the excavated works and the existing structures in the area secure against the destructive effects of the maximum expected storm water.
2. When a section of the pressure conduit trench to be left open for an appreciable length of time, the trench shall be closed with a 6' - 0" high plug of compacted selected common backfill. This plug shall be placed immediately upstream of the end of conduit and shall have sufficient drains to insure adequate control of run-off at all times during construction. The Engineer's decision of the adequacy of the contractor's provisions for drainage shall be final and binding.
3. For sequence of erection of pressure conduit "C" see Drawing No. F-2106-C-1.
4. New roads are shown as cross hatched.
5. 18 in. dia. cross drains to be installed when the conduit trench is being excavated. The unexcavated earth plugs (Clause C2.6) shall be left immediately downstream of the 18 in. dia. cross drains. The connection of the cross drains to the longitudinal drains shall be done after the erection of the conduit and just prior to the back-filling.
6. The location of the cross drains and earth plugs are approximate and the actual positions are to be determined in the field to the approval of the Engineer.
7. Impervious plugs (Clause C3.3). After erection of the conduit, the trench shall be filled to 1 ft. above the top of the pipe or to original grade, where this is below the top of the pipe, with selected common fill for a length of 6 feet at a point immediately downstream of the 18 in. dia. cross drains, to form a permanent impervious plug across the trench.
8. All the work indicated on this drawing must be done in accordance with Spec. M2-3714. Reference should be made to the following clauses:-
   C1 - Unwatering
   C2 - Excavation
   C3 - Backfill & Grading
   C4 - Foundation Drains

REFERENCE DRAWINGS.		
F-2107-C-70	P.H. UNITS 5 & 6 EXTENSION - GRADING & DRAINAGE	
F-2106-C-9	PRESSURE CONDUIT "C" & SURGE TANK "C" - BACKFILL DETAILS	
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLE - CONCRETE & REINFORCING DETAILS.	
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS	
F-2106-C-4	SURGE TANK "C" EXCAVATION & BACKFILL.	
F-2106-C-3	PRESSURE CONDUIT "C" EXCAVATION DETAILS - LOCAL TO SWITCHYARD EMBANKMENT	
F-2106-C-1	PRESSURE CONDUIT "C" PLAN, PROFILE AND DETAILS	

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
2	10.4.68	C.5.	EL. 360.4' D/S AT BENT 3.C ADDED; EL. 360.4' AT BENT 4.C REVISED FROM EL. 360.1'		
		D.4.	EL. 284.0' U/S & EL. 285.0' D/S AT BENT 6.C REVISED FROM EL. 286.6' U/S & EL. 287.0' D/S.	K.C.	D.B.
1	9.1.68	D.1.	DRAINAGE DETAILS BETWEEN BENDS 9C & 10C SHOWN	T.C.D.	D.B.

APPROVED FOR CONSTRUCTION
JUL 26 1968
APPROVED BY: [signature] ENGINEER
Per [signature]

CONST. | TRANS'N | ELECT'L | CIVIL
PASSED

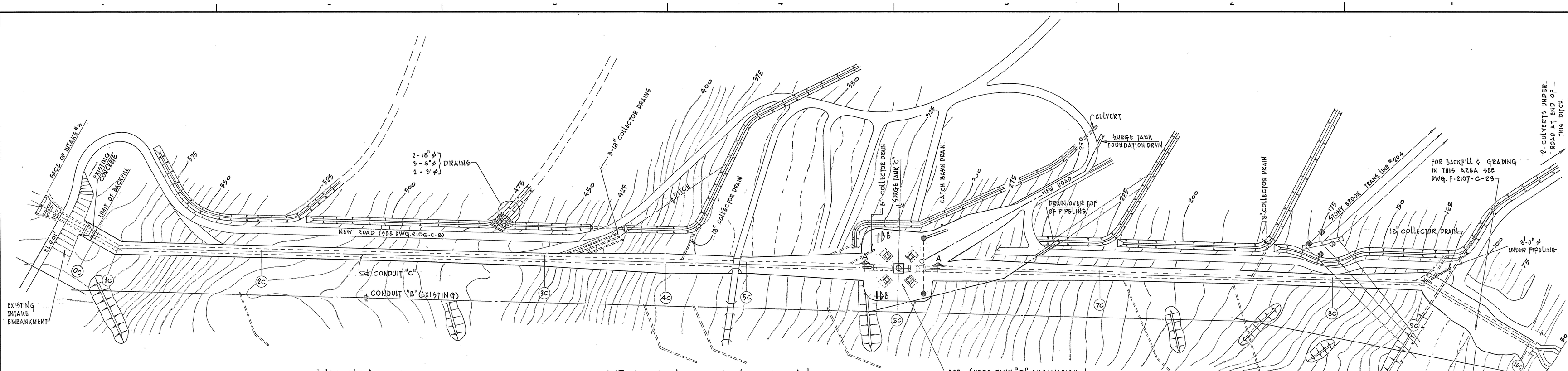
DESIGNED D.B.
DRAWN K.C.
CHECKED D.B.
RECOMMENDED R.M.J.

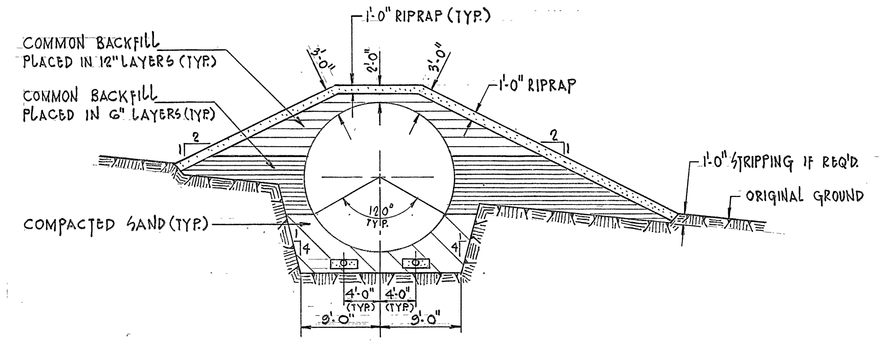
NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

PRESSURE CONDUIT "C"
EXCAVATION AND DRAINAGE

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	As Noted	2-15	July 24, 1968	F-2106-C-8	2

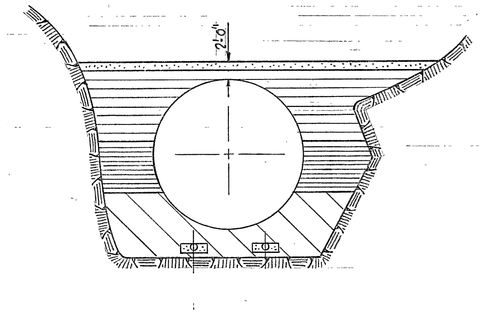
Pentstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 3b, Page 37 of 111





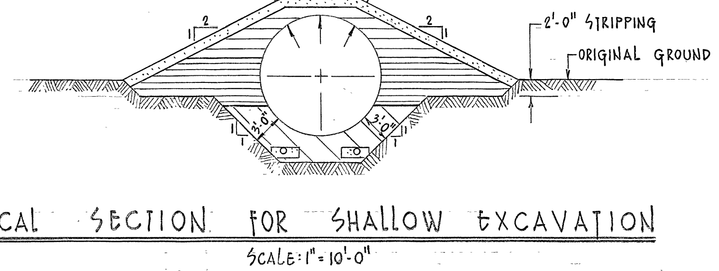
TYPICAL SECTION THROUGH ROCK CUT

SCALE: 1" = 10'-0"



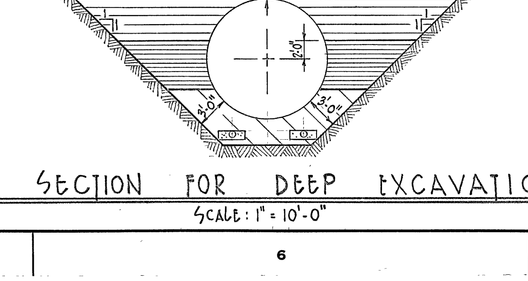
SECTION THROUGH EXISTING CUT ROCK

SCALE: 1" = 10'-0"



TYPICAL SECTION FOR SHALLOW EXCAVATION

SCALE: 1" = 10'-0"

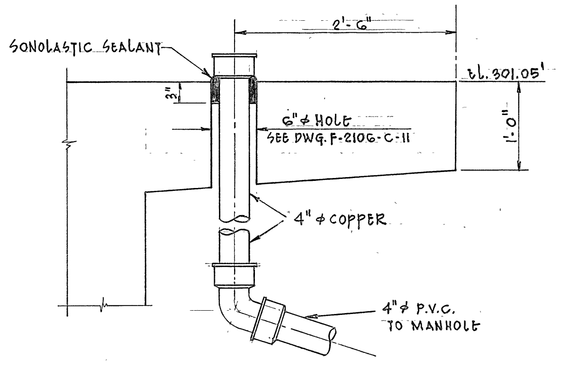


TYPICAL SECTION FOR DEEP EXCAVATION

SCALE: 1" = 10'-0"

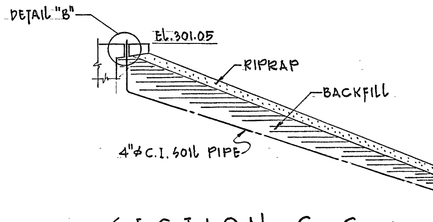
PLAN (2)

SCALE: 1" = 100'



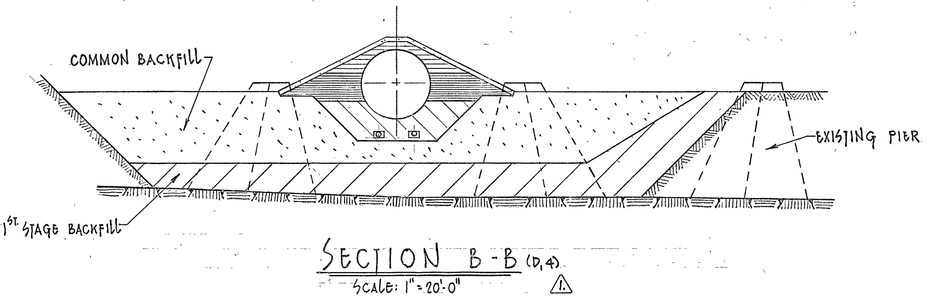
DETAIL - B (C,9) ⚠1 ⚠2

SCALE: 1" = 1'-0"



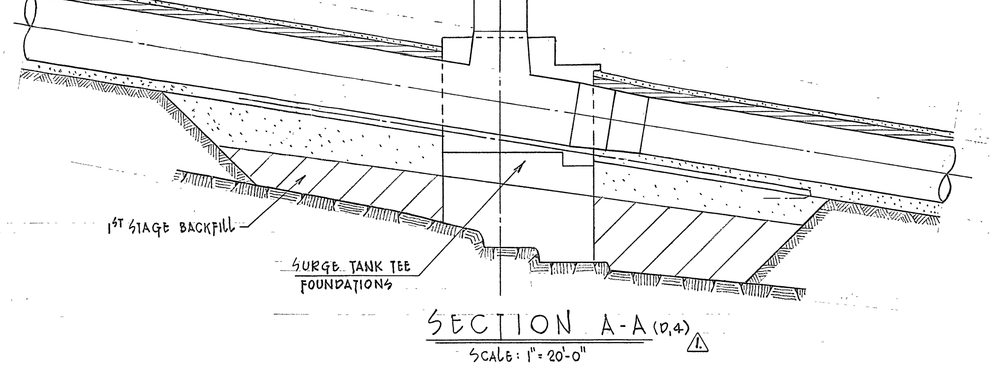
SECTION C-C (B,2) ⚠1

SCALE: 1" = 10'-0"



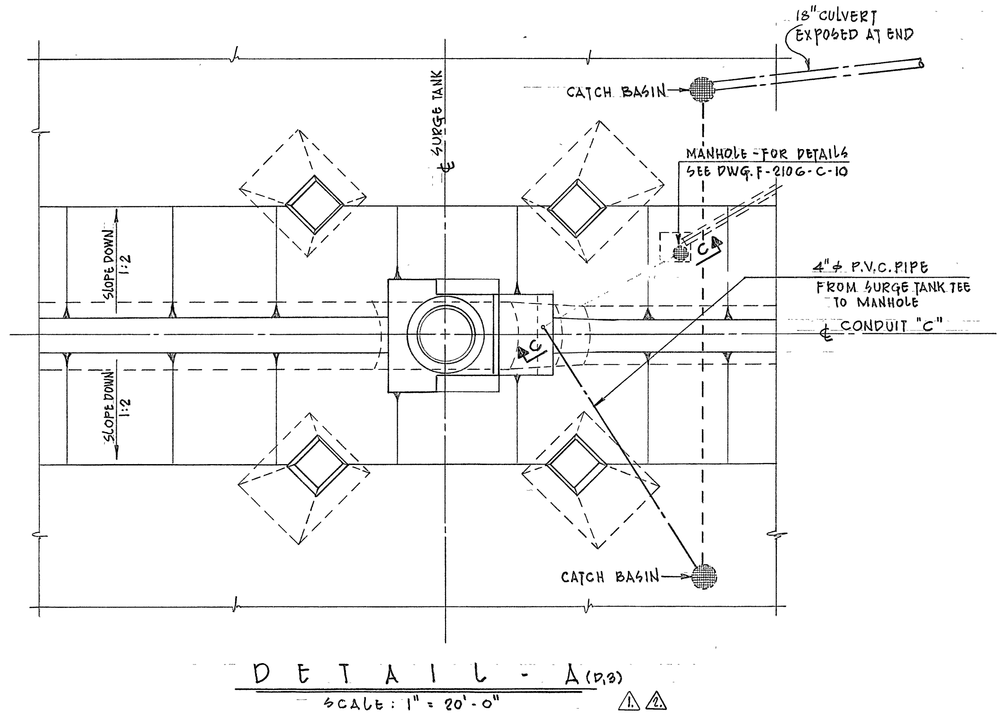
SECTION B-B (D,4) ⚠1

SCALE: 1" = 20'-0"



SECTION A-A (D,4) ⚠1

SCALE: 1" = 20'-0"



DETAIL - A (D,9)

SCALE: 1" = 20'-0" ⚠1 ⚠2

NOTE:

⚠1 1. CONTRACTOR TO SUPPLY & INSTALL CAST IRON SOIL PIPE FROM SURGE TANK TEE TO MANHOLE UNDER SCHEDULE OF PRICE ITEM C1003.

⚠2 2. CONDUIT & SURGE TANK FOUNDATION DRAINAGE OUTLETS SHALL BE INSPECTED TWICE YEARLY AND CLEANED AS REQUIRED TO INSURE PROPER DRAINAGE.

REGISTERED PROFESSIONAL ENGINEER — R.A.R. Robertson — SIGNATURE — PROVINCE OF NEWFOUNDLAND

FINAL

REFERENCE DRAWINGS

DWG. No.	TITLE
F-2106-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS
F-2106-C-2	SURGE TANK "C" - GENERAL LAYOUT & DETAILS
F-2106-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F-2106-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F-2106-C-5	" " " - FOUNDATIONS, CONCRETE DETAILS & ROCK DOWELS
F-2106-C-8	PRESSURE CONDUIT "C" - EXCAVATION & DRAINAGE
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLE - CONCRETE & REINF. DETAILS
F-2106-C-11	SURGE TANK "C" - TEE STAGE II - CONCRETE DETAILS

REVISIONS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
⚠1	12 NOV. 69		DWG. REVISED TO SHOW AS-BUILT	T.C.D	
			DETAILS. NOTE 2 ADDED		
⚠1	10 JUL. 69	A-C, 2-5.	SECTIONS A, B & C, DETAILS A & B NOTE ADDED	T.C.D.	D.B.

APPROVED FOR CONSTRUCTION
JUL 9 1969
APPROVED BY: CHIEF ENGINEER

PASSED

TRANS'N	ELECT'L	CIVIL

DESIGNED A.B.
DRAWN T.C. DAVIS
CHECKED D.B.
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

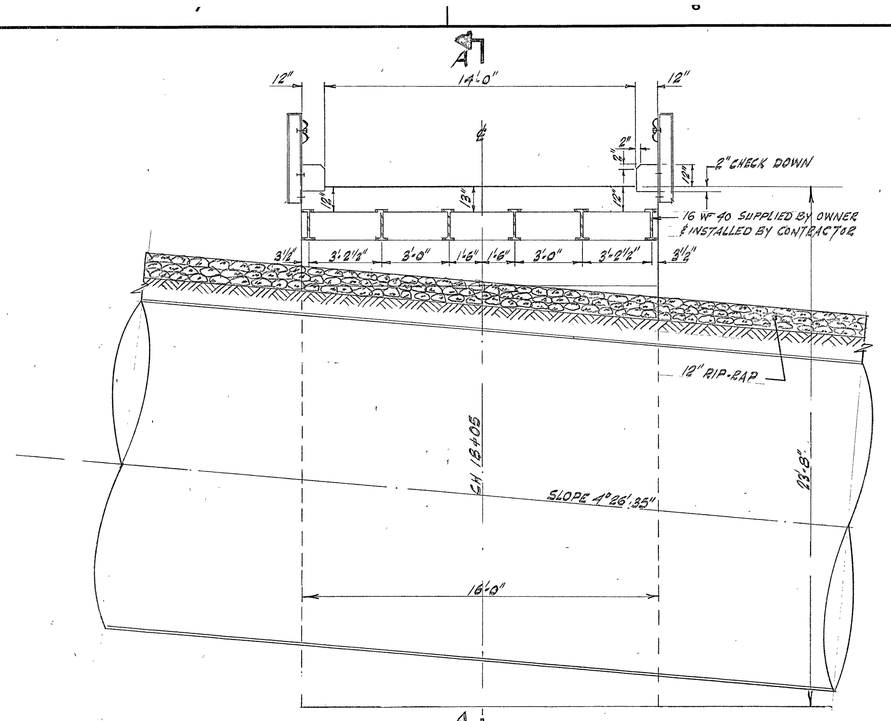
BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

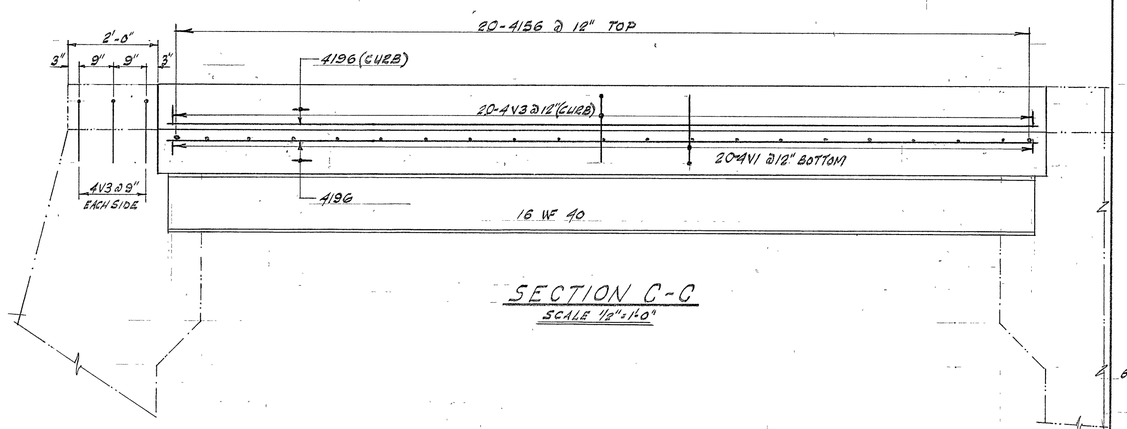
PRESSURE CONDUIT "C" & SURGE TANK "C"
BACKFILL DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	AS SHOWN	2-15	5TH SEPT. 1968	F-2106-C-9	2.

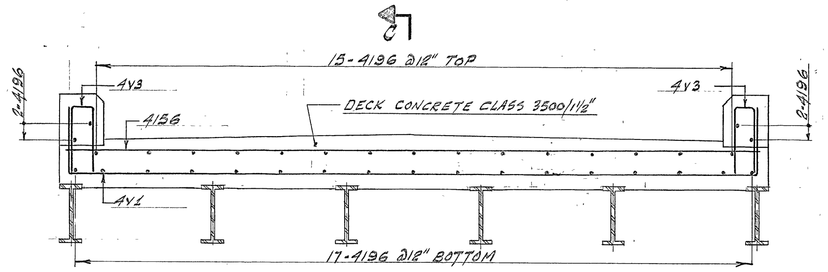
Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule A, Attachment 9, Page 38 of 111



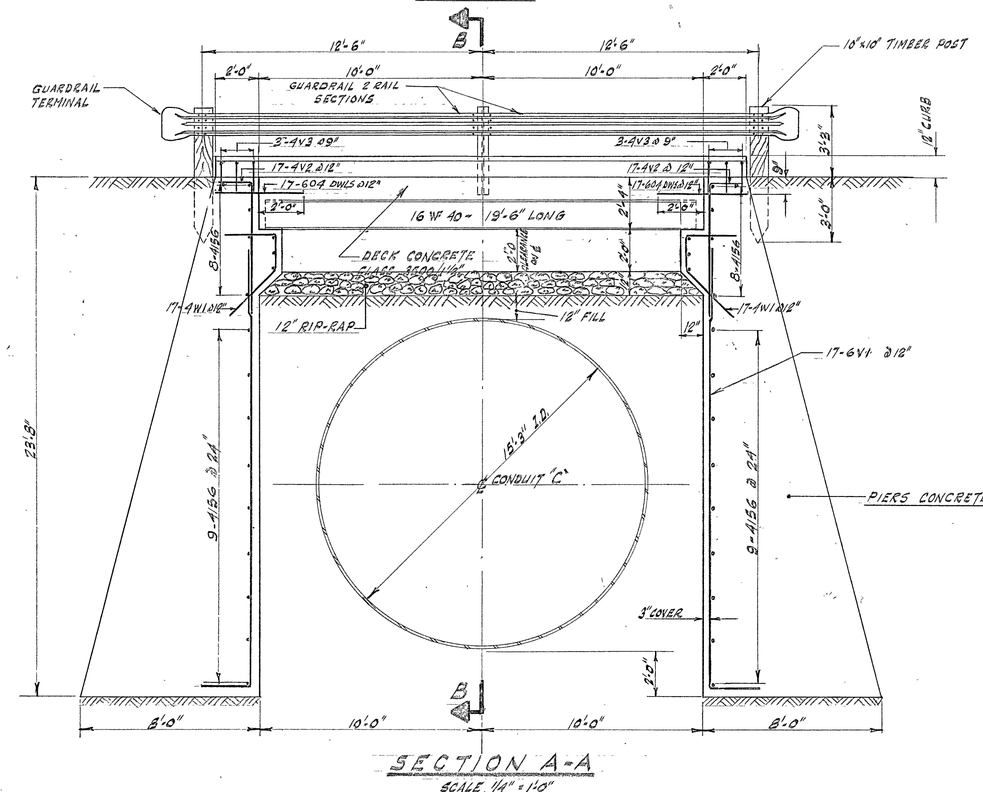
SECTION B-B
SCALE 1/4" = 1'-0"



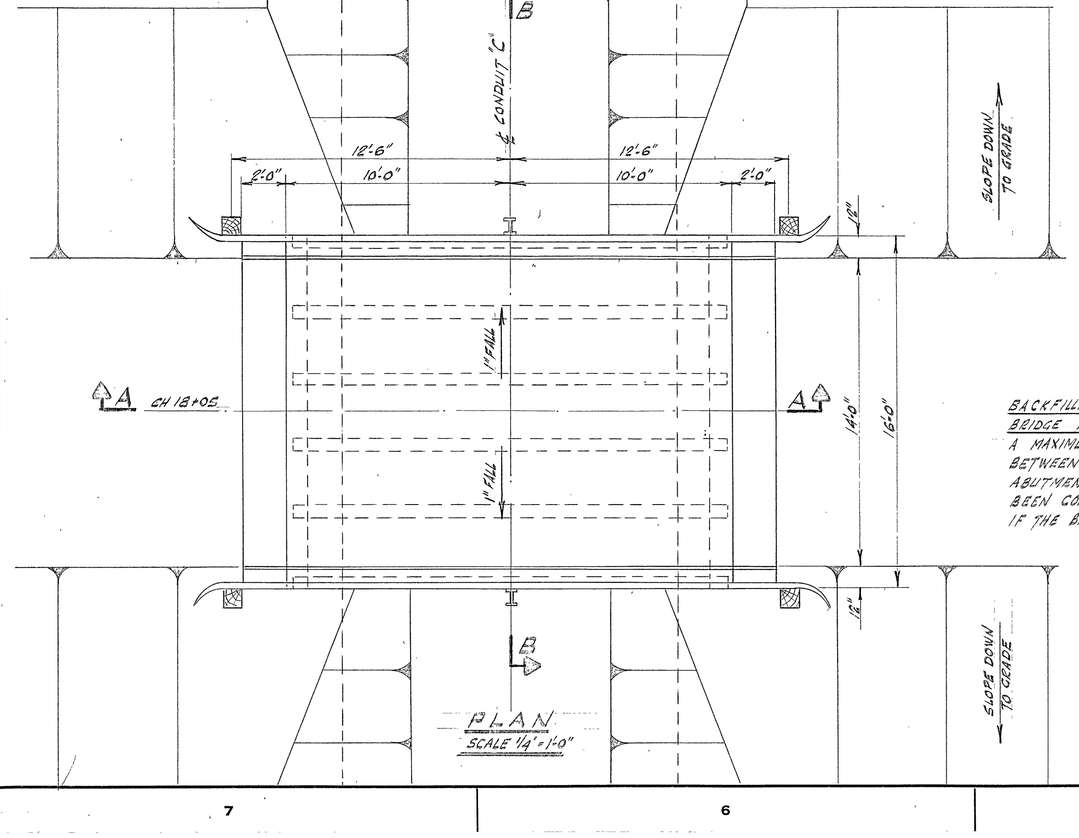
SECTION C-C
SCALE 1/2" = 1'-0"

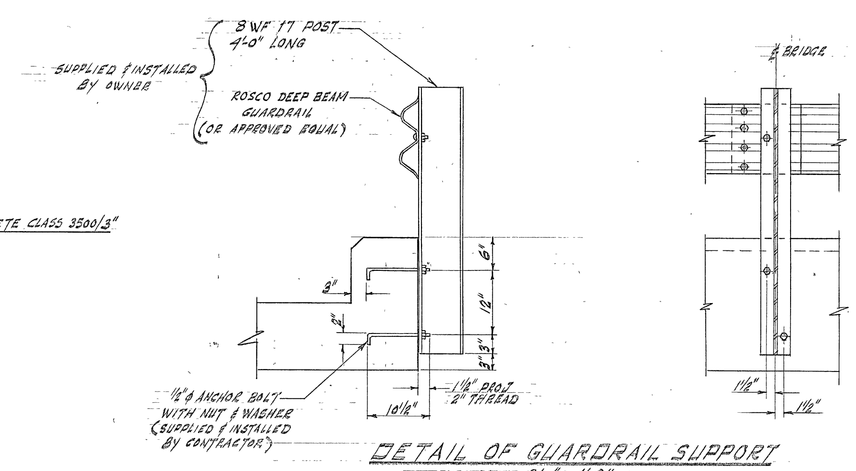


DECK SLAB
SCALE 1/2" = 1'-0"

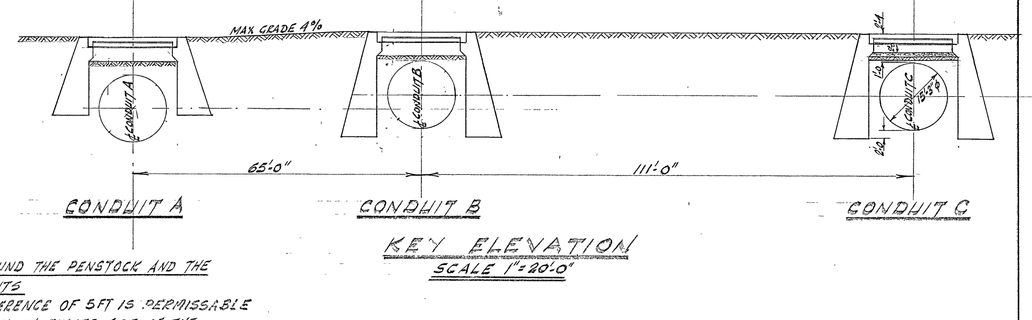


SECTION A-A
SCALE 1/4" = 1'-0"





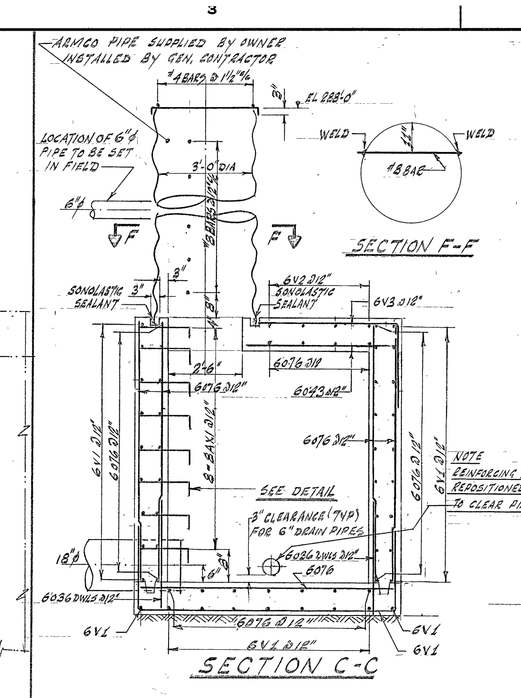
DETAIL OF GUARDRAIL SUPPORT
SCALE 3/4" = 1'-0"

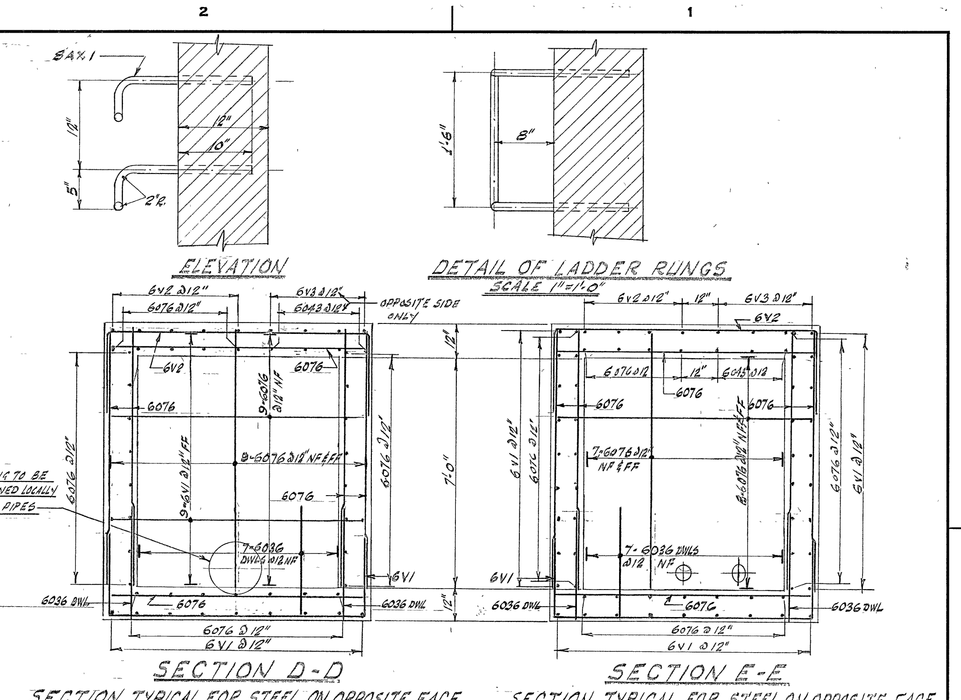


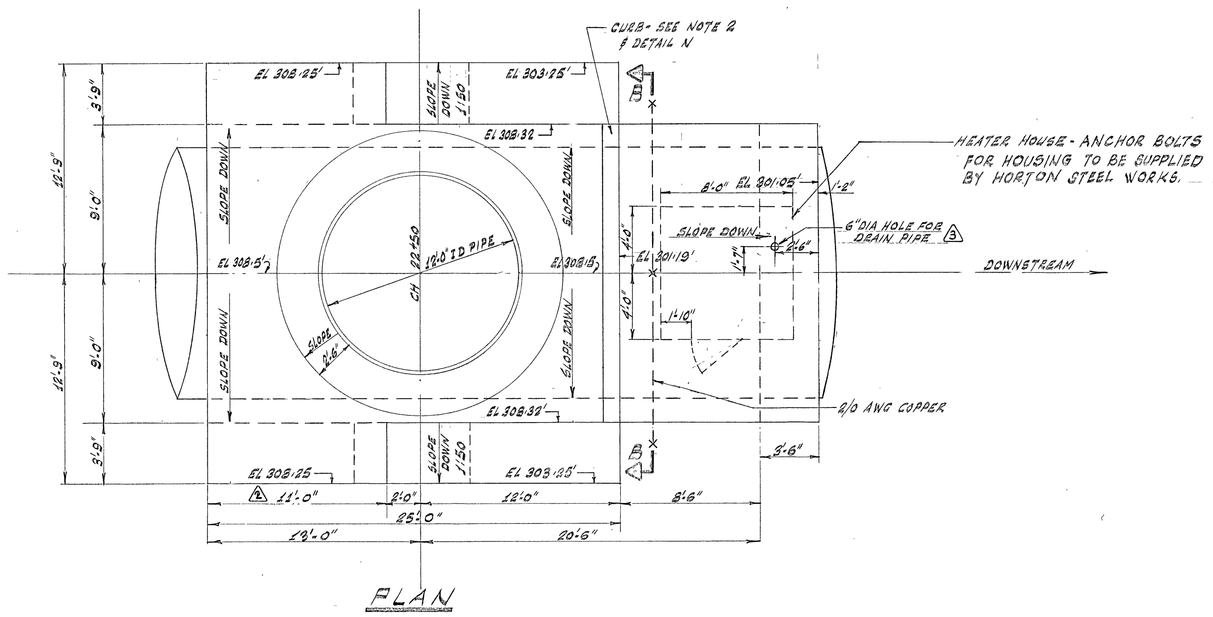
CONDUIT A — CONDUIT B — CONDUIT C

KEY ELEVATION
SCALE 1" = 200'-0"

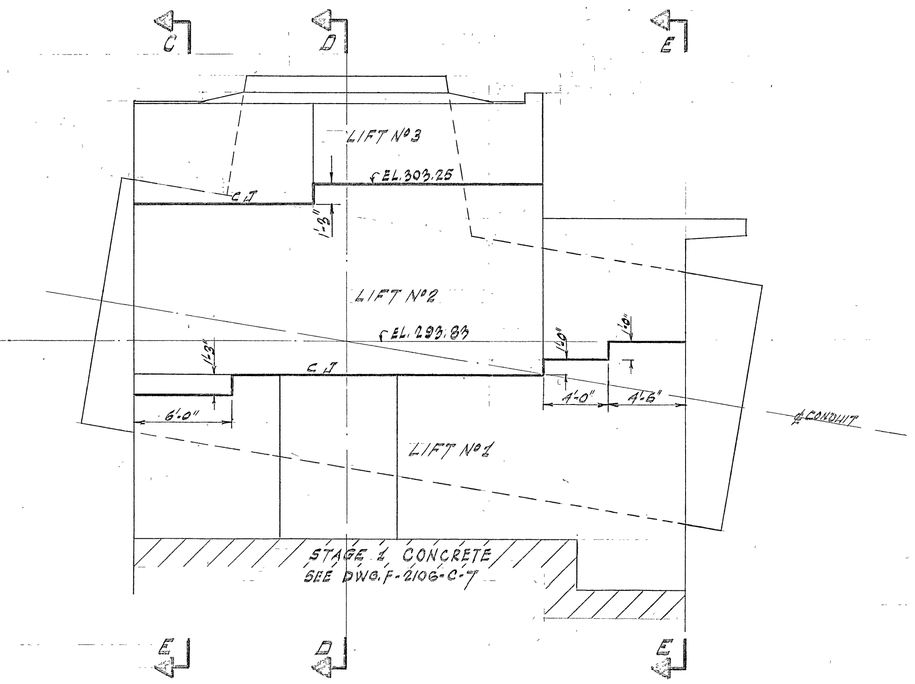
BACKFILLING AROUND THE PENSTOCK AND THE BRIDGE ABUTMENTS
A MAXIMUM DIFFERENCE OF 5FT IS PERMISSABLE BETWEEN THE FILL ON EITHER SIDE OF THE ABUTMENT IF THE BRIDGE DECK HAS NOT BEEN CONSTRUCTED. THERE IS NO LIMITATION IF THE BRIDGE IS COMPLETE



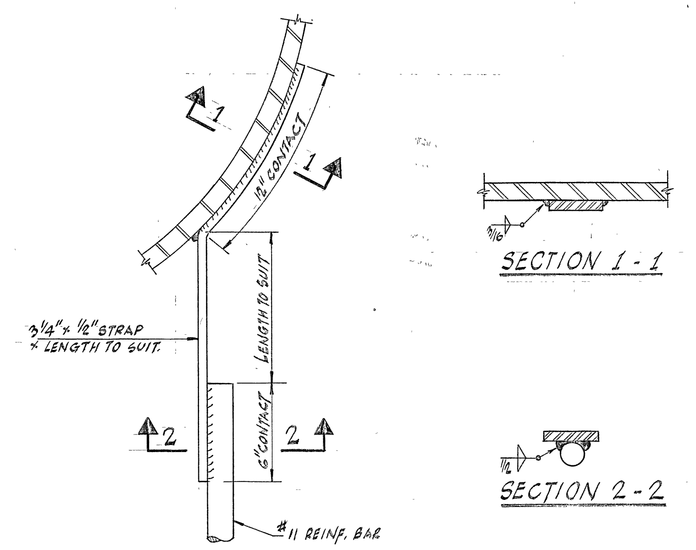

BAR 1
18"
12"
10"
5"
2"
ELEVATION
1'-6"
8"
DETAIL OF LADDER RUNGS
SCALE 1" = 1'-0"
6V2 @12"
6043 @12"
OPPOSITE SIDE ONLY
6V2 @12"
6076 @12"
6V3
6076
6076
6076



PLAN

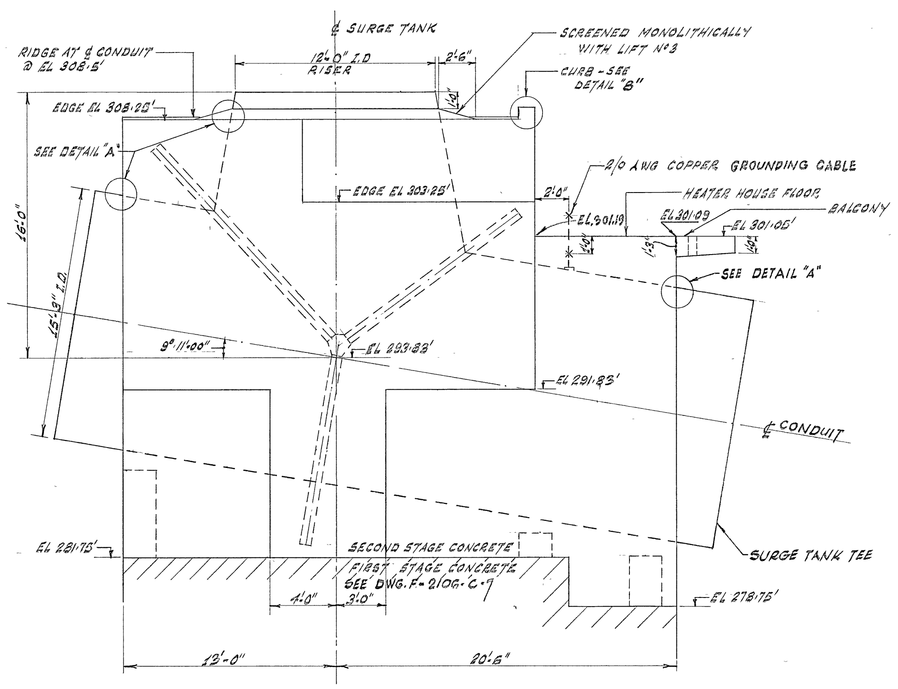


SIDE ELEVATION

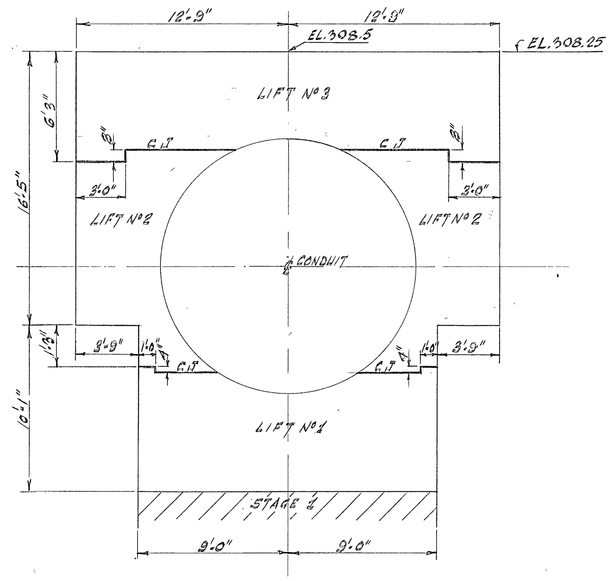


DETAIL OF HOLD DOWN STRAP ANCHOR

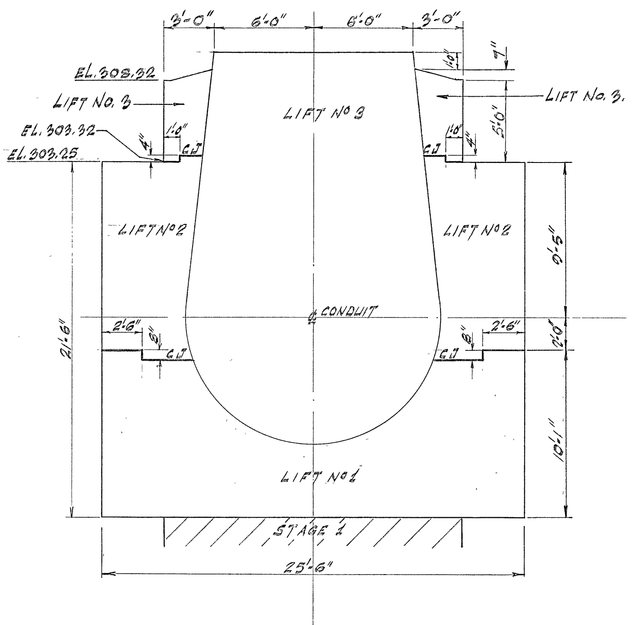
FOR LOCATION OF #11 REINF BARS SEE DWG. F-2106-C-7



SIDE ELEVATION OF SURGETANK TEE & CONCRETE

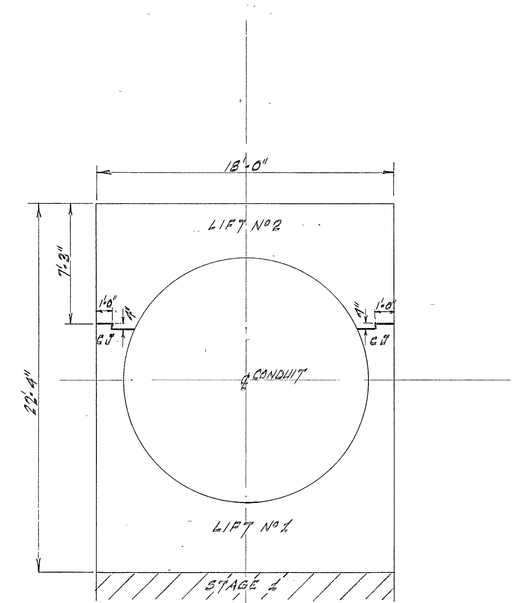


SECTION C-C

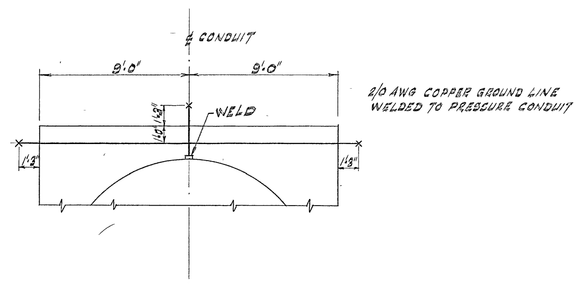


SECTION D-D

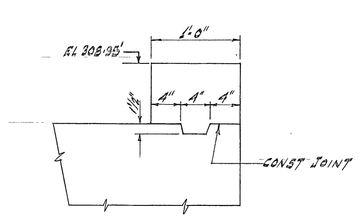
SYSTEM OF CONSTRUCTION JOINTS & LIFTS



SECTION E-E

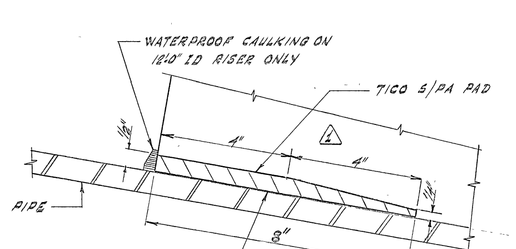


SECTION B-B



CURB DETAIL "B"

SCALE 1"=1'-0"



DETAIL A

SCALE = N.T.S.

TYPICAL AT ALL SURFACES WHERE PIPE EMERGES FROM CONCRETE BLOCK.

NOTE: WORTON STEEL WORKS TO SUPPLY AND INSTALL TICO PADS.

NOTE: ALL 2/0 AWG COPPER GROUNDING CABLE TO BE SUPPLIED AND WELDED BY THE OWNER AND INSTALLED BY GENERAL CONTRACTOR.

FINAL

DRWG No	TITLE	DWG No	TITLE
F-2106-C-4	SURGE TANK "C" TEE STAGE I - OUTLINE & REINFORCING		
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONC. DET'LS & ROCK DOWELS		

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	18 OCT 68	E. G.	6'9" DOWN RELOCATED HEATER HOUSE DIM ADDED	HL	DB
2	18 SEPT 68	D.T	DIMENSION CHANGE	HL	DB
1	30 AUG 68	A.G	TICO S/PA PAD RE-SHAPED & DIM ADDED	HL	D.B

REVISIONS

APPROVED FOR CONSTRUCTION
AUG 22 1968
APPROVED BY:
Regional Engineer

TRANS'N | ELECT'L | CIVIL
PASSED

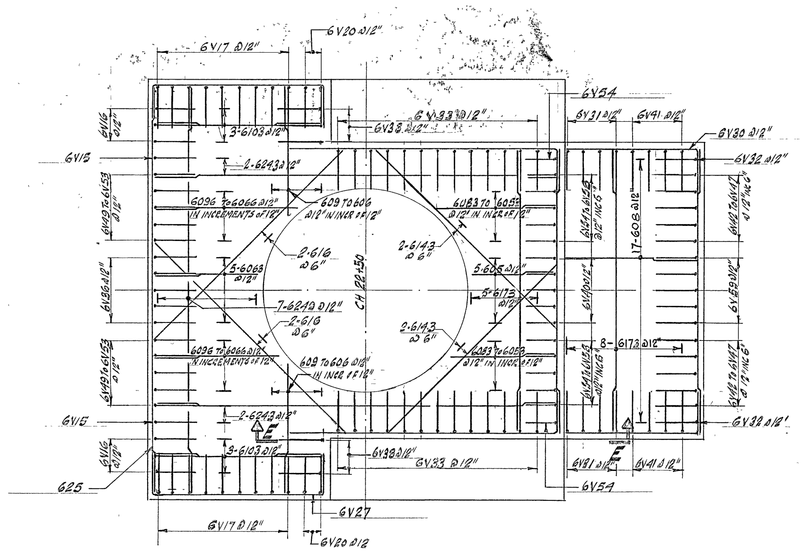
DESIGNED DB
DRAWN H.L.E.E.
CHECKED D.B.
RECOMMENDED R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

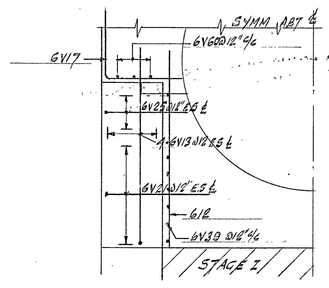
SURGE TANK "C"
TEE STAGE II CONCRETE
DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	3/16"=1'-0"	2-15	24TH JULY 68	F-2106-C-11	3

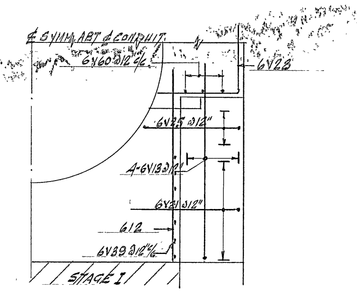
Pentstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 3, Page 40 of 112



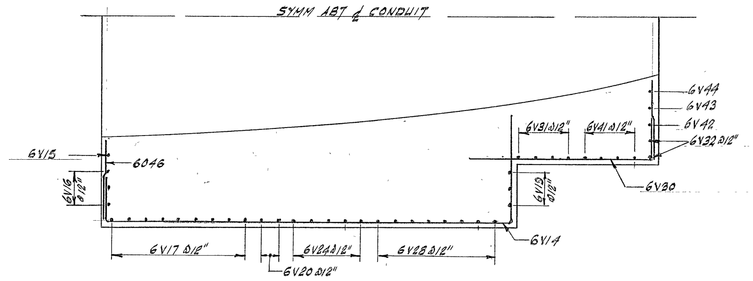
PLAN



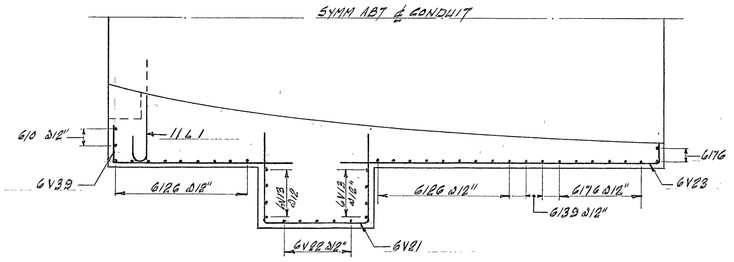
SECTION G-G



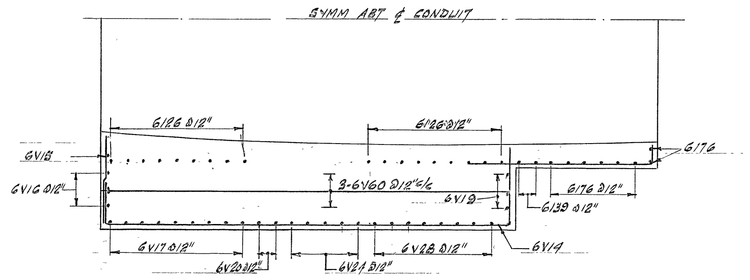
SECTION H-H



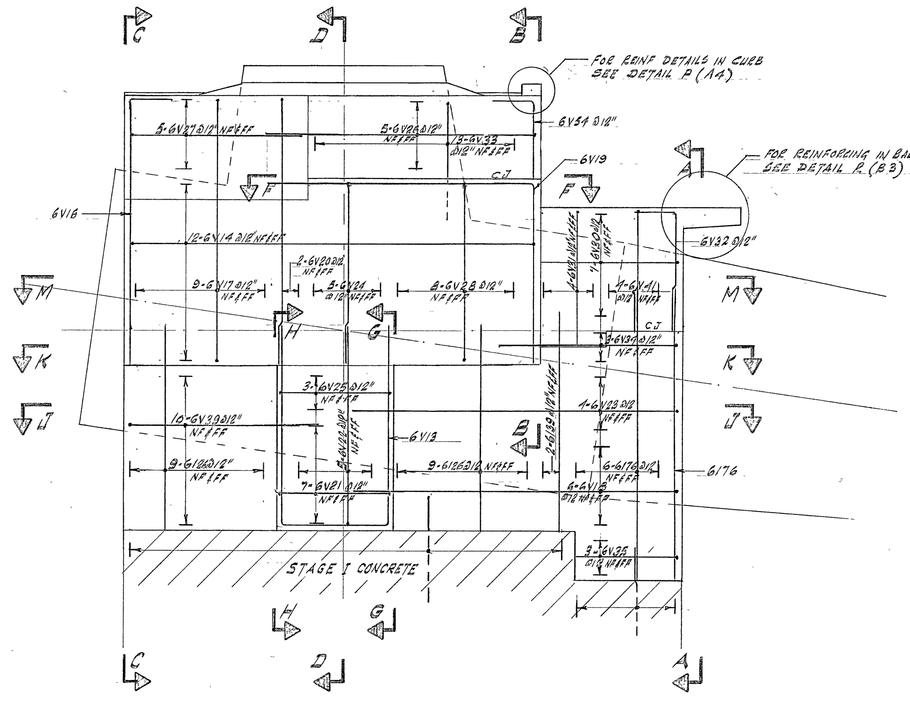
SECTION M-M



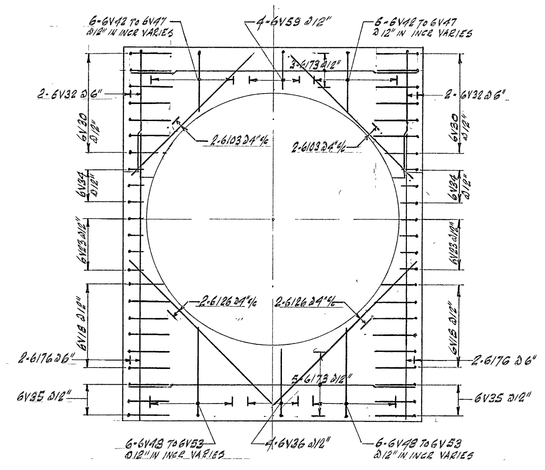
SECTION J-J



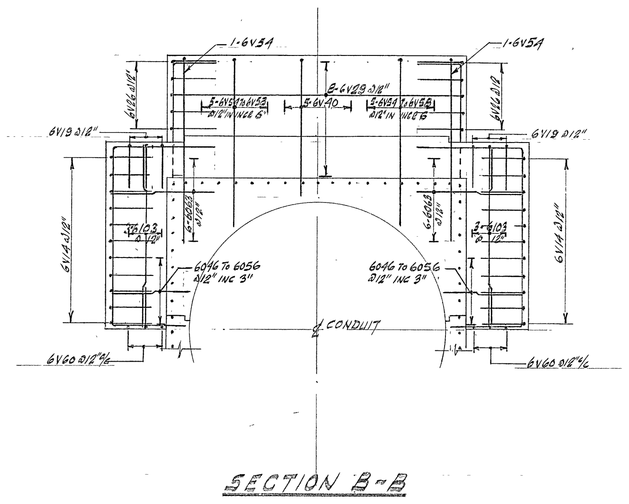
SECTION K-K



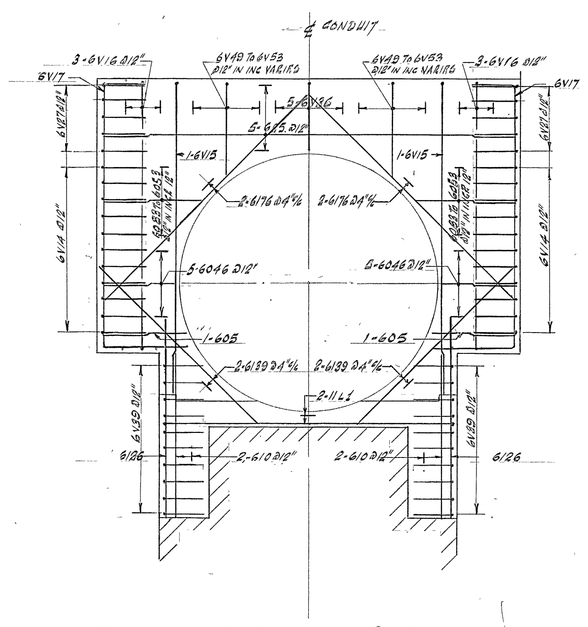
SIDE ELEVATION



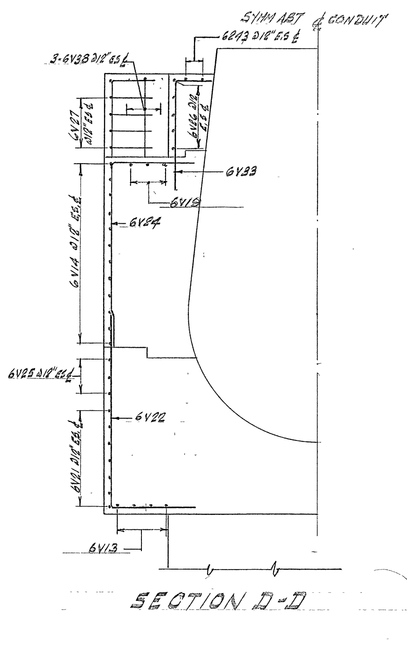
END VIEW A-A



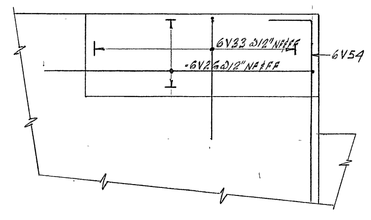
SECTION B-B



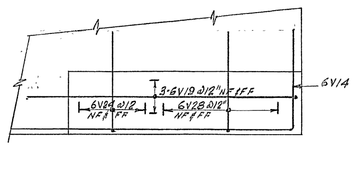
END VIEW C-C



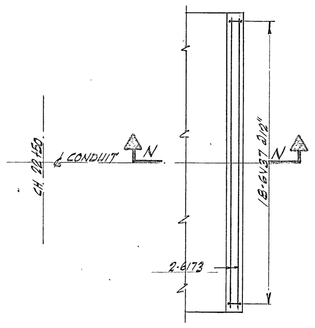
SECTION D-D



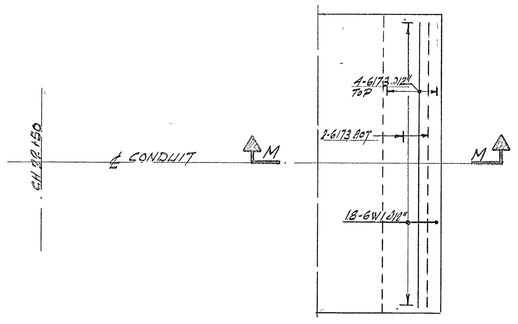
SECTION E-E



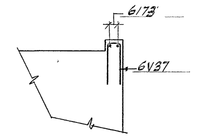
SECTION F-F



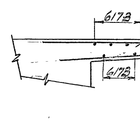
DETAIL P - PLAN OF CURB



DETAIL R - PLAN OF BALCONY



SECTION N-N



SECTION M-M

NOTE
COVER TO REINFORCEMENT TO BE 4" EXCEPT WHERE NOTED

REGISTERED PROFESSIONAL ENGINEER R.A. Robertson PROVINCE OF NEWFOUNDLAND

FINAL

F-2106-C-11	SURGE TANK 'C' - TEE STAGE II CONCRETE DETAIL												
DWG No	TITLE	NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D						
REFERENCE DRAWINGS		REVISIONS											

APPROVED FOR CONSTRUCTION
SEP 16 1983
APPROVED BY: CHIEF ENGINEER

TRANS'N	ELECT'L	CIVIL

PASSED

DESIGNED	DB
DRAWN	H. LEE
CHECKED	DB
RECOMMENDED	R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

SURGE TANK 'C'
TEE STAGE II REINFORCING DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	3/16"=1'-0		23RD AUG 68.	F-2106-C-12	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 4, Attachment 5, Page 41 of 111

APPENDIX B

PHOTOGRAPHS



Photo 1 New Gate



Photo 2 Small Leakage from bolt hole at bottom of Gate



Photo 3 Leakage from Left Side Seal



Photo 4 Leakage from Bolt Hole Midway on Middle Seam



Photo 5 Concrete Patching



Photo 6 Start of Steel Penstock



Photo 7 Steel Surface Can 21



Photo 8 Steel Surface Can 210



Photo 9 Surface Condition Can 252



Photo 10 Steel Surface Can 357



Photo 11 Uncleaned Surface and Original Weld Can 207



Photo 12 Surface Condition Repaired Weld, Can 126S



Photo 13 Surface Condition Repaired Weld Can 118S



Photo 14 New Organic Build Up, Can 126S

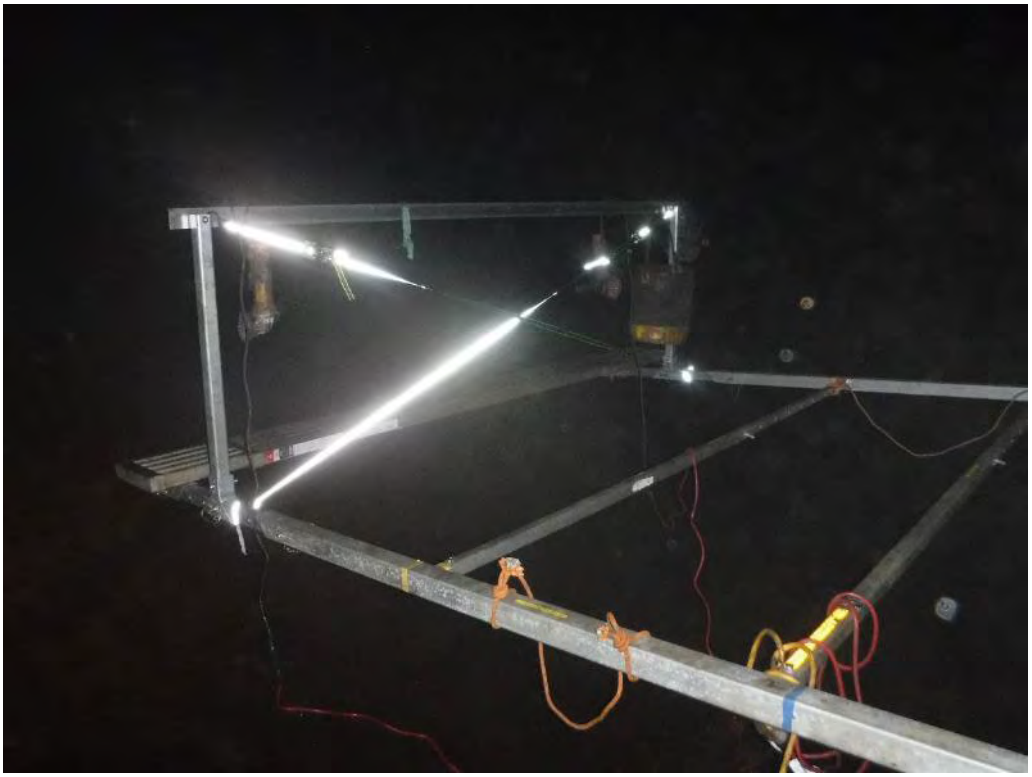


Photo 15 New Aluminum Weld Test Platform



Photo 16 Weld indication Can 11S



Photo 17 Weld Indication Can 11S – Likely Cap Separation



Photo 18 Weld indication Can 32N

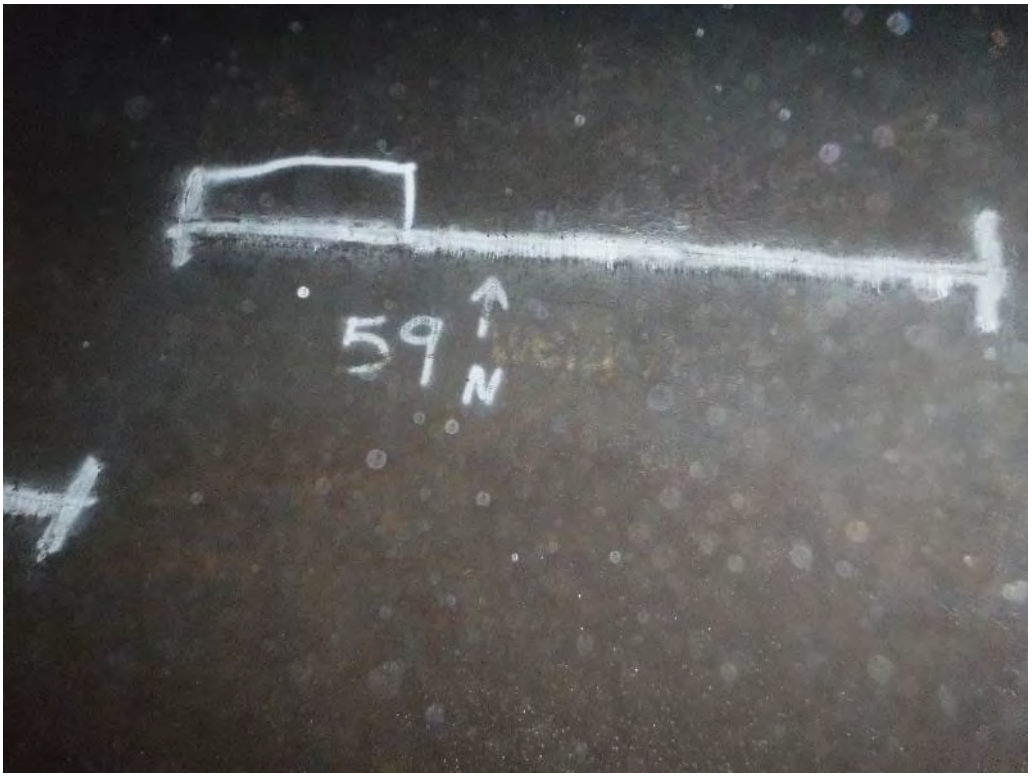


Photo 19 Weld Indication Can 59N



Photo 20 Weld Indication Can 59N – Visible Indication Top Toe

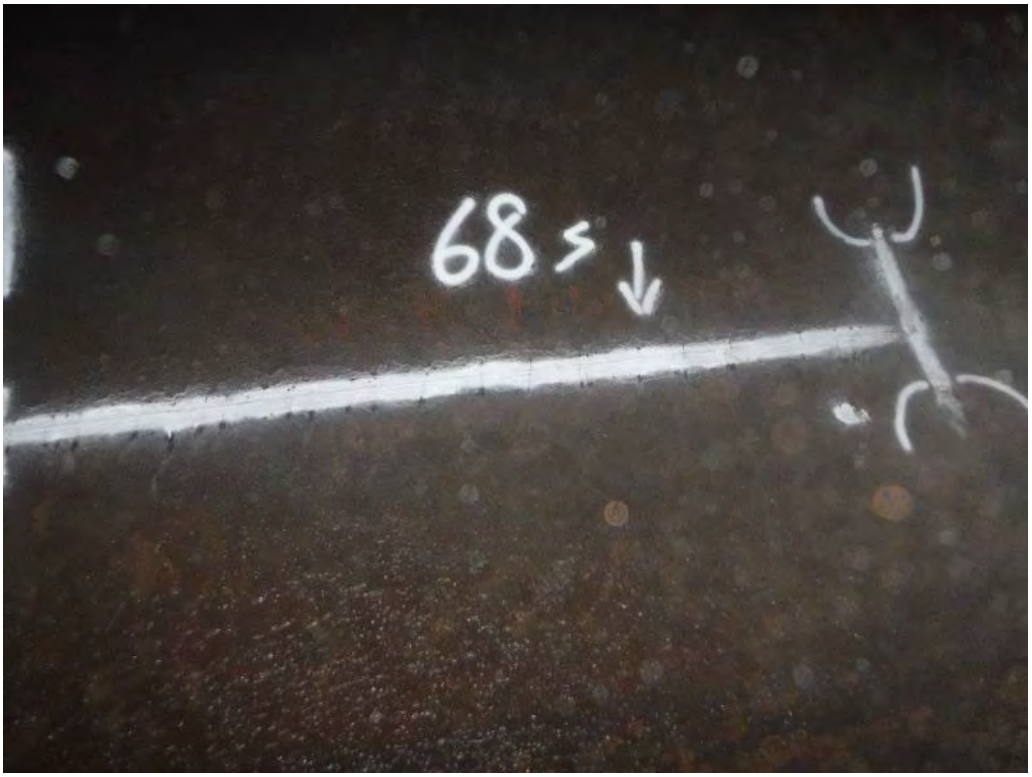


Photo 21 Circumferential Weld indication Can 68S

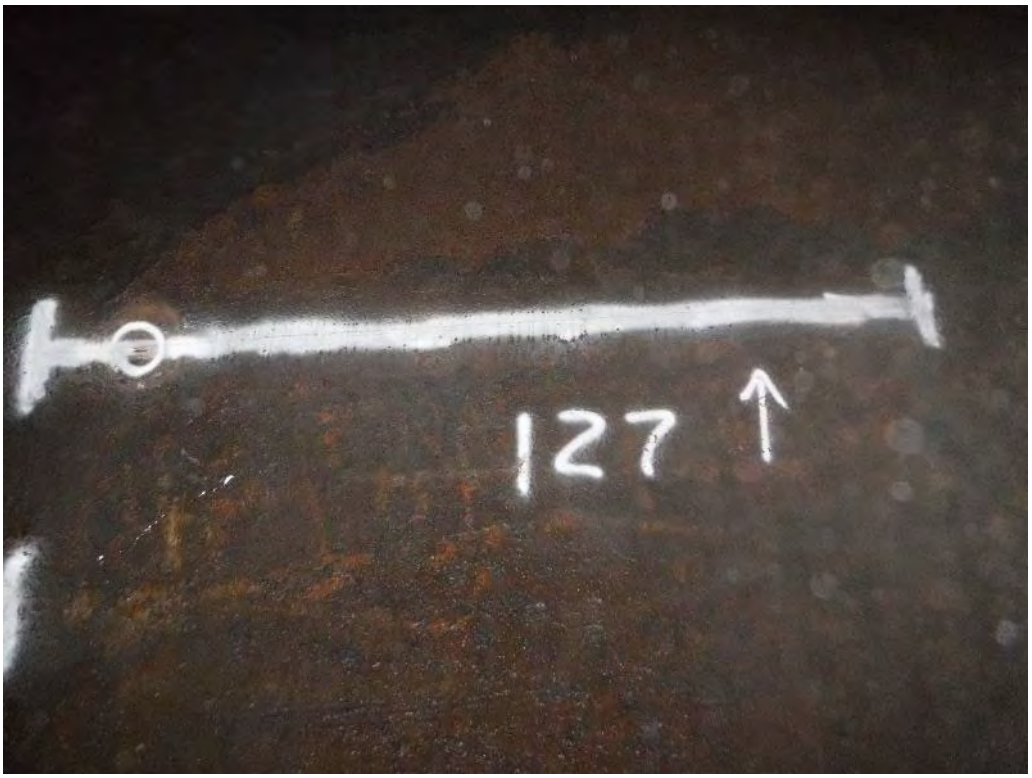


Photo 22 Weld Indication Can 127S



Photo 23 Weld Indication Can 127S

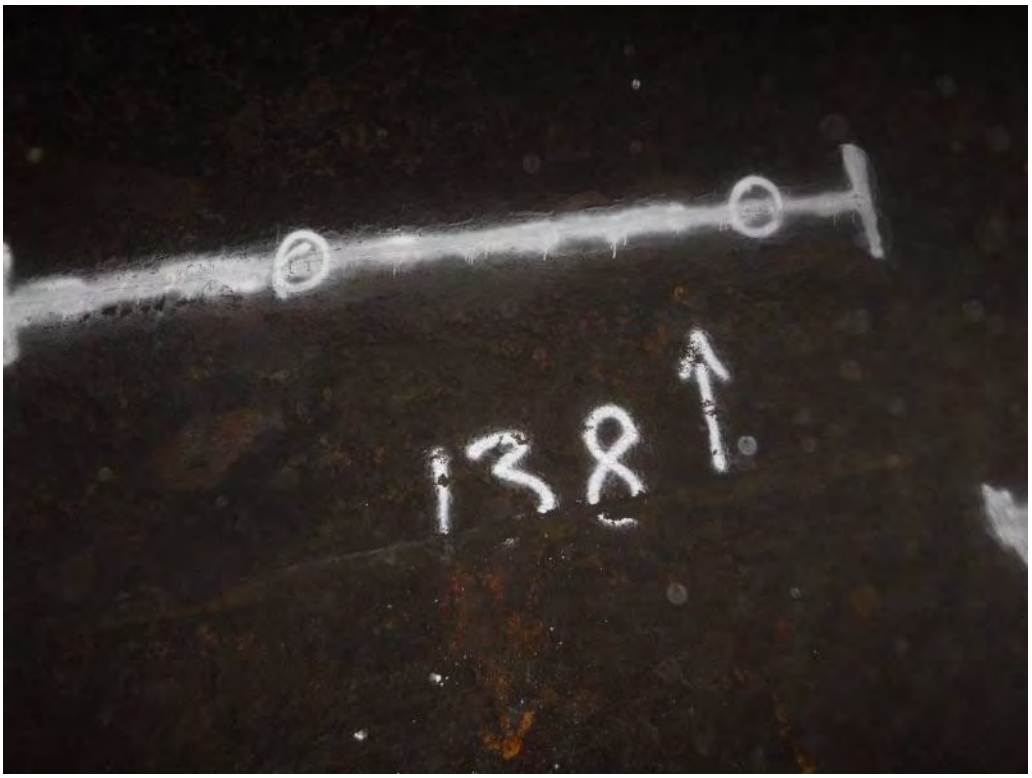


Photo 24 Two Weld Indications Can 138S



Photo 25 Upstream Weld Indication Toe Of Weld Can 138S



Photo 26 Downstream Weld Indication Toe of Weld Can 138S



Photo 27 Weld indication Can 217S



Photo 28 Weld Indication Can 217S



Photo 29 Weld Inspection Marked for Can 77S



Photo 30 Weld Inspection Marked Can 140S



Photo 31 Staging for Repair of Surge Tank Transition Piece Welds



Photo 32 Gouging for Repair of Surge Tank Transition Piece



Photo 33 Looking Upstream Towards Intake From About Station 0+100



Photo 34 Looking Upstream Towards Intake From About Station 0+220



Photo 35 Looking Upstream Along the Steep Section at About Station 400



Photo 36 Looking Upstream Along Penstock From Near Surge Tank Access Road



Photo 37 Looking Downstream Toward Surge Tank From Tank Access Road



Photo 38 Downstream Left of Surge Tank



Photo 39 Looking Downstream From Surge Tank



Photo 40 Access Hole 3



Photo 41 Looking Downstream at Switchyard From About Station 0+900



Photo 42 Shed Covering Weir N1



Photo 43 Weir N1



Photo 44 Weir N2

APPENDIX C

WELD TEST

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	23-442-1	Copy:	
Date:	2 June, 2023	Date Received:	29 May, 2023
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy, SNT TC-1A: UT, ET, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I XRF Level I
Attn:	Todd LeGrow		
P.O. No.	2023-0164		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3		
Testing Required:	Magnetic Particle Inspection	Signed:	NDT Inspector

Remarks

As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E709 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

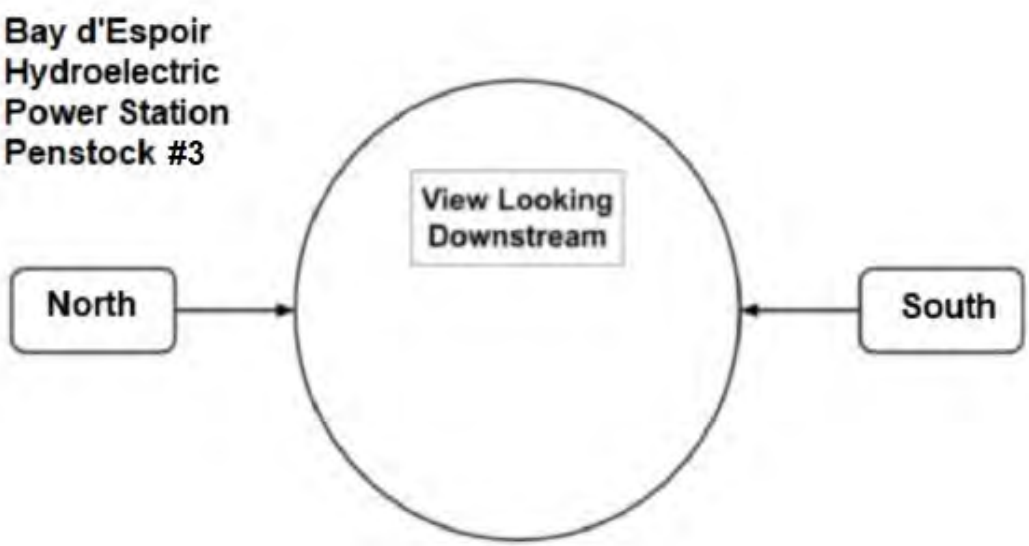
The following indications were noted:

Indication #1 - Toe of Weld indication noted on can #11 south longitudinal weld, approximately 210mm in length.
Indication #2 - Toe of Weld indication noted on can #32 north longitudinal weld, approximately 220mm in length.
Indication #3 - Cap washing was noted on weld #59 north longitudinal weld, was approximately 950mm In length.
Indication #4 - Toe of Weld indication was noted on can #69 South upstream circular weld, approximately 620mm in length. Indication continued up and down on the circular weld.
Indication #5 - Centre of weld indication was noted on can #127 south longitudinal weld, approximately 5mm in length.
Indication #6 - Toe of Weld indication was noted on can #138 south longitudinal weld, approximately 50mm in length.
Indication #7 - Toe of Weld indication was noted on can #138 south longitudinal weld, approximately 45mm in length.
Indication #8 - Toe of Weld indication was noted on can #217 south longitudinal weld, approximately 430mm in length.
Indication #9 - Toe of Weld indication was noted on can #217 south longitudinal weld, approximately 200mm in length.

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
2	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
3	-Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
10	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
11	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Longitudinal Weld Indication #1** MT Acceptable on Circular Weld	**Figure 1 & 2**
21	-Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
23	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
31	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
32	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Longitudinal Weld Indication #2** MT Acceptable on Circular Weld	**Figure 3 & 4**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
38	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
49	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
58	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
59	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Longitudinal Weld Indication #3** MT Acceptable on Circular Weld	**Figure 5 & 6**
68	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable on Longitudinal Weld **Indication Noted On Circular Weld Indication #4**	**Figure 7 & 8**
69	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
78	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
88	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
96	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
98	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
108	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
109	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
119	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
127	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Longitudinal Weld Indication #5** MT Acceptable on Circular Weld	**Figures 9 & 10**
128	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
137	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
138	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Horizontal Weld Indication #6 & #7** MT Acceptable on Circular Weld	**Figures 11,12,13**
147	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
148	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
158	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
170	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
178	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
179	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
186	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
187	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
197	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
201	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
207	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
208	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
217	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On South Longitudinal Weld Indication #8 & 9** MT Acceptable on Circular Weld	**Figures 14,15,16**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
227	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
241	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
243	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
248	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
249	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
258	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
267	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
276	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
277	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
285	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
297	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
299	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
308	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
309	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
317	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
318	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
328	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
329	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
337	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
338	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
347	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
357	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
358	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
366	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
367	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 1. Indication #1 - Indication noted in toe of weld - approximately 210mm in length



Figure 2. - Location Of Indication #1 Can #11 South Side Horizontal Weld

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 3 - Indication #2 Can #32 North Side Horizontal Weld - Indication Noted In Toe of Weld - Approximately 220mm In Length



Figure 4 - Location Of Indication #2 Can #32 North Side Horizontal Weld

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 5 - Indication #3 - Can #59 North Side Horizontal Weld - Indication Noted - Approximately 950mm in length



Figure 6 - Location of Indication #3 **-** Can 59N Horizontal Weld

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 7 - Indication #4 - Can #69 South Side Upstream Circular Weld - Indication Noted in Toes Of Weld On Circular Weld - Approximately 620mm+ in Length - Indication Continued Up and Down.



Figure 8 - Location Of Indication #4 **-** Can #69 South Side Upstream Circular Weld

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 9 - Indication #5 - Can #127N South Side Horizontal Weld - Indication Noted In Toe of Weld - Approximately 3mm In Length

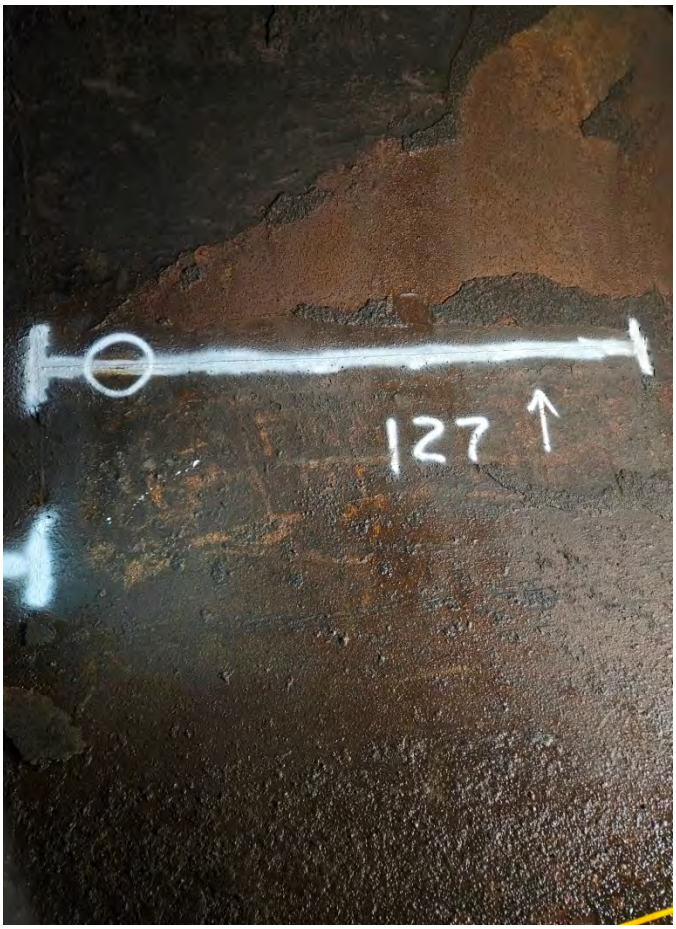


Figure 10 - Location of Indication #5 **-** Can #127 South Side Horizontal Weld

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 11 - Indication #6 **-** Can #138 South Side Horizontal Weld - Indication Noted In Toe of Weld - Approximately 50 mm in Length



Figure 12 - Indication #7 **-** Can #138 South Side Horizontal Weld - Indication Noted In Toe of Weld - Approximately 45 mm in Length

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

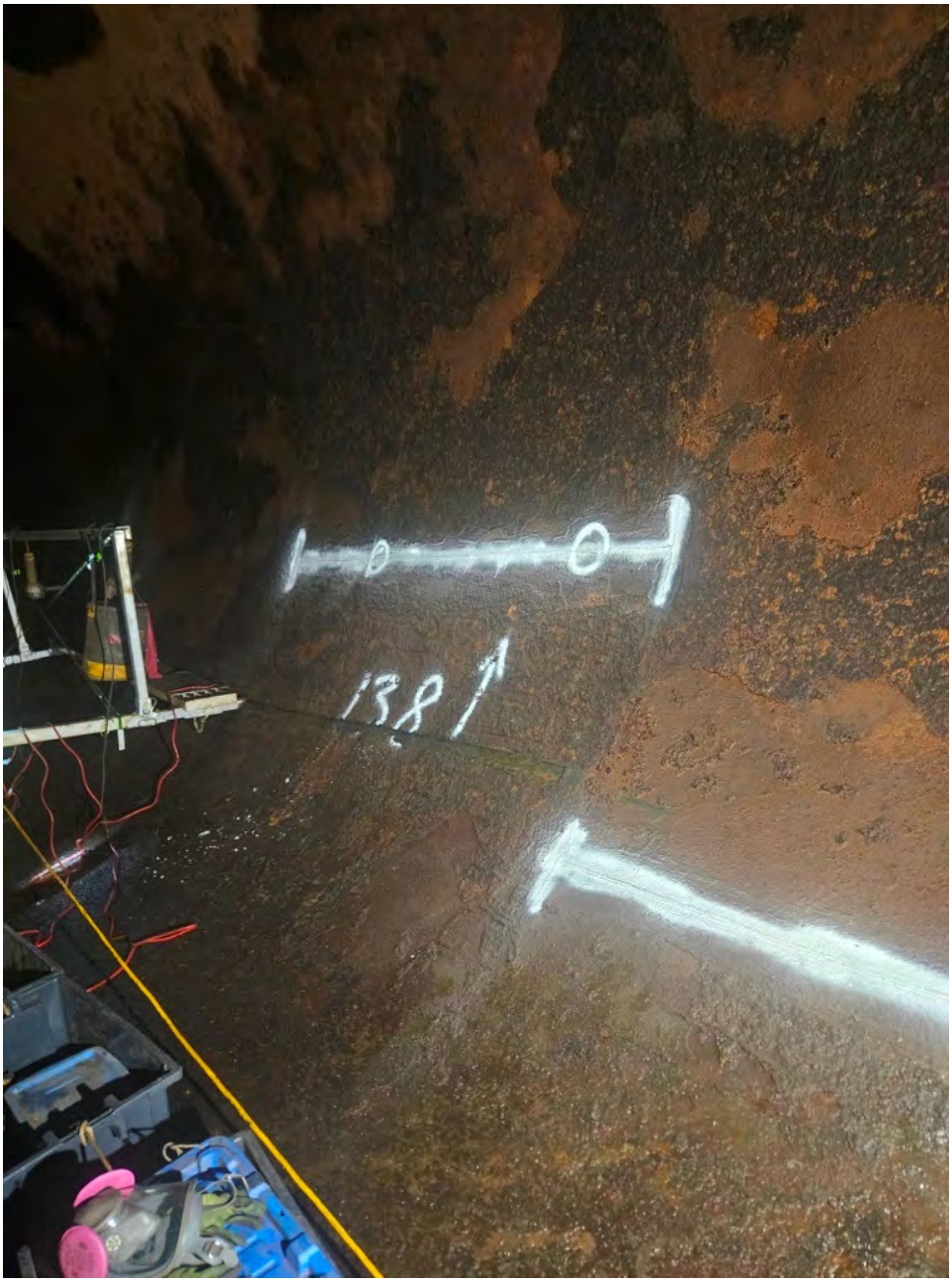


Figure 13 - Location of Indication #6 & 7 **-** Can #138 South Side Longitudinal Weld

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 14 - **Indication #8** - Can #217 South Side Horizontal Weld - Indication Noted In Toe of Weld - Approximately 430mm In Length



Figure 15 - **Indication #9** - Can #217 South Side Horizontal Weld - Indication Noted In Toe of Weld - Approximately 200mm In Length (Indication Extends past picture)

ETS No.: 23-442-1 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 16 - Location of Indications #8 And #9 - Can #217 South Side Horizontal Weld

Visual Inspections
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709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	23-485	Copy:	
Date:	2 June, 2023	Date Received:	29 May, 2023
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy, SNT TC-1A: UT, ET, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I XRF Level I
Attn:	Todd LeGrow		
P.O. No.	2023-0166		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3 - Scope #2		
Testing Required:	Magnetic Particle Inspection	Signed:	NDT Inspector

Remarks

As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E709 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.

Results

The following indications were noted:

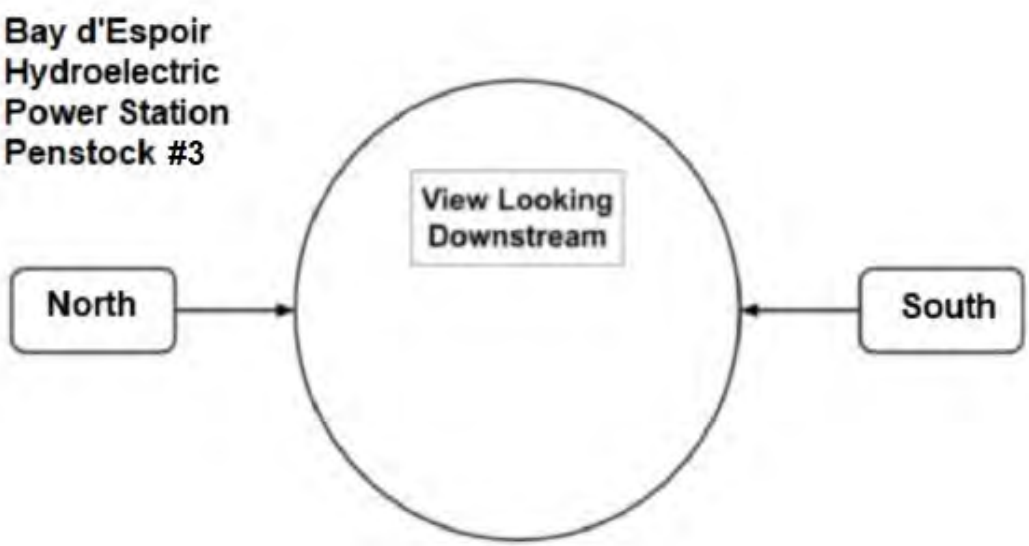
Indication #1 - Toe of weld indication noted on can #77 south longitudinal weld, approximately full length of can

Indication #2 - Toe of weld indication noted on can #140 south longitudinal weld, approximately 215mm in length.

ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.



ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
4	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
5	-Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
12	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
13	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
22	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
24	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
29	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
30	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
39	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
47	- Longitudinal left (north) weld.. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
48	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
60	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
66	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
67	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
76	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
77	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Longitudinal Weld Indication #1** MT Acceptable on Circular Weld	**Figure 1 & 2**

ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
86	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
87	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
95	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
97	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
106	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
107	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
118	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
120	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
125	- Longitudinal right (south) weld - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
126	- Longitudinal right (south) weld - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
138	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
140	- Longitudinal right (south) weld - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted On Longitudinal Weld Indication #2** MT Acceptable on Circular Weld	**Figure 3 & 4**
141	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
216	- Longitudinal right (south) weld - - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 1 - Indication #1 can #77 south side horizontal weld - Indication noted in toe of weld - Indications were intermittent for all of can 77S



Figure 2 - Location of indications on can #77 south side horizontal weld

ETS No.: 23-485 Date: June 2nd 2023
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 3 - Indication #2 can #140 south side horizontal weld - Indication noted In toe of weld - Approximately 215mm in length



Figure 4 - Location of indication #2 can #140 south side horizontal weld

APPENDIX D

THICKNESS MEASUREMENTS DATA AND STRESS CALCULATIONS

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

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709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	23-442-2	Copy:	
Date:	2 June 2023	Date Received:	29 May 2023
Client:	Technical Rope & Rescue 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Todd Legrow		
P.O. No.	2023-0164		
Project:	Penstock Inspection - Penstock #3		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	Conor Murphy

NDT Inspector

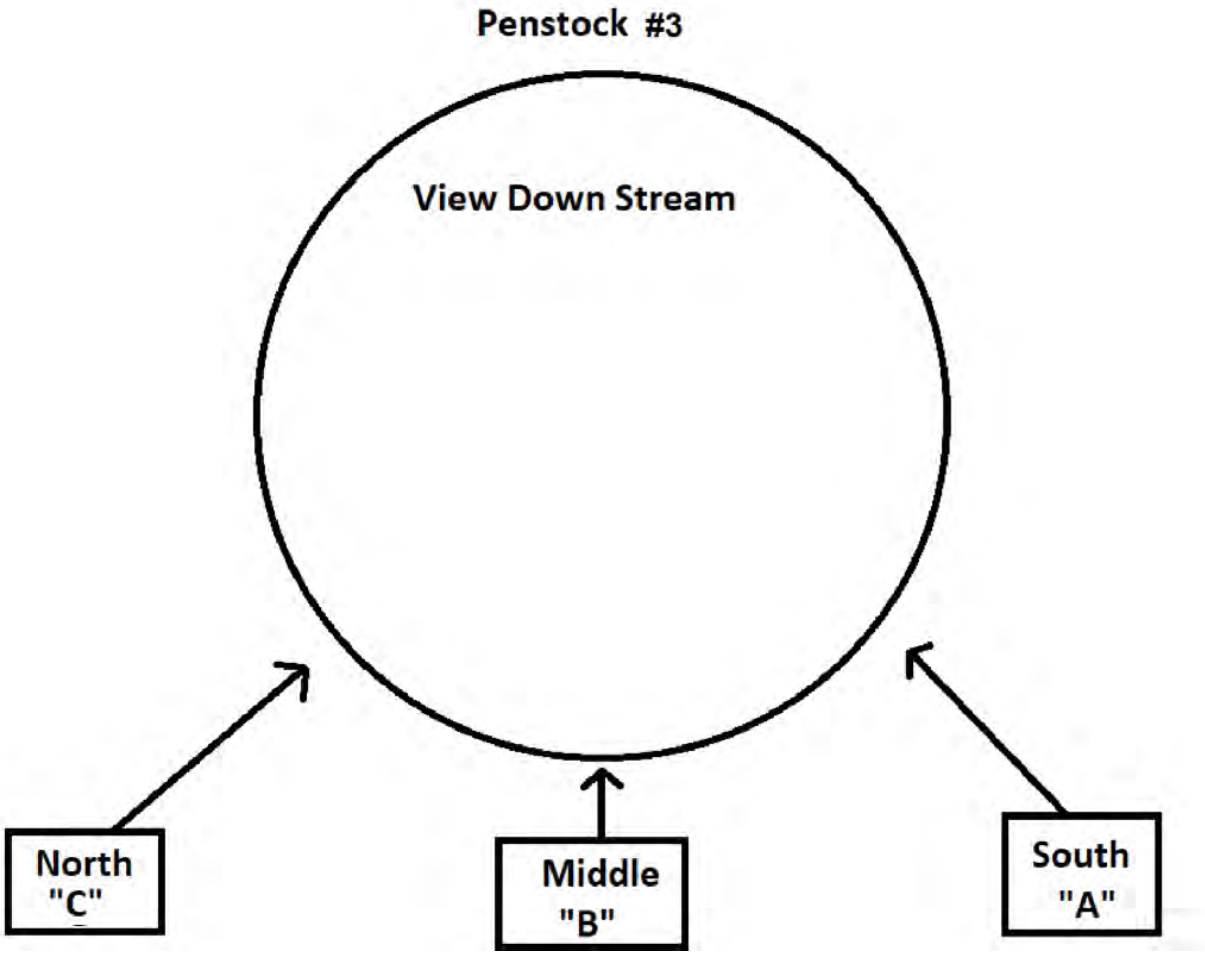
Remarks

As directed, ultrasonic thickness measurements were taken on Penstock #3 in areas as requested. 3 readings were taken at each location, readings are shown in mm's on the attached tables.

Equipment Used

GE DMS Go+ digital thickness gauge (S/N GOPLS20050054)
KBA 560 Probe (S/N F08945)
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 23-442-2 Date: 2 June 2023
Client: Technical Rope & Rescue
Location: Penstock #3
Ultrasonic Thickness Measurements



UTM Data Logger Location #	Can #	Location ID	Reading (mm) A	Reading (mm) B	Reading (mm) C	Original Thickness (mm)	10% Diminution (mm)	Location Average	Average Diminution (mm)	Average Diminution (%)	Comments
	Penstock #3 - (Shot 1: South, Shot 2: Bottom, Shot 3: North)										
1	**2**	**1**	12.9	12.4	12.4	11.1	10.0	12.6	0.0	**0.0%**	
1	**2**	**2**	12.1	12.1	12.1	11.1	10.0	12.1	0.0	**0.0%**	
1	**2**	**3**	12.6	12.1	12.0	11.1	10.0	12.2	0.0	**0.0%**	
2	**10**	**1**	12.2	12.2	12.2	11.1	10.0	12.2	0.0	**0.0%**	
2	**10**	**2**	11.8	11.8	11.8	11.1	10.0	11.8	0.0	**0.0%**	
2	**10**	**3**	11.6	11.5	11.5	11.1	10.0	11.5	0.0	**0.0%**	
3	**21**	**1**	10.4	10.4	10.5	11.1	10.0	10.4	0.7	**6.0%**	
3	**21**	**2**	10.5	10.5	10.6	11.1	10.0	10.5	0.6	**5.1%**	
3	**21**	**3**	10.6	10.2	10.5	11.1	10.0	10.4	0.7	**6.0%**	
4	**31**	**1**	10.4	10.4	10.4	11.1	10.0	10.4	0.7	**6.3%**	
4	**31**	**2**	10.7	10.6	10.8	11.1	10.0	10.7	0.4	**3.6%**	
4	**31**	**3**	10.6	10.6	10.5	11.1	10.0	10.6	0.5	**4.8%**	
5	**38**	**1**	10.1	10.1	10.1	11.1	10.0	10.1	1.0	**9.0%**	
5	**38**	**2**	10.2	10.2	10.4	11.1	10.0	10.3	0.8	**7.5%**	
5	**38**	**3**	10.4	10.5	10.5	11.1	10.0	10.5	0.6	**5.7%**	
6	**49**	**1**	10.1	10.0	10.1	11.1	10.0	10.1	1.0	**9.3%**	
6	**49**	**2**	10.4	10.5	10.4	11.1	10.0	10.4	0.7	**6.0%**	
6	**49**	**3**	10.6	10.6	10.7	11.1	10.0	10.6	0.5	**4.2%**	
7	**58**	**1**	10.2	10.2	10.3	11.1	10.0	10.2	0.9	**7.8%**	
7	**58**	**2**	10.5	10.5	10.6	11.1	10.0	10.5	0.6	**5.1%**	
7	**58**	**3**	10.8	10.5	10.7	11.1	10.0	10.7	0.4	**3.9%**	
8	**68**	**1**	10.4	10.4	10.2	11.1	10.0	10.3	0.8	**6.9%**	
8	**68**	**2**	10.3	10.3	10.3	11.1	10.0	10.3	0.8	**7.2%**	
8	**68**	**3**	10.3	10.4	10.3	11.1	10.0	10.3	0.8	**6.9%**	
9	**78**	**1**	10.0	10.1	10.0	11.1	10.0	10.0	1.1	**9.6%**	
9	**78**	**2**	10.5	10.5	10.5	11.1	10.0	10.5	0.6	**5.4%**	
9	**78**	**3**	10.5	10.5	10.5	11.1	10.0	10.5	0.6	**5.4%**	
10	**88**	**1**	10.0	10.0	10.2	11.1	10.0	10.1	1.0	**9.3%**	
10	**88**	**2**	10.3	10.3	10.4	11.1	10.0	10.3	0.8	**6.9%**	
10	**88**	**3**	10.2	10.3	10.2	11.1	10.0	10.2	0.9	**7.8%**	
11	**96**	**1**	10.2	10.4	10.3	11.1	10.0	10.3	0.8	**7.2%**	
11	**96**	**2**	10.1	10.6	10.6	11.1	10.0	10.4	0.7	**6.0%**	
11	**96**	**3**	10.1	10.1	10.1	11.1	10.0	10.1	1.0	**9.0%**	
12	**108**	**1**	10.5	10.5	10.3	11.1	10.0	10.4	0.7	**6.0%**	
12	**108**	**2**	10.5	10.4	10.6	11.1	10.0	10.5	0.6	**5.4%**	
12	**108**	**3**	10.6	10.4	10.5	11.1	10.0	10.5	0.6	**5.4%**	
13	**119**	**1**	10.5	10.5	10.5	11.1	10.0	10.5	0.6	**5.4%**	
13	**119**	**2**	10.4	10.7	10.5	11.1	10.0	10.5	0.6	**5.1%**	
13	**119**	**3**	10.1	10.1	10.1	11.1	10.0	10.1	1.0	**9.0%**	
14	**127**	**1**	10.5	10.3	10.3	11.1	10.0	10.4	0.7	**6.6%**	
14	**127**	**2**	10.5	10.5	10.4	11.1	10.0	10.5	0.6	**5.7%**	
14	**127**	**3**	10.0	10.0	10.1	11.1	10.0	10.0	1.1	**9.6%**	
15	**137**	**1**	10.5	10.6	10.6	11.1	10.0	10.6	0.5	**4.8%**	
15	**137**	**2**	10.7	10.6	10.8	11.1	10.0	10.7	0.4	**3.6%**	

UTM Data Logger Location #	Can #	Location ID	Reading (mm) A	Reading (mm) B	Reading (mm) C	Original Thickness (mm)	10% Diminution (mm)	Location Average	Average Diminution (mm)	Average Diminution (%)	Comments
	Penstock #3 - (Shot 1: South, Shot 2: Bottom, Shot 3: North)										
15	**137**	**3**	10.2	10.5	10.4	11.1	10.0	10.4	0.7	**6.6%**	
16	**147**	**1**	13.7	13.7	13.8	14.3	12.9	13.7	0.6	**4.0%**	
16	**147**	**2**	13.7	13.7	13.7	14.3	12.9	13.7	0.6	**4.2%**	
16	**147**	**3**	13.8	14.0	13.9	14.3	12.9	13.9	0.4	**2.8%**	
17	**158**	**1**	13.5	13.5	13.5	14.3	12.9	13.5	0.8	**5.6%**	
17	**158**	**2**	13.4	13.4	13.4	14.3	12.9	13.4	0.9	**6.3%**	
17	**158**	**3**	13.7	13.6	13.6	14.3	12.9	13.6	0.7	**4.7%**	
18	**170**	**1**	18.3	18.2	18.2	15.9	14.3	18.2	0.0	**0.0%**	Transition - Original Thickness Unknown.
18	**170**	**2**	19.2	19.2	19.1	15.9	14.3	19.2	0.0	**0.0%**	Transition - Original Thickness Unknown.
18	**170**	**3**	19.1	19.1	19.1	15.9	14.3	19.1	0.0	**0.0%**	Transition - Original Thickness Unknown.
19	**178**	**1**	15.3	15.3	15.3	15.9	14.3	15.3	0.6	**3.8%**	
19	**178**	**2**	15.6	15.5	15.5	15.9	14.3	15.5	0.4	**2.3%**	
19	**178**	**3**	15.3	15.6	15.5	15.9	14.3	15.5	0.4	**2.7%**	
20	**186**	**1**	15.6	15.4	15.5	15.9	14.3	15.5	0.4	**2.5%**	
20	**186**	**2**	15.5	15.6	15.5	15.9	14.3	15.5	0.4	**2.3%**	
20	**186**	**3**	15.1	15.0	15.1	15.9	14.3	15.1	0.8	**5.2%**	
21	**197**	**1**	15.3	15.3	15.3	15.2	13.7	15.3	0.0	**0.0%**	
21	**197**	**2**	15.7	15.7	15.7	15.2	13.7	15.7	0.0	**0.0%**	
21	**197**	**3**	15.1	15.3	15.4	15.2	13.7	15.3	0.0	**0.0%**	
22	**207**	**1**	15.4	15.4	15.3	15.9	14.3	15.4	0.5	**3.4%**	
22	**207**	**2**	15.3	15.1	15.3	15.9	14.3	15.2	0.7	**4.2%**	
22	**207**	**3**	15.1	15.1	15.1	15.9	14.3	15.1	0.8	**5.0%**	
23	**217**	**1**	15.3	15.3	15.2	19.1	17.2	15.3	3.8	**20.1%**	Table original 19.1 - Original to be confirmed
23	**217**	**2**	15.5	15.5	15.5	19.1	17.2	15.5	3.6	**18.8%**	Table original 19.1 - Original to be confirmed
23	**217**	**3**	15.0	15.0	15.1	19.1	17.2	15.0	4.1	**21.3%**	Table original 19.1 - Original to be confirmed
24	**227**	**1**	18.3	18.3	18.3	20.6	18.5	18.3	2.3	**11.2%**	Table original is 17.8, 20.6 is 4' Away
24	**227**	**2**	18.7	18.7	18.7	20.6	18.5	18.7	1.9	**9.2%**	Table original is 17.8, 20.6 is 4' Away
24	**227**	**3**	18.6	18.7	18.6	20.6	18.5	18.6	2.0	**9.5%**	Table original is 17.8, 20.6 is 4' Away
1	**241**	**1**	20.4	20.5	20.4	17.1	15.4	20.4	0.0	**0.0%**	Transition - Original Thickness Unknown.
1	**241**	**2**	19.7	19.7	20.4	17.1	15.4	19.9	0.0	**0.0%**	Transition - Original Thickness Unknown.
1	**241**	**3**	20.8	20.9	20.8	17.1	15.4	20.8	0.0	**0.0%**	Transition - Original Thickness Unknown.
11	**248**	**1**	16.7	16.5	16.6	17.9	16.1	16.6	1.3	**7.3%**	
11	**248**	**2**	16.1	16.0	16.0	17.9	16.1	16.0	1.9	**10.4%**	
11	**248**	**3**	15.7	15.5	15.4	17.9	16.1	15.5	2.4	**13.2%**	
21	**258**	**1**	17.5	17.5	18.2	18.8	16.9	17.7	1.1	**5.7%**	
21	**258**	**2**	17.5	17.5	17.5	18.8	16.9	17.5	1.3	**6.9%**	
21	**258**	**3**	17.5	17.3	17.3	18.8	16.9	17.4	1.4	**7.6%**	
31	**267**	**1**	18.4	18.4	18.4	19.5	17.6	18.4	1.1	**5.6%**	
31	**267**	**2**	18.4	18.4	18.4	19.5	17.6	18.4	1.1	**5.6%**	
31	**267**	**3**	19.3	18.6	19.3	19.5	17.6	19.1	0.4	**2.2%**	
41	**276**	**1**	20.4	20.4	20.4	21.1	19.0	20.4	0.7	**3.3%**	Table original is 25.3, 21.1 is 4' Away
41	**276**	**2**	20.7	21.3	21.3	21.1	19.0	21.1	0.0	**0.0%**	Table original is 25.3, 21.1 is 4' Away
41	**276**	**3**	20.4	20.6	20.5	21.1	19.0	20.5	0.6	**2.8%**	Table original is 25.3, 21.1 is 4' Away
51	**285**	**1**	20.0	19.9	19.3	21.7	19.5	19.7	2.0	**9.1%**	

UTM Data Logger Location #	Can #	Location ID	Reading (mm) A	Reading (mm) B	Reading (mm) C	Original Thickness (mm)	10% Diminution (mm)	Location Average	Average Diminution (mm)	Average Diminution (%)	Comments
	Penstock #3 - (Shot 1: South, Shot 2: Bottom, Shot 3: North)										
51	**285**	**2**	19.9	19.9	20.0	21.7	19.5	19.9	1.8	**8.1%**	
51	**285**	**3**	19.9	20.6	19.9	21.7	19.5	20.1	1.6	**7.2%**	
61	**297**	**1**	20.6	20.6	20.7	22.3	20.1	20.6	1.7	**7.5%**	
61	**297**	**2**	20.8	21.4	20.7	22.3	20.1	21.0	1.3	**6.0%**	
61	**297**	**3**	20.4	20.4	20.5	22.3	20.1	20.4	1.9	**8.4%**	
71	**308**	**1**	22.0	22.0	22.0	23.0	20.7	22.0	1.0	**4.3%**	
71	**308**	**2**	22.0	22.2	22.1	23.0	20.7	22.1	0.9	**3.9%**	
71	**308**	**3**	22.0	22.0	21.9	23.0	20.7	22.0	1.0	**4.5%**	
81	**317**	**1**	22.6	22.5	22.5	23.6	21.2	22.5	1.1	**4.5%**	
81	**317**	**2**	22.3	22.3	22.3	23.6	21.2	22.3	1.3	**5.5%**	
81	**317**	**3**	22.6	22.5	22.3	23.6	21.2	22.5	1.1	**4.8%**	
91	**328**	**1**	23.2	23.2	24.0	24.9	22.4	23.5	1.4	**5.8%**	
91	**328**	**2**	24.1	24.1	23.4	24.9	22.4	23.9	1.0	**4.1%**	
91	**328**	**3**	23.2	23.1	23.3	24.9	22.4	23.2	1.7	**6.8%**	
101	**337**	**1**	23.6	23.6	23.5	26.0	23.4	23.6	2.4	**9.4%**	
101	**337**	**2**	23.5	23.6	23.6	26.0	23.4	23.6	2.4	**9.4%**	
101	**337**	**3**	23.7	23.8	23.7	26.0	23.4	23.7	2.3	**8.7%**	
111	**347**	**1**	28.9	28.8	28.9	26.9	24.2	28.9	0.0	**0.0%**	Transition - Original Thickness Unknown.
111	**347**	**2**	29.2	29.0	29.0	26.9	24.2	29.1	0.0	**0.0%**	Transition - Original Thickness Unknown.
111	**347**	**3**	29.1	29.1	29.0	26.9	24.2	29.1	0.0	**0.0%**	Transition - Original Thickness Unknown.
121	**357**	**1**	26.3	26.2	26.2	27.8	25.0	26.2	1.6	**5.6%**	Table original is 32.8, 27.8 is 15' Away
121	**357**	**2**	26.5	26.5	26.5	27.8	25.0	26.5	1.3	**4.7%**	Table original is 32.8, 27.8 is 15' Away
121	**357**	**3**	26.2	26.2	26.2	27.8	25.0	26.2	1.6	**5.8%**	Table original is 32.8, 27.8 is 15' Away
131	**366**	**1**	26.9	27.0	26.9	30.3	27.3	26.9	3.4	**11.1%**	
131	**366**	**2**	27.3	27.5	27.3	30.3	27.3	27.4	2.9	**9.7%**	
131	**366**	**3**	26.9	26.9	26.9	30.3	27.3	26.9	3.4	**11.2%**	

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

TABLE 1 - FULL SUPPLY LEVEL (FSL)
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4 pcf	F_{Y_A285}=	26000 ksi	Project No:	2670043
Normal pond EL=	597 feet	$F_{Y\_G40.8}$=	36000 ksi	Date:	2023-07-03
Joint Efficiency=	0.7			By:	NPT
D_1 ID=	17.00 feet			Checked	NS
D_2 ID=	15.25 feet				
D_3 ID=	13.50 feet				

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	12.9000	0.5079	0.4375	16.1%			17000					
2-1			2	12.4000	0.4882	0.4375	11.6%			17000					Drawings indicate 7/16" (11mm) steel
			3	12.4000	0.4882	0.4375	11.6%			17000					
			4	12.1000	0.4764	0.4375	8.9%			17000					
2-2	8.17	8.50	5	12.1000	0.4764	0.4375	8.9%	0.4724	554.7840	17000	3949.6	0.23	5642.3	0.33	
			6	12.1000	0.4764	0.4375	8.9%			17000					
			7	12.6000	0.4961	0.4375	13.4%			17000					
2-3			8	12.1000	0.4764	0.4375	8.9%			17000					
			9	12.0000	0.4724	0.4375	8.0%			17000					
			1	12.2000	0.4803	0.4375	9.8%			17000					
10-1			2	12.2000	0.4803	0.4375	9.8%			17000					Drawings indicate 7/16" (11mm) steel
			3	12.2000	0.4803	0.4375	9.8%			17000					
			4	11.8000	0.4646	0.4375	6.2%			17000					
10-2	80.58	8.50	5	11.8000	0.4646	0.4375	6.2%	0.4528	552.4802	17000	4346.2	0.26	6208.9	0.37	
			6	11.8000	0.4646	0.4375	6.2%			17000					
			7	11.6000	0.4567	0.4375	4.4%			17000					
10-3			8	11.5000	0.4528	0.4375	3.5%			17000					
			9	11.5000	0.4528	0.4375	3.5%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
21-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.5000	0.4134	0.4375	-5.5%			17000					
21-2	172.58	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.4016	542.6662	17000	5980.4	0.35	8543.4	0.50	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.6000	0.4173	0.4375	-4.6%			17000					
21-3			8	10.2000	0.4016	0.4375	-8.2%			17000					
			9	10.2500	0.4035	0.4375	-7.8%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
31-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.4000	0.4094	0.4375	-6.4%			17000					
			4	10.7000	0.4213	0.4375	-3.7%			17000					
31-2	242.17	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.4094	535.2435	17000	6666.6	0.39	9523.8	0.56	
			6	10.8000	0.4252	0.4375	-2.8%			17000					
			7	10.6000	0.4173	0.4375	-4.6%			17000					
31-3			8	10.6000	0.4173	0.4375	-4.6%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.1000	0.3976	0.4375	-9.1%			17000					
38-1			2	10.1000	0.3976	0.4375	-9.1%			17000					
			3	10.1000	0.3976	0.4375	-9.1%			17000					
			4	10.2000	0.4016	0.4375	-8.2%			17000					
38-2	311.58	8.50	5	10.2000	0.4016	0.4375	-8.2%	0.3976	527.8385	17000	7687.8	0.45	10982.5	0.65	
			6	10.4000	0.4094	0.4375	-6.4%			17000					
			7	10.4000	0.4094	0.4375	-6.4%			17000					
38-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.1000	0.3976	0.4375	-9.1%			17000					
49-1			2	10.0000	0.3937	0.4375	-10.0%			17000					
			3	10.1000	0.3976	0.4375	-9.1%			17000					
			4	10.4000	0.4094	0.4375	-6.4%			17000					
49-2	420.83	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.3937	516.1844	17000	9073.0	0.53	12961.5	0.76	
			6	10.4000	0.4094	0.4375	-6.4%			17000					
			7	10.6000	0.4173	0.4375	-4.6%			17000					
49-3			8	10.6000	0.4173	0.4375	-4.6%			17000					
			9	10.7000	0.4213	0.4375	-3.7%			17000					
			1	10.2000	0.4016	0.4375	-8.2%			17000					
58-1			2	10.2000	0.4016	0.4375	-8.2%			17000					
			3	10.3000	0.4055	0.4375	-7.3%			17000					
			4	10.5000	0.4134	0.4375	-5.5%			17000					
58-2	510.33	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.4016	508.5039	17000	9740.5	0.57	13915.0	0.82	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.8000	0.4252	0.4375	-2.8%			17000					
58-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.7000	0.4213	0.4375	-3.7%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
68-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.2000	0.4016	0.4375	-8.2%			17000					
			4	10.3000	0.4055	0.4375	-7.3%			17000					
68-2	609.58	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4016	500.0278	17000	10673.4	0.63	15247.8	0.90	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.3000	0.4055	0.4375	-7.3%			17000					
68-3			8	10.4000	0.4094	0.4375	-6.4%			17000					
			9	10.3000	0.4055	0.4375	-7.3%			17000					
			1	10.0000	0.3937	0.4375	-10.0%			17000					End of ASTM A285 Steel
78-1			2	10.1000	0.3976	0.4375	-9.1%			17000					
			3	10.0000	0.3937	0.4375	-10.0%			17000					
			4	10.5000	0.4134	0.4375	-5.5%			17000					
78-2	709.00	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.3937	491.5373	17000	11840.1	0.70	16914.5	0.99	
			6	10.5000	0.4134	0.4375	-5.5%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
78-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.0000	0.3937	0.4375	-10.0%			24000					Start of G40.8-B Steel
88-1			2	10.0000	0.3937	0.4375	-10.0%			24000					
			3	10.2000	0.4016	0.4375	-8.2%			24000					
			4	10.3000	0.4055	0.4375	-7.3%			24000					
88-2	808.42	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.3937	483.0469	24000	12793.3	0.53	18276.2	0.76	
			6	10.4000	0.4094	0.4375	-6.4%			24000					
			7	10.2000	0.4016	0.4375	-8.2%			24000					
88-3			8	10.3000	0.4055	0.4375	-7.3%			24000					
			9	10.2000	0.4016	0.4375	-8.2%			24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	10.2000	0.4016	0.4375	-8.2%			24000					
96-1			2	10.4000	0.4094	0.4375	-6.4%			24000					
			3	10.3000	0.4055	0.4375	-7.3%			24000					
			4	10.1000	0.3976	0.4375	-9.1%			24000					
96-2	888.08	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.3976	476.2432	24000	13422.9	0.56	19175.6	0.80	
			6	10.6000	0.4173	0.4375	-4.6%			24000					
			7	10.1000	0.3976	0.4375	-9.1%			24000					
96-3			8	10.1000	0.3976	0.4375	-9.1%			24000					
			9	10.1000	0.3976	0.4375	-9.1%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					
108-1			2	10.5000	0.4134	0.4375	-5.5%			24000					
			3	10.3000	0.4055	0.4375	-7.3%			24000					
			4	10.5000	0.4134	0.4375	-5.5%			24000					
108-2	1007.25	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.4055	466.0660	24000	14271.6	0.59	20388.0	0.85	
			6	10.6000	0.4173	0.4375	-4.6%			24000					
			7	10.6000	0.4173	0.4375	-4.6%			24000					
108-3			8	10.4000	0.4094	0.4375	-6.4%			24000					
			9	10.5000	0.4134	0.4375	-5.5%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					
119-1			2	10.5000	0.4134	0.4375	-5.5%			24000					
			3	10.5000	0.4134	0.4375	-5.5%			24000					
			4	10.4000	0.4094	0.4375	-6.4%			24000					
119-2	1116.58	8.50	5	10.7000	0.4213	0.4375	-3.7%	0.3976	456.7287	24000	15592.1	0.65	22274.4	0.93	
			6	10.5000	0.4134	0.4375	-5.5%			24000					
			7	10.1000	0.3976	0.4375	-9.1%			24000					
119-3			8	10.1000	0.3976	0.4375	-9.1%			24000					
			9	10.1000	0.3976	0.4375	-9.1%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					Start of 15.25' dia. section.
127-1			2	10.3000	0.4055	0.4375	-7.3%			24000					
			3	10.3000	0.4055	0.4375	-7.3%			24000					
			4	10.5000	0.4134	0.4375	-5.5%			24000					
127-2	1196.25	7.63	5	10.5000	0.4134	0.4375	-5.5%	0.3937	436.4016	24000	16174.1	0.67	23105.8	0.96	
			6	10.4000	0.4094	0.4375	-6.4%			24000					
			7	10.0000	0.3937	0.4375	-10.0%			24000					
127-3			8	10.0000	0.3937	0.4375	-10.0%			24000					
			9	10.1000	0.3976	0.4375	-9.1%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					
137-1			2	10.6000	0.4173	0.4375	-4.6%			24000					
			3	10.6000	0.4173	0.4375	-4.6%			24000					
			4	10.7000	0.4213	0.4375	-3.7%			24000					
137-2	1274.08	7.63	5	10.6000	0.4173	0.4375	-4.6%	0.4016	414.9533	24000	17974.7	0.75	25678.1	1.07	
			6	10.8000	0.4252	0.4375	-2.8%			24000					
			7	10.2000	0.4016	0.4375	-8.2%			24000					
137-3			8	10.5000	0.4134	0.4375	-5.5%			24000					
			9	10.4000	0.4094	0.4375	-6.4%			24000					
			1	13.7000	0.5394	0.5625	-4.1%			24000					
147-1			2	13.7000	0.5394	0.5625	-4.1%			24000					
			3	13.8000	0.5433	0.5625	-3.4%			24000					
			4	13.7000	0.5394	0.5625	-4.1%			24000					
147-2	1364.33	7.63	5	13.7000	0.5394	0.5625	-4.1%	0.5394	390.0834	24000	15210.8	0.63	21729.8	0.91	
			6	13.7000	0.5394	0.5625	-4.1%			24000					
			7	13.8000	0.5433	0.5625	-3.4%			24000					
147-3			8	14.0000	0.5512	0.5625	-2.0%			24000					
			9	13.9000	0.5472	0.5625	-2.7%			24000					
			1	13.5000	0.5315	0.5625	-5.5%			24000					
158-1			2	13.5000	0.5315	0.5625	-5.5%			24000					
			3	13.5000	0.5315	0.5625	-5.5%			24000					
			4	13.4000	0.5276	0.5625	-6.2%			24000					
158-2	1462.83	7.63	5	13.4000	0.5276	0.5625	-6.2%	0.5276	368.0150	24000	17210.0	0.72	24585.7	1.02	
			6	13.4000	0.5276	0.5625	-6.2%			24000					
			7	13.7000	0.5394	0.5625	-4.1%			24000					
158-3			8	13.6000	0.5354	0.5625	-4.8%			24000					
			9	13.6000	0.5354	0.5625	-4.8%			24000					
			1	18.3000	0.7205	0.7500	-3.9%			24000					
170-1			2	18.2000	0.7165	0.7500	-4.5%			24000					
			3	18.2000	0.7165	0.7500	-4.5%			24000					
			4	19.2000	0.7559	0.7500	0.8%			24000					
170-2	1560.08	7.63	5	19.2000	0.7559	0.7500	0.8%	0.7165	360.4812	24000	13088.0	0.55	18697.1	0.78	
			6	19.1000	0.7520	0.7500	0.3%			24000					
			7	19.1000	0.7520	0.7500	0.3%			24000					
170-3			8	19.1000	0.7520	0.7500	0.3%			24000					
			9	19.1000	0.7520	0.7500	0.3%			24000					
			1	15.3000	0.6024	0.6250	-3.6%			24000					
178-1			2	15.3000	0.6024	0.6250	-3.6%			24000					
			3	15.3000	0.6024	0.6250	-3.6%			24000					
			4	15.6000	0.6142	0.6250	-1.7%			24000					
178-2	1625.58	7.63	5	15.5000	0.6102	0.6250	-2.4%	0.6024	355.4070	24000	15902.7	0.66	22718.2	0.95	
			6	15.5000	0.6102	0.6250	-2.4%			24000					
			7	15.3000	0.6024	0.6250	-3.6%			24000					
178-3			8	15.6000	0.6142	0.6250	-1.7%			24000					
			9	15.5000	0.6102	0.6250	-2.4%			24000					
			1	15.6000	0.6142	0.6250	-1.7%			24000					
186-1			2	15.4000	0.6063	0.6250	-3.0%			24000					
			3	15.5000	0.6102	0.6250	-2.4%			24000					
			4	15.5000	0.6102	0.6250	-2.4%			24000					
186-2	1696.58	7.63	5	15.6000	0.6142	0.6250	-1.7%	0.5905	345.0801	24000	16914.1	0.70	24163.0	1.01	
			6	15.5000	0.6102	0.6250	-2.4%			24000					
			7	15.1000	0.5945	0.6250	-4.9%			24000					
186-3			8	15.0000	0.5905	0.6250	-5.5%			24000					
			9	15.1000	0.5945	0.6250	-4.9%			24000					
			1	15.3000	0.6024	0.5990	0.6%			24000					
197-1			2	15.3000	0.6024	0.5990	0.6%			24000					
			3	15.3000	0.6024	0.5990	0.6%			24000					
			4	15.7000	0.6181	0.5990	3.2%			24000					
197-2	1785.33	7.63	5	15.7000	0.6181	0.5990	3.2%	0.5945	330.9162	24000	17746.8	0.74	25352.6	1.06	
			6	15.7000	0.6181	0.5990	3.2%			24000					
			7	15.1000	0.5945	0.5990	-0.8%			24000					
197-3			8	15.3000	0.6024	0.5990	0.6%			24000					
			9	15.4000	0.6063	0.5990	1.2%			24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	15.4000	0.6063	0.6250	-3.0%			24000					
207-1			2	15.4000	0.6063	0.6250	-3.0%			24000					
			3	15.3000	0.6024	0.6250	-3.6%			24000					
			4	15.3000	0.6024	0.6250	-3.6%			24000					
207-2	1867.17	7.63	5	15.1000	0.5945	0.6250	-4.9%	0.5945	317.8560	24000	18617.8	0.78	26596.9	1.11	
			6	15.3000	0.6024	0.6250	-3.6%			24000					
			7	15.1000	0.5945	0.6250	-4.9%			24000					
207-3			8	15.1000	0.5945	0.6250	-4.9%			24000					
			9	15.1000	0.5945	0.6250	-4.9%			24000					
			1	15.3000	0.6024	0.7500	-19.7%			24000					3/4" (19mm) original thickness per
217-1			2	15.3000	0.6024	0.7500	-19.7%			24000					
			3	15.2000	0.5984	0.7500	-20.2%			24000					
			4	15.5000	0.6102	0.7500	-18.6%			24000					
217-2	1966.50	7.63	5	15.5000	0.6102	0.7500	-18.6%	0.5905	302.0030	24000	19806.4	0.83	28294.8	1.18	
			6	15.5000	0.6102	0.7500	-18.6%			24000					
			7	15.0000	0.5905	0.7500	-21.3%			24000					
217-3			8	15.0000	0.5905	0.7500	-21.3%			24000					
			9	15.1000	0.5945	0.7500	-20.7%			24000					
			1	18.3000	0.7205	0.8125	-11.3%			24000					Start of 13.5' dia. section.
227-1			2	18.3000	0.7205	0.8125	-11.3%			24000					
			3	18.3000	0.7205	0.8125	-11.3%			24000					
			4	18.7000	0.7362	0.8125	-9.4%			24000					
227-2	2064.67	6.75	5	18.7000	0.7362	0.8125	-9.4%	0.7205	286.3312	24000	15135.2	0.63	21621.7	0.90	
			6	18.7000	0.7362	0.8125	-9.4%			24000					
			7	18.6000	0.7323	0.8125	-9.9%			24000					
227-3			8	18.7000	0.7362	0.8125	-9.4%			24000					
			9	18.6000	0.7323	0.8125	-9.9%			24000					
			1	20.4000	0.8031	0.6720	19.5%			24000					0.672" original thickness per drawings.
241-1			2	20.5000	0.8071	0.6720	20.1%			24000					
			3	20.4000	0.8031	0.6720	19.5%			24000					
			4	19.7000	0.7756	0.6720	15.4%			24000					
241-2	2177.33	6.75	5	19.7000	0.7756	0.6720	15.4%	0.7756	268.3503	24000	14873.4	0.62	21247.7	0.89	
			6	20.4000	0.8031	0.6720	19.5%			24000					
			7	20.8000	0.8189	0.6720	21.9%			24000					
241-3			8	20.9000	0.8228	0.6720	22.4%			24000					
			9	20.8000	0.8189	0.6720	21.9%			24000					
			1	16.7000	0.6575	0.7060	-6.9%			24000					
248-1			2	16.5000	0.6496	0.7060	-8.0%			24000					
			3	16.6000	0.6535	0.7060	-7.4%			24000					
			4	16.1000	0.6339	0.7060	-10.2%			24000					
248-2	2247.67	6.75	5	16.0000	0.6299	0.7060	-10.8%	0.6063	257.1255	24000	19676.1	0.82	28108.8	1.17	
			6	16.0000	0.6299	0.7060	-10.8%			24000					
			7	15.7000	0.6181	0.7060	-12.4%			24000					
248-3			8	15.5000	0.6102	0.7060	-13.6%			24000					
			9	15.4000	0.6063	0.7060	-14.1%			24000					
			1	17.5000	0.6890	0.7390	-6.8%			24000					
258-1			2	17.5000	0.6890	0.7390	-6.8%			24000					
			3	18.2000	0.7165	0.7390	-3.0%			24000					
			4	17.5000	0.6890	0.7390	-6.8%			24000					
258-2	2347.75	6.75	5	17.5000	0.6890	0.7390	-6.8%	0.6811	241.1528	24000	18338.3	0.76	26197.6	1.09	
			6	17.5000	0.6890	0.7390	-6.8%			24000					
			7	17.5000	0.6890	0.7390	-6.8%			24000					
258-3			8	17.3000	0.6811	0.7390	-7.8%			24000					
			9	17.3000	0.6811	0.7390	-7.8%			24000					
			1	18.4000	0.7244	0.7680	-5.7%			24000					
267-1			2	18.4000	0.7244	0.7680	-5.7%			24000					
			3	18.4000	0.7244	0.7680	-5.7%			24000					
			4	18.4000	0.7244	0.7680	-5.7%			24000					
267-2	2437.92	6.75	5	18.4000	0.7244	0.7680	-5.7%	0.7244	226.7627	24000	17939.3	0.75	25627.5	1.07	
			6	18.4000	0.7244	0.7680	-5.7%			24000					
			7	19.3000	0.7598	0.7680	-1.1%			24000					
267-3			8	18.6000	0.7323	0.7680	-4.7%			24000					
			9	19.3000	0.7598	0.7680	-1.1%			24000					
			1	20.4000	0.8031	0.8290	-3.1%			24000					
276-1			2	20.4000	0.8031	0.8290	-3.1%			24000					
			3	20.4000	0.8031	0.8290	-3.1%			24000					
			4	20.7000	0.8150	0.8290	-1.7%			24000					
276-2	2528.00	6.75	5	21.3000	0.8386	0.8290	1.2%	0.8031	212.6814	24000	16795.9	0.70	23994.1	1.00	
			6	21.3000	0.8386	0.8290	1.2%			24000					
			7	20.4000	0.8031	0.8290	-3.1%			24000					
276-3			8	20.6000	0.8110	0.8290	-2.2%			24000					
			9	20.5000	0.8071	0.8290	-2.6%			24000					
			1	20.0000	0.7874	0.8540	-7.8%			24000					
285-1			2	19.9000	0.7835	0.8540	-8.3%			24000					
			3	19.3000	0.7598	0.8540	-11.0%			24000					
			4	19.9000	0.7835	0.8540	-8.3%			24000					
285-2	2618.00	6.75	5	19.9000	0.7835	0.8540	-8.3%	0.7598	205.1943	24000	18099.0	0.75	25855.8	1.08	
			6	20.0000	0.7874	0.8540	-7.8%			24000					
			7	19.9000	0.7835	0.8540	-8.3%			24000					
285-3			8	20.6000	0.8110	0.8540	-5.0%			24000					
			9	19.9000	0.7835	0.8540	-8.3%			24000					
			1	20.6000	0.8110	0.8790	-7.7%			24000					
297-1			2	20.6000	0.8110	0.8790	-7.7%			24000					
			3	20.7000	0.8150	0.8790	-7.3%			24000					
			4	20.8000	0.8189	0.8790	-6.8%			24000					
297-2	2734.42	6.75	5	21.4000	0.8425	0.8790	-4.2%	0.8031	195.5096	24000	17546.4	0.73	25066.2	1.04	
			6	20.7000	0.8150	0.8790	-7.3%			24000					
			7	20.4000	0.8031	0.8790	-8.6%			24000					
297-3			8	20.4000	0.8031	0.8790	-8.6%			24000					
			9	20.5000	0.8071	0.8790	-8.2%			24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	22.0000	0.8661	0.9040	-4.2%			24000					
308-1			2	22.0000	0.8661	0.9040	-4.2%			24000					
			3	22.0000	0.8661	0.9040	-4.2%			24000					
			4	22.0000	0.8661	0.9040	-4.2%			24000					
308-2	2845.17	6.75	5	22.2000	0.8740	0.9040	-3.3%	0.8622	186.2963	24000	16719.6	0.70	23885.2	1.00	
			6	22.1000	0.8701	0.9040	-3.8%			24000					
			7	22.0000	0.8661	0.9040	-4.2%			24000					
308-3			8	22.0000	0.8661	0.9040	-4.2%			24000					
			9	21.9000	0.8622	0.9040	-4.6%			24000					
			1	22.6000	0.8898	0.9540	-6.7%			24000					
317-1			2	22.5000	0.8858	0.9540	-7.1%			24000					
			3	22.5000	0.8858	0.9540	-7.1%			24000					
			4	22.3000	0.8780	0.9540	-8.0%			24000					
317-2	2935.58	6.75	5	22.3000	0.8780	0.9540	-8.0%	0.8780	178.7746	24000	16720.4	0.70	23886.3	1.00	
			6	22.3000	0.8780	0.9540	-8.0%			24000					
			7	22.6000	0.8898	0.9540	-6.7%			24000					
317-3			8	22.5000	0.8858	0.9540	-7.1%			24000					
			9	22.3000	0.8780	0.9540	-8.0%			24000					
			1	23.2000	0.9134	0.9790	-6.7%			24000					
328-1			2	23.2000	0.9134	0.9790	-6.7%			24000					
			3	24.0000	0.9449	0.9790	-3.5%			24000					
			4	24.1000	0.9488	0.9790	-3.1%			24000					
328-2	3046.25	6.75	5	24.1000	0.9488	0.9790	-3.1%	0.9094	169.5682	24000	16496.7	0.69	23566.7	0.98	
			6	23.4000	0.9213	0.9790	-5.9%			24000					
			7	23.2000	0.9134	0.9790	-6.7%			24000					
328-3			8	23.1000	0.9094	0.9790	-7.1%			24000					
			9	23.3000	0.9173	0.9790	-6.3%			24000					
			1	23.6000	0.9291	1.0250	-9.4%			24000					
337-1			2	23.6000	0.9291	1.0250	-9.4%			24000					
			3	23.5000	0.9252	1.0250	-9.7%			24000					
			4	23.5000	0.9252	1.0250	-9.7%			24000					
337-2	3136.83	6.75	5	23.6000	0.9291	1.0250	-9.4%	0.9252	156.0233	24000	16729.8	0.70	23899.7	1.00	
			6	23.6000	0.9291	1.0250	-9.4%			24000					
			7	23.7000	0.9331	1.0250	-9.0%			24000					
337-3			8	23.8000	0.9370	1.0250	-8.6%			24000					
			9	23.7000	0.9331	1.0250	-9.0%			24000					
			1	28.9000	1.1378	1.0610	7.2%			24000					1.061" original thickness per drawings.
347-1			2	28.8000	1.1339	1.0610	6.9%			24000					
			3	28.9000	1.1378	1.0610	7.2%			24000					
			4	29.2000	1.1496	1.0610	8.4%			24000					
347-2	3233.58	6.75	5	29.0000	1.1417	1.0610	7.6%	1.1339	131.6705	24000	14404.9	0.60	20578.4	0.86	
			6	29.0000	1.1417	1.0610	7.6%			24000					
			7	29.1000	1.1457	1.0610	8.0%			24000					
347-3			8	29.1000	1.1457	1.0610	8.0%			24000					
			9	29.0000	1.1417	1.0610	7.6%			24000					
			1	26.3000	1.0354	1.0950	-5.4%			24000					1.2920" (32.8mm) original thickness per drawings and measured stationing. Plate thickness is likely 1.095"
357-1			2	26.2000	1.0315	1.0950	-5.8%			24000					
			3	26.2000	1.0315	1.0950	-5.8%			24000					
			4	26.5000	1.0433	1.0950	-4.7%			24000					
357-2	3321.67	6.75	5	26.5000	1.0433	1.0950	-4.7%	1.0315	109.3192	24000	16595.0	0.69	23707.1	0.99	
			6	26.5000	1.0433	1.0950	-4.7%			24000					
			7	26.2000	1.0315	1.0950	-5.8%			24000					
357-3			8	26.2000	1.0315	1.0950	-5.8%			24000					
			9	26.2000	1.0315	1.0950	-5.8%			24000					
			1	26.9000	1.0591	1.1910	-11.1%			24000					
366-1			2	27.0000	1.0630	1.1910	-10.7%			24000					
			3	26.9000	1.0591	1.1910	-11.1%			24000					
			4	27.3000	1.0748	1.1910	-9.8%			24000					
366-2	3410.00	6.75	5	27.5000	1.0827	1.1910	-9.1%	1.0591	79.0483	24000	17166.4	0.72	24523.4	1.02	
			6	27.3000	1.0748	1.1910	-9.8%			24000					
			7	26.9000	1.0591	1.1910	-11.1%			24000					
366-3			8	26.9000	1.0591	1.1910	-11.1%			24000					
			9	26.9000	1.0591	1.1910	-11.1%			24000					

Equations:

1.Pressure: $P = h\lambda_w = \frac{h * 62.4pcf}{144in/ft}$

2. Hoop Stress: $\sigma_h = \frac{Pr}{et}$

3. Allowable Stress: $S_A = \min(\frac{F_u}{2.4}, \frac{F_y}{1.5})$

4. Stress Ratio: $\frac{\sigma_h}{S_A}$

5. Percent Section Loss in Thickness $\frac{(Original\ Section\ Thickness) - (Thickness\ Reading)}{(Orignal\ Section\ Thickness)} * 100$

Minimum Wall Thickness	
All	0.3937
17dia	0.3937
15.25dia	0.3937
13.5dia	0.6063

TABLE 2 - TRANSIENT
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4 pcf	F_{y_A285}=	26000 ksi	Project No:	2670043
Normal pond EL=	597 feet	$F_{y\_G40.8}$=	36000 ksi	Date:	2023-07-03
Joint Efficiency=	0.7			By:	NPT
D_1 ID=	17.00 feet			Checked	NS
D_2 ID=	15.25 feet				
D_3 ID=	13.50 feet				

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	12.9000	0.5079	0.4375	16.1%			17000					
2-1			2	12.4000	0.4882	0.4375	11.6%			17000					Drawings indicate 7/16" (11mm) steel
			3	12.4000	0.4882	0.4375	11.6%			17000					
			4	12.1000	0.4764	0.4375	8.9%			17000					
2-2	8.17	8.50	5	12.1000	0.4764	0.4375	8.9%	0.4724	554.7840	17000	5134.5	0.30	7335.0	0.43	
			6	12.1000	0.4764	0.4375	8.9%			17000					
			7	12.6000	0.4961	0.4375	13.4%			17000					
2-3			8	12.1000	0.4764	0.4375	8.9%			17000					
			9	12.0000	0.4724	0.4375	8.0%			17000					
			1	12.2000	0.4803	0.4375	9.8%			17000					
10-1			2	12.2000	0.4803	0.4375	9.8%			17000					Drawings indicate 7/16" (11mm) steel
			3	12.2000	0.4803	0.4375	9.8%			17000					
			4	11.8000	0.4646	0.4375	6.2%			17000					
10-2	80.58	8.50	5	11.8000	0.4646	0.4375	6.2%	0.4528	552.4802	17000	5650.1	0.33	8071.6	0.47	
			6	11.8000	0.4646	0.4375	6.2%			17000					
			7	11.6000	0.4567	0.4375	4.4%			17000					
10-3			8	11.5000	0.4528	0.4375	3.5%			17000					
			9	11.5000	0.4528	0.4375	3.5%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
21-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.5000	0.4134	0.4375	-5.5%			17000					
21-2	172.58	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.4016	542.6662	17000	7774.5	0.46	11106.4	0.65	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.6000	0.4173	0.4375	-4.6%			17000					
21-3			8	10.2000	0.4016	0.4375	-8.2%			17000					
			9	10.2500	0.4035	0.4375	-7.8%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
31-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.4000	0.4094	0.4375	-6.4%			17000					
			4	10.7000	0.4213	0.4375	-3.7%			17000					
31-2	242.17	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.4094	535.2435	17000	8666.6	0.51	12380.9	0.73	
			6	10.8000	0.4252	0.4375	-2.8%			17000					
			7	10.6000	0.4173	0.4375	-4.6%			17000					
31-3			8	10.6000	0.4173	0.4375	-4.6%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.1000	0.3976	0.4375	-9.1%			17000					
38-1			2	10.1000	0.3976	0.4375	-9.1%			17000					
			3	10.1000	0.3976	0.4375	-9.1%			17000					
			4	10.2000	0.4016	0.4375	-8.2%			17000					
38-2	311.58	8.50	5	10.2000	0.4016	0.4375	-8.2%	0.3976	527.8385	17000	9994.1	0.59	14277.3	0.84	
			6	10.4000	0.4094	0.4375	-6.4%			17000					
			7	10.4000	0.4094	0.4375	-6.4%			17000					
38-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.1000	0.3976	0.4375	-9.1%			17000					
49-1			2	10.0000	0.3937	0.4375	-10.0%			17000					
			3	10.1000	0.3976	0.4375	-9.1%			17000					
			4	10.4000	0.4094	0.4375	-6.4%			17000					
49-2	420.83	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.3937	516.1844	17000	11794.9	0.69	16849.9	0.99	
			6	10.4000	0.4094	0.4375	-6.4%			17000					
			7	10.6000	0.4173	0.4375	-4.6%			17000					
49-3			8	10.6000	0.4173	0.4375	-4.6%			17000					
			9	10.7000	0.4213	0.4375	-3.7%			17000					
			1	10.2000	0.4016	0.4375	-8.2%			17000					
58-1			2	10.2000	0.4016	0.4375	-8.2%			17000					
			3	10.3000	0.4055	0.4375	-7.3%			17000					
			4	10.5000	0.4134	0.4375	-5.5%			17000					
58-2	510.33	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.4016	508.5039	17000	12662.6	0.74	18089.5	1.06	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.8000	0.4252	0.4375	-2.8%			17000					
58-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.7000	0.4213	0.4375	-3.7%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
68-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.2000	0.4016	0.4375	-8.2%			17000					
			4	10.3000	0.4055	0.4375	-7.3%			17000					
68-2	609.58	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4016	500.0278	17000	13875.5	0.82	19822.1	1.17	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.3000	0.4055	0.4375	-7.3%			17000					
68-3			8	10.4000	0.4094	0.4375	-6.4%			17000					
			9	10.3000	0.4055	0.4375	-7.3%			17000					
			1	10.0000	0.3937	0.4375	-10.0%			17000					End of ASTM A285 Steel
78-1			2	10.1000	0.3976	0.4375	-9.1%			17000					
			3	10.0000	0.3937	0.4375	-10.0%			17000					
			4	10.5000	0.4134	0.4375	-5.5%			17000					
78-2	709.00	8.50	5	10.5000	0.4134	0.4375	-5.5%	0.3937	491.5373	17000	15392.2	0.91	21988.8	1.29	
			6	10.5000	0.4134	0.4375	-5.5%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
78-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.0000	0.3937	0.4375	-10.0%			24000					Start of G40.8-B Steel
88-1			2	10.0000	0.3937	0.4375	-10.0%			24000					
			3	10.2000	0.4016	0.4375	-8.2%			24000					
			4	10.3000	0.4055	0.4375	-7.3%			24000					
88-2	808.42	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.3937	483.0469	24000	16631.3	0.69	23759.0	0.99	
			6	10.4000	0.4094	0.4375	-6.4%			24000					
			7	10.2000	0.4016	0.4375	-8.2%			24000					
88-3			8	10.3000	0.4055	0.4375	-7.3%			24000					
			9	10.2000	0.4016	0.4375	-8.2%			24000					

			1	10.2000	0.4016	0.4375	-8.2%			24000					
96-1			2	10.4000	0.4094	0.4375	-6.4%			24000					
			3	10.3000	0.4055	0.4375	-7.3%			24000					
			4	10.1000	0.3976	0.4375	-9.1%			24000					
96-2	888.08	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.3976	476.2432	24000	17449.8	0.73	24928.3	1.04	
			6	10.6000	0.4173	0.4375	-4.6%			24000					
			7	10.1000	0.3976	0.4375	-9.1%			24000					
96-3			8	10.1000	0.3976	0.4375	-9.1%			24000					
			9	10.1000	0.3976	0.4375	-9.1%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					
108-1			2	10.5000	0.4134	0.4375	-5.5%			24000					
			3	10.3000	0.4055	0.4375	-7.3%			24000					
			4	10.5000	0.4134	0.4375	-5.5%			24000					
108-2	1007.25	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.4055	466.0660	24000	18553.1	0.77	26504.4	1.10	
			6	10.6000	0.4173	0.4375	-4.6%			24000					
			7	10.6000	0.4173	0.4375	-4.6%			24000					
108-3			8	10.4000	0.4094	0.4375	-6.4%			24000					
			9	10.5000	0.4134	0.4375	-5.5%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					
119-1			2	10.5000	0.4134	0.4375	-5.5%			24000					
			3	10.5000	0.4134	0.4375	-5.5%			24000					
			4	10.4000	0.4094	0.4375	-6.4%			24000					
119-2	1116.58	8.50	5	10.7000	0.4213	0.4375	-3.7%	0.3976	456.7287	24000	20269.7	0.84	28956.8	1.21	
			6	10.5000	0.4134	0.4375	-5.5%			24000					
			7	10.1000	0.3976	0.4375	-9.1%			24000					
119-3			8	10.1000	0.3976	0.4375	-9.1%			24000					
			9	10.1000	0.3976	0.4375	-9.1%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					Start of 15.25' dia. section.
127-1			2	10.3000	0.4055	0.4375	-7.3%			24000					
			3	10.3000	0.4055	0.4375	-7.3%			24000					
			4	10.5000	0.4134	0.4375	-5.5%			24000					
127-2	1196.25	7.63	5	10.5000	0.4134	0.4375	-5.5%	0.3937	436.4016	24000	21026.3	0.88	30037.6	1.25	
			6	10.4000	0.4094	0.4375	-6.4%			24000					
			7	10.0000	0.3937	0.4375	-10.0%			24000					
127-3			8	10.0000	0.3937	0.4375	-10.0%			24000					
			9	10.1000	0.3976	0.4375	-9.1%			24000					
			1	10.5000	0.4134	0.4375	-5.5%			24000					
137-1			2	10.6000	0.4173	0.4375	-4.6%			24000					
			3	10.6000	0.4173	0.4375	-4.6%			24000					
			4	10.7000	0.4213	0.4375	-3.7%			24000					
137-2	1274.08	7.63	5	10.6000	0.4173	0.4375	-4.6%	0.4016	414.9533	24000	23367.1	0.97	33381.5	1.39	
			6	10.8000	0.4252	0.4375	-2.8%			24000					
			7	10.2000	0.4016	0.4375	-8.2%			24000					
137-3			8	10.5000	0.4134	0.4375	-5.5%			24000					
			9	10.4000	0.4094	0.4375	-6.4%			24000					
			1	13.7000	0.5394	0.5625	-4.1%			24000					
147-1			2	13.7000	0.5394	0.5625	-4.1%			24000					
			3	13.8000	0.5433	0.5625	-3.4%			24000					
			4	13.7000	0.5394	0.5625	-4.1%			24000					
147-2	1364.33	7.63	5	13.7000	0.5394	0.5625	-4.1%	0.5394	390.0834	24000	19774.1	0.82	28248.7	1.18	
			6	13.7000	0.5394	0.5625	-4.1%			24000					
			7	13.8000	0.5433	0.5625	-3.4%			24000					
147-3			8	14.0000	0.5512	0.5625	-2.0%			24000					
			9	13.9000	0.5472	0.5625	-2.7%			24000					
			1	13.5000	0.5315	0.5625	-5.5%			24000					
158-1			2	13.5000	0.5315	0.5625	-5.5%			24000					
			3	13.5000	0.5315	0.5625	-5.5%			24000					
			4	13.4000	0.5276	0.5625	-6.2%			24000					
158-2	1462.83	7.63	5	13.4000	0.5276	0.5625	-6.2%	0.5276	368.0150	24000	22373.0	0.93	31961.4	1.33	
			6	13.4000	0.5276	0.5625	-6.2%			24000					
			7	13.7000	0.5394	0.5625	-4.1%			24000					
158-3			8	13.6000	0.5354	0.5625	-4.8%			24000					
			9	13.6000	0.5354	0.5625	-4.8%			24000					
			1	18.3000	0.7205	0.7500	-3.9%			24000					
170-1			2	18.2000	0.7165	0.7500	-4.5%			24000					
			3	18.2000	0.7165	0.7500	-4.5%			24000					
			4	19.2000	0.7559	0.7500	0.8%			24000					
170-2	1560.08	7.63	5	19.2000	0.7559	0.7500	0.8%	0.7165	360.4812	24000	17014.4	0.71	24306.2	1.01	
			6	19.1000	0.7520	0.7500	0.3%			24000					
			7	19.1000	0.7520	0.7500	0.3%			24000					
170-3			8	19.1000	0.7520	0.7500	0.3%			24000					
			9	19.1000	0.7520	0.7500	0.3%			24000					
			1	15.3000	0.6024	0.6250	-3.6%			24000					
178-1			2	15.3000	0.6024	0.6250	-3.6%			24000					
			3	15.3000	0.6024	0.6250	-3.6%			24000					
			4	15.6000	0.6142	0.6250	-1.7%			24000					
178-2	1625.58	7.63	5	15.5000	0.6102	0.6250	-2.4%	0.6024	355.4070	24000	20673.5	0.86	29533.6	1.23	
			6	15.5000	0.6102	0.6250	-2.4%			24000					
			7	15.3000	0.6024	0.6250	-3.6%			24000					
178-3			8	15.6000	0.6142	0.6250	-1.7%			24000					
			9	15.5000	0.6102	0.6250	-2.4%			24000					
			1	15.6000	0.6142	0.6250	-1.7%			24000					
186-1			2	15.4000	0.6063	0.6250	-3.0%			24000					
			3	15.5000	0.6102	0.6250	-2.4%			24000					
			4	15.5000	0.6102	0.6250	-2.4%			24000					
186-2	1696.58	7.63	5	15.6000	0.6142	0.6250	-1.7%	0.5905	345.0801	24000	21988.4	0.92	31411.9	1.31	
			6	15.5000	0.6102	0.6250	-2.4%			24000					
			7	15.1000	0.5945	0.6250	-4.9%			24000					
186-3			8	15.0000	0.5905	0.6250	-5.5%			24000					
			9	15.1000	0.5945	0.6250	-4.9%			24000					
			1	15.3000	0.6024	0.5990	0.6%			24000					
197-1			2	15.3000	0.6024	0.5990	0.6%			24000					
			3	15.3000	0.6024	0.5990	0.6%			24000					
			4	15.7000	0.6181	0.5990	3.2%			24000					
197-2	1785.33	7.63	5	15.7000	0.6181	0.5990	3.2%	0.5945	330.9162	24000	23070.8	0.96	32958.3	1.37	
			6	15.7000	0.6181	0.5990	3.2%			24000					
			7	15.1000	0.5945	0.5990	-0.8%			24000					
197-3			8	15.3000	0.6024	0.5990	0.6%			24000					
			9	15.4000	0.6063	0.5990	1.2%			24000					
			1	15.4000	0.6063	0.6250	-3.0%			24000					
207-1			2	15.4000	0.6063	0.6250	-3.0%			24000					
			3	15.3000	0.6024	0.6250	-3.6%			24000					
			4	15.3000	0.6024	0.6250	-3.6%			24000					
207-2	1867.17	7.63	5	15.1000	0.5945	0.6250	-4.9%	0.5945	317.8560	24000	24203.2	1.01	34576.0	1.44	
			6	15.3000	0.6024	0.6250	-3.6%			24000					
			7	15.1000	0.5945	0.6250	-4.9%			24000					
207-3			8	15.1000	0.5945	0.6250	-4.9%			24000					
			9	15.1000	0.5945	0.6250	-4.9%			24000					

			1	15.3000	0.6024	0.7500	-19.7%			24000					3/4" (19mm) original thickness per
217-1			2	15.3000	0.6024	0.7500	-19.7%			24000					
			3	15.2000	0.5984	0.7500	-20.2%			24000					
			4	15.5000	0.6102	0.7500	-18.6%			24000					
217-2	1966.50	7.63	5	15.5000	0.6102	0.7500	-18.6%	0.5905	302.0030	24000	25748.3	1.07	36783.2	1.53	
			6	15.5000	0.6102	0.7500	-18.6%			24000					
			7	15.0000	0.5905	0.7500	-21.3%			24000					
217-3			8	15.0000	0.5905	0.7500	-21.3%			24000					
			9	15.1000	0.5945	0.7500	-20.7%			24000					
			1	18.3000	0.7205	0.8125	-11.3%			24000					Start of 13.5' dia. section.
227-1			2	18.3000	0.7205	0.8125	-11.3%			24000					
			3	18.3000	0.7205	0.8125	-11.3%			24000					
			4	18.7000	0.7362	0.8125	-9.4%			24000					
227-2	2064.67	6.75	5	18.7000	0.7362	0.8125	-9.4%	0.7205	286.3312	24000	19675.8	0.82	28108.3	1.17	
			6	18.7000	0.7362	0.8125	-9.4%			24000					
			7	18.6000	0.7323	0.8125	-9.9%			24000					
227-3			8	18.7000	0.7362	0.8125	-9.4%			24000					
			9	18.6000	0.7323	0.8125	-9.9%			24000					
			1	20.4000	0.8031	0.6720	19.5%			24000					0.672" original thickness per drawings.
241-1			2	20.5000	0.8071	0.6720	20.1%			24000					
			3	20.4000	0.8031	0.6720	19.5%			24000					
			4	19.7000	0.7756	0.6720	15.4%			24000					
241-2	2177.33	6.75	5	19.7000	0.7756	0.6720	15.4%	0.7756	268.3503	24000	19335.4	0.81	27622.0	1.15	
			6	20.4000	0.8031	0.6720	19.5%			24000					
			7	20.8000	0.8189	0.6720	21.9%			24000					
241-3			8	20.9000	0.8228	0.6720	22.4%			24000					
			9	20.8000	0.8189	0.6720	21.9%			24000					
			1	16.7000	0.6575	0.7060	-6.9%			24000					
248-1			2	16.5000	0.6496	0.7060	-8.0%			24000					
			3	16.6000	0.6535	0.7060	-7.4%			24000					
			4	16.1000	0.6339	0.7060	-10.2%			24000					
248-2	2247.67	6.75	5	16.0000	0.6299	0.7060	-10.8%	0.6063	257.1255	24000	25579.0	1.07	36541.4	1.52	
			6	16.0000	0.6299	0.7060	-10.8%			24000					
			7	15.7000	0.6181	0.7060	-12.4%			24000					
248-3			8	15.5000	0.6102	0.7060	-13.6%			24000					
			9	15.4000	0.6063	0.7060	-14.1%			24000					
			1	17.5000	0.6890	0.7390	-6.8%			24000					
258-1			2	17.5000	0.6890	0.7390	-6.8%			24000					
			3	18.2000	0.7165	0.7390	-3.0%			24000					
			4	17.5000	0.6890	0.7390	-6.8%			24000					
258-2	2347.75	6.75	5	17.5000	0.6890	0.7390	-6.8%	0.6811	241.1528	24000	23839.8	0.99	34056.9	1.42	
			6	17.5000	0.6890	0.7390	-6.8%			24000					
			7	17.5000	0.6890	0.7390	-6.8%			24000					
258-3			8	17.3000	0.6811	0.7390	-7.8%			24000					
			9	17.3000	0.6811	0.7390	-7.8%			24000					
			1	18.4000	0.7244	0.7680	-5.7%			24000					
267-1			2	18.4000	0.7244	0.7680	-5.7%			24000					
			3	18.4000	0.7244	0.7680	-5.7%			24000					
			4	18.4000	0.7244	0.7680	-5.7%			24000					
267-2	2437.92	6.75	5	18.4000	0.7244	0.7680	-5.7%	0.7244	226.7627	24000	23321.0	0.97	33315.8	1.39	
			6	18.4000	0.7244	0.7680	-5.7%			24000					
			7	19.3000	0.7598	0.7680	-1.1%			24000					
267-3			8	18.6000	0.7323	0.7680	-4.7%			24000					
			9	19.3000	0.7598	0.7680	-1.1%			24000					
			1	20.4000	0.8031	0.8290	-3.1%			24000					
276-1			2	20.4000	0.8031	0.8290	-3.1%			24000					
			3	20.4000	0.8031	0.8290	-3.1%			24000					
			4	20.7000	0.8150	0.8290	-1.7%			24000					
276-2	2528.00	6.75	5	21.3000	0.8386	0.8290	1.2%	0.8031	212.6814	24000	21834.7	0.91	31192.4	1.30	
			6	21.3000	0.8386	0.8290	1.2%			24000					
			7	20.4000	0.8031	0.8290	-3.1%			24000					
276-3			8	20.6000	0.8110	0.8290	-2.2%			24000					
			9	20.5000	0.8071	0.8290	-2.6%			24000					
			1	20.0000	0.7874	0.8540	-7.8%			24000					
285-1			2	19.9000	0.7835	0.8540	-8.3%			24000					
			3	19.3000	0.7598	0.8540	-11.0%			24000					
			4	19.9000	0.7835	0.8540	-8.3%			24000					
285-2	2618.00	6.75	5	19.9000	0.7835	0.8540	-8.3%	0.7598	205.1943	24000	23528.8	0.98	33612.5	1.40	
			6	20.0000	0.7874	0.8540	-7.8%			24000					
			7	19.9000	0.7835	0.8540	-8.3%			24000					
285-3			8	20.6000	0.8110	0.8540	-5.0%			24000					
			9	19.9000	0.7835	0.8540	-8.3%			24000					
			1	20.6000	0.8110	0.8790	-7.7%			24000					
297-1			2	20.6000	0.8110	0.8790	-7.7%			24000					
			3	20.7000	0.8150	0.8790	-7.3%			24000					
			4	20.8000	0.8189	0.8790	-6.8%			24000					
297-2	2734.42	6.75	5	21.4000	0.8425	0.8790	-4.2%	0.8031	195.5096	24000	22810.3	0.95	32586.1	1.36	
			6	20.7000	0.8150	0.8790	-7.3%			24000					
			7	20.4000	0.8031	0.8790	-8.6%			24000					
297-3			8	20.4000	0.8031	0.8790	-8.6%			24000					
			9	20.5000	0.8071	0.8790	-8.2%			24000					
			1	22.0000	0.8661	0.9040	-4.2%			24000					
308-1			2	22.0000	0.8661	0.9040	-4.2%			24000					
			3	22.0000	0.8661	0.9040	-4.2%			24000					
			4	22.0000	0.8661	0.9040	-4.2%			24000					
308-2	2845.17	6.75	5	22.2000	0.8740	0.9040	-3.3%	0.8622	186.2963	24000	21735.5	0.91	31050.7	1.29	
			6	22.1000	0.8701	0.9040	-3.8%			24000					
			7	22.0000	0.8661	0.9040	-4.2%			24000					
308-3			8	22.0000	0.8661	0.9040	-4.2%			24000					
			9	21.9000	0.8622	0.9040	-4.6%			24000					
			1	22.6000	0.8898	0.9540	-6.7%			24000					
317-1			2	22.5000	0.8858	0.9540	-7.1%			24000					
			3	22.5000	0.8858	0.9540	-7.1%			24000					
			4	22.3000	0.8780	0.9540	-8.0%			24000					
317-2	2935.58	6.75	5	22.3000	0.8780	0.9540	-8.0%	0.8780	178.7746	24000	21736.6	0.91	31052.2	1.29	
			6	22.3000	0.8780	0.9540	-8.0%			24000					
			7	22.6000	0.8898	0.9540	-6.7%			24000					
317-3			8	22.5000	0.8858	0.9540	-7.1%			24000					
			9	22.3000	0.8780	0.9540	-8.0%			24000					
			1	23.2000	0.9134	0.9790	-6.7%			24000					
328-1			2	23.2000	0.9134	0.9790	-6.7%			24000					
			3	24.0000	0.9449	0.9790	-3.5%			24000					
			4	24.1000	0.9488	0.9790	-3.1%			24000					
328-2	3046.25	6.75	5	24.1000	0.9488	0.9790	-3.1%	0.9094	169.5682	24000	21445.7	0.89	30636.7	1.28	
			6	23.4000	0.9213	0.9790	-5.9%			24000					
			7	23.2000	0.9134	0.9790	-6.7%			24000					
328-3			8	23.1000	0.9094	0.9790	-7.1%			24000					
			9	23.3000	0.9173	0.9790	-6.3%			24000					

			1	23.6000	0.9291	1.0250	-9.4%			24000					
337-1			2	23.6000	0.9291	1.0250	-9.4%			24000					
			3	23.5000	0.9252	1.0250	-9.7%			24000					
			4	23.5000	0.9252	1.0250	-9.7%			24000					
337-2	3136.83	6.75	5	23.6000	0.9291	1.0250	-9.4%	0.9252	156.0233	24000	21748.7	0.91	31069.6	1.29	
			6	23.6000	0.9291	1.0250	-9.4%			24000					
			7	23.7000	0.9331	1.0250	-9.0%			24000					
337-3			8	23.8000	0.9370	1.0250	-8.6%			24000					
			9	23.7000	0.9331	1.0250	-9.0%			24000					
			1	28.9000	1.1378	1.0610	7.2%			24000					1.061" original thickness per drawings.
347-1			2	28.8000	1.1339	1.0610	6.9%			24000					
			3	28.9000	1.1378	1.0610	7.2%			24000					
			4	29.2000	1.1496	1.0610	8.4%			24000					
347-2	3233.58	6.75	5	29.0000	1.1417	1.0610	7.6%	1.1339	131.6705	24000	18726.4	0.78	26752.0	1.11	
			6	29.0000	1.1417	1.0610	7.6%			24000					
			7	29.1000	1.1457	1.0610	8.0%			24000					
347-3			8	29.1000	1.1457	1.0610	8.0%			24000					
			9	29.0000	1.1417	1.0610	7.6%			24000					
			1	26.3000	1.0354	1.0950	-5.4%			24000					1.2920" (32.8mm) original thickness per drawings and measured stationing. Plate thickness is likely 1.095"
357-1			2	26.2000	1.0315	1.0950	-5.8%			24000					
			3	26.2000	1.0315	1.0950	-5.8%			24000					
			4	26.5000	1.0433	1.0950	-4.7%			24000					
357-2	3321.67	6.75	5	26.5000	1.0433	1.0950	-4.7%	1.0315	109.3192	24000	21573.5	0.90	30819.2	1.28	
			6	26.5000	1.0433	1.0950	-4.7%			24000					
			7	26.2000	1.0315	1.0950	-5.8%			24000					
357-3			8	26.2000	1.0315	1.0950	-5.8%			24000					
			9	26.2000	1.0315	1.0950	-5.8%			24000					
			1	26.9000	1.0591	1.1910	-11.1%			24000					
366-1			2	27.0000	1.0630	1.1910	-10.7%			24000					
			3	26.9000	1.0591	1.1910	-11.1%			24000					
			4	27.3000	1.0748	1.1910	-9.8%			24000					
366-2	3410.00	6.75	5	27.5000	1.0827	1.1910	-9.1%	1.0591	79.0483	24000	22316.3	0.93	31880.5	1.33	
			6	27.3000	1.0748	1.1910	-9.8%			24000					
			7	26.9000	1.0591	1.1910	-11.1%			24000					
366-3			8	26.9000	1.0591	1.1910	-11.1%			24000					
			9	26.9000	1.0591	1.1910	-11.1%			24000					

Equations:

1.Pressure: $$P = h\lambda_w = \frac{h * 62.4pcf}{144in/ft}$$

2. Hoop Stress: $$\sigma_h = \frac{Pr}{et}$$

3. Allowable Stress: $$S_A = \min(\frac{F_u}{2.4}, \frac{F_y}{1.5})$$

4. Stress Ratio: $$\frac{\sigma_h}{S_A}$$

5. Percent Section Loss in Thickness $$\frac{(Original\ Section\ Thickness) - (Minimum\ Thickness)}{(Orignal\ Section\ Thickness)} * 100$$

Minimum Wall Thickness	
All	0.3937
17dia	0.3937
15.25dia	0.3937
13.5dia	0.6063

EXTERNAL PRESSURES EVALUATION- PENSTOCK 3 BAY D'ESPOIR

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 17 feet									
Height of water above conduit=	0	feet	Live load:	100.00	psf	Unit Weight of Water=	62.4	pcf	
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	P_v=	0		
Height of fill above conduit=	2	feet				Rip Rap Unit Weight=	150	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	0.44	inches	Fill Unit Weight=	120	lb/ft^3	
OD Conduit Diameter=	17.07	feet	ID:	17.00	feet	(soil load) W_c=	6655.6	lb/ft	
		Assume well				(live load) W_l=	1706.6	lb/ft	
Buoyancy Factor R_w=	1	drained = 1				W_s=	351.7	lb/ft	
B_prime=	0.2330					W_{steel}=	957.8	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	**3.10**	psi	Ratio Q/q_a= **0.77**
(Minimum measured wall thickness) t_{MIN}=	0.3937	inches				[1]External pressure with snow load=	**3.24**	psi	Ratio Q/q_a= **0.80**
I=	0.0051	$inches^4$				[1]External pressure with snow and live=	**3.72**	psi	Ratio Q/q_a= **0.92**
[1,2]FS=	2								
[2]Allowable pressure q_a=	**4.05**	psi							

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 15.25 feet									
						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	1.19	inches	(soil load) W_c=	5973.1	lb/ft	
OD Conduit Diameter=	15.3156166	feet	ID:	15.25	feet	(live load) W_l=	1531.6	lb/ft	100 psf per foot section
		Assume well							
Buoyancy Factor R_w=	1	drained = 1				W_s=	316	lb/ft	
B_prime=	0.2330					W_{steel}=	2333	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	**3.76**	psi	Ratio Q/q_a= **0.79**
(Minimum measured wall thickness) t_{MIN}=	0.3937	inches				[1]External pressure with snow load=	**3.91**	psi	Ratio Q/q_a= **0.82**
I=	0.0051	$inches^4$				[1]External pressure with snow and live=	**4.39**	psi	Ratio Q/q_a= **0.92**
[1,2]FS=	2								
[2]Allowable pressure q_a=	**4.76**	psi							

Allowable pressures (kPa)/External Pressures (kPa)

Diameter 13.5 feet									
						Unit Weight of Water=	62.4	pcf	
Height of water above conduit=	0	feet	Live load:	100.00	psf	P_v=	0		
Height of rip rap above conduit=	1	feet	Snow load:	20.61	psf	Rip Rap Unit Weight=	150	lb/ft^3	
Height of fill above conduit=	2	feet				Fill Unit Weight=	120	lb/ft^3	
Total Height of Soil=	3	feet	(for DL calc) t=	1.63	inches	(soil load) W_c=	5304.4	lb/ft	
OD Conduit Diameter=	13.60	feet	ID:	13.50	feet	(live load) W_l=	1360.1	lb/ft	
		Assume well							
Buoyancy Factor R_w=	1	drained = 1				W_s=	280.3	lb/ft	
B_prime=	0.2330					W_{steel}=	2835.2	lb/ft	
(coarse grain soils with fines) E_prime=	500	psi				Density steel=	490	pcf	
E=	30000000	psi							
b=	1					External pressure with vacuum=	**4.15**	psi	Ratio Q/q_a= **0.38**
(Minimum measured wall thickness) t_{MIN}=	0.6063	inches				[1]External pressure with snow load=	**4.30**	psi	Ratio Q/q_a= **0.40**
I=	0.0186	$inches^4$				[1]External pressure with snow and live=	**4.78**	psi	Ratio Q/q_a= **0.44**
[1,2]FS=	2								
[2]Allowable pressure q_a=	**10.81**	psi							

References:

[1]ASCE No. 79, Steel Penstocks, 2nd Edition, 2012

[2]AWWA M11, Steel Pipe - A Guide for Design and Installation, current version.

SLOPE SUMMARY									
Section	Degrees, Minutes, Seconds	θ	Distance			Elevation			Slope
			From (ft)	To (ft)	Delta (ft)	Initial Elevation (ft)	Final Elevation (ft)	Change in Elevation (ft)	
0C - 1C	0,15,10	0.253	0	61.18	61.18	554.82	554.55	0.27	0.004413207
1C - 2C	6,7,25	6.124	61.18	422.56	361.38	554.55	516	38.55	0.106674415
2C - 3C	4,53,57	4.899	422.56	1125.13	702.57	516	456	60	0.085400743
3C - 4C	15,59,45	15.996	1125.13	1437.21	312.08	456	370	86	0.275570367
4C - 5C	4,26,35	4.443	1437.21	1637.81	200.6	370	354.46	15.54	0.077467597
5C - 6C	9,11,00	9.183	1637.81	2017.68	379.87	354.46	293.83	60.63	0.159607234
6C - 7C	9,11,00	9.183	2017.68	2524.17	506.49	293.83	213	80.83	0.159588541
7C - 8C	4,46,19	4.772	2524.17	3101.17	577	213	165	48	0.083188908
8C - 9C	14,34,43	14.579	3101.17	3319.68	218.51	165	110	55	0.251704727
9C - 10C	20,02,27	20.041	3319.68	3631.45	311.77	110	3	107	0.343201719
10C - PH	0	0.000	3631.45	3710.73	79.28	3	3	0	0
11B-12B	19,43,00	19.72	3710.73	3.00	3707.73	3788.04	3851.93	63.89	13.5
12B-PH	0	0.00	3.00	3.00	0.00	3851.93	3897.03	45.1	13.5

ELEVATION CALCULATIONS							
Can #	**Distance (ft)**	**Distance (ft)**	**Slope (θ)**	**Distance from Slope Change (ft)**	**Change in Elevation (ft)**	**Final Elevation (ft)**	**Section**
						554.8200	Intake
2	8.17	8.17	0.25	8.17	0.04	554.7840	0C - 1C
10	80.58	80.58	6.12	19.40	2.07	552.4802	1C - 2C
21	172.58	172.58	6.12	111.40	11.88	542.6662	
31	242.17	242.17	6.12	180.99	19.31	535.2435	
38	311.58	311.58	6.12	250.40	26.71	527.8385	
49	420.83	420.83	6.12	359.65	38.37	516.1844	
58	510.33	510.33	4.90	87.77	7.50	508.5039	2C - 3C
68	609.58	609.58	4.90	187.02	15.97	500.0278	
78	709.00	709.00	4.90	286.44	24.46	491.5373	
88	808.42	808.42	4.90	385.86	32.95	483.0469	
96	888.08	888.08	4.90	465.52	39.76	476.2432	
108	1007.25	1007.25	4.90	584.69	49.93	466.0660	
119	1116.58	1116.58	4.90	694.02	59.27	456.7287	
127	1196.25	1196.25	16.00	71.12	19.60	436.4016	3C - 4C
137	1274.08	1274.08	16.00	148.95	41.05	414.9533	
147	1364.33	1364.33	16.00	239.20	65.92	390.0834	
158	1462.83	1462.83	4.44	25.62	1.98	368.0150	4C - 5C
170	1560.08	1560.08	4.44	122.87	9.52	360.4812	
178	1625.58	1625.58	4.44	188.37	14.59	355.4070	
186	1696.58	1696.58	9.18	58.77	9.38	345.0801	5C - 6C
197	1785.33	1785.33	9.18	147.52	23.54	330.9162	
207	1867.17	1867.17	9.18	229.36	36.60	317.8560	
217	1966.50	1966.50	9.18	328.69	52.46	302.0030	
227	2064.67	2064.67	9.18	46.99	7.50	286.3312	6C - 7C
241	2177.33	2177.33	9.18	159.65	25.48	268.3503	
248	2247.67	2247.67	9.18	229.99	36.70	257.1255	
258	2347.75	2347.75	9.18	330.07	52.68	241.1528	
267	2437.92	2437.92	9.18	420.24	67.07	226.7627	
276	2528.00	2528.00	4.77	3.83	0.32	212.6814	7C - 8C
285	2618.00	2618.00	4.77	93.83	7.81	205.1943	
297	2734.42	2734.42	4.77	210.25	17.49	195.5096	
308	2845.17	2845.17	4.77	321.00	26.70	186.2963	
317	2935.58	2935.58	4.77	411.41	34.23	178.7746	
328	3046.25	3046.25	4.77	522.08	43.43	169.5682	
337	3136.83	3136.83	14.58	35.66	8.98	156.0233	8C - 9C
347	3233.58	3233.58	14.58	132.41	33.33	131.6705	
357	3321.67	3321.67	20.04	1.99	0.68	109.3192	9C - 10C
366	3410.00	3410.00	20.04	90.32	30.95	79.0483	

PLATE THICKNESS SUMMARY		
From - To (ft)	**Thickness (in)**	**Steel**
0 - 61	0.4375	ASTM A285
61 - 753	0.4375	
753 - 1114	0.4375	CSA G40.8 B STEEL
1114.3 - 1136	0.5625	
1136-1217	0.4375	
1217-1427	0.5625	
1427-1448	0.7500	
1448-1475	0.5625	
1475-1630	0.6250	
1630-1646	0.7500	
1646-1699	0.6250	
1699-1733	0.6875	
1733-1743	0.6530	HSB 50 STEEL
1743-1831	0.5990	
1831-1919	0.6250	
1919-1929	0.7240	
1929-2002	0.7500	G40.8B
2002-2042	SURGE TANK	
2042-2050	UNKNOWN	
2050-2060	0.8125	
2060-2069	0.7000	HSB 50 STEEL
2069-2138	0.6380	
2138-2218	0.6720	
2218-2298	0.7060	
2298-2377	0.7390	
2377-2447	0.7680	
2447-2517	0.7980	
2517-2532	0.9550	
2532-2612	0.8290	
2612-2692	0.8540	
2692-2772	0.8790	
2772-2852	0.9040	
2852-2932	0.9290	
2952-3012	0.9540	
3012-3092	0.9790	
3092-3111	1.1570	
3111-3179	1.0250	
3179-3247	1.0610	
3247-3305	1.0950	
3305-3336	1.2920	
3336-3394	1.1520	
3394-3453	1.1910	
3453-3512	1.2310	
3512-3571	1.2710	
3571-3620	1.3030	

Schedule 1, Attachment 10

Penstock 3 Inspection and Evaluation - Bay d'Espoir Hydroelectric Development - Penstock 1-3 Project

Kleinschmidt Associates

December 2024



PENSTOCK 3 INSPECTION AND EVALUATION

BAY D'ESPOIR HYDROELECTRIC DEVELOPMENT
PENSTOCKS 1-3 INSPECTION PROJECT

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
Kleinschmidt Associates

Kleinschmidt

December 2024

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NLH) contracted with Kleinschmidt Associates Canada Inc. (Kleinschmidt) in January 2023 to inspect and evaluate the condition of Penstocks 1, 2, and 3 at the Bay d'Espoir Hydroelectric Development.

In 2016, cracking was identified in Penstock 1 and Kleinschmidt assisted NLH with the inspection and weld repair design. Penstock 1 was repaired the same year as the inspection. Kleinschmidt inspected Penstock 2 later in 2016 and discovered similar weld deterioration of Penstock 2, which was repaired in 2017. Subsequent to the previous inspections of Penstock 1 and 2, deteriorated welds were repaired in Penstock 3 after inspection in 2018.

As indicated in the record drawings, Penstock 3 was installed in 1968, a year after the Penstock 1 and 2, using similar plate materials, thicknesses, and weld procedures. Due to the three penstocks being of similar age and design and because of the identified weld deterioration and corrosion, NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks are fully refurbished or replaced. The main focus of the Penstock 3 inspection was to assess the integrity of the welds and complete steel thickness measurements to evaluate metal loss and corrosion to determine if the penstock condition is acceptable to operate through another calendar year.

An inspection of Penstock 3 was conducted by Kleinschmidt in May 2024, which consisted of a visual walk-over of the penstock exterior, and a detailed evaluation of the condition of the interior of the penstock. The interior inspection included a visual condition assessment by Kleinschmidt's Structural Engineer, which consisted of cleaning and visually inspecting the steel shell and the longitudinal and circumferential welds. Non-destructive weld tests and ultrasonic thickness measurements of the penstock steel shell were also performed during the inspection.

The 2024 inspection found six (6) Cans with weld indications as listed in Section 3.2. The indications were repaired by the contractor working on the Surge Tank transition section with repairs complete within two weeks of this inspection. All cans were in the 17-foot diameter section and were previously repaired welds.

The inspection revealed minimal loss of material thickness of the penstock shell. The plate thickness was comparable to the record drawings, and the interior of the shell displayed a layer of rust with moderate corrosion and pitting common for a 50-year-old penstock. Definitions for qualitative terminology such as fair and good are in Table 3-1 in Section 3.

The welded joints at the penstock to surge tank transition were being tested and repaired again during this inspection due to leakage found on the exterior following the 2023 repairs in the area.

The sinkhole discovered in 2019 downstream of the surge tank on the left side of the penstock has been filled in previous years and appears to have stabilized. The area should continue to be monitored for further erosion.

The structural evaluation showed stress ratios for a combined static and dynamic internal pressures peak at 1.45 (Can 209). This indicates that the penstock joints in this area does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.04, which is not acceptable for late 1960 steel pipe. The calculated stress at the joints assumes a 0.7 joint efficiency factor. A higher joint efficiency factor could be used for the analysis, as discussed in Section 4, if RT weld testing is performed to verify the integrity of the welds. A higher joint efficiency would result in favorable factors of safety; however, considering the known weld deterioration, a higher joint efficiency is not justified at this time.

The base plate material away from the joints has stress ratios that varies significantly ranging from 0.3 to 1.01. Only one of the 35 cans measured had a ratio above 1.0.

This approximately 50-year-old penstock has shown minimal loss of thickness from the original plate thicknesses. Kleinschmidt anticipates that the penstock plating has an additional 50 years of useful service life (est. 2070). However, because of the condition of the existing welds, the 17-ft section of penstock will need to be replaced, the remaining penstock welds refurbished, and the interior re-coated before the steel deteriorates further.

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ACRONYMS

ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
CH	Chainage (in metres)
cms	Cubic Metres per Second
ETS	EasternTechnical Services Ltd.
Fu	Ultimate Tensile Stress
Fy	Yield Stress
GWh	Gigawatt Hours
kPa	Kilo-Pascals
Kleinschmidt	Kleinschmidt Associates
MW	Megawatts
NLH	Newfoundland and Labrador Hydro
SPRAT	Society of Professional Rope Access Technicians
STA	Station (in feet)
TRR	Technical Rope and Rescue
UT	Ultrasonic Thickness

1.0 INTRODUCTION

The focus of the Penstock 3 inspection in 2024 was to assess the integrity of the welds and to complete steel plate thickness measurements to evaluate the current condition of the steel. The 2024 inspection concentrated on welds that have never been inspected from the headgate downstream to the last bend near the powerhouse and welds not inspected during the previous year.

The May 2024 inspection of Penstock 3 consisted of weld inspections and steel plate thickness measurements completed by Technical Rope and Rescue (TRR) and Eastern Technical Services (ETS). Kleinschmidt engineers Chris Vella and Ade Olatunde travelled to the Bay d'Espoir Hydro Site to complete an interior and exterior condition assessment of the penstock and assist with the weld inspection.

This report presents our evaluation of the capacity of the penstock in its current condition, provides recommendations for inspection procedures in the future, and estimates the remaining service life.

2.0 PROJECT DESCRIPTION

NLH owns and operates the Bay d'Espoir Hydroelectric Development in Bay d'Espoir, Newfoundland and Labrador. The Project went into service in 1967 and is supplied by Long Pond. The tailrace feeds a canal leading to the tidal waters of Bay d'Espoir and the Atlantic Ocean. The plant has a hydraulic head of approximately 577 ft (176 metres [m]) and seven generating units with a total capacity of 604 megawatts (MW). The hydro development is comprised of four intake structures, feeding four penstocks into two powerhouses, where seven units operate with a total annual generation of approximately 2,650 gigawatt hours (GWh). Penstocks Nos. 1, 2, and 3 have surge towers approximately 2,400 ft (727 m) upstream of the powerhouse. The first phase of the initial project construction included installation of two intake structures and a four-unit powerhouse with Penstocks 1 and 2 connecting the two intakes to the powerhouse. The second phase of the project consisted of installing Penstock 3 with a third intake and two additional units in the powerhouse. A separate intake structure and powerhouse for Unit 7, connected by Penstock 4 was built in 1970. Penstock 3 supplies Units 5 and 6. The rated flow across all seven units is 397 cubic metres per second (m^3/s) (14,020 cubic feet per second [cfs]).

Penstock 3 is a 1,100-m-long buried steel penstock, tapering from 5.2 m in diameter (at the intake) to 4.1 m in diameter at the powerhouse bifurcation. At the flattest point, the penstock has a 0.0% slope and has a 20% slope at the steepest. There are at least three areas to access the interior of Penstock 3, one at the well in the intake structure, three manholes along the length of the penstock, and one through the scroll cases in the powerhouse.

Appendix A includes the original 1968 profile drawings of the penstock including original plate thicknesses. The penstock steel plate thicknesses range from 7/16 inches at the intake to 1 5/8 inches at the bifurcation upstream of the powerhouse (plate thicknesses in this report are expressed in inches to match the drawings provided). The penstock is constructed of A285, G40.88 and HSB 50 steel. The penstock is 17.0 ft in diameter until STA 12+41 (CH 376.2), 15.25 ft in diameter between STA 12+41 (CH 376.2) and STA 27+50 (CH 833.3) where it then reduces to 13.5 ft in diameter for the remaining 1,581 ft (479.1 m) to the bifurcation. The welds are double V groove full penetration welds.

A majority of the penstock has a cover of 2 ft (0.61 m) of clayey soil and 1 ft (0.30 m) minimum thick layer of riprap. The penstock crosses underneath the switchyard and terminates at the powerhouse. Several weirs are located where the drainage daylights to the ditches and wells for inspection and monitoring purposes.

3.0 INSPECTION

Christopher Vella, P.Eng. of Kleinschmidt, inspected the interior and exterior of Penstock 3 from May 6 to May 10, 2024, with the assistance of personnel from Technical Rope and Rescue (TRR), Eastern Technical Services (ETS), and NLH. NLH were present to participate in morning safe talks and to answer questions about the history, operation, and maintenance of the station. ETS assisted with the ultrasonic thickness (UT) and MT testing of the penstock steel and welds. TRR rope access personnel assisted with safe access, confined space entry protocols, communication, and provided standby at the penstock entry for rescue.

Kleinschmidt's inspection consisted of measuring shell thicknesses, identifying pitting or cracking, and an overall general condition assessment of the interior of the shell. ETS personnel performed MT weld tests on approximately 20% of the longitudinal welds from inside the 17-ft diameter section of penstock on the first pass. After discovering indications in 6 longitudinal welds, a further 48% of welds were tested in the area, and 16% of the longitudinal welds overall. ETS took UT measurements from approximately 10% of the cans for the portion of penstock inspected.

The exterior of the buried penstock was examined for signs of leakage including around the surge tank. For this inspection, all references to penstock left and right are oriented looking downstream.

Table 3-1 Definitions for Condition Assessment

Term	Definition
Excellent	New or near new condition. No visible deterioration present and remedial action is not required
Good	General or light deterioration where performance is not affected, and remedial action is not expected to be required in the next 10 years
Fair	Medium deterioration or defects are visible that do not require maintenance in the next 12 months but may require preventative maintenance in the next 5 to 10 years
Poor	Significant deterioration is visible, and remediation is required in the next 1 to 5 years
Very Poor	Severe deterioration or defect is visible, and remediation is required within 1 year

References to right and left are from the perspective of someone looking downstream unless noted otherwise.

3.1 Working Conditions

Kleinschmidt's inspection team reviewed confined space protocols and reviewed safety procedures and requirements with NLH on the morning of Monday May 6, 2024. The inspection team entered the penstock on the same day at Manhole 2 of Penstock 3. TRR assisted with confined space entrance and rigging for fall protection. The internal inspection finished on May 10, 2024. The exterior inspection commenced on May 7 and was completed by Kleinschmidt the same day. Kleinschmidt pre-marked welds to be inspected inside of the penstock so TRR and ETS could proceed with the internal inspection and weld testing while Kleinschmidt performed the external inspection. Air quality in the penstock remained good for the duration of the inspection.

The internal penstock inspection commenced at the headgate location. At the time of the inspection leakage around the gate was very low as expected from the new gate (Photos 1 and 2, Appendix B). There were just a few spots of leakage including the left side seal, and two bolts as noted last year. The limited leakage allowed for easier and drier travel inside the penstock. The organics upstream of the surge tank had been removed during previous penstock weld repairs, which facilitated the current inspection. More effort was required downstream of the surge tank to remove organics and clean welds as there were a greater quantity of existing welds not previously inspected.

The exterior inspection was completed in sunny, warm and dry conditions. The ground surface was rocky with steep slopes with short vegetation (Photo 23). Some areas were noted to have significant alder bush growth and taller vegetation that was impeding inspection and sight of the ground surface. The ground was reasonably dry reducing slip potential. There were areas of saturated soil on the left-hand side of the penstock located adjacent and downstream of the surge tank, which has been noted in previous inspections as an area that is typically wet with runoff from the adjacent hill. The grade followed the penstock slope between the intake and the switchyard. The deeply buried sections under the dam and switchyard were not inspected from the exterior.

3.2 Interior Inspection

The penstock consists of approximately 435 "Cans" into the powerhouse scroll case. A can, referred to in this report is defined as a whole penstock pipe section from circumferential weld joint to the next circumferential weld joint. The Can number is used

in this report to reference location within the penstock during the inspection, with Can No. 1 located at the upstream end of the penstock at the intake.

Penstock thickness readings were recorded at the interior surface at various locations. Shell thickness measurements were taken by ETS with a GE DMS Go+ digital thickness gauge (S/N GOPLS20050054) with a KBA 560 Probe (S/N F08945). The gauge was calibrated before the field measurements to an accuracy of 0.01 mm. The field measurements and Appendix A drawings were measured in inches, while the UT shell thicknesses were provided in millimeters.

Thickness readings were recorded from the interior of the penstock generally near the invert of the penstock, typically near 4 o'clock, 6 o'clock, and 8 o'clock based on an orientation looking downstream. Points higher up the side of the penstock were not safely accessible due to the slippery sides of the penstock. Appendix D provides the ETS report of shell thickness readings.

The following sections describe the interior shell, joint condition and presents our observations.

3.2.1 Interior Surface, Coating and Joint Condition

Penstock 3 is fabricated from 30 different plate sizes ranging from 7/16 to 1 5/8 inches with 21 of these plate sizes occurring downstream of the surge tank. Inspection thickness readings were taken of 7 plate sizes upstream of the surge tank, ranging from 7/16-inch (11 mm) to 3/4-inch (19 mm). The average measured change in material thickness upstream of the surge tank compared to design was found to be approximately -4.8%. The steel plate thicknesses below the surge tank range from 0.638 inches (16 mm) to 1.625 inches (41 mm). The average change in material thickness below the surge tank was found to be approximately -1.2%. Appendix D provides the ETS report of the UT testing.

The interior of the penstock is generally in fair condition with consistent moderate corrosion and pitting with tubercles and growth. Pitting was moderate, relative to the plate thickness, and gets more significant and deeper further downstream. A significant number of weld repairs were observed, and the previous weld repair work made this inspection a little easier as much of the organic build-up had been previously removed.

Welds in Penstock 3 were cleaned with a wire wheel on a grinder, then wiped clean and painted with a white contrast paint to facilitate the MT weld test. MT testing included 101 full-length longitudinal welds and approximately 2 ft of each of the 202 circumferential welds adjacent to the tested longitudinal welds. An initial visual inspection of the weld was conducted, concentrating on the condition of the bead with regard to pitting, corrosion, cracking, undermining or washout. Particular attention was paid to welds not previously tested or repaired as part of Kleinschmidt's annual inspections. The welded joints inspected included original joints and previously repaired joints. The condition of the welded joints varied. On average welds were in fair condition (Photos 11 thru 13) and most did not exhibit excessive deterioration. Some undercutting and pitting was observed in the welds inspected this year.

Five weld indications were identified during the 2024 weld inspection during the first pass. Following discussions with Hydro the decision was made to test as many welds as possible in the remainder of the week in the 17-diameter section where most of the indications were found. This resulted in testing approximately 68% of the welds and finding an additional two indications in one longitudinal weld. A complete list of indications are as follows:

- Can 55 South - Indications noted toe of longitudinal weld, intermittent full length. Repair recommended.
- Can 61 Crown - Indication noted toe of longitudinal weld, approximately 230 mm in length. Repair recommended
- Can 65 South - - Indications noted toe of longitudinal weld, intermittent full length. Repair recommended.
- Can 70 South – Two indications noted toe of longitudinal weld, approximately 35 mm and 20 mm long. Repair recommended
- Can 70 North – original weld with small section previously repaired. New small indication at end of previous repairs.
- Can 71 South- Indication noted toe of weld, 150 mm long. Repair recommended.
- Can 75 South – Indications noted toe of longitudinal weld, intermittent full length. Repair recommended.

The Cahill surge tank transition weld repair crew was used to repair all of the indications listed above. During the 2024 inspection, the surge tank transition welds were being tested and repaired following leakage found after the 2023 surge tank transition repairs.

3.2.2 Appurtenances

Penstock appurtenances include vents, valves, access ports, manholes, and other components of the penstock other than supports. Bay d'Espoir's Penstock 3 has three large manholes and a bifurcation at the powerhouse.

The penstock drainage pipes and culverts were noted to be in fair condition. The wooded area to the left of Penstock 3 had been cleared for a new pole line and this made it easier to locate the drainage areas. Kleinschmidt identified and inspected two monitoring weirs, labelled N–1 and N-2. Drainage weir N-1, located in a wooden shack, was in fair condition and had a small amount of drainage flowing through the weir. Vegetation surrounding the shack has been cut back allowing for easier inspection and rock and debris has been cleaned from the intake.

Drainage weir N-2 was in fair condition and also had a small amount of drainage flowing through the weir (Photos 26 and 27). Light moss growth was noted within the drainage pipe but was less than previous years. Moss should continue to be kept clear. The drainage layout is depicted along the length of the penstock in Drawing F2106-C-1 (Appendix A); however, the termination of the drainage plumbing, and weirs are not shown.

3.3 Exterior Inspection

Kleinschmidt began the exterior inspection on May 7 at the intake and proceeded to move downstream. The inspection was completed the same day and terminated at the switchyard. The interior weld testing and UT measurements performed by ETS continued inside the penstock while Mr. Vella walked the exterior. The penstock is buried along its entire length with rock fill over the penstock as seen in Photos 24 and 25. Kleinschmidt observed the exterior ground surface for evidence of signs of leakage such as sloughing of the soil or depressions while walking the length of the penstock. No obvious indications were observed during the 2024 exterior inspection of the penstock.

During the 2019 exterior inspection of the penstock, a sink hole was discovered 9 ft downstream of the surge tank concrete encasement, located on the left side of the penstock. The hole was about 4 ft in diameter and 4 ft deep and was repaired and

maintained in following years. The 2024 inspection found the repair of the sink hole holding with no further settlement observed. Vegetation in the area had been cleaned out as recommended in the 2022 report making observation of the area easier.

There was some erosion around the surge tank concrete block base (Photo 32). It was noted that there was seepage coming from the steel to concrete interface when the penstock was full of water. This could not be observed during this inspection. A weld repair crew was on site to test and repair welds in the surge tank transition area to mitigate this leakage.

4.0 EVALUATION

The purpose of the evaluation is to assess the condition of the penstock and its suitability for continued operation and to identify repairs or maintenance that may be required to ensure its safe operation. Based on Kleinschmidt's experience and judgment, the four potential ways that the penstock could fail are:

1) bursting due to excessive internal pressure or loss of shell thickness;
2) general buckling due to external pressure;
3) local buckling leading to tensile cracking or general buckling; and
4) local weld failure due to improper weld procedures during construction.

4.1 Loading Conditions and Allowable Stresses

The loading conditions and allowable stresses were determined from the criteria presented in the American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 79 Steel Penstocks, 2nd Edition. The allowable primary stress intensity is the lesser of the material yield stress (F_y) divided by 1.5 or of the ultimate tensile stress (F_u) divided by 2.4. A summary of assumed yield stress, ultimate tensile stress, and allowable stress intensity for each section of penstock can be found in E. The allowable steel stress used in this analysis was 17,000 pounds per square inch (psi) for the ASTM A285 steel and 24,000 psi for the CSA G40.8 Grade B steel.

The strength of the welded seams is reduced compared to the base material. The strength reductions are designated as "joint efficiency, E" and are included in the penstock stress tables in Appendix C. A joint efficiency of 70 percent was assumed for all welded joints per Table 3-3 of ASCE No. 79. A higher joint efficiency could be used for the analysis if weld testing is performed to verify the integrity of the welds. As per Manual No. 79, a joint efficiency of:

- 0.8 or 0.85 could be used if radiographic testing (RT) of the welds is performed on a percentage of welds and shows no issues; and
- 0.9 to 1.0 could be used if RT or ultrasonic testing of 100% of the welds requiring higher joint efficiency is performed.

Load cases considered include:

- stresses in the penstock under normal operating conditions;
- transient stresses in the penstock during a load rejection at normal pond elevations; and
- external surcharge loads in a dewatered condition.

4.2 Shell Stresses Induced by Internal Pressure

Table 4-1 summarizes the analysis of steel-shell thickness data and internal pressure steel stress analysis results. See D for detailed thickness data and stress calculations.

The minimum thickness measurement was determined for each penstock can and was used to calculate the allowable stresses within each penstock section. Three thickness measurements were taken at each location, A, B, and C, for each can that was inspected with a UT gauge, with nine thickness measurements in total for each can.

The maximum hoop stress in the penstock shell is due to internal static and dynamic water pressures. The stress ratio is the maximum hoop stress divided by the allowable steel stress. A hoop stress ratio less than 1.0 indicates that the penstock meets industry-standard factors of safety as designated in *ASCE Engineering Practice No. 79, Steel Penstocks* (2012).

Normal pond or Full Supply Level (FSL) and dynamic water hammer pressures were determined based on elevations given in the Appendix A drawings. Normal pond static pressures were based on an elevation of 182 m (597 ft) at the intake. Transient pressures were conservatively taken 1.3 times the static pressure applied to the entire alignment of the penstock from the intake to the powerhouse. Kleinschmidt recommends a water hammer analysis be conducted to verify peak internal pressures within the penstock. The maximum stress ratio at a joint was determined to be 1.45 (Can 209) for transient pressure load case, greater than the current allowable industry guidelines for new design. When the hoop stress is compared to the plate yield stress, also shown in Table 4-1, the minimum factor of safety is 1.04 (Can 209), which is unacceptable for the late 1960 steel pipe.

An increase in the joint efficiency factor can be justified through weld testing to verify the existing pipe joint integrity. A factor of 0.9 to 1.0 could be used for the joint efficiency upon 100 percent RT or UT of the joints. By utilizing a higher joint efficiency factor, the

joint stress ratios would decrease while the factor of safety would increase. The calculations, as provided in Appendix E, include joint stress ratios calculated with an efficiency factor of 0.7.

For the steel plate away from the joints, the material has a maximum stress ratio of 1.01 and a safety factor of 1.48, also at Can 209, which is not acceptable for current design practices.

In addition to Table 4-1, which summarizes the 2024 thickness data and stresses due to internal pressure, a summary table included within Appendix E summarizes all base material and joint stress ratios calculated from 2019 through 2024. Penstock cans that have not been inspected and analyzed are not included in the table.

Table 4-1 Summary of Thickness Data and Stresses Due to Internal Pressure

Can	Joint Stress (FSL)[1,3] (psi	Max Base Material Stress (Transient) (psi)	Dynamic Hoop Stress Increase[1,3] (psi)	Total Water Hammer Stress (Surge at Joints)[1,3] (psi)	Allowable Stress (psi)	Max Joint Stress Ratio[1,2,3]	Max Base Material Stress Ratio	Factor of Safety Against Yield (Joints)	Factor of Safety Against Yield (Base Material)
4	5,633.1	5,126.1	1,689.9	7,323.0	17,000	0.43	0.30	3.55	5.07
14	6,568.5	5,977.4	1,970.6	8,539.1	17,000	0.50	0.35	3.04	4.35
24	6,766.0	6,157.0	2,029.8	8,795.8	17,000	0.52	0.36	2.96	4.22
34	7,220.3	6,570.5	2,166.1	9,386.4	17,000	0.55	0.39	2.77	3.96
44	9,852.1	8,965.4	2,955.6	12,807.7	17,000	0.75	0.53	2.03	2.90
55	11,460.9	10,429.4	3,438.3	14,899.1	17,000	0.88	0.61	1.75	2.49
65	13,190.8	12,003.6	3,957.2	17,148.0	17,000	1.01	0.71	1.52	2.17
75	14,664.1	13,344.3	4,399.2	19,063.3	17,000	1.12	0.78	1.36	1.95
85	15,846.0	14,419.9	4,753.8	20,599.8	17,000	1.21	0.85	1.26	1.80
95	17,175.8	15,630.0	5,152.7	22,328.6	24,000	0.93	0.65	1.61	2.30
105	19,060.8	17,345.3	5,718.2	24,779.0	24,000	1.03	0.72	1.45	2.08
115	20,625.3	18,769.1	6,187.6	26,813.0	24,000	1.12	0.78	1.34	1.92
125	21,363.8	19,441.1	6,409.1	27,773.0	24,000	1.16	0.81	1.30	1.85
144	17,223.4	15,673.3	5,167.0	22,390.5	24,000	0.93	0.65	1.61	2.30
173	24,042.8	21,879.0	7,212.9	31,255.7	24,000	1.30	0.91	1.15	1.65
180	23,255.0	21,162.0	6,976.5	30,231.4	24,000	1.26	0.88	1.19	1.70
190	22,461.2	20,439.7	6,738.3	29,199.5	24,000	1.22	0.85	1.23	1.76
200	22,118.3	20,127.7	6,635.5	28,753.8	24,000	1.20	0.84	1.25	1.79
209	26,677.8	24,276.8	8,003.3	34,681.1	24,000	1.45	1.01	1.04	1.48
219	26,096.2	23,747.6	7,828.9	33,925.1	24,000	1.41	0.99	1.06	1.52
229	23,580.6	21,458.4	7,074.2	30,654.8	24,000	1.28	0.89	1.17	1.68
239	18,563.7	16,893.0	5,569.1	24,132.8	24,000	1.01	0.70	1.49	2.13
250	25,077.3	22,820.3	7,523.2	32,600.5	24,000	1.36	0.95	1.10	1.58
260	24,425.8	22,227.5	7,327.7	31,753.5	24,000	1.32	0.93	1.13	1.62
270	24,523.6	22,316.5	7,357.1	31,880.7	24,000	1.33	0.93	1.13	1.61
280	24,560.8	22,350.3	7,368.2	31,929.0	24,000	1.33	0.93	1.13	1.61
290	24,037.1	21,873.7	7,211.1	31,248.2	24,000	1.30	0.91	1.15	1.65
301	23,795.6	21,654.0	7,138.7	30,934.3	24,000	1.29	0.90	1.16	1.66
311	23,630.4	21,503.7	7,089.1	30,719.5	24,000	1.28	0.90	1.17	1.67
320	23,852.6	21,705.9	7,155.8	31,008.4	24,000	1.29	0.90	1.16	1.66
334	22,302.6	20,295.4	6,690.8	28,993.4	24,000	1.21	0.85	1.24	1.77
339	22,156.0	20,162.0	6,646.8	28,802.8	24,000	1.20	0.84	1.25	1.79
349	22,148.1	20,154.8	6,644.4	28,792.5	24,000	1.20	0.84	1.25	1.79
359	22,842.2	20,786.4	6,852.7	29,694.9	24,000	1.24	0.87	1.21	1.73
365	23,609.7	21,484.8	7,082.9	30,692.6	24,000	1.28	0.90	1.17	1.68

Notes:
[1] Joint efficiency of 0.7 included
[2] Total stress / Allowable stress
[3] Uses minimum can thickness
[4] SF = Fy/Total stress

4.3 General Buckling Induced by External Loads

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 pounds per square foot (psf), and the depth of soil cover on the penstock was assumed to be 0.9 m (3 ft). Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment. Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis. An earthquake analysis could be performed, but it would be more involved and time-consuming and was not included in the scope of work.
- We assume the penstock is located in cohesive fine-grained soil above the local groundwater table, with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated was for the 5.2-m (17-ft) diameter pipe due to shell dead load, soil cover, live load, and snow load. The maximum pressure was determined to be 3.72 psi, which is less than the allowable buckling pressure of 3.99 psi. The 4.6-m (15.25-ft) and 4.1-m (13.5-ft) diameter sections were also analyzed, and the max pressures are summarized in Table 4-2.

4.3.1 Surcharge Load Analysis

A surcharge load analysis was completed for the shallow buried sections of penstock with 100 pounds per square foot external live load with the snow load combination. Lowest measured steel thickness values were used. See General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the

pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 pounds per square foot (psf), and the depth of soil cover on the penstock was assumed to be 0.9 m (3 ft). Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment. Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) VCXZ+ snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

General shell buckling occurs when an external pressure implodes the penstock shell along its longitudinal axis. The penstock was analyzed for buckling due to external loads applied to the top 120 degrees of the pipe. Per the National Building Code of Canada, the snow load calculated is 20.61 pounds per square foot (psf), and the depth of soil cover on the penstock was assumed to be 0.9 m (3 ft). Conservatively, an additional live load of 100 psf was used for analysis to account for potential off-road vehicle loads or equipment. Three external loading combinations were considered in the analysis of the penstock. Load combinations include the following:

1. DL (water and steel) + internal vacuum pressure
2. DL (water and steel) + snow load
3. DL (water and steel) + combination snow (75%) and live load (75%)

Notes:

- No vehicular loading was used in the analysis where it does not pass under roadways and, because of the rough rock cover, could not be driven over.
- The penstock is buried; therefore, wind and earthquake were not used in the analysis. An earthquake analysis could be performed, but it would be more involved and time-consuming and was not included in the scope of work.
- We assume the penstock is located in cohesive fine-grained soil above the local groundwater table, with drainage piping provided underneath the penstock. External water pressure on the dewatered penstock is not considered an applicable loading condition as there is adequate drainage.

The maximum pressure calculated was for the 5.2-m (17-ft) diameter pipe due to shell dead load, soil cover, live load, and snow load. The maximum pressure was determined to be 3.72 psi, which is less than the allowable buckling pressure of 3.99 psi. The 4.6-m

(15.25-ft) and 4.1-m (13.5-ft) diameter sections were also analyzed, and the max pressures are summarized in Table 4-2.

4.3.2 Surcharge Load Analysis

Table 4-2 Summary of Surcharge Load Analysis

Penstock Diameter (ft)	Allowable External Pressure (psi)	Snow Load (psi)	Snow + 100 psf Live Load (psi)
17.00	3.99	3.24	3.72
15.25	7.59	3.91	4.39
13.50	11.97	4.30	4.78

There was no new vehicular surcharge analysis conducted as we are not expecting changes in the results from the original analysis conducted by Kleinschmidt in 2016 for Penstock No. 2. The 2016 analysis for Penstock No. 2 showed the soil pressures due to an HS-20 truck load per AASHTO Standard Specifications (AWWA 2004), which is a 72,000-pound, three-axle truck with axles spaced at 4.3 m (14 ft) from the front axle to the middle axle, then variable from 4.3 to 8.5 m (14 to 28 ft) to the rear axle, was approximately five times less than the allowable buckling loads at that location. For the section of penstock analyzed, live loads have minimal increase in soil pressures to the penstock given the depth of overburden.

4.3.3 Sub-atmospheric Internal Penstock Pressure Analysis

Sub-atmospheric internal pressure can occur if the penstock is dewatered quickly without adequate venting downstream of a headgate or as the result of a negative transient wave pressure. Evaluating negative internal pressures due to transient pressures was outside the scope of this project and a detailed hydrodynamic model was not created for this report, but the likelihood of occurrence of sub-atmospheric pressure is minimal, and allowable buckling pressures are greater than potential negative pressures due to transient waves at startup. Vent capacity was evaluated according to the *Hydroelectric Handbook*, Section 31 – Air Inlets (Creager and Justin 1950), assuming that water is stopped due to a headgate closing and that the full flow of the penstock is stopped all at once at the intake. Based on this calculation the required vent area is approximately 0.29 m^2 (3.07 ft^2), which is well below the area provided by the approximately 5.1-m^2 (55-ft^2) existing openings.

4.4 Local Buckling and Stresses

Local buckling occurs when a point load causes a small area of the shell to be stressed beyond its material buckling stress limits, and it becomes permanently deformed. Boulders and rocks could be a source of point loads, but no serious deformations were noted in the inspection. The penstock is continuously supported by the soil, so it is unlikely there are excessive local buckling stresses in the penstock.

5.0 CONCLUSIONS

Based on inspection findings and evaluation, the existing steel plating has about 50 years of remaining service life. However, the 17 ft section of the penstock should be replaced, the remaining welds refurbished, and the interior of the penstock re-coated to prevent further corrosion. Replacing the welds from the inside of the penstock only may not fully mitigate the issues in the 17 ft section of penstock and will prove costly while resulting in a repair that does not instill confidence in the longevity of the repair and continued safe operation. This has been highlighted again this year with multiple indications discovered in Penstock 3 in previously repaired welds. Indications found in 5-year-old welds indicates that the weld repairs may have a limited life expectancy. Most indications were found in the 17-ft diameter section this year indicating again that this section of penstock is particularly prone to weld indications. This section of penstock has the largest diameter and the thinnest plate, is made of a different steel grade than the rest of the penstock and has peaking induced residual stresses at the joints. The 17-ft diameter section of Penstock 3 should be replaced to remove the risk of future failures during operation and to provide confidence in the 17 ft section that will not be gained by repairing the welds. The remainder of the penstock should have extensive weld replacement from the inside and the outside if it can be completed both economically and effectively within 7 years.

5.1 Shell Condition and Thickness

Measurements of the penstock shell thickness indicate minimal loss of material thickness over design. Significant moderate pitting was noted with organic material buildup on the interior penstock surface. Assuming similar rates of material loss, the penstock should have 50 to 70 years of service life remaining if recoated. The base plate material away from the joints can tolerate up to 3 mm (1/8 inch) further material loss in many locations and maintain a stress ratio below 1.0, but some cans may require reinforcement depending on further analysis.

5.2 Internal Pressure Strength

Stress ratios for a combined static and dynamic internal pressures peak at 1.53 (Table 4-1). This indicates that the penstock does not meet present day design criteria for new penstock design. When the hoop stress is compared to the plate yield stress the minimum factor of safety is 1.04. As noted previously this assumes a joint efficiency of 0.7 which can be improved upon with RT testing of the welds as noted in Section 4.1. The first step

should be to perform at least spot RT testing per the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1. Positive results will validate the use of a higher joint efficiency improving the results by lowering the stress ratios and improve confidence in the performance of the penstock.

The second step should be to run a more accurate surge stress analysis if one has not already been completed to verify the pressures. Consideration should be given to coating the penstock to limit further deterioration.

5.3 Remaining Service Life

The expected service life for a steel penstock is typically at least 80 years (ASCE 2012). This approximately 50-year-old penstock has shown little loss of thickness from the original plate thicknesses, but the stress analyses indicate sections of the penstock do not meet acceptable factors of safety at the joints by today's standards and there have been issues with the welds that justify the use of the 0.7 joint efficiency factor.

6.0 RECOMMENDATIONS

Penstock 3 17-ft diameter section should be replaced within 7 years. The penstock plating is in fair condition and Kleinschmidt has the following recommendations to extend the life of the penstock provided that the penstock welds are replaced. These recommendations include:

- recoating the interior of the penstock;
- Radiographic testing of the welds if possible;
- Surge Analysis to verify peak pressure and resulting stresses;
- inspection and repair of the drainage system;
- monitoring of the exterior for signs of leakage; and
- continued inspections of the interior including MP weld testing. An increase in testing in the 17-ft diameter section is recommended as noted in Section 6.3 below.

The Surge Analysis should be completed before refurbishment to confirm stresses that may be used in weld sizing. Monitoring for leakage is something that should be done for every penstock regardless of age, construction, or condition. It is an early indicator of issues. Leakage for buried penstocks is most effectively done by monitoring drainage pipes and looking for wet areas and sink holes along the penstock alignment. MP weld testing after coating is applied may not be possible without removing the coating but not unheard of and will be dependent on coating system used. Other forms of weld testing are available that can test through paint such as the MagnaFORM Probe from Olympus. Considering indications were found at previously repaired welds this is something that will require further investigation and consideration.

6.1 Coating

Kleinschmidt recommends coating the interior of the penstock in the next 7 years. At this stage, Kleinschmidt is unable to estimate the rate of corrosion of the steel. There is no standard rate of corrosion as there are many variables; the specific properties and components of the steel, the acidic properties of the water, silt amounts in the water, the acidity and corrosiveness of the surrounding solids, and the penstock also has organic build-up along the pipe which can either contribute to accelerated corrosion on bare steel or help build a protective barrier. Stress ratios are high enough that it would be prudent to plan for a recoating to reduce loss of material thickness and extend the service life of

the penstock. A quality field applied penstock coating can last 20-40 years. If the penstock is recoated prior to significant steel deterioration every 20-40 years, NLH can anticipate extending the life of the penstock potentially another 80 years depending on the section loss realized when cleaning the penstock. The coating will not prevent the eventual corrosion of the shell from the exterior. The exterior is currently coated, but it is difficult to tell its condition.

6.2 Exterior Inspection

The repaired sinkhole downstream of the surge tank should continue to be monitored.

It is recommended that the observation well downstream, and to the left of the surge tank, be inspected from the bottom. It is recommended that the drainage system be scoped with a camera from the bottom of this well and from the other wells in the area to determine if there is blockage upstream or downstream of the wells. A properly functioning and monitored penstock drainage system can provide early warning of penstock leakage. It would be good to have a better understanding of the drainage system prior to penstock refurbishment to scope modifications if required.

Kleinschmidt recommends continuing to monitor the exterior of the penstocks for signs of leakage. Drainpipes should also be monitored at times with consistent weather conditions.

6.3 Interior Inspections

Kleinschmidt recommends that NLH conducts a Level II inspection with MP testing of the welds and UT thickness measurements every year the penstock is dewatered until the life extension work is complete. Weld indications continue to be found and yearly testing is warranted. Based on 2024 findings in Penstock 3 and subsequent repairs, it is recommended that the quantity of welds tested remain at a minimum of 20 percent in the 7/16-inch-thick plated section in 2025. Staging was used in 2024 to inspect crown welds and welds too high to test normally. Due to weld indications being found, and further testing being done, almost 70% of all welds were tested in the 7/16" thick section of penstock. It is not recommended that crown welds be inspected in 2025 in Penstock 3 due to the significant number tested this year. It is also noted that the majority of indications have been found closer to the spring line which can be reached from the TRR standard platform. Interior inspections should continue yearly until the penstock is refurbished.

7.0 REFERENCES

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Hatch. 2018. Bay d'Espoir Level II Condition Assessment of Penstocks No. 1, 2, and 3. Rev 0 Final. December 13, 2018.

Hatch. 2019. Newfoundland and Labrador Hydro Final Report for Condition Assessment and Refurbishment Options for Penstocks No. 1, 2 and 3. Rev 0. March 28, 2019.

Kleinschmidt Associates. 2016. Crack Investigation and Repair Report, Penstock No. 1 Bay d'Espoir Hydroelectric Development. Kleinschmidt Technical Report to Newfoundland and Labrador Hydro.

SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.

Chris M. Vella, P.Eng.
Senior Hydro Engineer

CMV:NSS:SCB

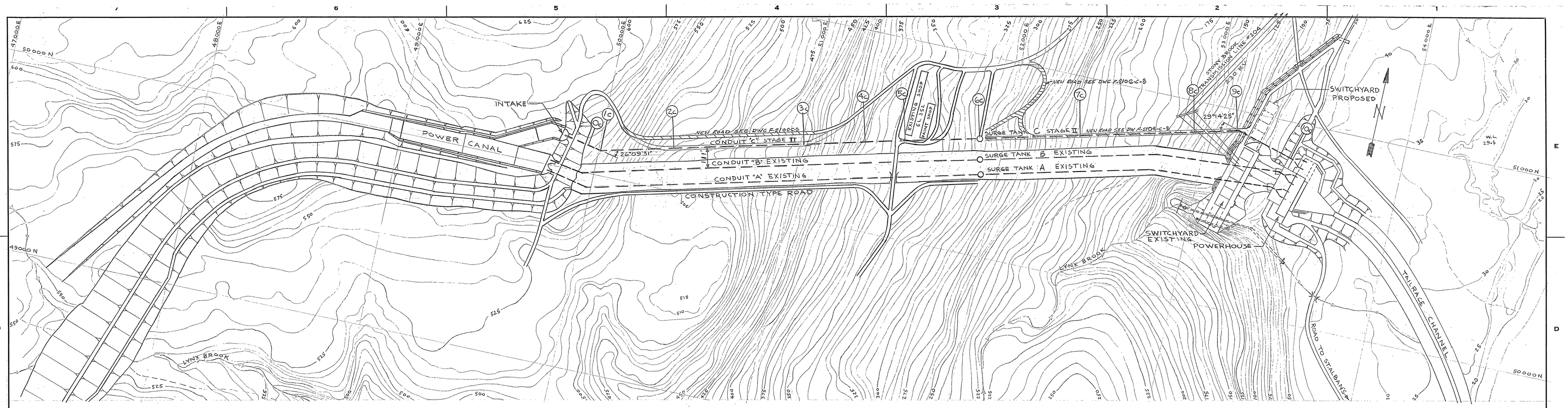
REGISTERED PROFESSIONAL ENGINEER
PEGNL Newfoundland and Labrador
CHRISTOPHER M. VELLA
SIGNATURE
Dec. 5 2024
DATE
NEWFOUNDLAND & LABRADOR

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEGNL Newfoundland and Labrador
PERMIT HOLDER
This Permit Allows
KLEINSCHMIDT ASSOCIATES CANADA INC.
To practice Professional Engineering
In Newfoundland and Labrador.
Permit No. as issued by PEGNL N0708
which is valid for the year 2024

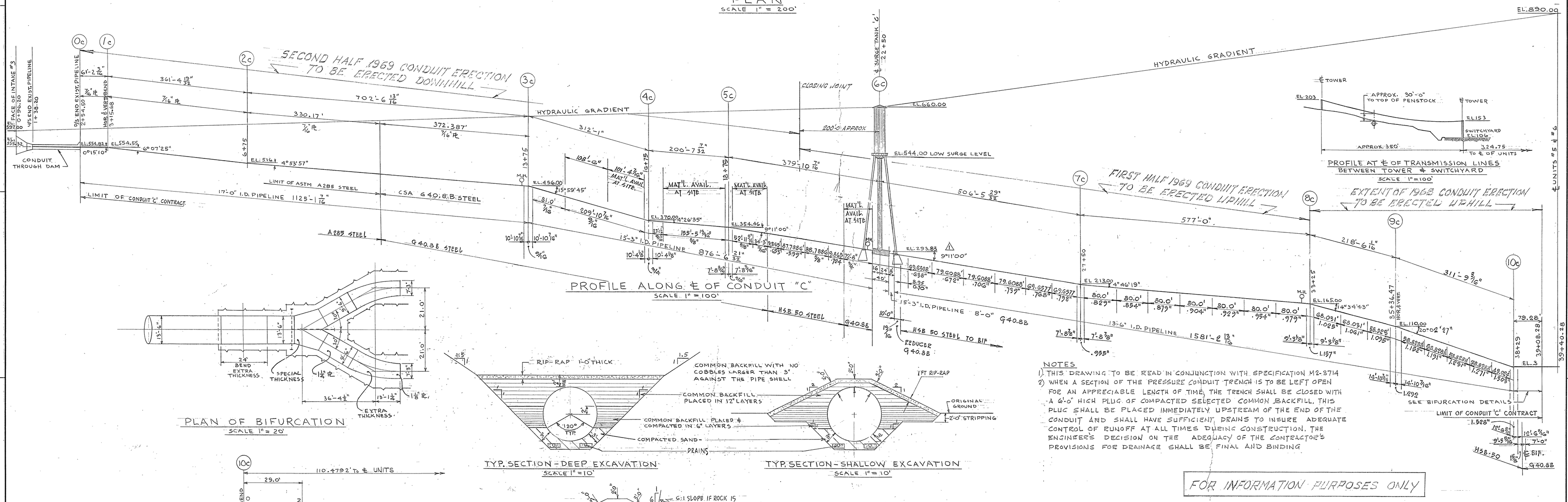
\\EgnyteDrive\Kleinschmidt\Jobs\2670\043\Docs\2024 Penstock Inspections\Penstock 3\2670043_Bay d'Espoir Penstock 3 Inspection 2024 Final.docx

APPENDIX A

PENSTOCK LAYOUT DRAWINGS



PLAN
SCALE 1" = 200'



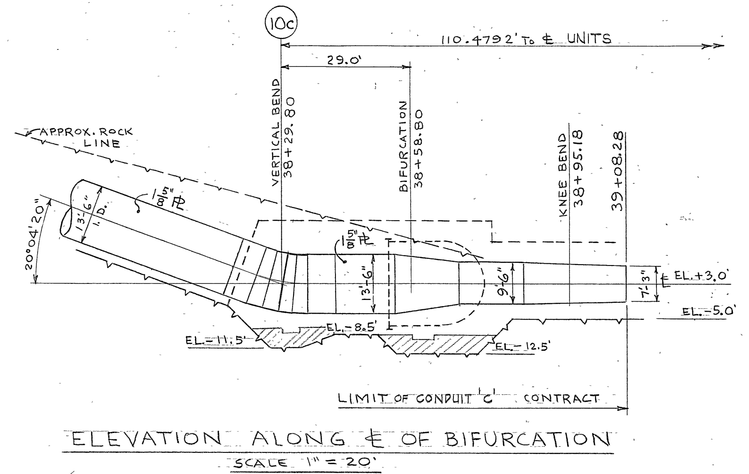
PROFILE ALONG ℄ OF CONDUIT "C"
SCALE 1" = 100'

PROFILE AT ℄ OF TRANSMISSION LINES
BETWEEN TOWER ℄ SWITCHYARD
SCALE 1" = 100'

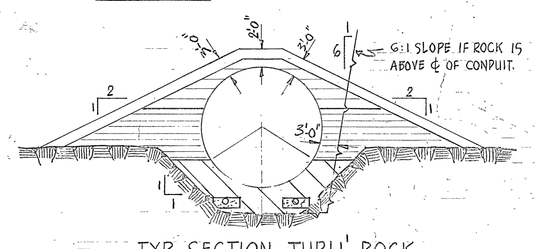
PLAN OF BIFURCATION
SCALE 1" = 20'

TYP. SECTION - DEEP EXCAVATION
SCALE 1" = 10'

TYP. SECTION - SHALLOW EXCAVATION
SCALE 1" = 10'



ELEVATION ALONG ℄ OF BIFURCATION
SCALE 1" = 20'



TYP. SECTION THRU' ROCK
SCALE: 1" = 10'

NOTES
1) THIS DRAWING TO BE READ IN CONJUNCTION WITH SPECIFICATION M2-3714
2) WHEN A SECTION OF THE PRESSURE CONDUIT TRENCH IS TO BE LEFT OPEN FOR AN APPRECIABLE LENGTH OF TIME, THE TRENCH SHALL BE CLOSED WITH A 6'-0" HIGH PLUG OF COMPACTED SELECTED COMMON BACKFILL. THIS PLUG SHALL BE PLACED IMMEDIATELY UPSTREAM OF THE END OF THE CONDUIT AND SHALL HAVE SUFFICIENT DRAINS TO INSURE ADEQUATE CONTROL OF RUNOFF AT ALL TIMES DURING CONSTRUCTION. THE ENGINEER'S DECISION ON THE ADEQUACY OF THE CONTRACTOR'S PROVISIONS FOR DRAINAGE SHALL BE FINAL AND BINDING

NOTE
FOR DETAIL OF DRAINS SEE DRAWING NO F-2020-C-109

FOR INFORMATION PURPOSES ONLY

F-210G-C-5	SURGE TANK 'C' - FOUNDATIONS - CONCRETE DETAILS
F-210G-C-4	SURGE TANK 'C' - EXCAVATION & BACKFILL
F-210G-C-3	PRESSURE CONDUIT 'C' & SURGE TANK 'C', EXCAVATION & DRAINAGE
F-210G-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS.
DRG NO	TITLE

REFERENCE DRAWINGS.

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
4	MAY 68		EL. AT SURGE TANK TOE WAS 893.84	HL	JDB

REVISIONS

FINAL

TRANS'N | ELECT'L | CIVIL — PASSED

DESIGNED
DRAWN F.D. AR
CHECKED HL
RECOMMENDED

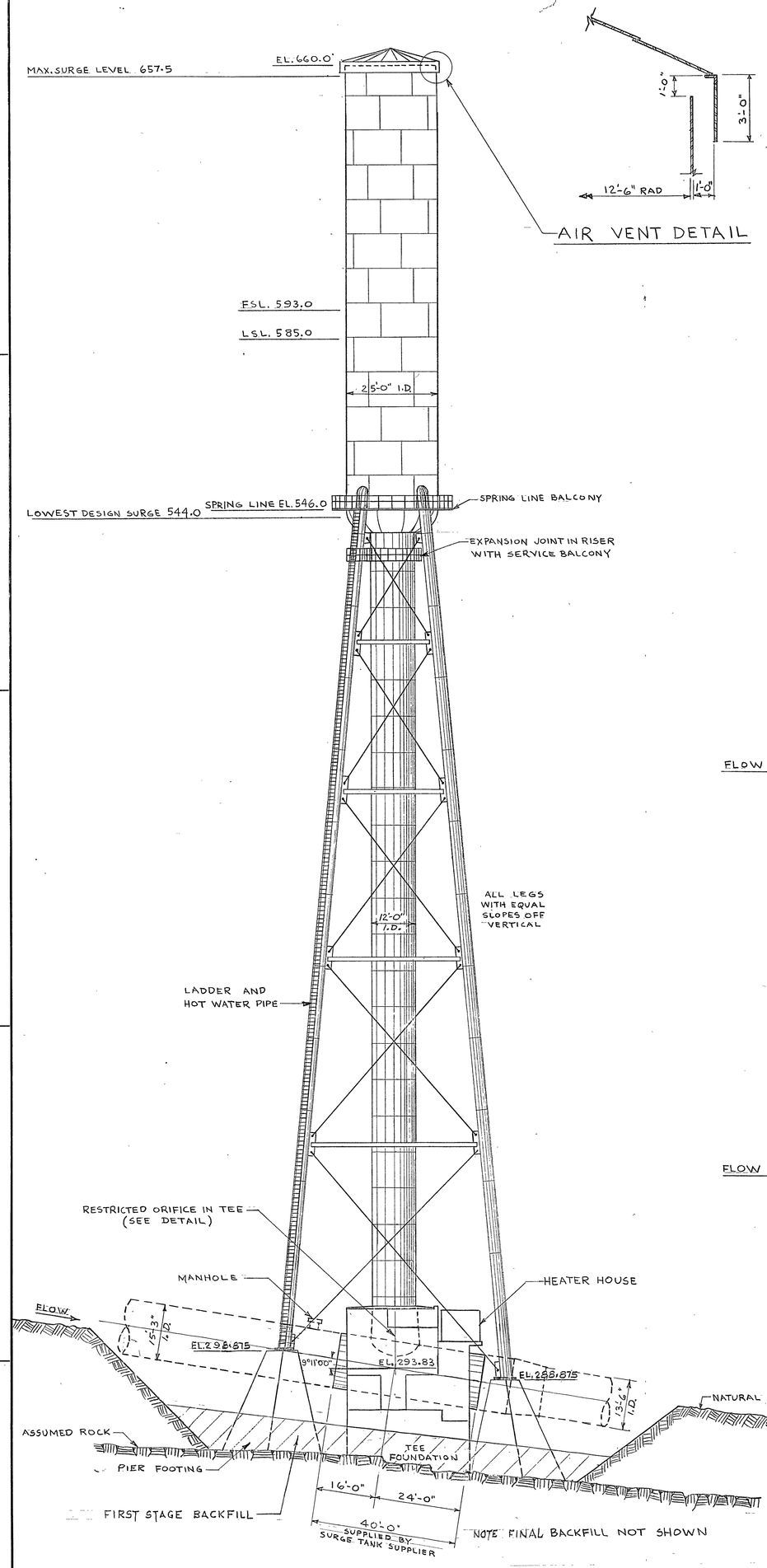
NEWFOUNDLAND AND LABRADOR POWER COMMISSION

BAY D'ESPOIR DEVELOPMENT
STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL QUEBEC

PRESSURE CONDUIT "C"
PLAN, PROFILE, & DETAILS.

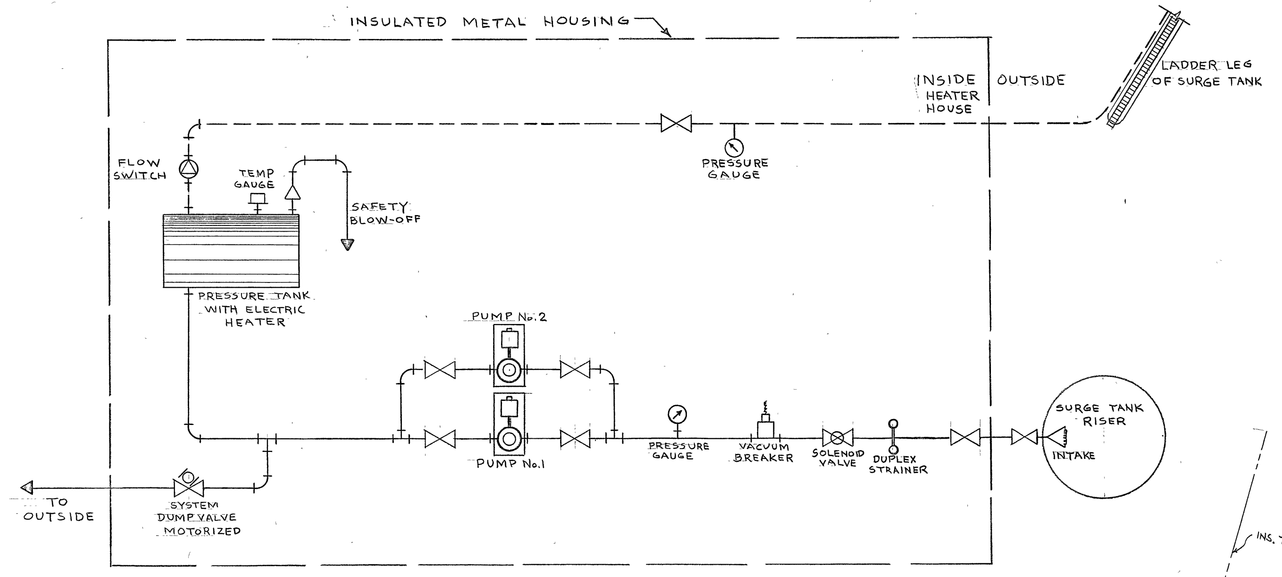
CONTRACT	SCALE	FILE NO	DATE	DWG NO	REVISION
	NOTED	2-15	APR 18 68	F-210G-C-1	4

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 3, Attachment 30, Page 31 of 95

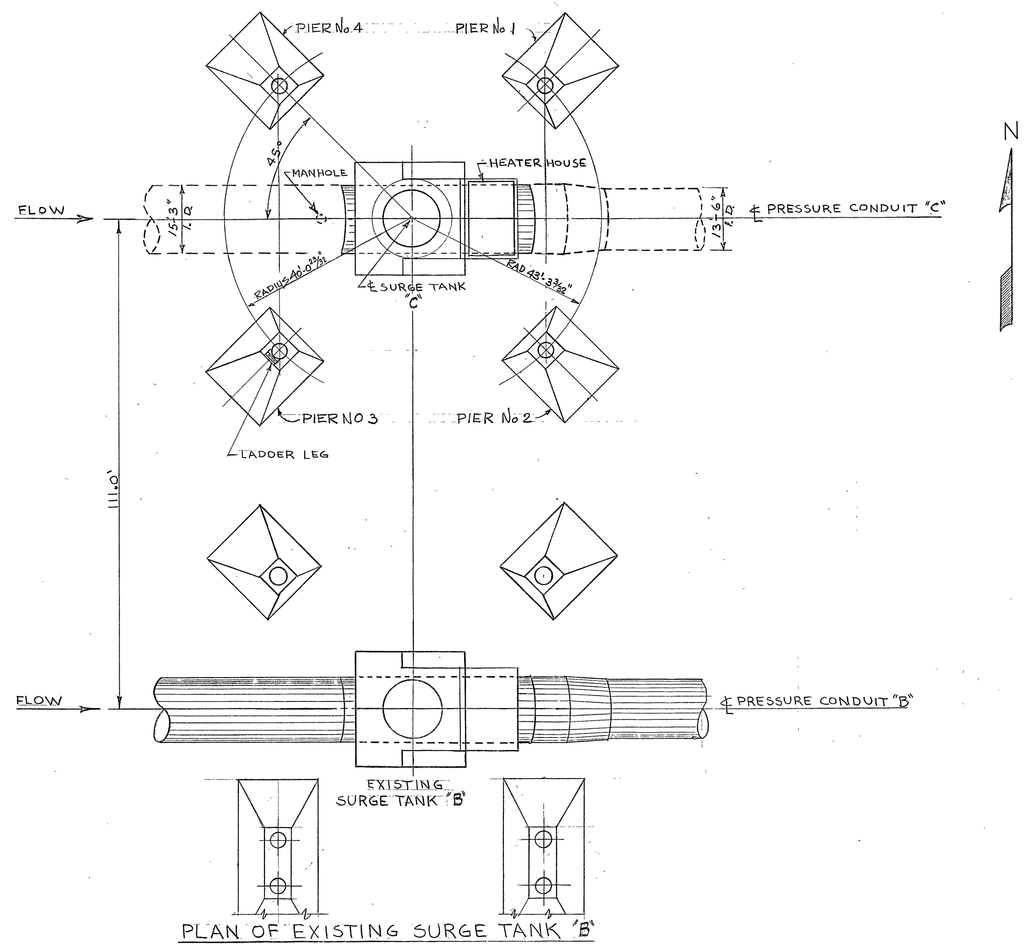


ELEVATION
NOT TO SCALE

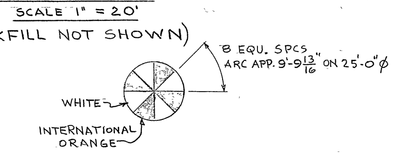
AIR VENT DETAIL

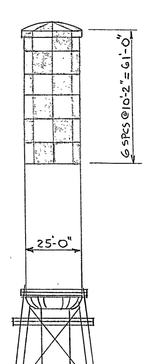


SCHEMATIC DIAGRAM OF SURGE TANK HEATER SYSTEM PIPING
FOR ELECTRICAL SCHEMATIC DIAGRAM



PLAN OF EXISTING SURGE TANK 'B' AND SURGE TANK 'C'
SCALE 1" = 20'
(BACKFILL NOT SHOWN)



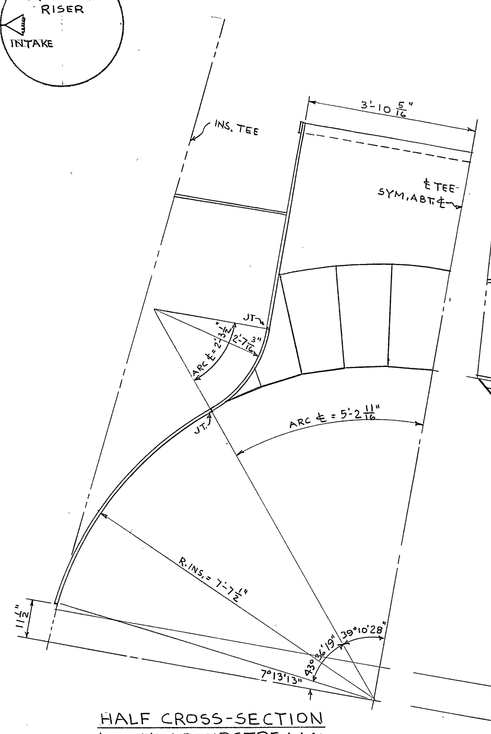


PAINT DETAIL
OBSTRUCTION PAINTING

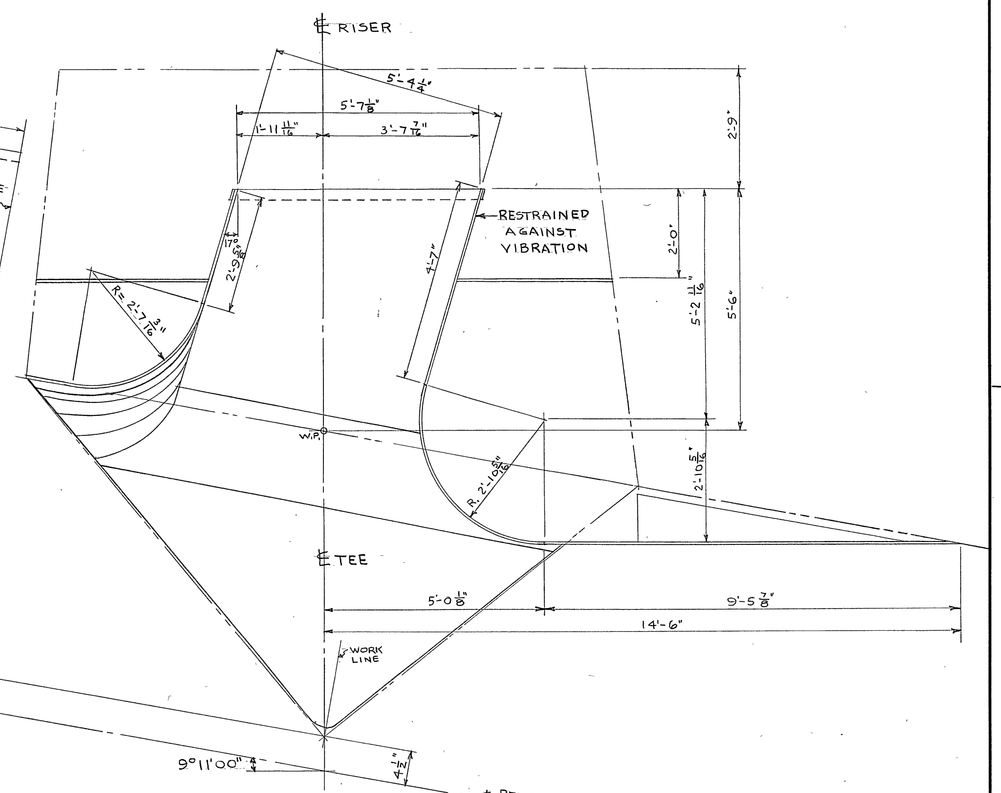
HYDRAULIC DATA

THE SURGE TANK RISER AND TEE SHALL BE DESIGNED TO SUSTAIN LOADS CAUSED BY THE FOLLOWING HYDRAULIC CONDITIONS.

1. MAXIMUM INTERNAL WATER PRESSURE WITH WATER UP TO ELEVATION 657.5 FEET
2. HEAD LOSS OF 40 FEET ACROSS THE ORIFICE WITH WATER FLOWING INTO THE SURGE TANK
3. HEAD LOSS OF 10 FEET AT THE ENLARGEMENT FROM RISER TO TANK WITH THE WATER FLOWING INTO THE SURGE TANK
4. HEAD LOSS OF 140 FEET ACROSS THE ORIFICE WITH THE WATER FLOWING FROM THE SURGE TANK TO THE PRESSURE CONDUIT
5. MAXIMUM DESIGN FLOW 2900 CFS THROUGH THE ORIFICE



HALF CROSS-SECTION
LOOKING UPSTREAM



SECTION ALONG ℄ CONDUIT

RESTRICTED ORIFICE DETAILS
SCALE 1/2" = 1'-0"
HYDRAULIC BOUNDARIES ONLY SHOWN

THIS DRAWING IS ISSUED FOR INFORMATION PURPOSES ONLY

DWG No	TITLE
F 2106-C-2	SURGE TANK "C" - FOUNDATION - CONCRETE DETAILS & ROCK DWLS
F 2106-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F 2106-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F 2106-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D

REVISIONS

FINAL

TRANS'N	ELECT'L	CIVIL

PASSED

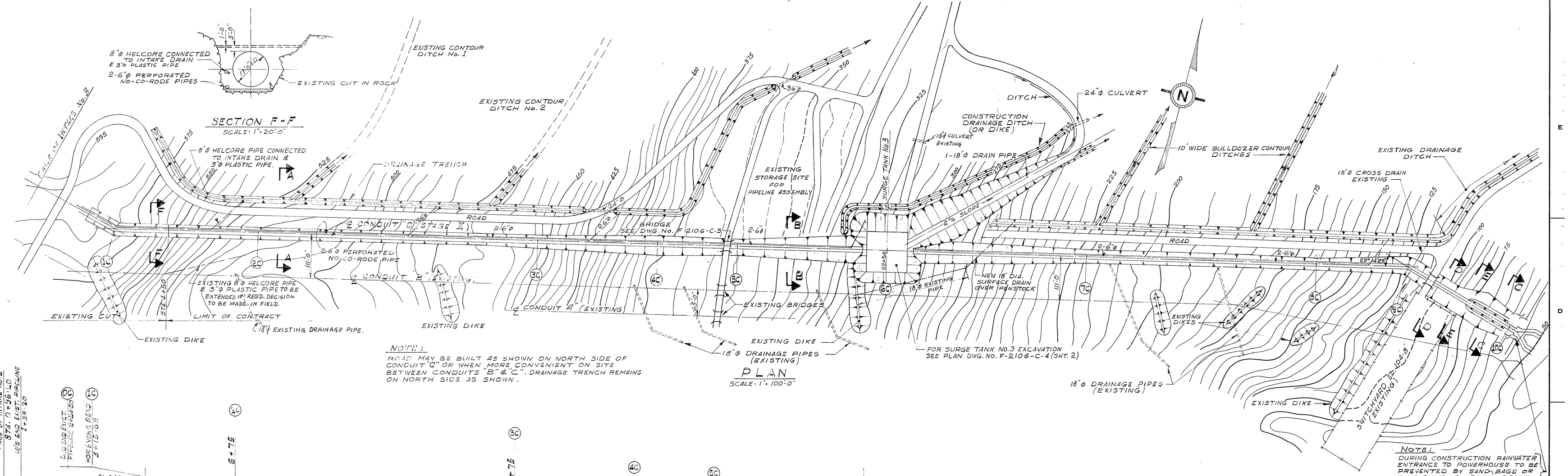
DESIGNED HK
DRAWN F.G.M./A.R.
CHECKED JHM
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

SURGE TANK "C"
GENERAL LAYOUT & DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
		2-15	20 Oct '67	F-2106-C-2	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 2, Attachment A0, Page 25 of 35



NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
			REVISIONS		

	TRANS'N	ELECT'L	CIVIL
PASSED			

DESIGNED N.P.
DRAWN A.B.
CHECKED
RECOMMENDED

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

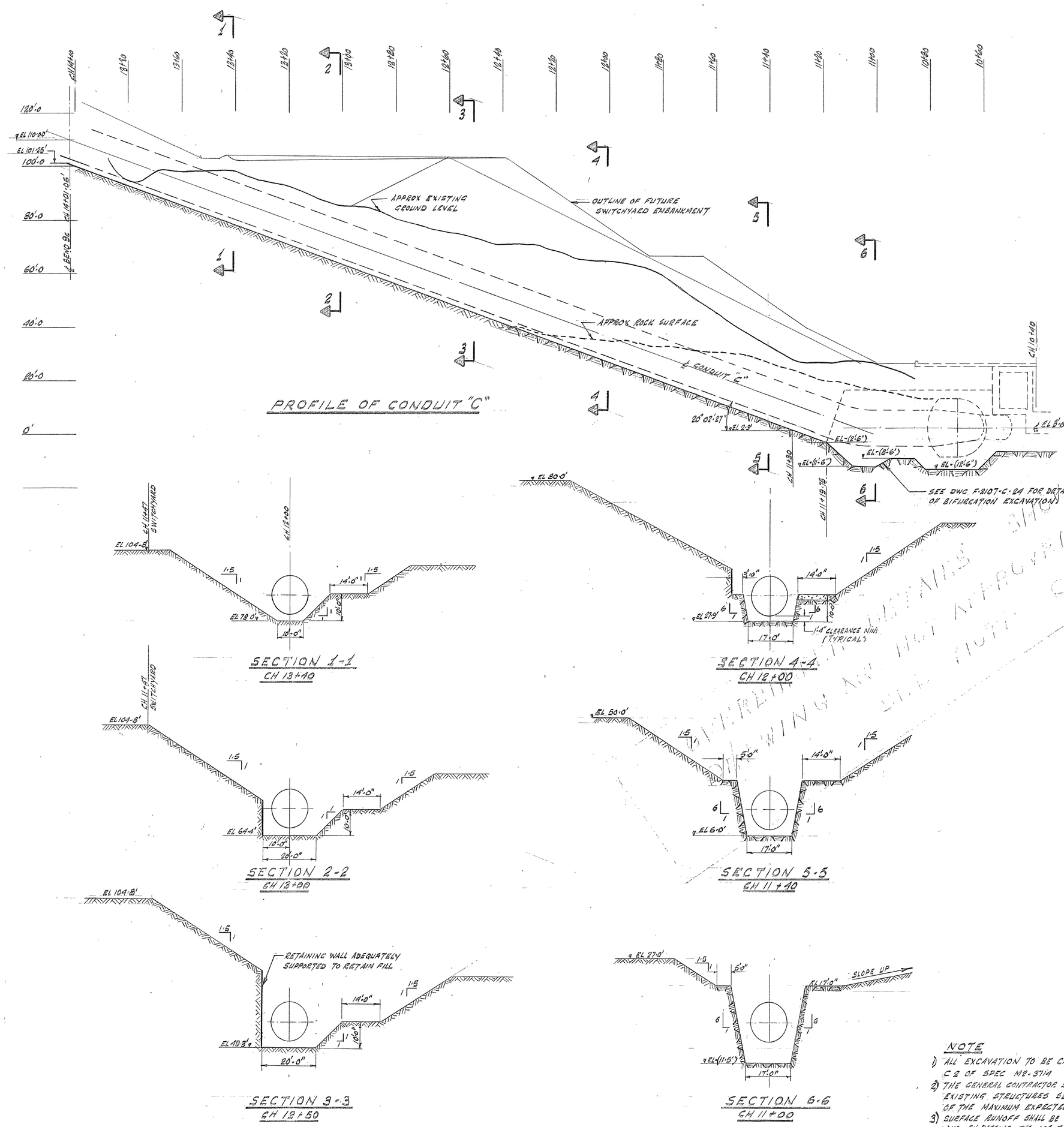
BAY D'ESPOIR DEVELOPMENT STAGE II

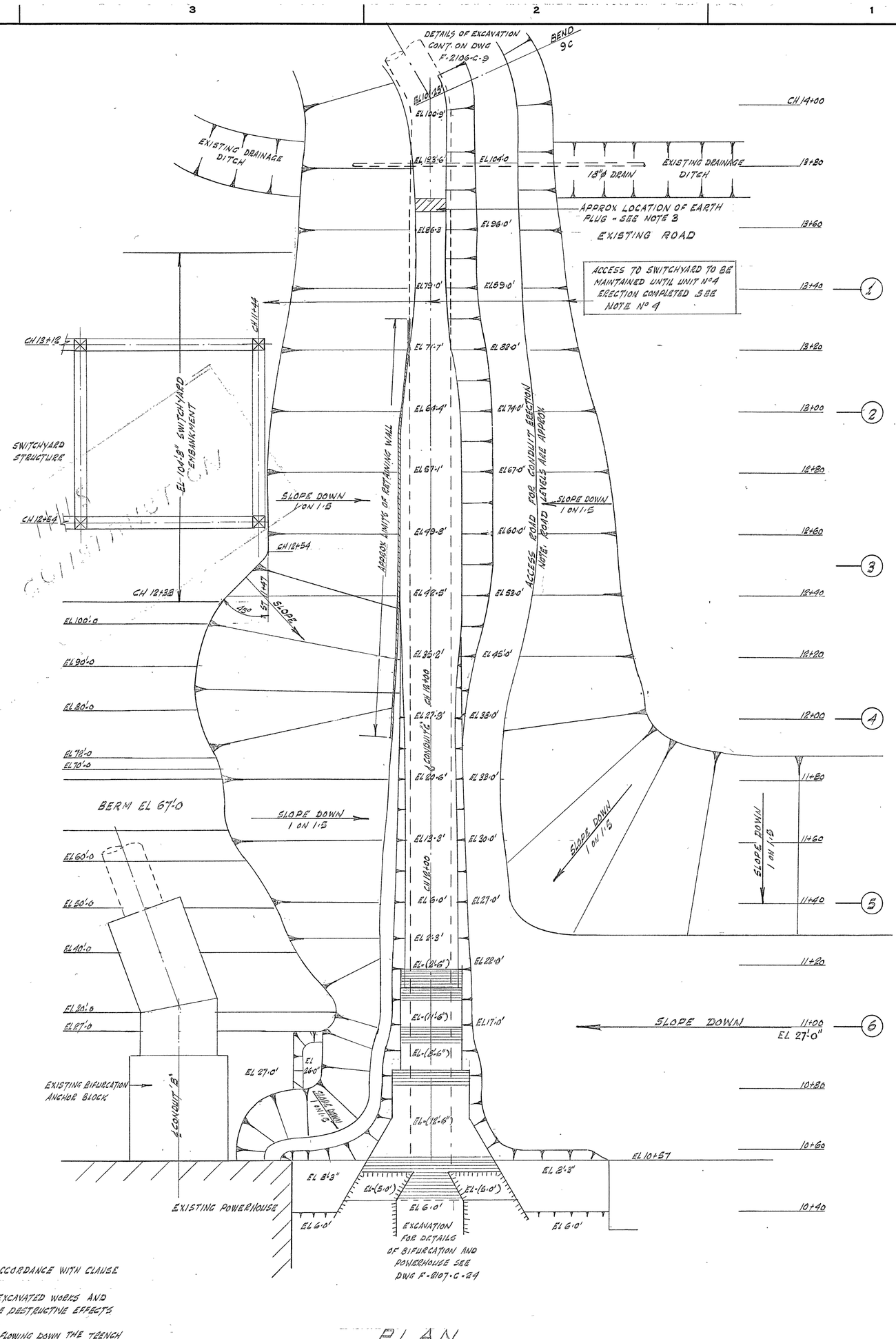
ENGINEERING AND DESIGN BY SHAWMONT NEWFOUNDLAND LIMITED MONTREAL, QUEBEC

PRESSURE CONDUIT "C" & SURGE TANK No. 3 EXCAVATION & DRAINAGE (SHEET 1 OF 2)

CONTRACT	SCALE	FILE NO	DATE	DWG NO.	REVISION
	NOTED		JAN. 19, 1968	F-2106-C-3	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 10, Page 39 of 95





PLAN

NOTE

1) ALL EXCAVATION TO BE CARRIED OUT IN ACCORDANCE WITH CLAUSE C 2 OF SPEC NB-3714
2) THE GENERAL CONTRACTOR SHALL KEEP THE EXCAVATED WORKS AND EXISTING STRUCTURES SECURE AGAINST THE DESTRUCTIVE EFFECTS OF THE MAXIMUM EXPECTED STORM WATER.
3) SURFACE RUNOFF SHALL BE PREVENTED FROM FLOWING DOWN THE TRENCH AND BY-PASSING THE OFF-TAKE DITCH AT CH 13+30 BY LEAVING AN UNEXCAVATED EARTH PLUG IN THE PRESSURE CONDUIT TRENCH IMMEDIATELY DOWNSTREAM OF THIS OFF-TAKE DITCH. THE EARTH PLUG SHALL ONLY BE REMOVED WHEN THE CONDUIT BEING ERECTED IS WITHIN 100 TO 150 FEET OF THE PLUG
4) ACCESS TO THE EXISTING SWITCHYARD IS TO BE MAINTAINED FOR HEAVY VEHICULAR TRAFFIC UNTIL THE ERECTION OF THE SUPERSTRUCTURE STEEL AND INSTALLATION OF THE ELECTRICAL EQUIPMENT HAS BEEN COMPLETED FOR UNIT Nº4 (AUG 86/88)
5) THE SIDE SLOPE OF THE EXCAVATION SHOWN ON THIS DRAWING ARE THOSE PROPOSED BY THE GENERAL CONTRACTOR. THE ACTUAL SLOPES USED ARE TO BE DETERMINED BY THE GENERAL CONTRACTOR BUT MUST BE CONSISTANT WITH STABILITY AND SAFETY.
6) THIS DRAWING IS APPROVED FOR CONSTRUCTION ONLY IN REGARDS TO THE DETAILS FOR THE ACTUAL CONDUIT TRENCH i.e. BOTTOM ELEVATION BOTTOM WIDTH, AND ROCK SIDE SLOPES. OVERBURDEN EXCAVATION AND SIDE SLOPES ARE NOT APPROVED FOR CONSTRUCTION BUT SHALL BE DETERMINED IN THE FIELD TO THE APPROVAL OF THE ENGINEER TO SUIT ROCK ELEVATIONS AND OVERBURDEN CONDITIONS ENCOUNTERED

THIS DRAWING SHALL NOT BE USED FOR CONSTRUCTION UNLESS APPROVED BY THE CONSULTING ENGINEERS

NEWFOUNDLAND PROFESSIONAL ENGINEER — P.E.P. PETTEN — SIGNATURE — PROVINCE OF NEWFOUNDLAND

FINAL

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
REVISIONS					

APPROVED FOR CONSTRUCTION
JUN 5 1988
APPROVED BY:
DEPUTY MINISTER, ENERGY
P.E.P.

CONSTR.	TRANS'N	ELECT'L	CIVIL
PASSED			

DESIGNED	D.B.
DRAWN	H. LEE
CHECKED	D.B.
RECOMMENDED	R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

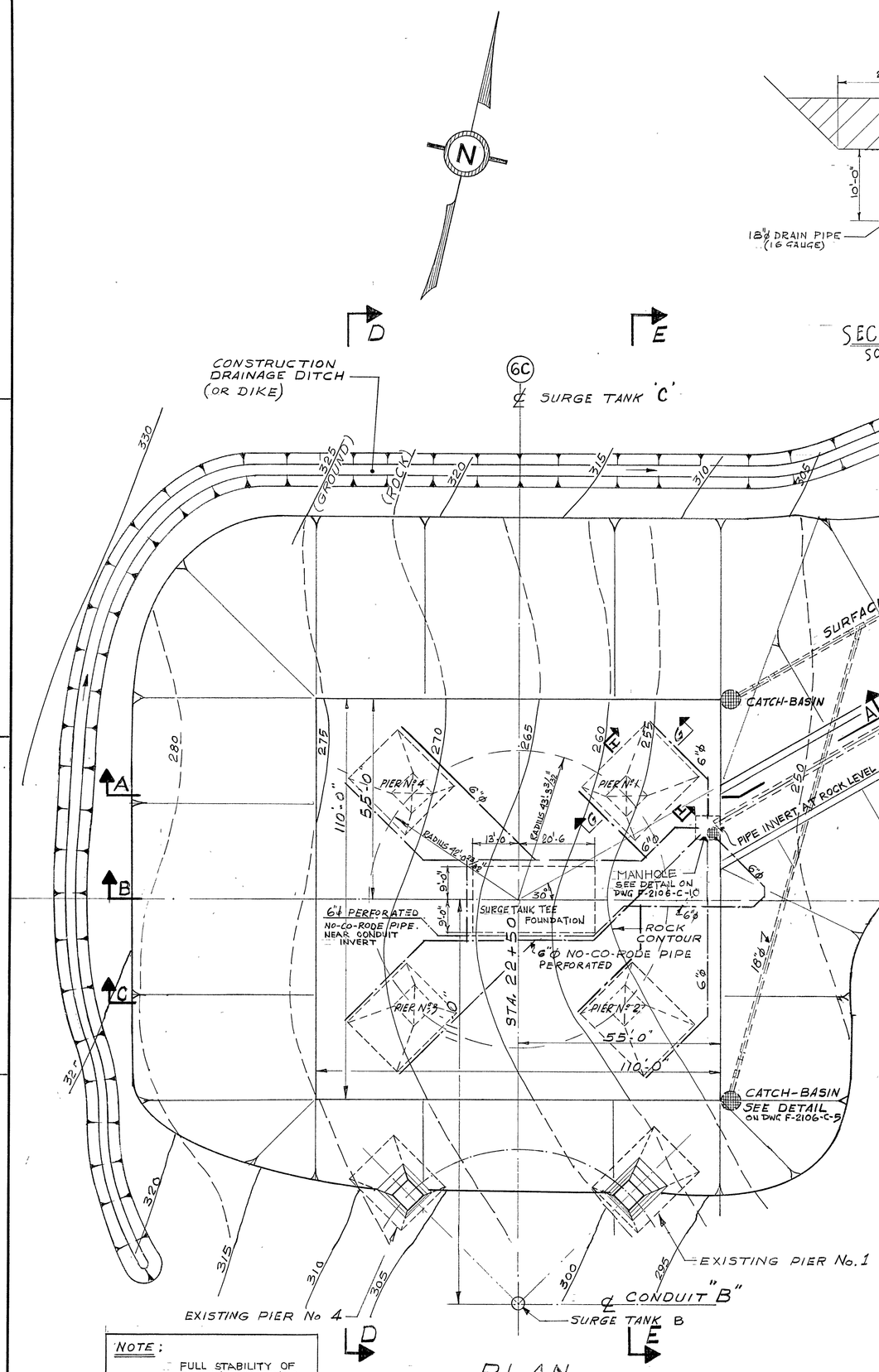
BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

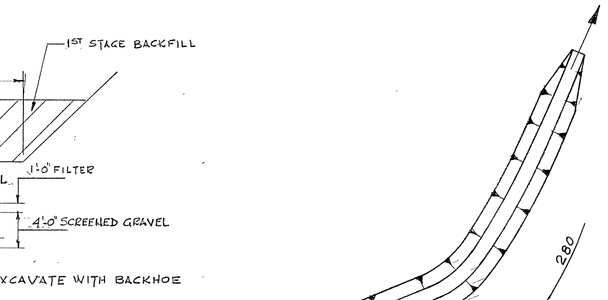
PRESSURE CONDUIT "C"
EXCAVATION DETAILS - LOCAL TO SWITCHYARD EMBANKMENT

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1"=80'	2-1E	30TH MAY 68	F-2106-C-3	0

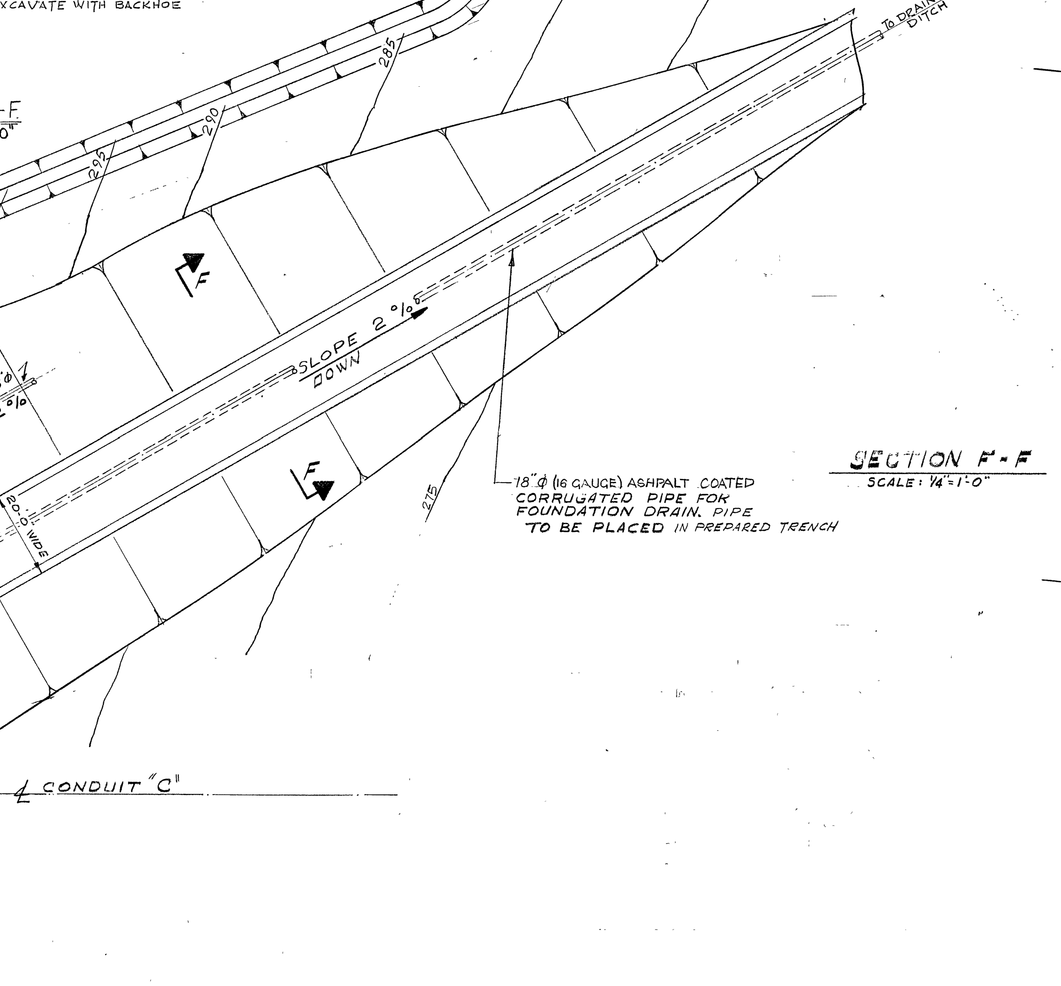
SH.2 OF 2



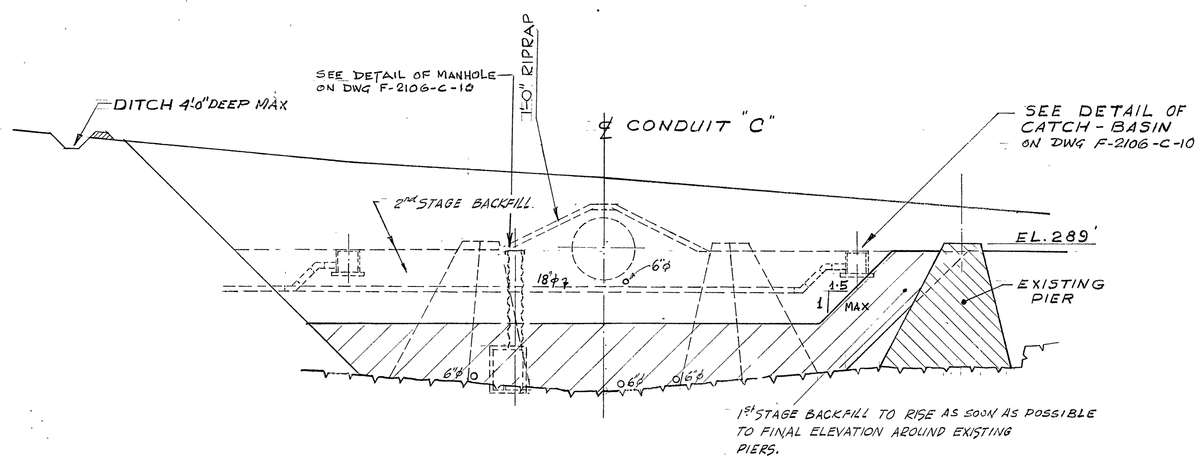
PLAN
EXCAVATION TO ROCK
SCALE: 1"=20'-0"



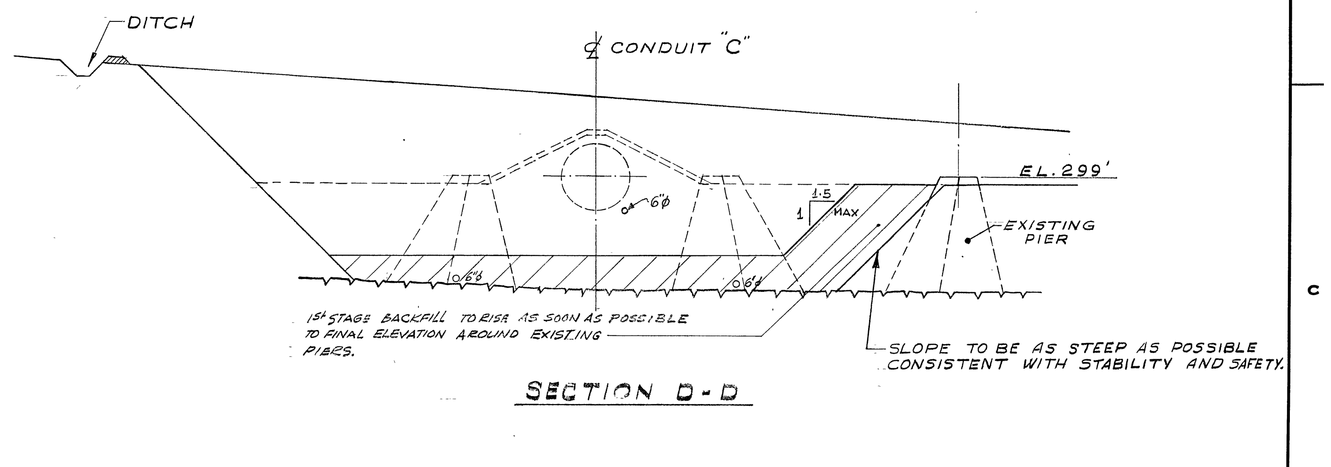
SECTION F-F
SCALE: 1"=10'-0"



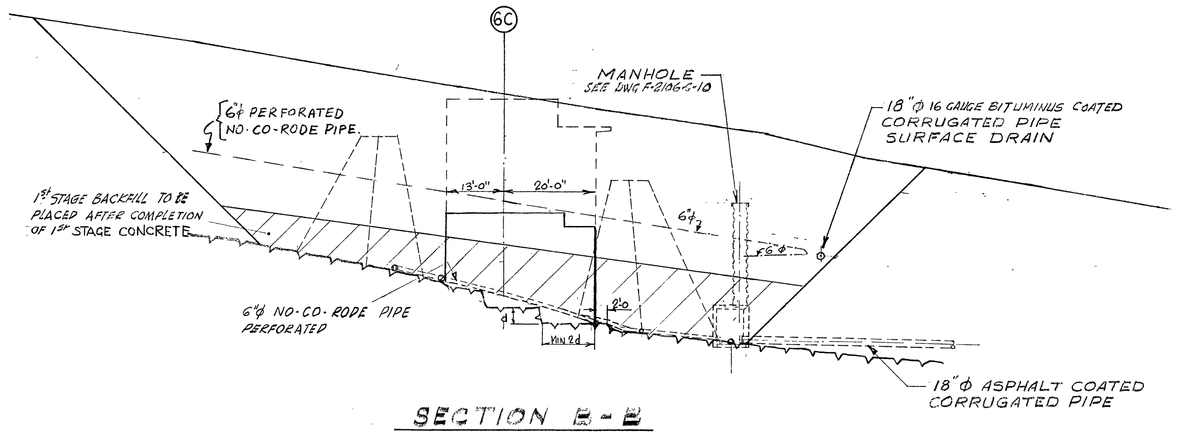
SECTION F-F
SCALE: 1/4"=1'-0"



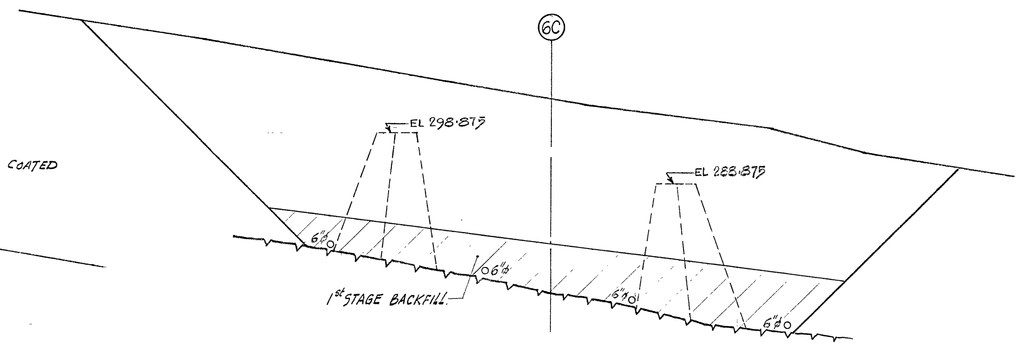
SECTION E-E



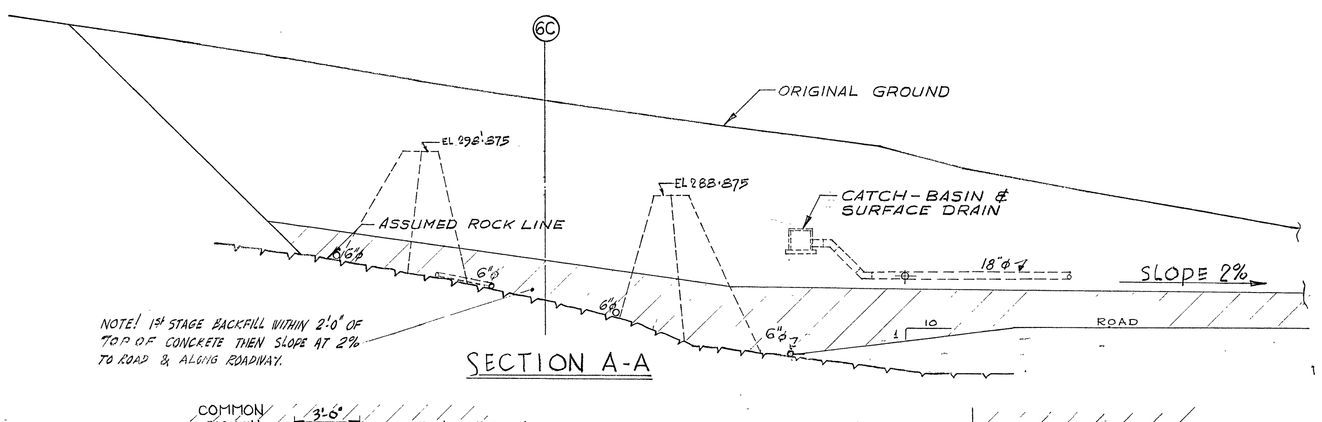
SECTION D-D



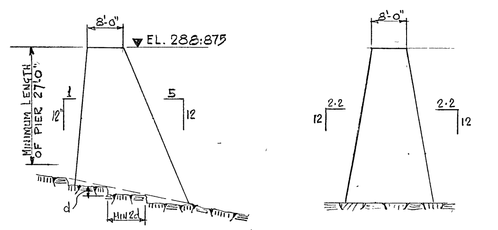
SECTION B-B



SECTION C-C



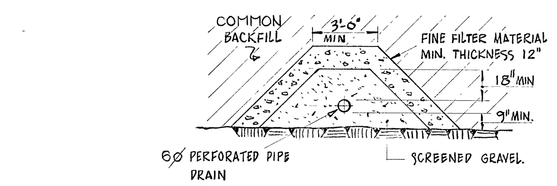
SECTION A-A



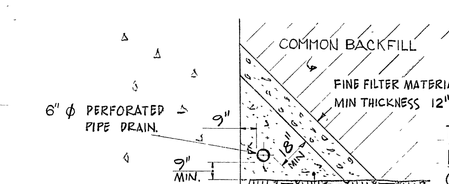
SECTION G-G
SCALE: 1"=20'-0"

SECTION H-H
SCALE 1"=20'-0"

NOTES:
1) SURFACE & FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.
2) ENDS OF 6"ϕ PERFORATED PIPES TO BE BLANKED OF WITH A MASS CONCRETE PLUG OR BLANKED OFF.
3) FIRST STAGE BACKFILL SHOULD BE PLACED AROUND EXISTING PIERS TO FINAL ELEVATION AS SOON AS POSSIBLE.
4) BACKFILL SHALL FOLLOW CONCRETE POURS AND CONDUIT INSTALLATION AS CLOSELY AS PRACTICAL
5) EXCAVATE PIER BASES AND SURGE TANK TEE FOUNDATION TO SOLID ROCK. IF NECESSARY STEP ROCK RADIALLY FROM CENTRE FOR SURGE TANK AND PIERS.



TYPICAL SUB-SURFACE DRAIN IN BACKFILL
SCALE: 1/4"=1'-0"



TYPICAL SUB-SURFACE DRAIN ADJACENT TO CONCRETE STRUCTURE
SCALE: 1/4"=1'-0"

TYPICAL DETAIL FOR ALL PIERS WHERE THE ROCK IS TO BE STEPPED

REFERENCE DRAWINGS

DRG N°	TITLE
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & DRAINAGE - CONCRETE AND REINFORCING DETAILS
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS
F-2106-C-3	PRESSURE CONDUIT 'C' AND SURGE TANK 'C' EXCAVATION AND DRAINAGE
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT AND DETAILS
F-2106-C-1	PRESSURE CONDUIT 'C' - PLAN, PROFILE AND DETAILS

REVISIONS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D

APPROVED FOR CONSTRUCTION
MAY 6 1968
APPROVED BY: R.A. Robertson
MANAGER, ENGINEERING

PASSED: TRANS'N | ELECT'L | CIVIL

DESIGNED N.P.
DRAWN A.B.
CHECKED W.K. R.M.
RECOMMENDED N.P. Eng.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

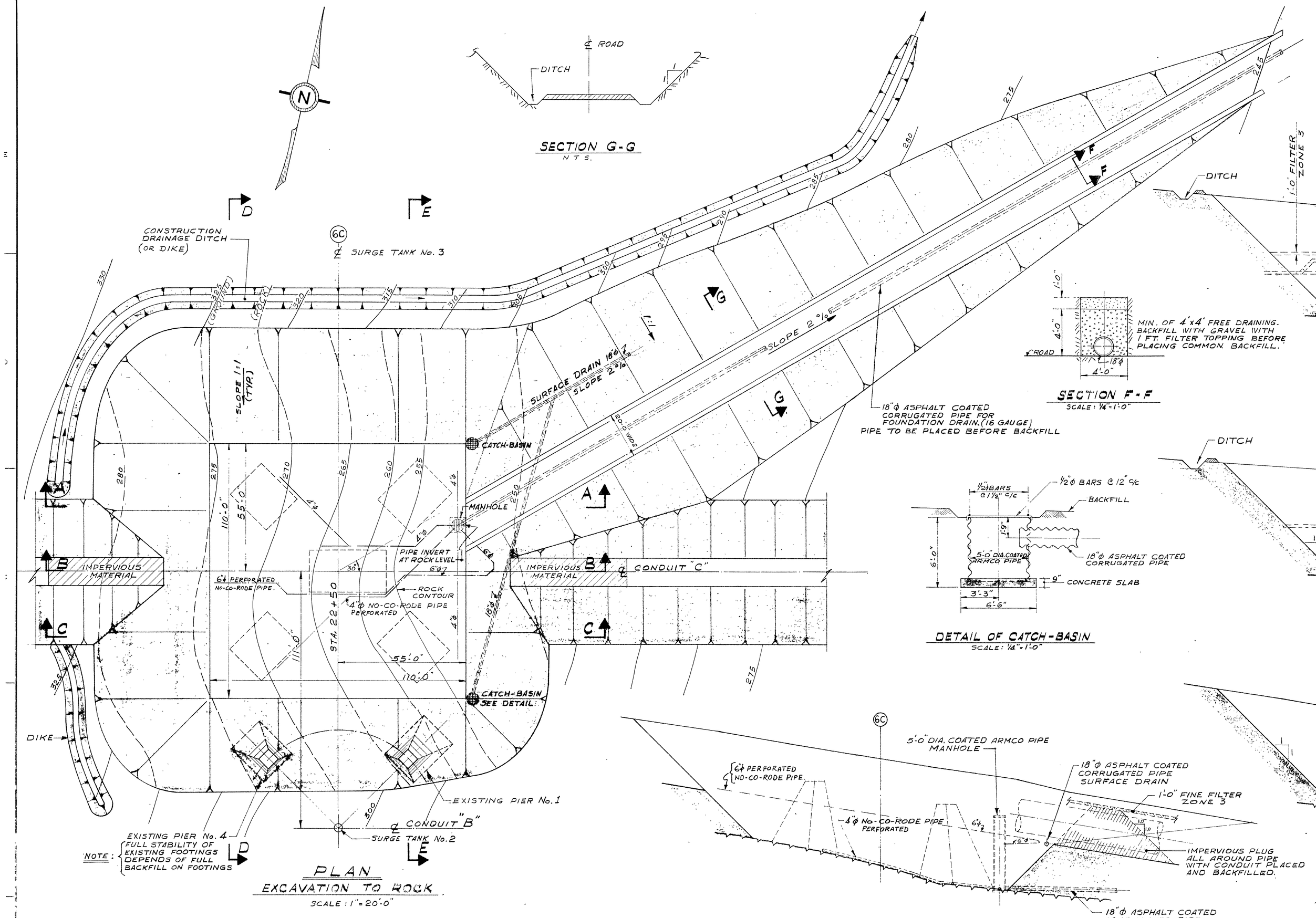
SURGE TANK 'C' EXCAVATION & BACKFILL (SH 1 OF 2)

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1"=20'-0" 1/4"=1'-0"	2-15	FEB 1968	F-2106-C-4	0

RETAIL

Pentstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 2, Attachment 10, Page 35 of 95

7 6 5 4 3 2 1



NOTE:
SURFACE AND FOUNDATION DRAINS TO BE BUILT AS INDEPENDENT SYSTEMS.

REF. DWGS:

F-2106-C-3 PRESSURE CONDUIT "C" & SURGE TANK No. 3 & EXCAVATION & DRAINAGE (SHEET 1).

F-2106-C-5 CONCRETE DETAILS SURGE TANK FOUNDATION PRESSURE CONDUIT ANCHORS & BRIDGE.

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
			REVISIONS		

PASSED: TRANS'N | ELECT'L | CIVIL

DESIGNED: N.P.
DRAWN: A.B.
CHECKED: W.K.
RECOMMENDED:

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

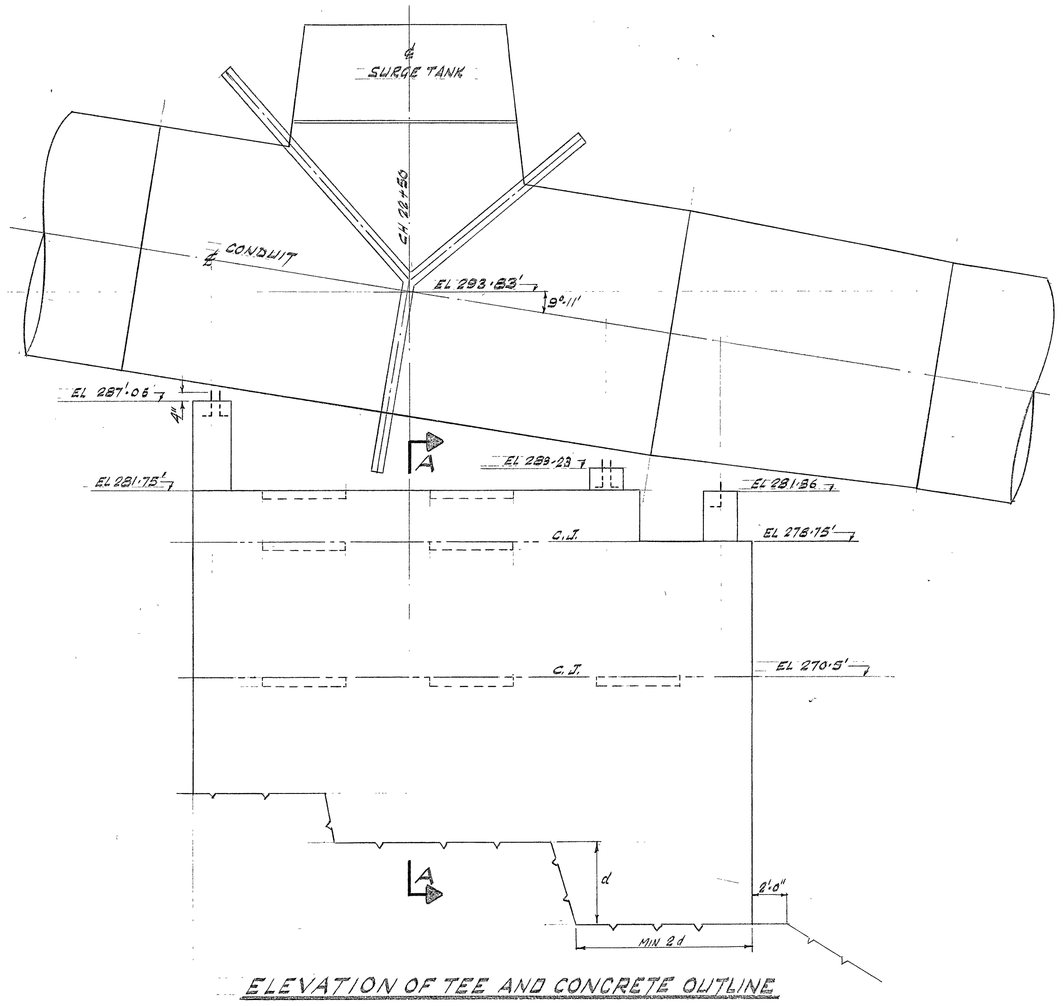
BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

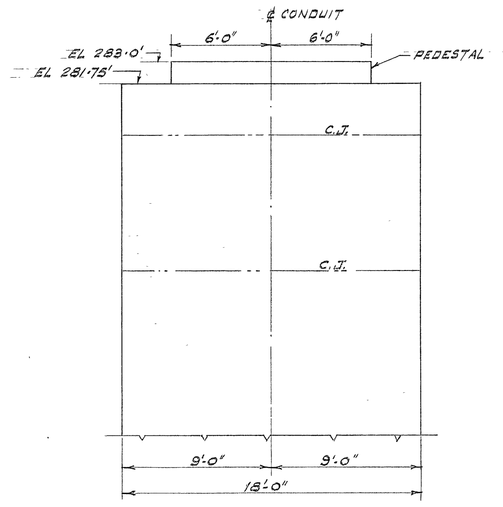
SURGE TANK OVERBURDEN EXCAVATION (SHEET 2 OF 2)

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1"=20'-0" 1/4"=1'-0"		JAN. 18, 1968	F-2106-C-4	0

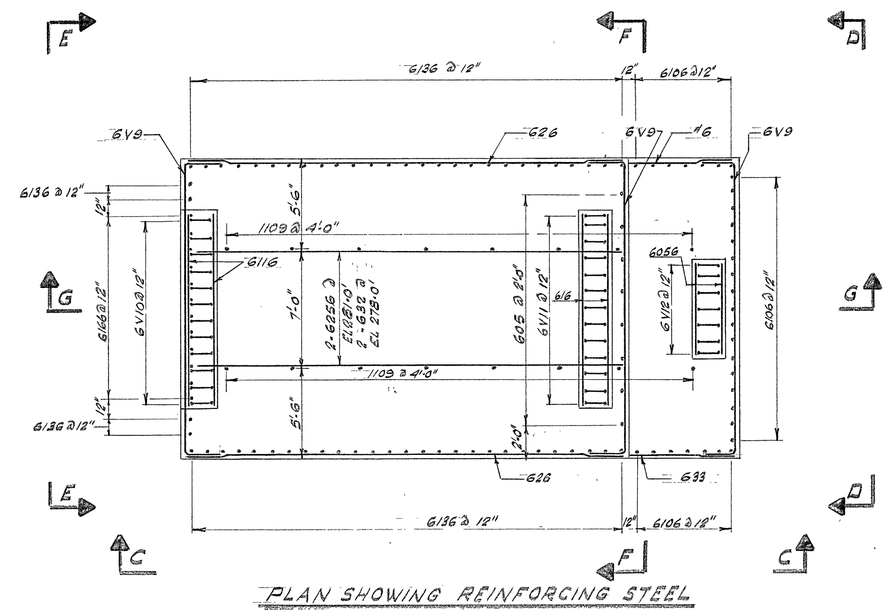
Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 10, Page 36 of 95



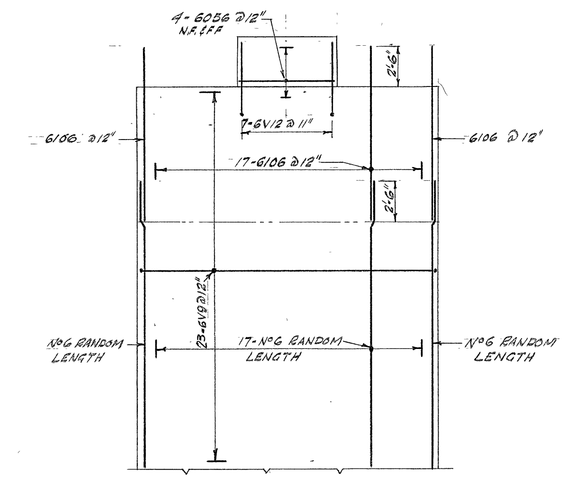
ELEVATION OF TEE AND CONCRETE OUTLINE



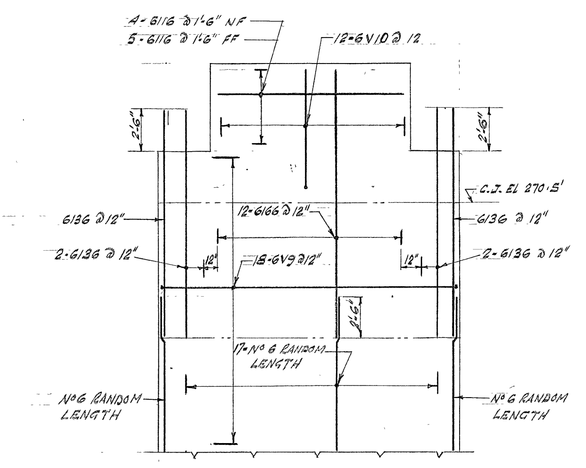
SECTION A-A @ CH 22+50



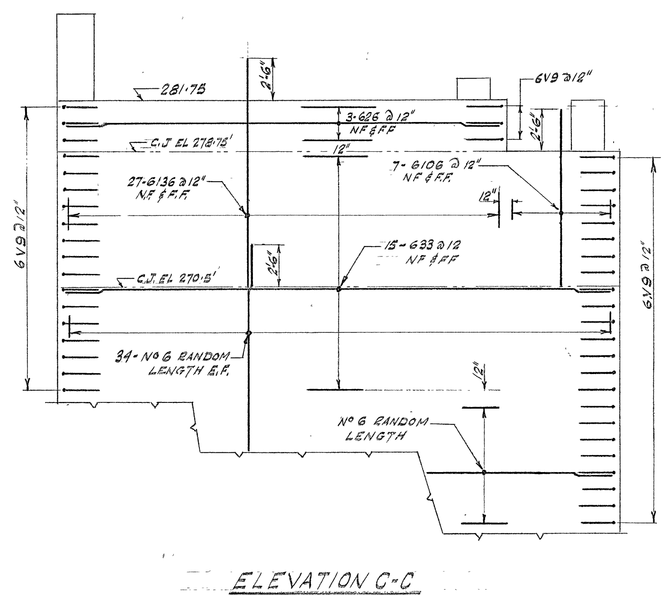
PLAN SHOWING REINFORCING STEEL



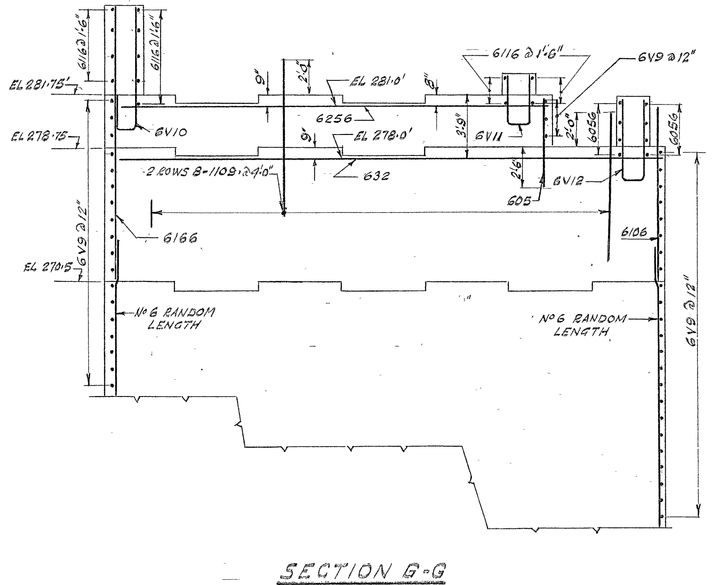
ELEVATION D-D



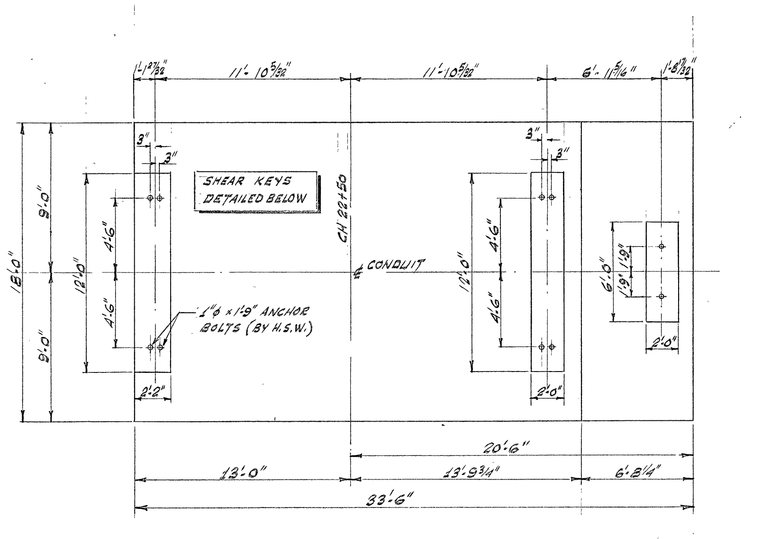
ELEVATION E-E



ELEVATION C-C

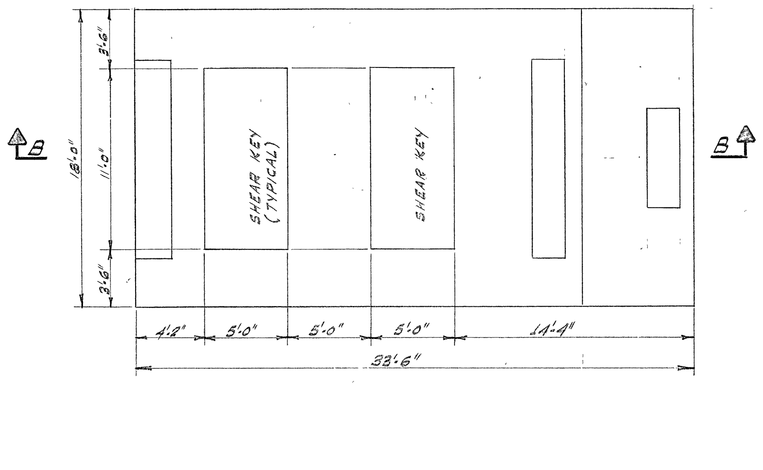


SECTION G-G

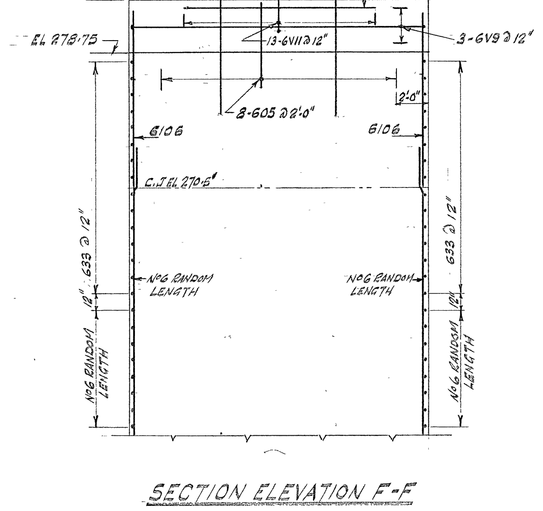


PLAN OF CONCRETE OUTLINE AND ANCHOR BOLT LOCATION

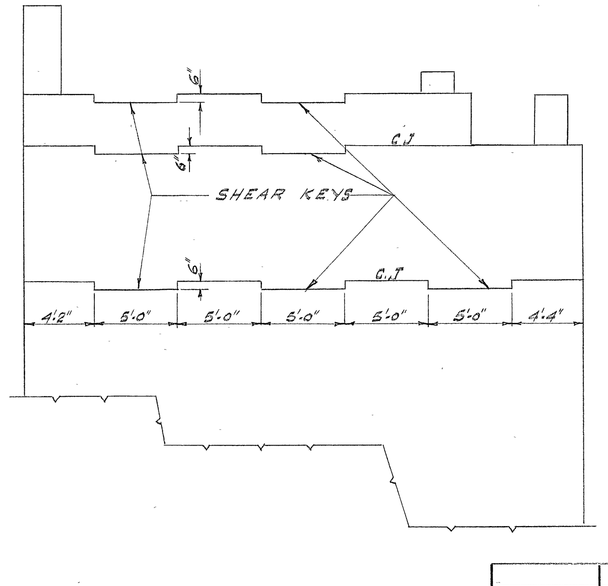
NOTE.
ANCHOR BOLTS SUPPLIED BY HORTON STEEL WORKS AND INSTALLED BY GENERAL CONTRACTOR.



PLAN OF SHEAR KEYS AT EL 281·75'



SECTION ELEVATION F-F



SECTION B-B

REGISTERED PROFESSIONAL ENGINEER
R.A. Robertson
PROVINCE OF NEWFOUNDLAND

FINAL

NOTES.
1) CONCRETE CLASS 2500 M.C.I. AGGREGATE 3" EXCEPT
   a. SUPPORT PEDESTALS CLASS 3500 PSI 1½" AGGREGATE
   b. GROUT IF REQD 3500 P.S.I.
2) MINIMUM COVER ON MAIN BARS 4" EXCEPT PEDESTALS 3"
3) EVERY COLD JOINT BETWEEN POURS SHALL BE SHEAR KEYED AS SHOWN
4) APPROX ROCK LEVEL IS SHOWN, CUT VERTICAL FACE STEEL AND PLACE HORIZONTAL FACE STEEL TO SUIT ACTUAL SOLID ROCK LEVELS

DWG Nº	TITLE
	REFERENCE DRAWINGS
F-2106-C-5	SURGE TANK 'C' FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS
F-2106-C-A	SURGE TANK 'C' - EXCAVATION & BACKFILL
F-2106-C-2	SURGE TANK 'C' - GENERAL LAYOUT & DETAILS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
			REVISIONS		

APPROVED FOR CONSTRUCTION
MAY 6 1968
APPROVED BY: [signature]
CHIEF ENGINEER

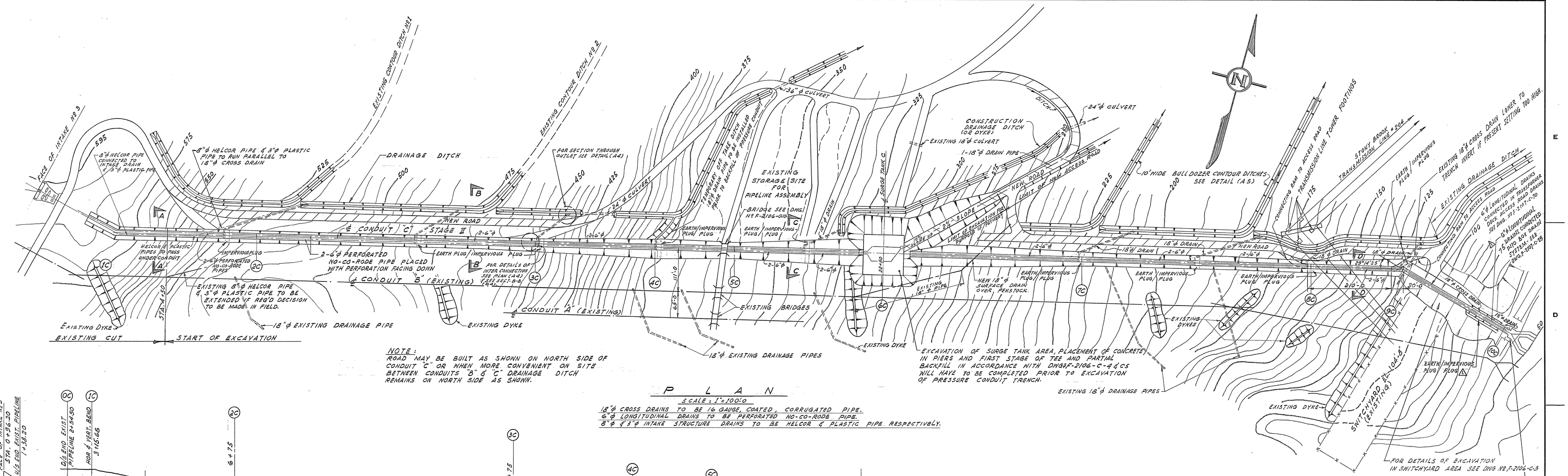
TRANS'N	ELECT'L	CIVIL
PASSED		

DESIGNED	D.B.
DRAWN	M.LEE
CHECKED	D.B.
RECOMMENDED	R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND
SURGE TANK "C"
TEE STAGE I
OUTLINE AND REINFORCING

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	3/16"=1'-0"	2-15	28TH FEB/68	F-2106-C-7	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 10, Page 37 of 39

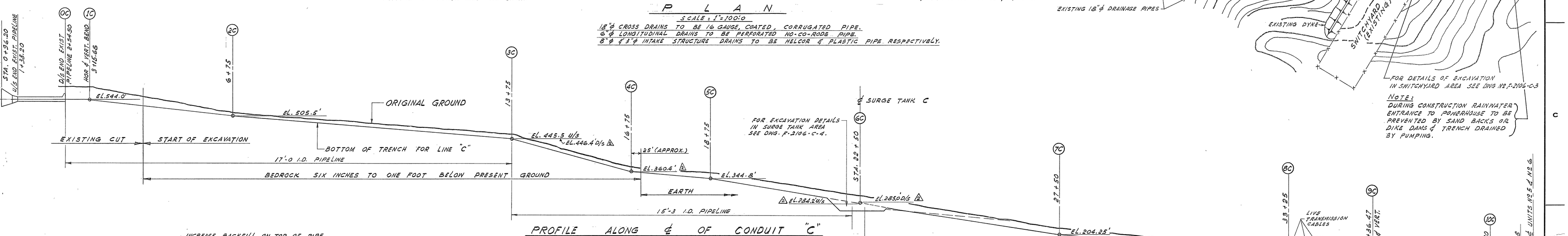


NOTE:
ROAD MAY BE BUILT AS SHOWN ON NORTH SIDE OF CONDUIT "C" OR WHEN MORE CONVENIENT ON SITE BETWEEN CONDUITS "B" & "C" DRAINAGE DITCH REMAINS ON NORTH SIDE AS SHOWN.

P L A N

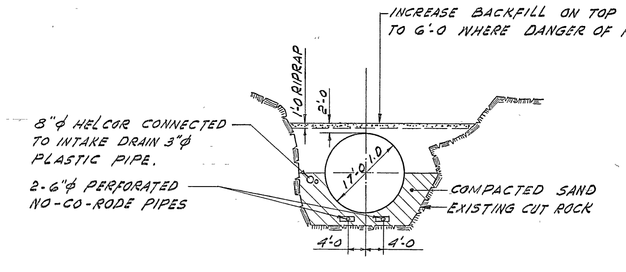
SCALE: 1"=100'-0

18"ϕ CROSS DRAINS TO BE 16 GAUGE, COATED, CORRUGATED PIPE.
6"ϕ LONGITUDINAL DRAINS TO BE PERFORATED NO-CO-RODE PIPE.
8"ϕ & 3"ϕ INTAKE STRUCTURE DRAINS TO BE HELCOR & PLASTIC PIPE RESPECTIVELY.



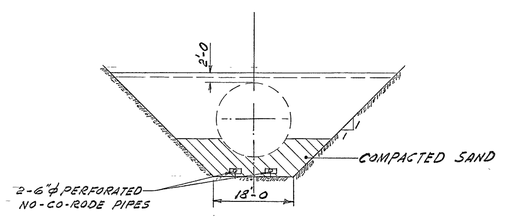
PROFILE ALONG ℄ OF CONDUIT "C"

SCALE: 1"=100'-0



SECTION A-A

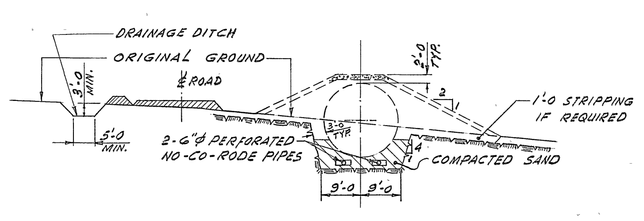
SCALE: 1"=20'-0



SECTION D-D

SCALE: 1"=20'-0

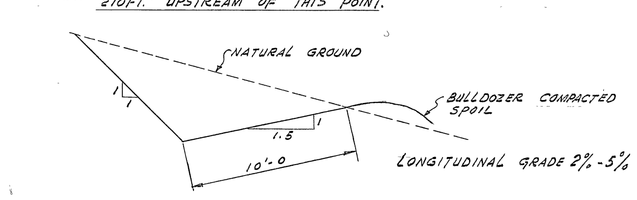
SECTION OF SPECIALLY EXCAVATED TRENCH FOR ERECTION OF PRESSURE CONDUIT UNDER TRANSMISSION LINE FROM A POINT 30 FT. U/S OF BEND 9C AND EXTENDING 210 FT. UPSTREAM OF THIS POINT.



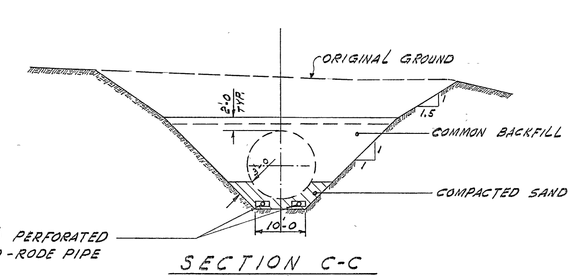
SECTION B-B

SCALE: 1"=20'-0

TYPICAL SECTION THROUGH ROCK CUT



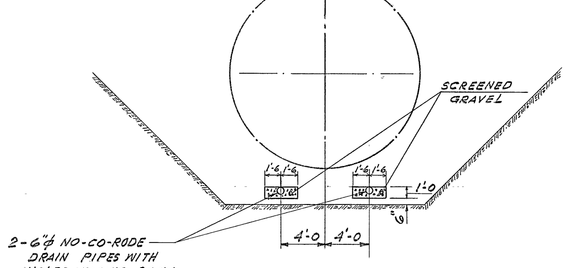
TYPICAL SECTION - BULLDOZER CONTOUR DITCH



SECTION C-C

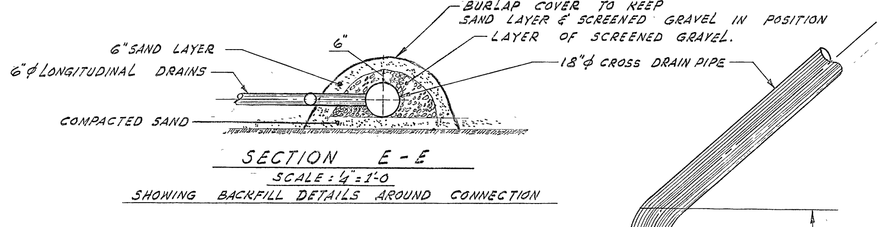
SCALE: 1"=20'-0

TYPICAL SECTION THROUGH EARTH CUT



DETAIL OF DRAIN

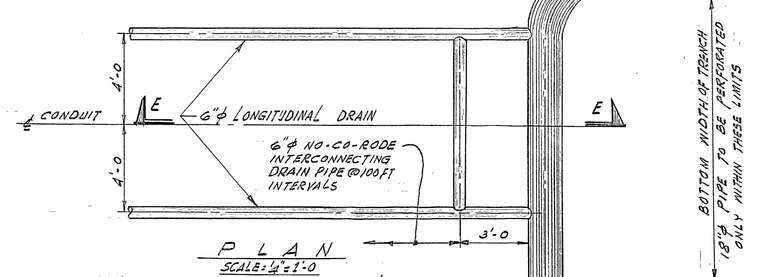
SCALE: ½"=1'-0



SECTION E - E

SCALE: ½"=1'-0

SHOWING BACKFILL DETAILS AROUND CONNECTION

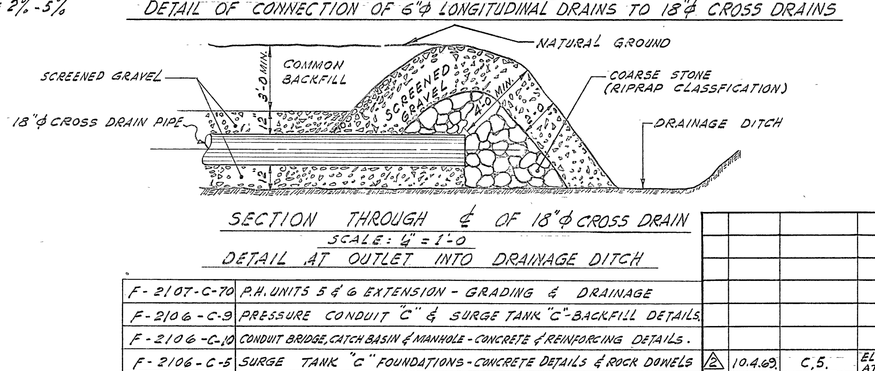


P L A N

SCALE: ½"=1'-0

SHOWING PIPE CONNECTION ONLY

DETAIL OF CONNECTION OF 6"ϕ LONGITUDINAL DRAINS TO 18"ϕ CROSS DRAINS



SECTION THROUGH ℄ OF 18"ϕ CROSS DRAIN

SCALE: ½"=1'-0

DETAIL AT OUTLET INTO DRAINAGE DITCH

NOTES

1. The civil works contractor shall keep the excavated works and the existing structures in the area secure against the destructive effects of the maximum expected storm water.
2. When a section of the pressure conduit trench to be left open for an appreciable length of time, the trench shall be closed with a 6' - 0" high plug of compacted selected common backfill. This plug shall be placed immediately upstream of the end of conduit and shall have sufficient drains to insure adequate control of run-off at all times during construction. The Engineer's decision of the adequacy of the contractor's provisions for drainage shall be final and binding.
3. For sequence of erection of pressure conduit "C" see Drawing No. F-2106-C-1.
4. New roads are shown as cross hatched.
5. 18 in. dia. cross drains to be installed when the conduit trench is being excavated. The unexcavated earth plugs (Clause C2.6) shall be left immediately downstream of the 18 in. dia. cross drains. The connection of the cross drains to the longitudinal drains shall be done after the erection of the conduit and just prior to the back-filling.
6. The location of the cross drains and earth plugs are approximate and the actual positions are to be determined in the field to the approval of the Engineer.
7. Impervious plugs (Clause C3.3). After erection of the conduit, the trench shall be filled to 1 ft. above the top of the pipe or to original grade, where this is below the top of the pipe, with selected common fill for a length of 6 feet at a point immediately downstream of the 18 in. dia. cross drains, to form a permanent impervious plug across the trench.
8. All the work indicated on this drawing must be done in accordance with Spec. M2-3714. Reference should be made to the following clauses:-
   C1 - Unwatering
   C2 - Excavation
   C3 - Backfill & Grading
   C4 - Foundation Drains

F-2107-C-70	P.H. UNITS 5 & 6 EXTENSION - GRADING & DRAINAGE						
F-2106-C-9	PRESSURE CONDUIT "C" & SURGE TANK "C" - BACKFILL DETAILS						
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLE - CONCRETE & REINFORCING DETAILS.						
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONCRETE DETAILS & ROCK DOWELS	2	10.4.68	C.S.	EL. 360.4' D/S AT BENT 3 C ADDED; EL. 360.4' AT BENT 4 C REVISED FROM EL. 360.1'		
F-2106-C-4	SURGE TANK "C" EXCAVATION & BACKFILL.			D.A.	EL. 284.0' U/S & EL. 285.0' D/S AT BENT 6 C REVISED FROM EL. 286.6' U/S & EL. 287.0' D/S	K.C.	D.B.
F-2106-C-3	PRESSURE CONDUIT "C" EXCAVATION DETAILS - LOCAL TO SWITCHYARD ENHANCEMENT	1	3.1.68	D.I.	DRAINAGE DETAILS BETWEEN BENDS 9C & 10C SHOWN	T.C.D.	D.B.
F-2106-C-1	PRESSURE CONDUIT "C" PLAN, PROFILE AND DETAILS	NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APP'D
	REFERENCE DRAWINGS.	REVISIONS					

APPROVED FOR CONSTRUCTION
JUL 26 1968
APPROVED BY: [signature] ENGINEER
Per [signature]

CONST.	TRANS'N	ELECT'L	CIVIL
PASSED			

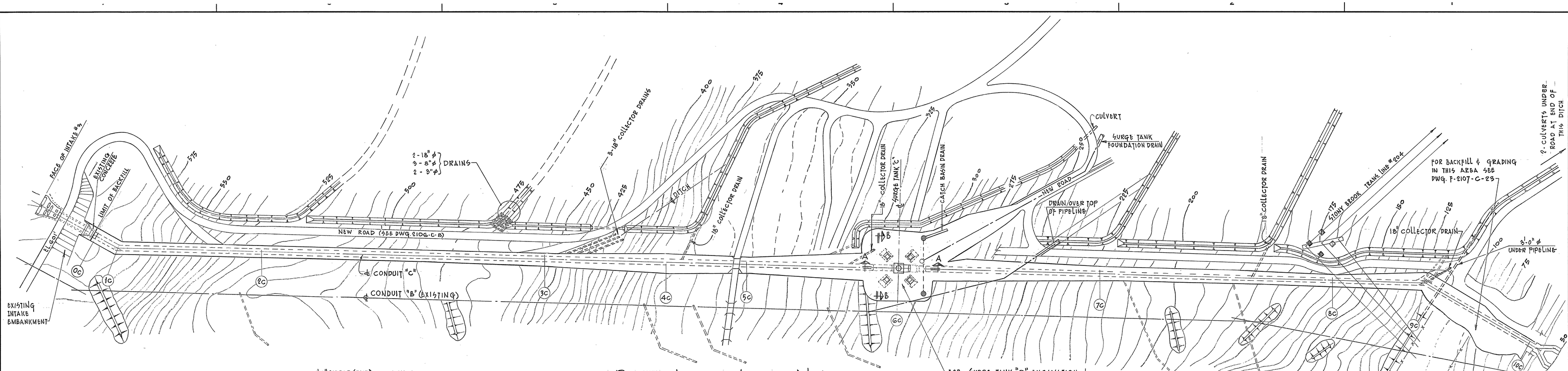
DESIGNED D.B.
DRAWN K.C.
CHECKED D.B.
RECOMMENDED R.H.L.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

PRESSURE CONDUIT "C" EXCAVATION AND DRAINAGE

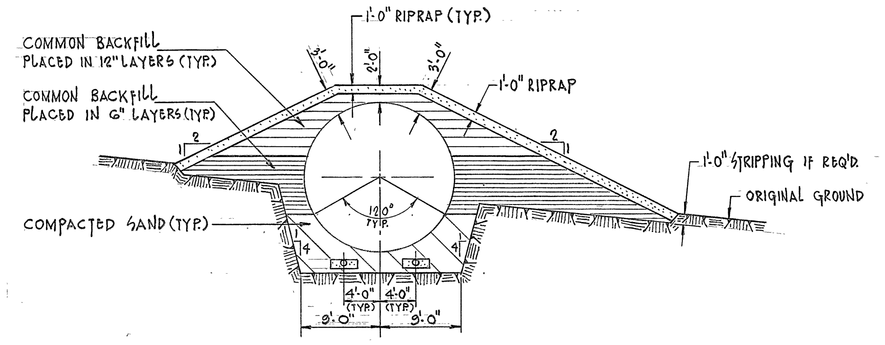
CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	As Noted	2-15	July 24, 1968	F-2106-C-8	2

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 10, Page 39 of 95



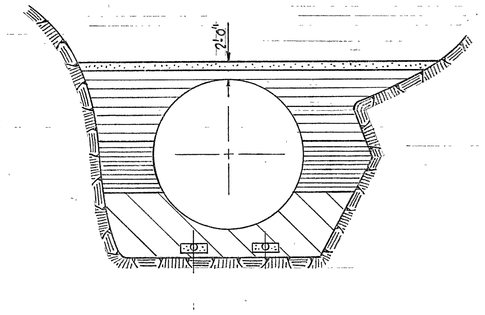
P L A N (2)

SCALE : 1" = 100'



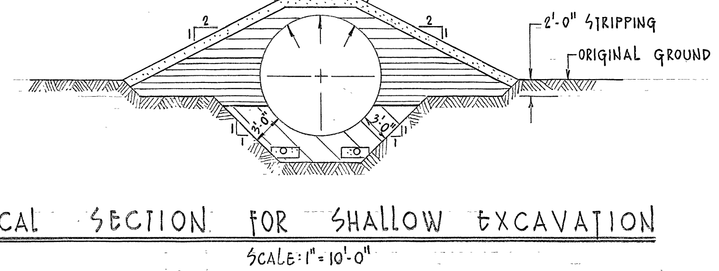
TYPICAL SECTION THROUGH ROCK CUT

SCALE : 1" = 10'-0"



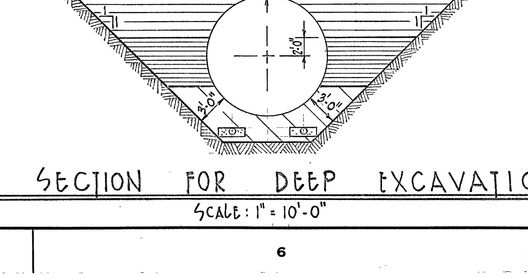
SECTION THROUGH EXISTING CUT ROCK

SCALE : 1" = 10'-0"



TYPICAL SECTION FOR SHALLOW EXCAVATION

SCALE : 1" = 10'-0"



TYPICAL SECTION FOR DEEP EXCAVATION

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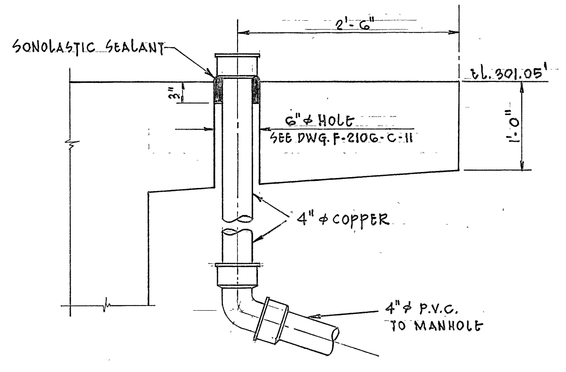
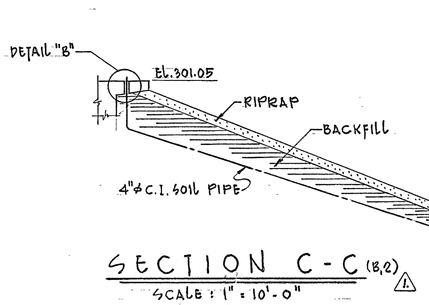


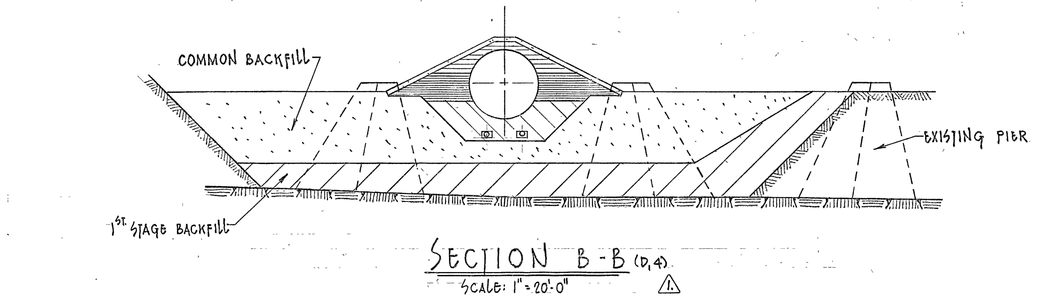
D E T A I L - B (C,9) ⚠1 ⚠2

SCALE : 1" = 1'-0"



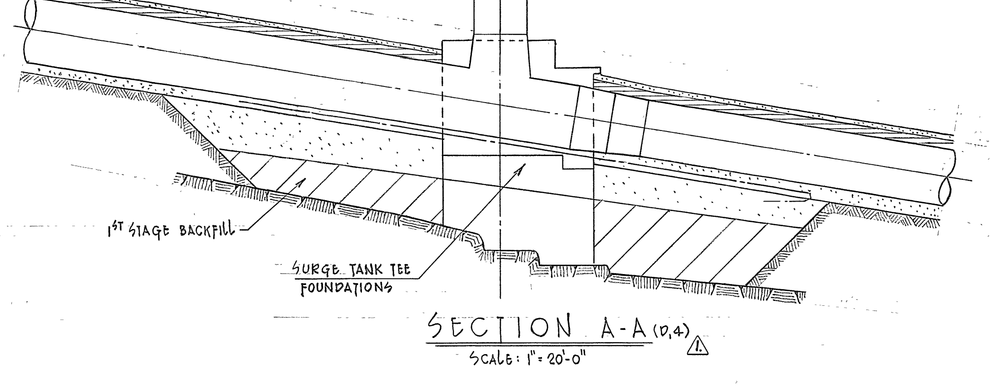
SECTION C-C (B,2) ⚠1

SCALE : 1" = 10'-0"



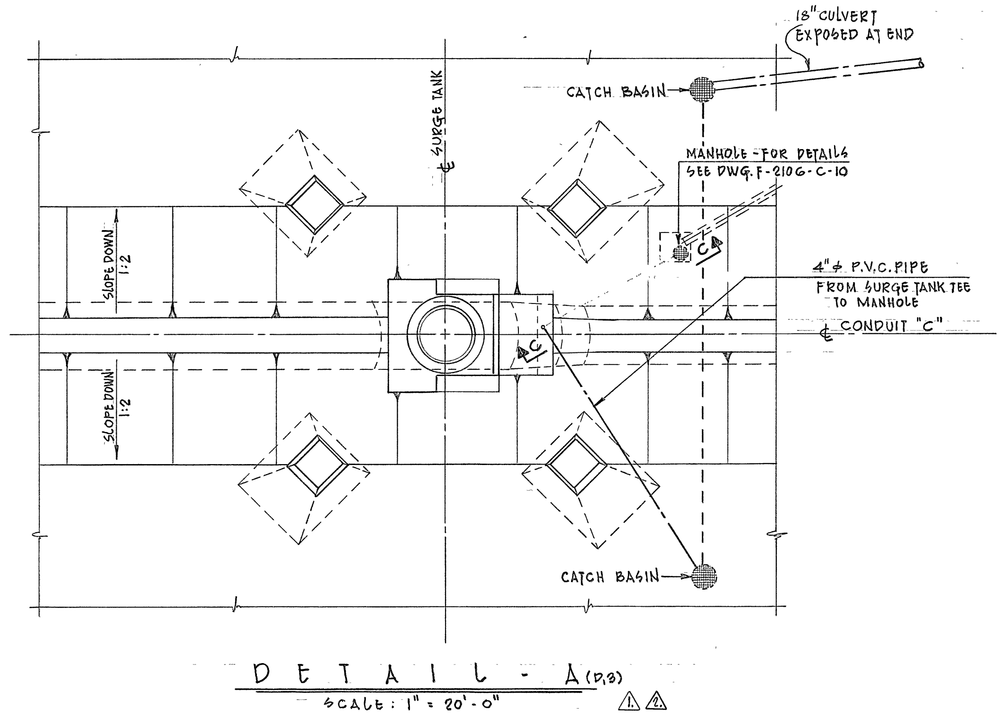
SECTION B-B (D,4)

SCALE : 1" = 20'-0" ⚠1



SECTION A-A (D,4) ⚠1

SCALE : 1" = 20'-0"



D E T A I L - A (D,9) ⚠1 ⚠2

SCALE : 1" = 20'-0"

NOTE:

⚠1 1. CONTRACTOR TO SUPPLY & INSTALL CAST IRON SOIL PIPE FROM SURGE TANK TEE TO MANHOLE UNDER SCHEDULE OF PRICE ITEM C1003.

⚠2 2. CONDUIT & SURGE TANK FOUNDATION DRAINAGE OUTLETS SHALL BE INSPECTED TWICE YEARLY AND CLEANED AS REQUIRED TO INSURE PROPER DRAINAGE.

REGISTERED PROFESSIONAL ENGINEER — R.A.R. Robertson — SIGNATURE — PROVINCE OF NEWFOUNDLAND

FINAL

DWG. No.	TITLE
F-2106-C-1	PRESSURE CONDUIT "C" - PLAN, PROFILE & DETAILS
F-2106-C-2	SURGE TANK "C" - GENERAL LAYOUT & DETAILS
F-2106-C-3	PRESSURE CONDUIT "C" & SURGE TANK "C" - EXCAVATION & DRAINAGE
F-2106-C-4	SURGE TANK "C" - EXCAVATION & BACKFILL
F-2106-C-5	" " " - FOUNDATIONS, CONCRETE DETAILS & ROCK DOWELS
F-2106-C-8	PRESSURE CONDUIT "C" - EXCAVATION & DRAINAGE
F-2106-C-10	CONDUIT BRIDGE, CATCH BASIN & MANHOLE - CONCRETE & REINF. DETAILS
F-2106-C-11	SURGE TANK "C" - TEE STAGE II - CONCRETE DETAILS

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
⚠1	12 NOV. 69		DWG. REVISED TO SHOW AS-BUILT	T.C.D	
			DETAILS. NOTE 2 ADDED		
⚠1	6 JUL. 69	A-C, 2-5.	SECTIONS A, B & C, DETAILS A & B NOTE ADDED	T.C.D	D.B.

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 9 1969
APPROVED BY: CHIEF ENGINEER

PASSED: TRANS'N | ELECT'L | CIVIL

DESIGNED	A.B.
DRAWN	T.C. DAVIS
CHECKED	D.B.
RECOMMENDED	

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

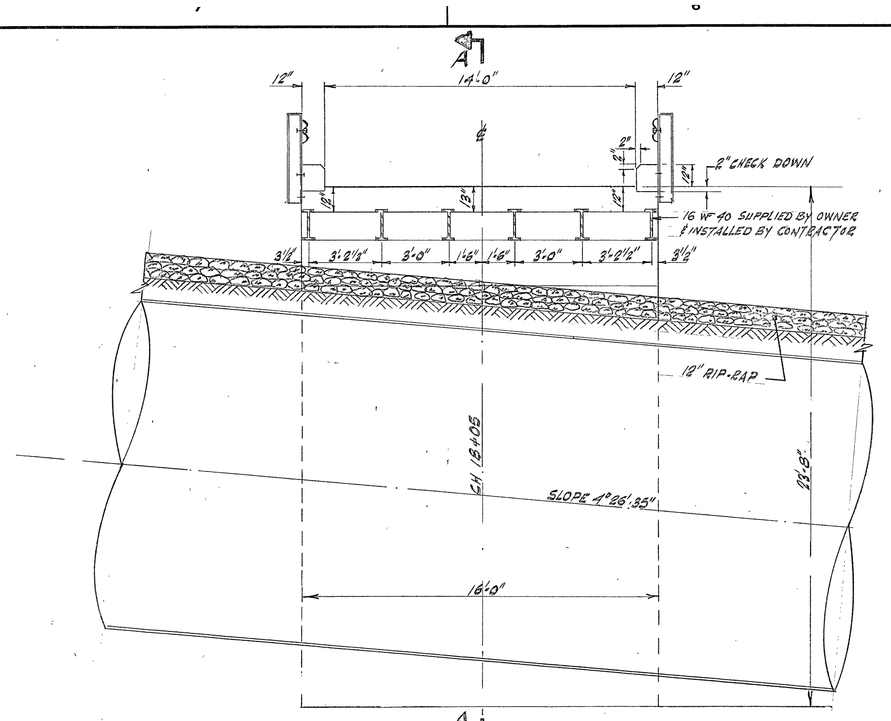
BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

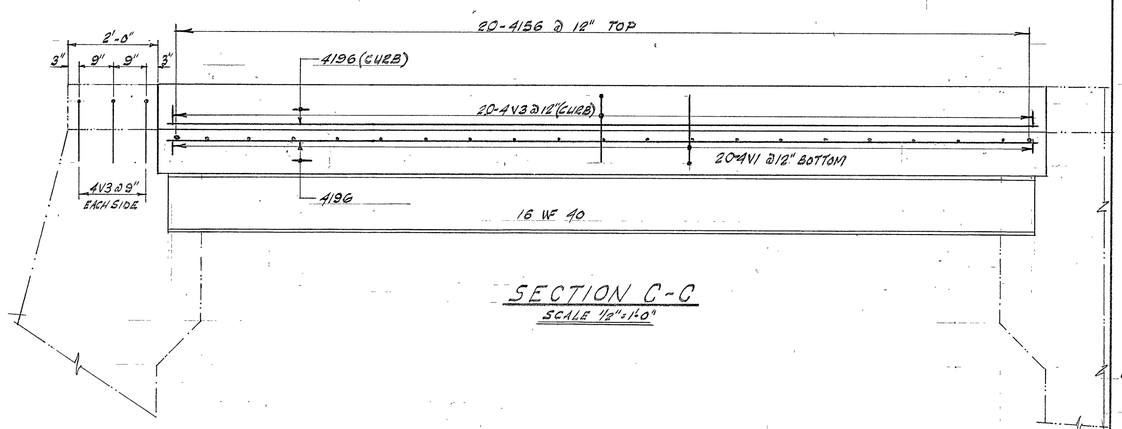
PRESSURE CONDUIT "C" & SURGE TANK "C" BACKFILL DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	AS SHOWN	2-15	5TH SEPT. 1968	F-2106-C-9	2.

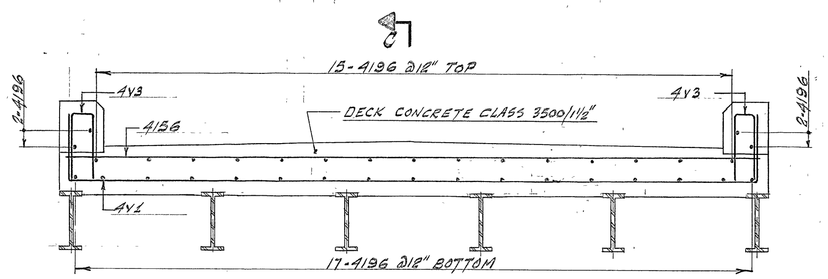
Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule A, Attachment 10, Page 39 of 95



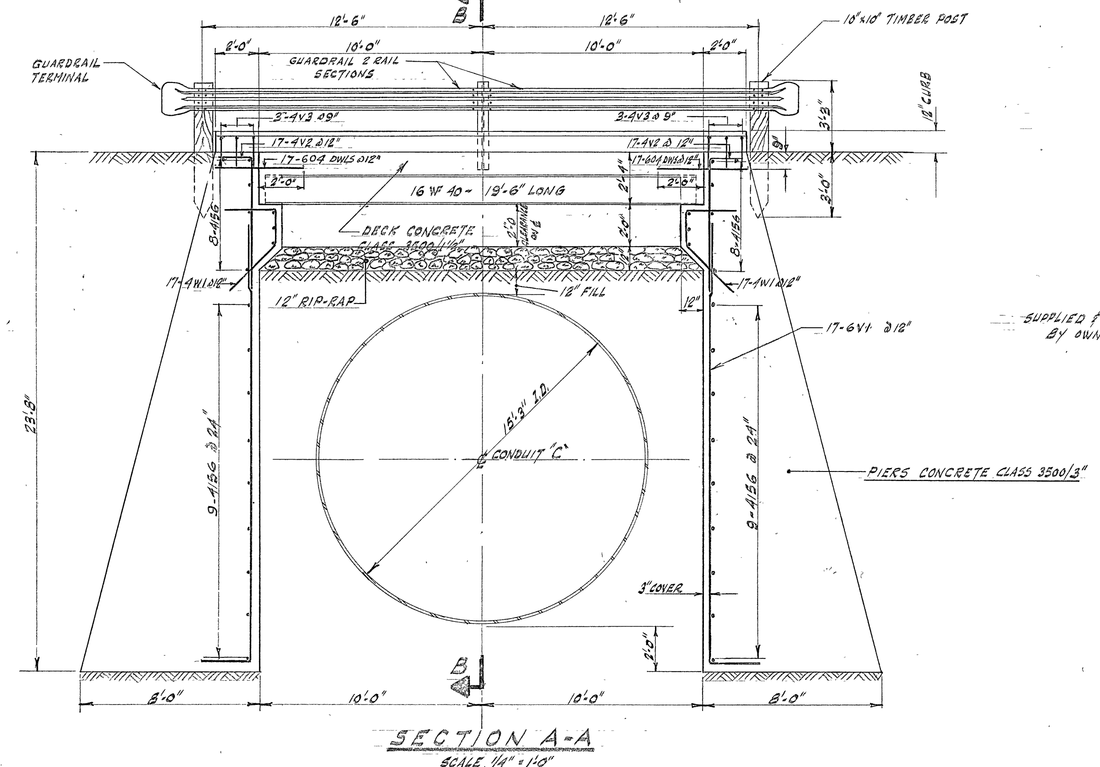
SECTION B-B
SCALE 1/4" = 1'-0"



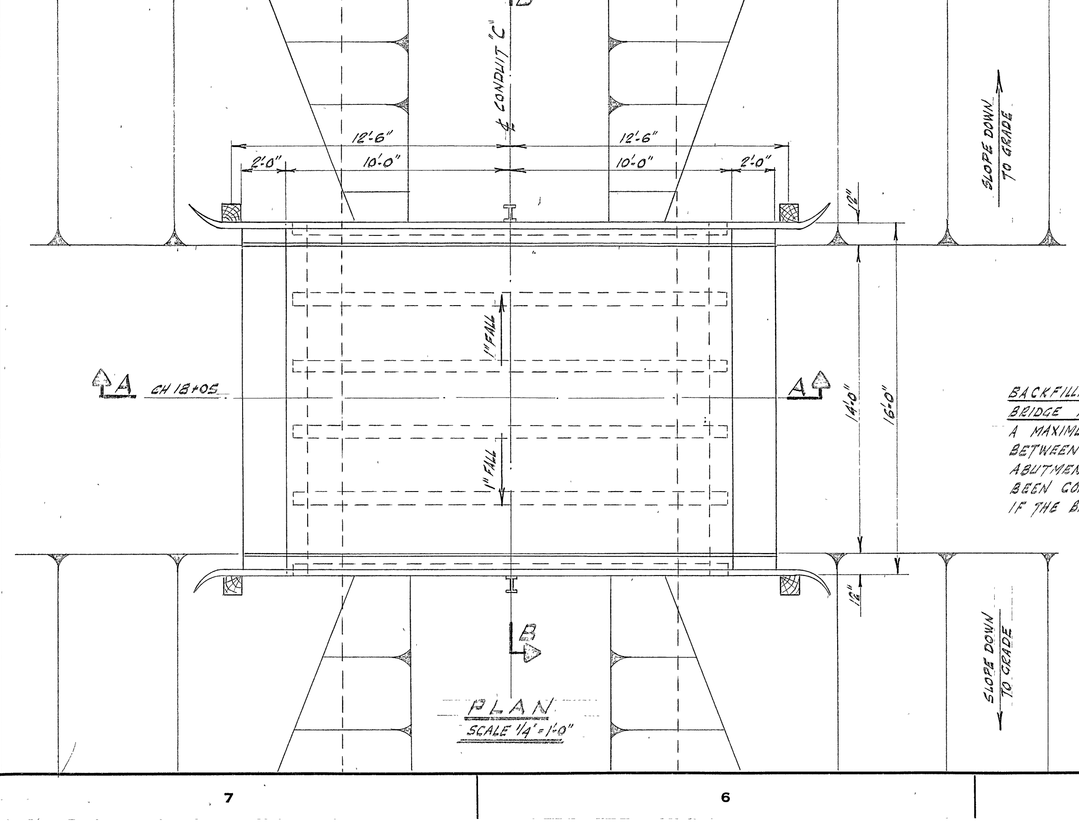
SECTION C-C
SCALE 1/2" = 1'-0"



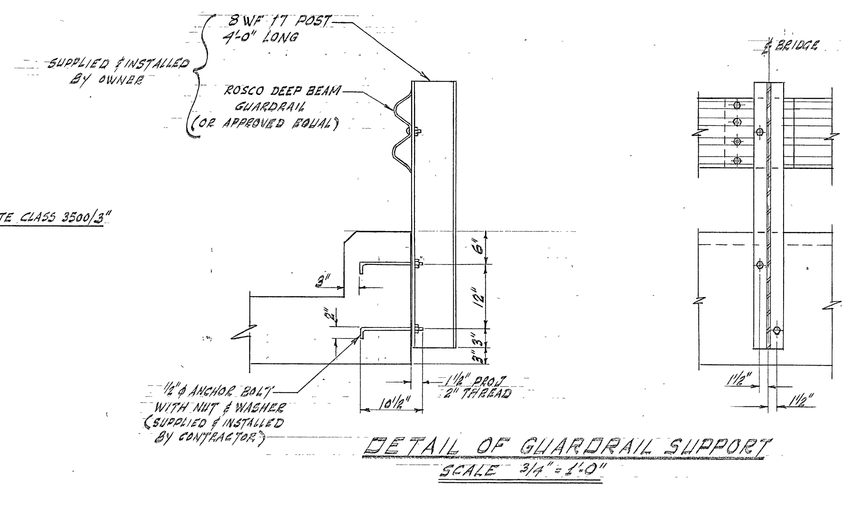
DECK SLAB
SCALE 1/2" = 1'-0"



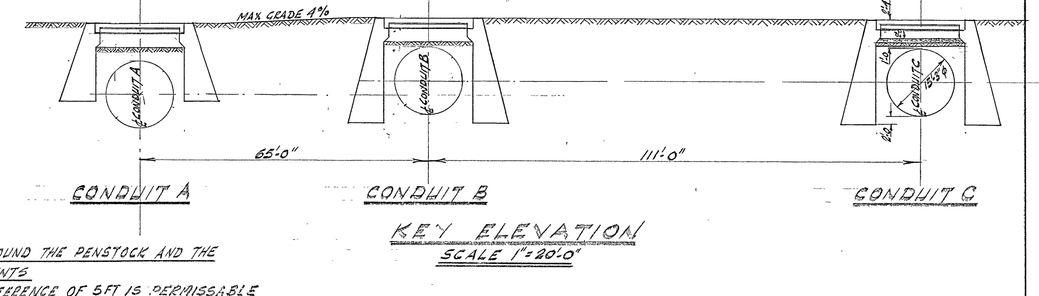
SECTION A-A
SCALE 1/4" = 1'-0"



PLAN
SCALE 1/4" = 1'-0"



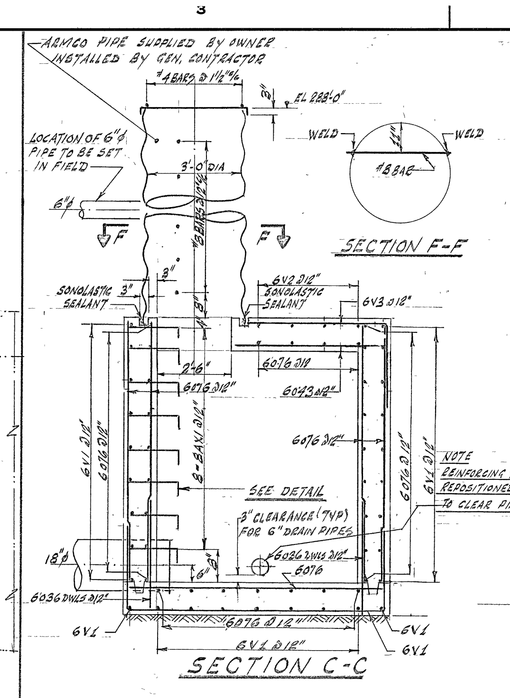
DETAIL OF GUARDRAIL SUPPORT
SCALE 3/4" = 1'-0"



CONDUIT A — CONDUIT B — CONDUIT C

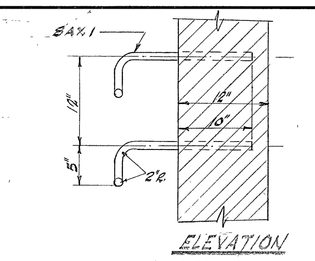
KEY ELEVATION
SCALE 1" = 200'

BACKFILLING AROUND THE PENSTOCK AND THE BRIDGE ABUTMENTS
A MAXIMUM DIFFERENCE OF 5FT IS PERMISSABLE BETWEEN THE FILL ON EITHER SIDE OF THE ABUTMENT IF THE BRIDGE DECK HAS NOT BEEN CONSTRUCTED. THERE IS NO LIMITATION IF THE BRIDGE IS COMPLETE

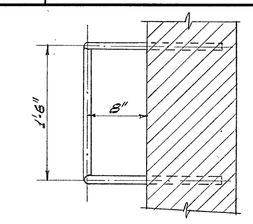


SECTION F-F

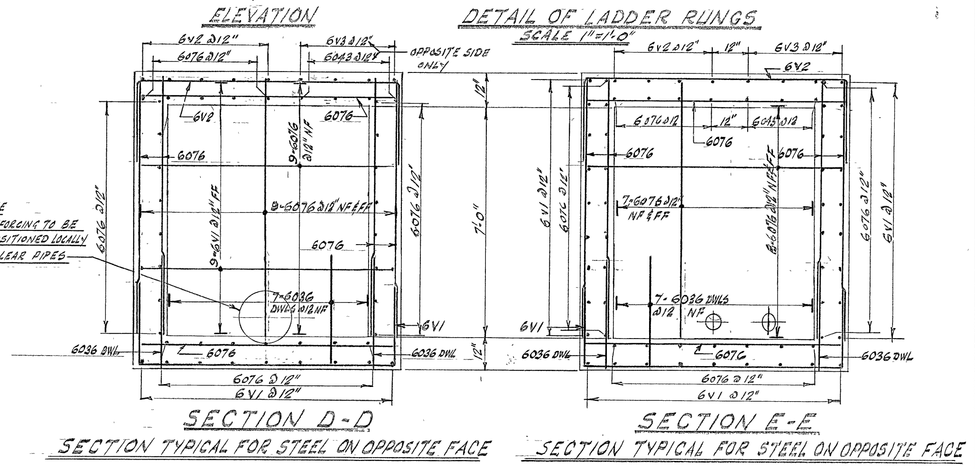
SECTION C-C



ELEVATION

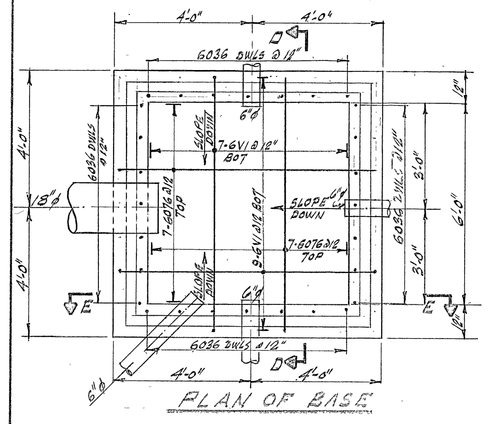


DETAIL OF LADDER RUNGS
SCALE 1" = 1'-0"

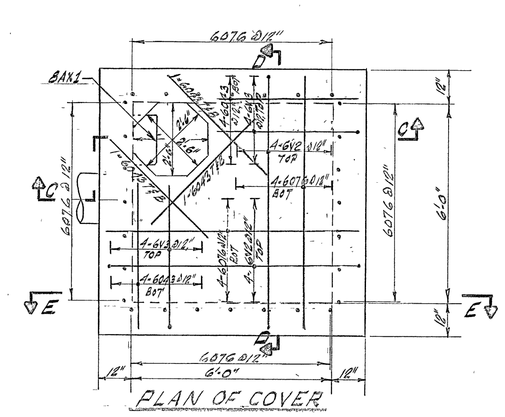


SECTION D-D
SECTION TYPICAL FOR STEEL ON OPPOSITE FACE

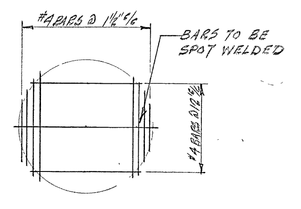
SECTION E-E
SECTION TYPICAL FOR STEEL ON OPPOSITE FACE



PLAN OF BASE



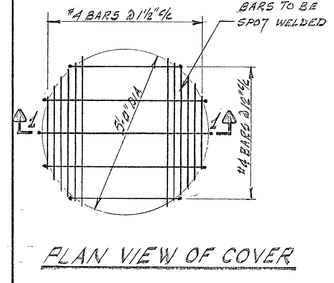
PLAN OF COVER



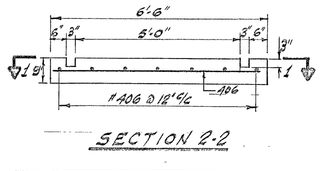
PLAN VIEW OF COVER

MANHOLE DETAILS
SCALE 3/8" = 1'-0"

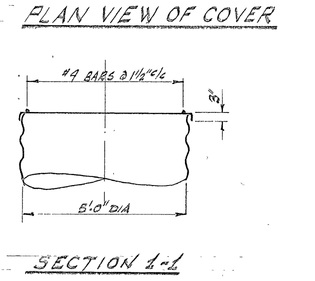
FOR MANHOLE LOCATION SEE DWG F-2106-C-4



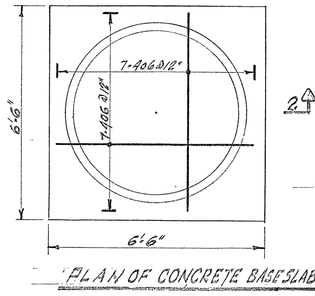
PLAN VIEW OF COVER



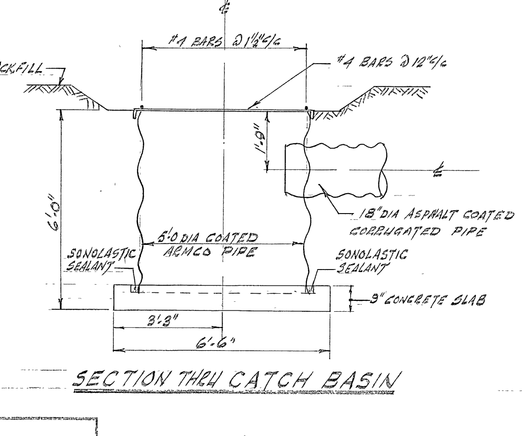
SECTION 2-2



SECTION 1-1



PLAN OF CONCRETE BASESLAB



SECTION THRU CATCH BASIN

CATCH BASIN DETAILS
SCALE 3/8" = 1'-0"
Nº REQUIRED 2

FOR LOCATION OF CATCH BASIN SEE DWG F-2106-C-A

FINAL

FOR CATCH BASIN MATERIAL SUPPLIED BY GENERAL CONTRACTOR

DWG Nº	TITLE
BL-2106-C-10	BAR LIST
BM-2106-C-10	BILL OF MATERIAL
F-2106-C-3	PRESSURE CONDUIT 'C' EXCAVATION & DRAINAGE
F-2106-C-1	PRESSURE CONDUIT 'C' PLAN PROFILE & DETAILS
F-2106-C-4	SURGE TANK - EXCAVATION & BACKFILL

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 19 1988
APPROVED BY
CHIEF ENGINEER

CONST	TRANS'N	ELECT'L	CIVIL

PASSED

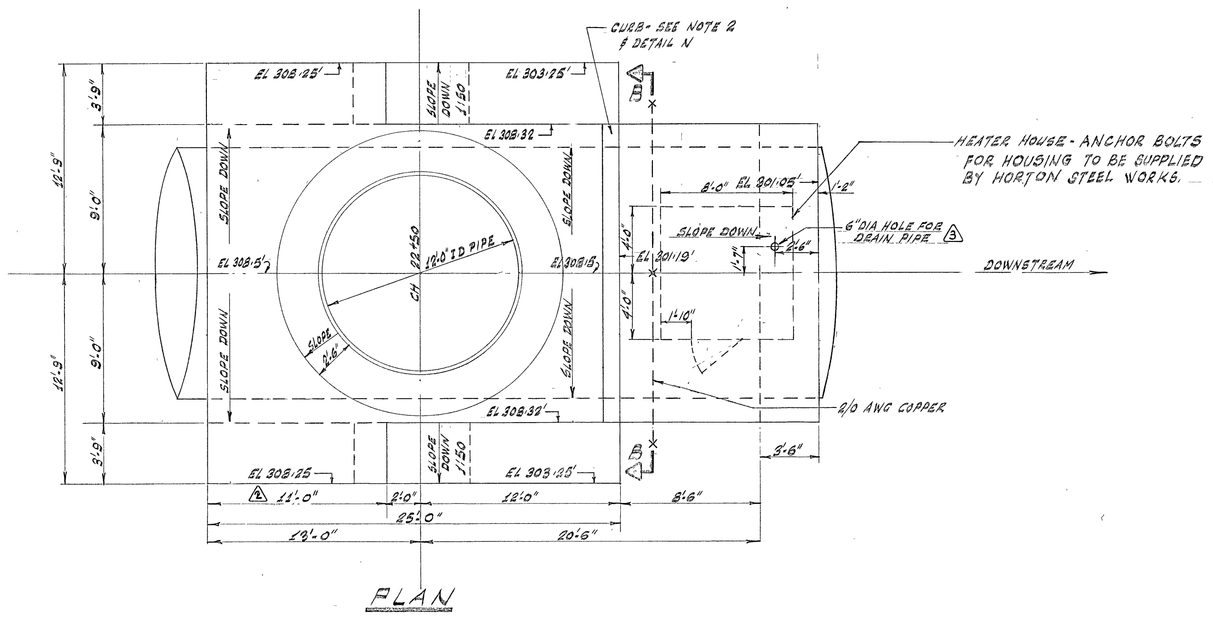
DESIGNED DB
DRAWN H.LEE
CHECKED DB
RECOMMENDED R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

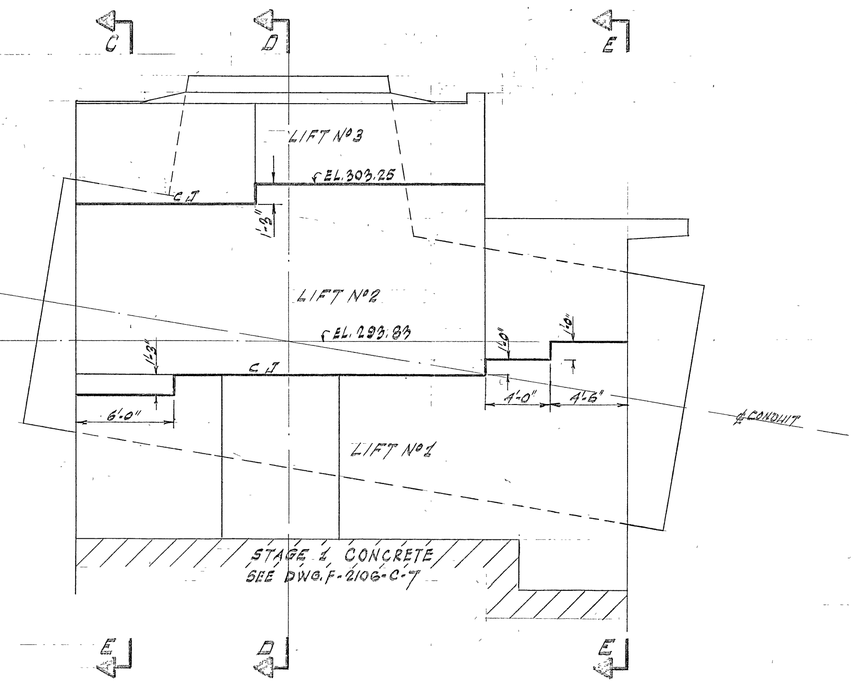
SURGE TANK 'C'
CONDUIT BRIDGE - CATCH BASIN & MANHOLE CONCRETE & REINFORCING DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	NOTED	2-12	10TH JUNE 88	F-2106-C-10	

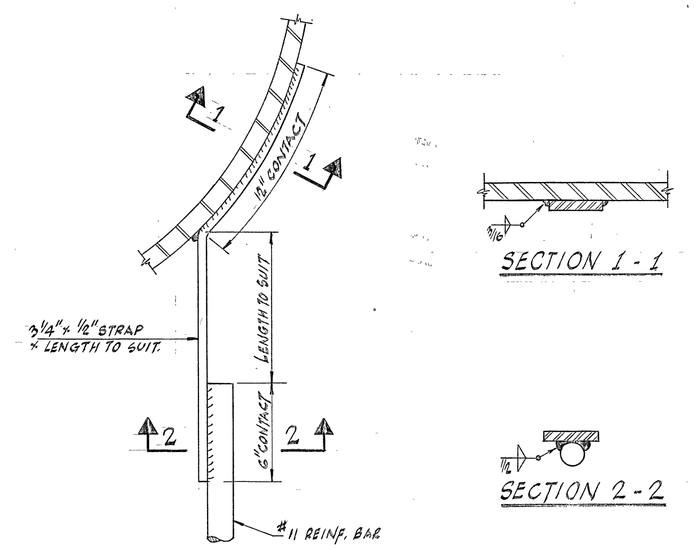
Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 10, Page 46 of 55



PLAN

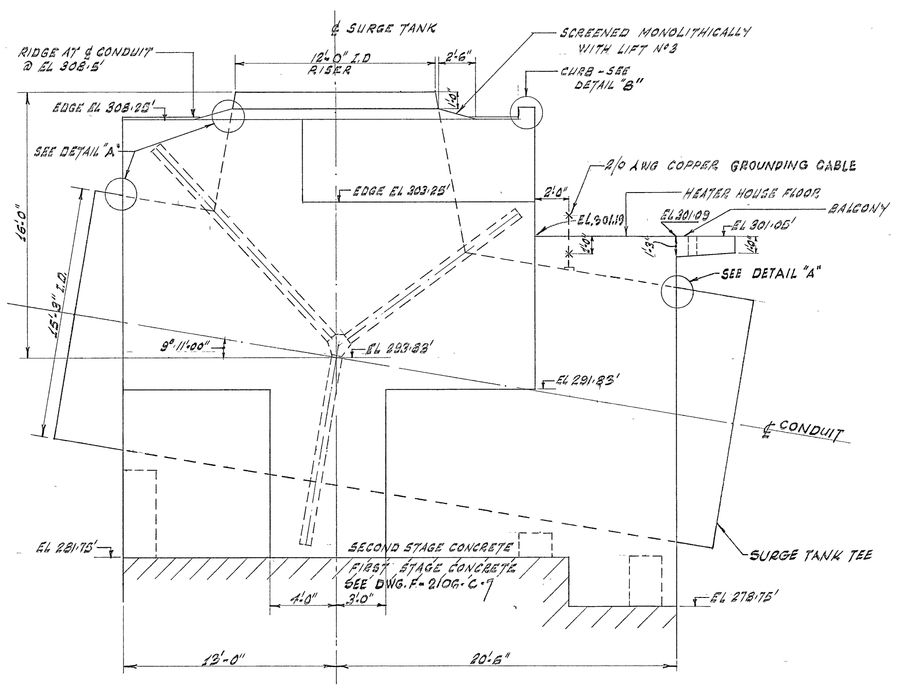


SIDE ELEVATION

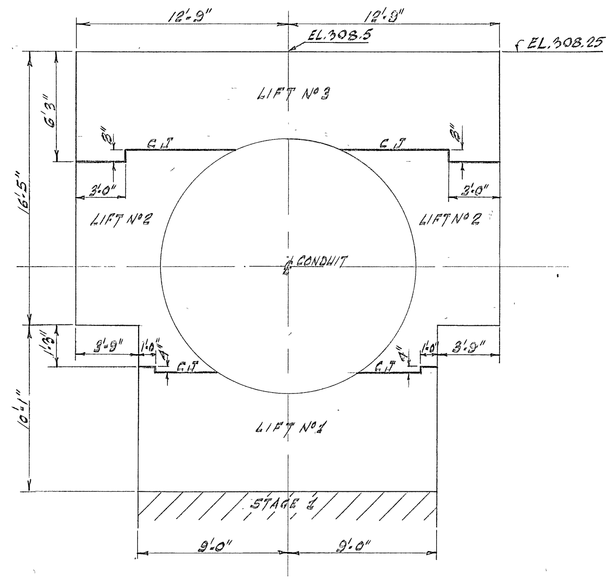


DETAIL OF HOLD DOWN STRAP ANCHOR

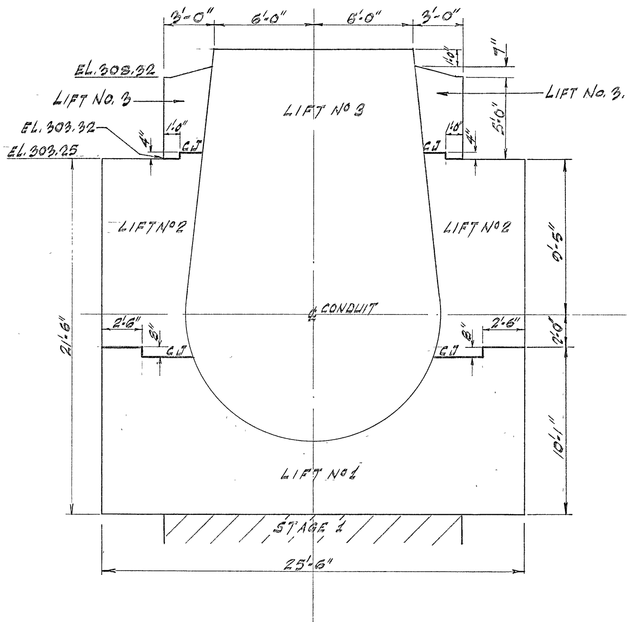
FOR LOCATION OF #11 REINF BARS SEE DWG. F-2106-C-7



SIDE ELEVATION OF SURGETANK TEE & CONCRETE

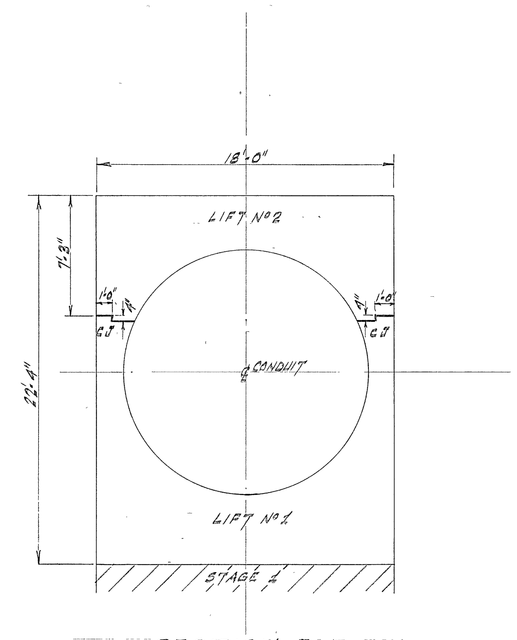


SECTION C-C

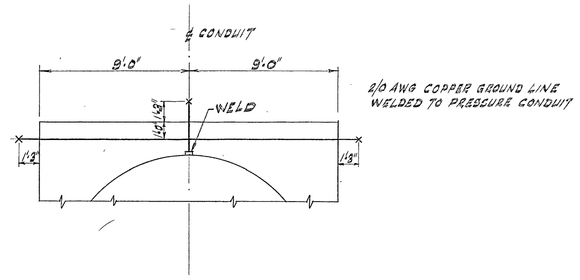


SECTION D-D

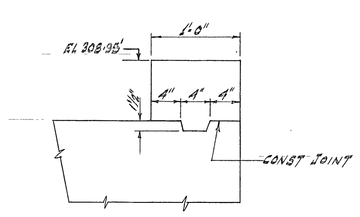
SYSTEM OF CONSTRUCTION JOINTS & LIFTS



SECTION E-E

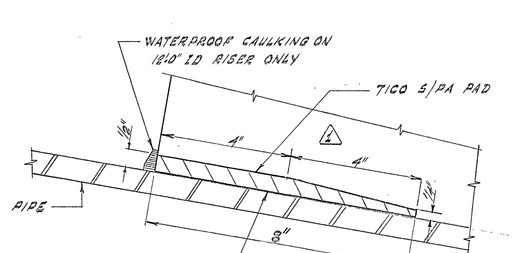


SECTION B-B



CURB DETAIL "B"

SCALE 1"=1'-0"



DETAIL A

SCALE = N.T.S.

TYPICAL AT ALL SURFACES WHERE PIPE EMERGES FROM CONCRETE BLOCK.

NOTE: WORTON STEEL WORKS TO SUPPLY AND INSTALL TICO PADS.

NOTE: ALL 2/0 AWG COPPER GROUNDING CABLE TO BE SUPPLIED AND WELDED BY THE OWNER AND INSTALLED BY GENERAL CONTRACTOR.

FINAL

DRWG No	TITLE	DWG No	TITLE
F-2106-C-4	SURGE TANK "C" TEE STAGE I - OUTLINE & REINFORCING		
F-2106-C-5	SURGE TANK "C" FOUNDATIONS - CONC. DET'LS & ROCK DOWELS		

REFERENCE DRAWINGS

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	18 OCT 68	E. G.	6'9" DOWN RELOCATED HEATER HOUSE DIM ADDED	HL	DB
2	18 SEPT 68	D.T	DIMENSION CHANGE	HL	DB
1	30 AUG 68	A.G	TICO S/PA PAD RE-SHAPED & DIM ADDED	HL	D.B

REVISIONS

APPROVED FOR CONSTRUCTION

AUG 22 1968

APPROVED BY: Rose Drinkwater

TRANS'N | ELECT'L | CIVIL

PASSED

DESIGNED DB

DRAWN H.L.E.E.

CHECKED D.B.

RECOMMENDED R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION

BAY D'ESPOIR DEVELOPMENT STAGE II

ENGINEERING AND DESIGN BY

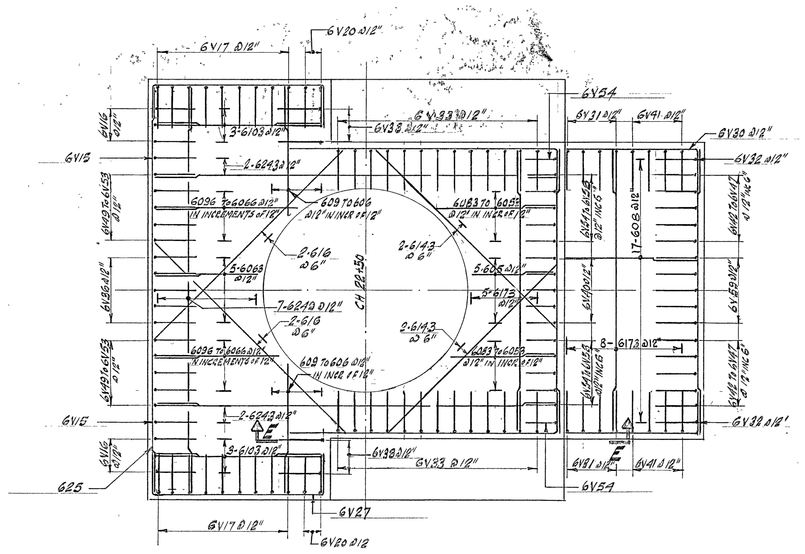
SHAWMONT NEWFOUNDLAND LIMITED

ST JOHN'S NEWFOUNDLAND

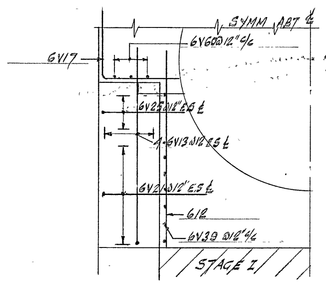
SURGE TANK "C" TEE STAGE II CONCRETE DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	3/16"=1'-0"	2-15	24TH JULY 68	F-2106-C-11	3

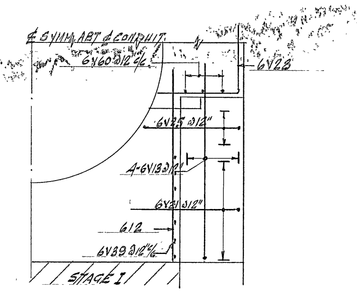
Pentstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 10, Page 41 of 95



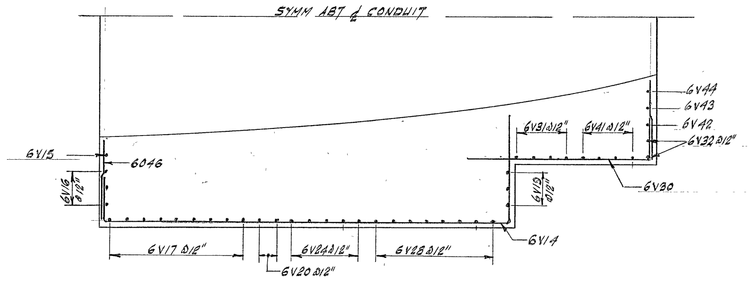
PLAN



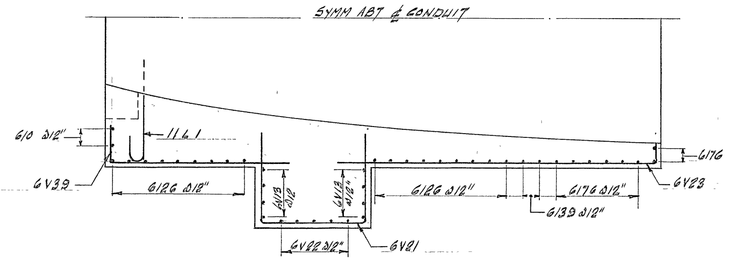
SECTION G-G



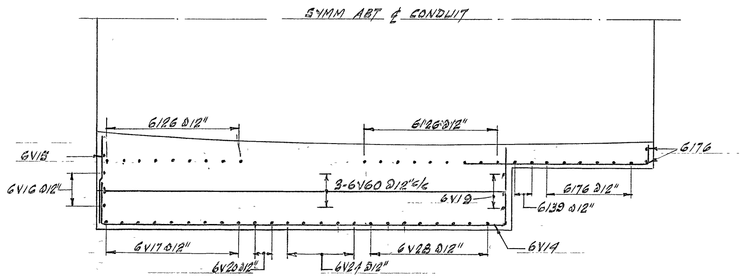
SECTION H-H



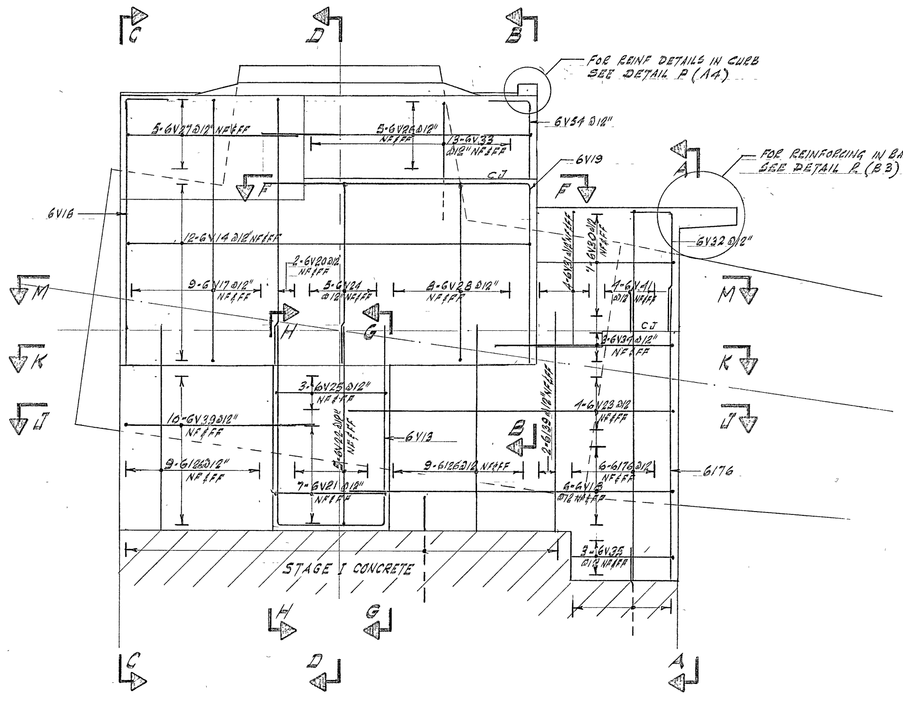
SECTION M-M



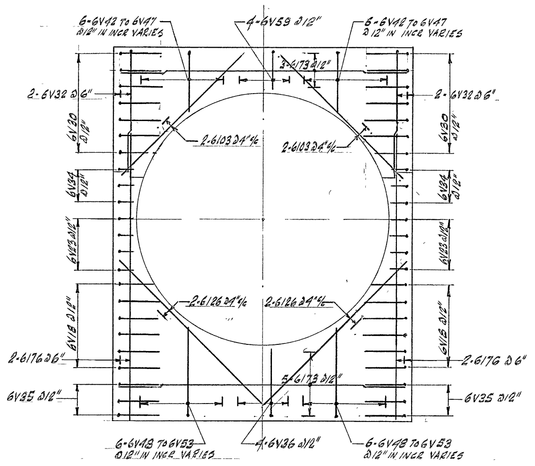
SECTION J-J



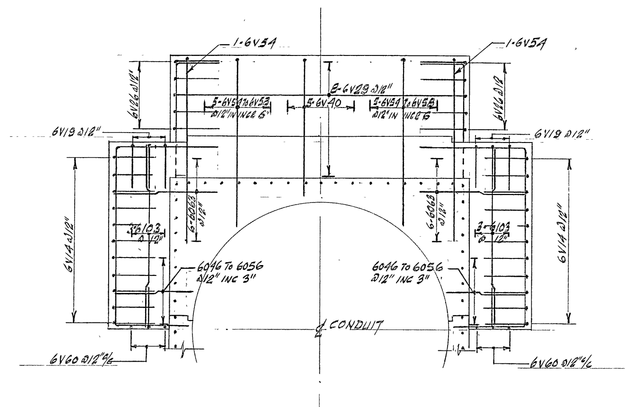
SECTION K-K



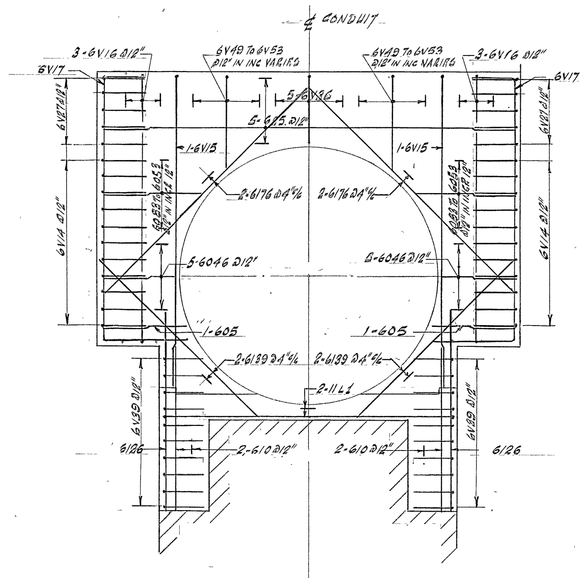
SIDE ELEVATION



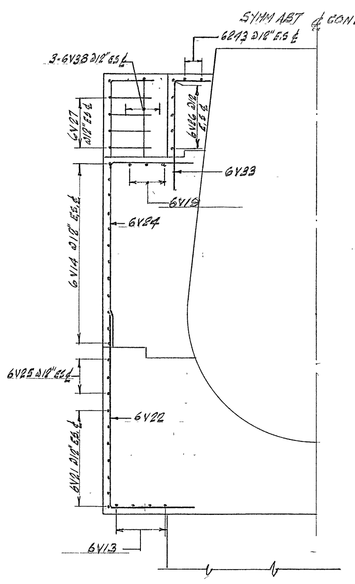
END VIEW A-A



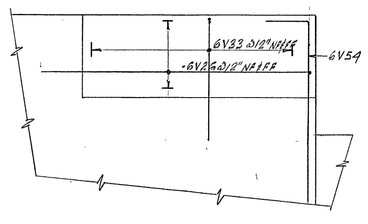
SECTION B-B



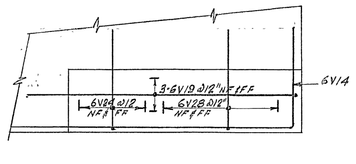
END VIEW C-C



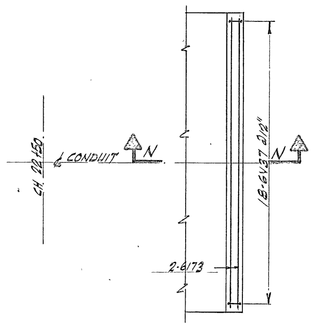
SECTION D-D



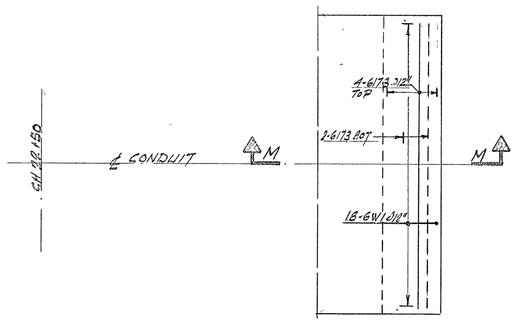
SECTION E-E



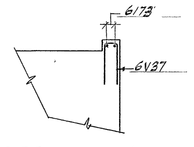
SECTION F-F



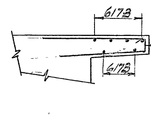
DETAIL P-PLAN OF CURB



DETAIL R-PLAN OF BALCONY



SECTION N-N



SECTION M-M

NOTE
COVER TO REINFORCEMENT TO BE 4" EXCEPT WHERE NOTED

REGISTERED PROFESSIONAL ENGINEER
R.A. Robertson
PROVINCE OF NEWFOUNDLAND

FINAL

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
			REVISIONS		

APPROVED FOR CONSTRUCTION
SEP 16 1993
APPROVED BY: CHIEF ENGINEER

TRANS'N	ELECT'L	CIVIL
PASSED		

F-2106-C-11 | SURGE TANK 'C' - TEE STAGE II CONCRETE DETAIL
DWG N° | TITLE
REFERENCE DRAWINGS

DESIGNED: DB
DRAWN: H. LEE
CHECKED: D.B.
RECOMMENDED: R.M.J.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT STAGE II
ENGINEERING AND DESIGN BY
SHAWMONT NEWFOUNDLAND LIMITED
ST JOHN'S NEWFOUNDLAND

SURGE TANK 'C'
TEE STAGE II REINFORCING DETAILS

CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	3/16"=1'-0		23RD AUG 68.	F-2106-C-12	0

Penstock 3 Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 4, Attachment 2(c) Page 42 of 95

APPENDIX B

PHOTOGRAPHS



Photo 1 Top of New Gate



Photo 2 Bottom of New Gate and Leakage at North Seal



Photo 3 Transition Between Intake and Steel Penstock – Looking North



Photo 4 Typical Condition of Concrete at Transition – Looking South



Photo 5 Steel Surface Can 160



Photo 6 New Organic Growth



Photo 7 Steel Surface Can 192



Photo 8 Steel Surface Can 219



Photo 9 Surface Condition Can 252



Photo 10 Steel Surface Can 315



Photo 11 Cleaned and Prepped Surface of Original Weld - Can 144



Photo 12 Pitting on Longitudinal and Circumferential Welds - Can 173



Photo 13 Pitting on Longitudinal Weld - Can 260S



Photo 14 Condition of Previously Repaired Weld - Can 339S



Photo 15 Scaffolding Platform Platform

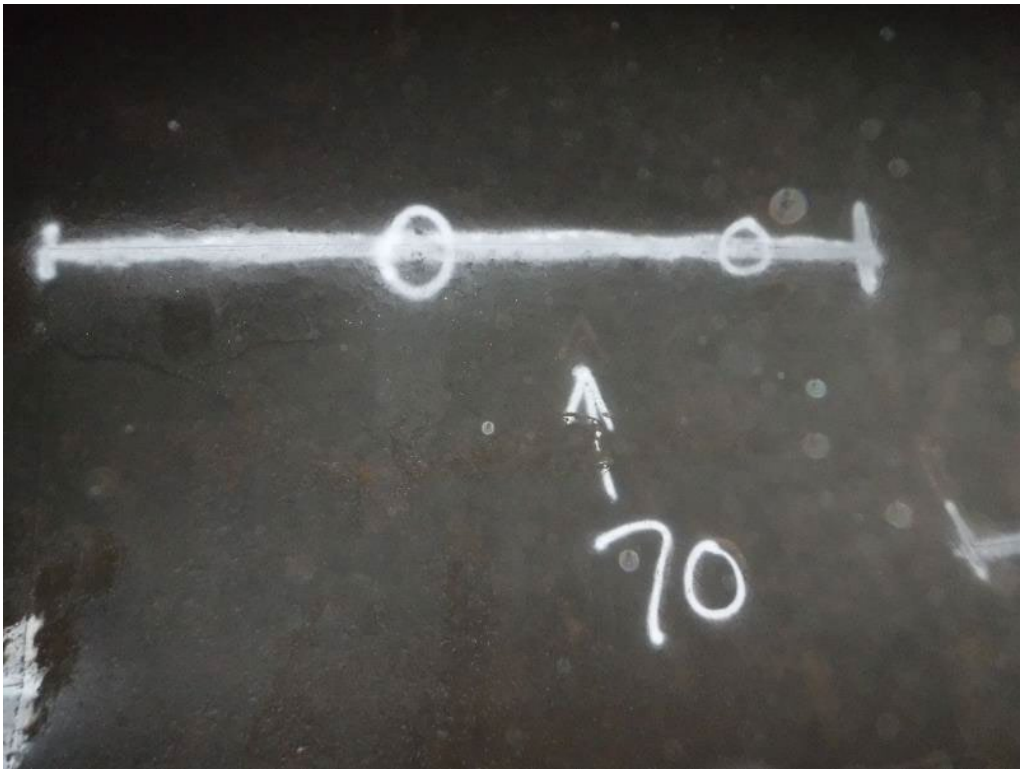


Photo 16 Weld indications Can 70



Photo 17 Weld Indication No.1 at Can 70



Photo 18 Weld indication No.2 at Can 70

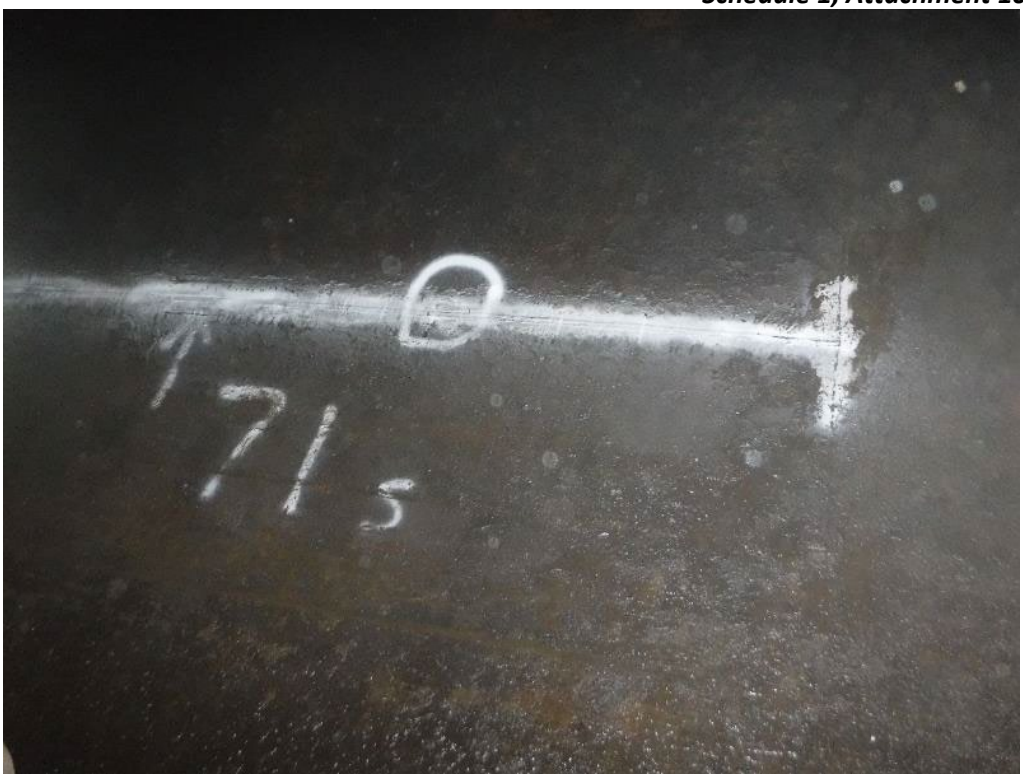


Photo 19 Weld indication at Can 71S



Photo 20 Weld indication at Can 71S



Photo 21 Surge Tower Riser Opening



Photo 22 Looking Downstream from About Station 00+50



Photo 23 Looking Upstream Towards Intake from Station 01+50



Photo 24 Looking Downstream Towards Surge Tower from Station 01+50



Photo 25 Looking Downstream Towards Surge Tower



Photo 26 Weir N2



Photo 27 Weir N2



Photo 28 Looking Upstream from Access Road Crossing Penstocks



Photo 29 Looking Downstream at Surge Tower



0

Photo 30 Base of Surge Tower



Photo 31 Base of Surge Tower – Looking South



Photo 32 Erosion Around Base of Surge Tower



Photo 33 Efflorescence on Concrete Base



Photo 34 Looking Upstream Towards Surge Tower



Photo 35 Looking Downstream at Switchyard



Photo 36 Drainage Pipe on Northside of Penstock



Photo 37 Drainage Basin on Northside of Penstock Near Switchyard



Photo 38 Maintenance Hole Near Switchyard



Photo 39 Looking Downstream at Switchyard

APPENDIX C

WELD TEST

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

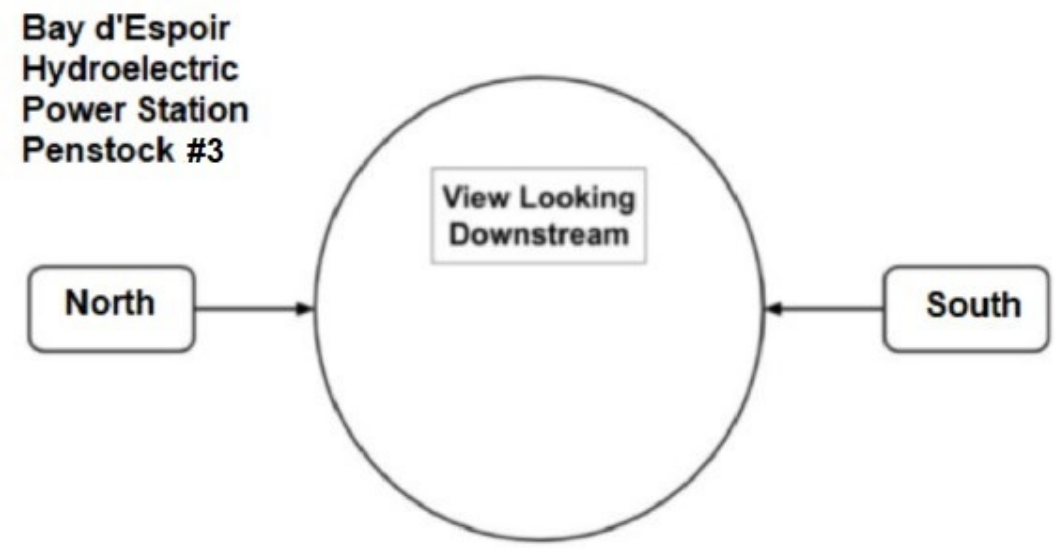
Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	24-402-1	Copy:	
Date:	5-9 May, 2024	Date Received:	5 May, 2024
Client:	Technical Rope & Rescue Inc. 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy, SNT TC-1A: UT, ET, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I XRF Level I
Attn:	Todd LeGrow		
P.O. No.	2024-0133		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3		
Testing Required:	Magnetic Particle Inspection	Signed:	NDT Inspector

Remarks

As directed, our technicians performed magnetic particle inspections on existing horizontal and circumferential welds of the above noted penstock. The magnetic particle inspection was carried out using the wet continuous visible method, to detect surface cracks. Testing was performed as per the requirements of A.S.T.M. E709 Standard Practice for Magnetic Particle Examination and the ETS Procedure for magnetic particle inspections (Procedure No. MT-02). Items inspected as detailed in attached tables and pictures.



ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Results

The following indications were noted:

Indication #1 - Intermittent Indications 1100mm long, noted on can 55 south horizontal weld (Figures 1 & 2)
Indication #2 - Indication 200mm long, noted on can 61 crown weld (Figures 3 & 4)
Indication #3 - Intermittent Indications 3000mm long, noted on can 65 south horizontal weld (Figures 5 & 6)
Indication #4 - Indication 150mm long, noted on can 71 south horizontal weld (Figures 7 & 8)
Indication #5 - Intermittent Indications 2700mm long, noted on can 75 south horizontal weld (Figures 9 & 10)

All other inspected welds were found free of cracks at the time of inspection.

Equipment Used

Parker P2 Yoke (120 V.A.C.).
Magnaflux white background paint.
Magnaflux black magnetic ink.

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
4	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
8	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
14	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
19	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
24	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
28	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
34	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
37	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
44	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
50	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
55	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
55	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted**	**Figures 1 & 2**
61	- Crown Weld - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted**	**Figures 3 & 4**
62	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
65	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted**	**Figures 5 & 6**
65	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
71	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted**	**Figures 7 & 8**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
71	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld	MT Acceptable	**N/A**
75	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	**Indication Noted**	**Figures 9 & 10**
75	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
80	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
85	- Longitudinal right (south) weld. - Longitudinal left (north) weld. 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
90	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
95	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds South side only.	MT Acceptable	**N/A**
100	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
105	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
110	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
115	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
121	- Longitudinal right (south) weld. - Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
133	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
134	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
142	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
144	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
149	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
150	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
160	- Longitudinal right (south) weld. X 2 - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
172	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
173	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
180	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
181	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
190	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
191	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
200	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
202	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
209	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
210	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
219	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
220	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
229	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
239	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
241	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
246	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
250	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
250	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
251	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
260	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
262	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
270	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
280	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
282	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
287	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
290	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
301	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
302	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
311	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
312	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
320	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
334	- Longitudinal left (north) weld. - Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
339	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
340	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
349	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

Can Number	Details	Result	Image #
351	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
359	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
360	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
364	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
365	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
378	- Longitudinal right (south) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
386	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**
397	- Longitudinal left (north) weld. - 12" Section of upstream & downstream circumferential welds adjacent to longitudinal weld.	MT Acceptable	**N/A**

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

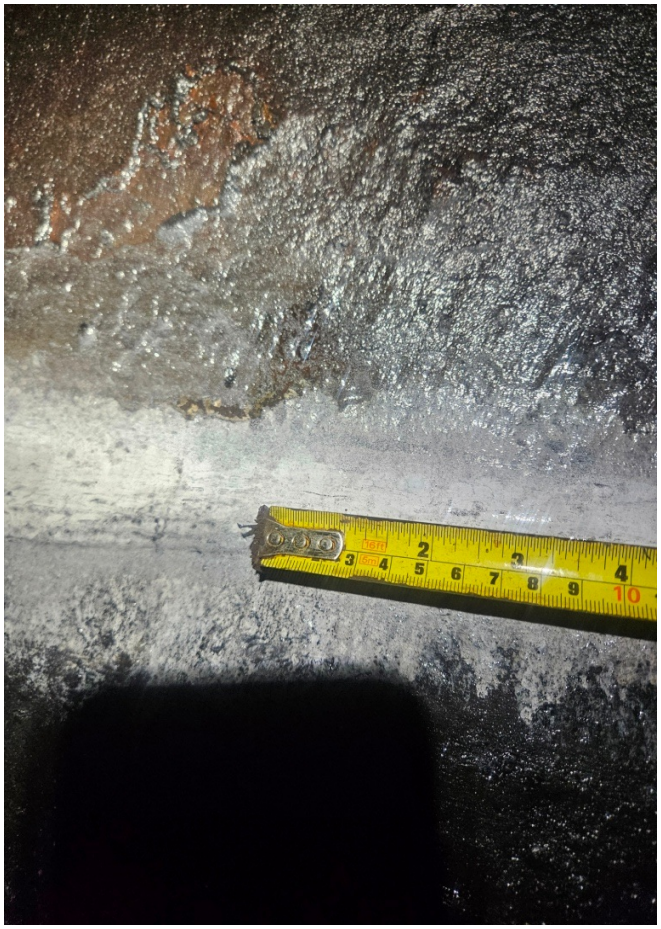


Figure 1 - **Indication #1** - Can 55S - Example of Indication



Figure 2 - **Indication #1** - Can 55S - Example of Indication

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

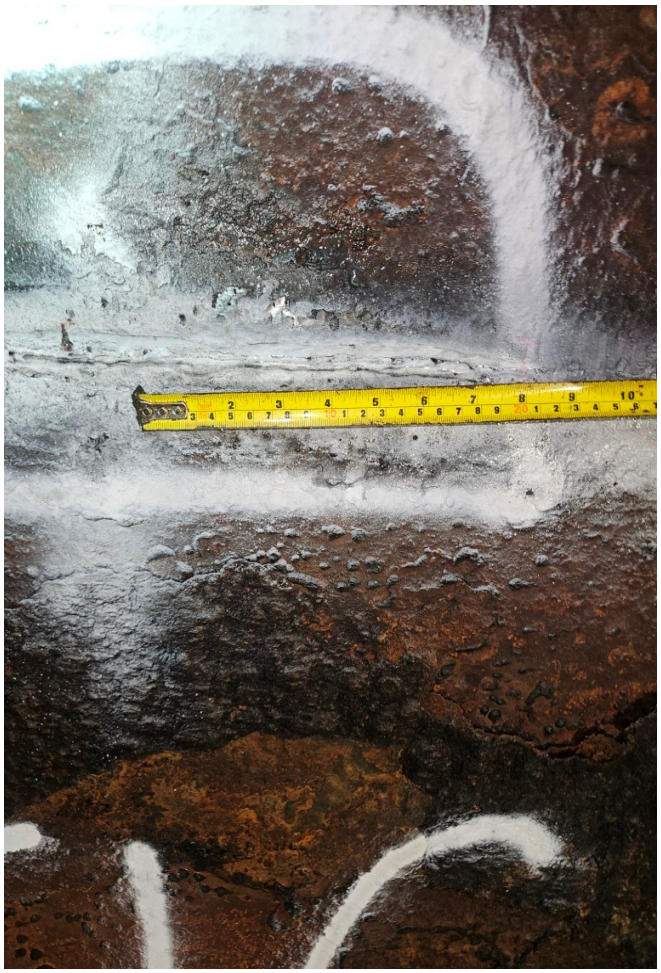


Figure 3 - Indication #2 - Can 61C - Example of Indication - Crown Weld



Figure 4 - Indication #2 - Can 61C - Location of Indication - Crown Weld

ETS No.: 23-402 Date: May 5-9th 2024
Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection

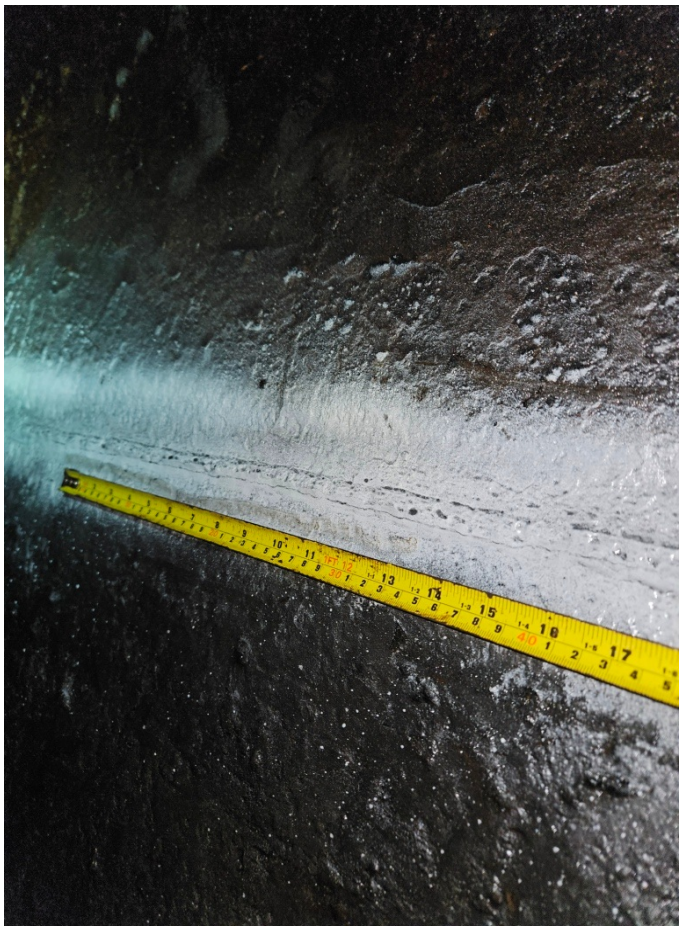


Figure 5 - **Indication #3 -** Can 65S - Example of Indications - Horizontal Weld - Intermittent Indications Noted

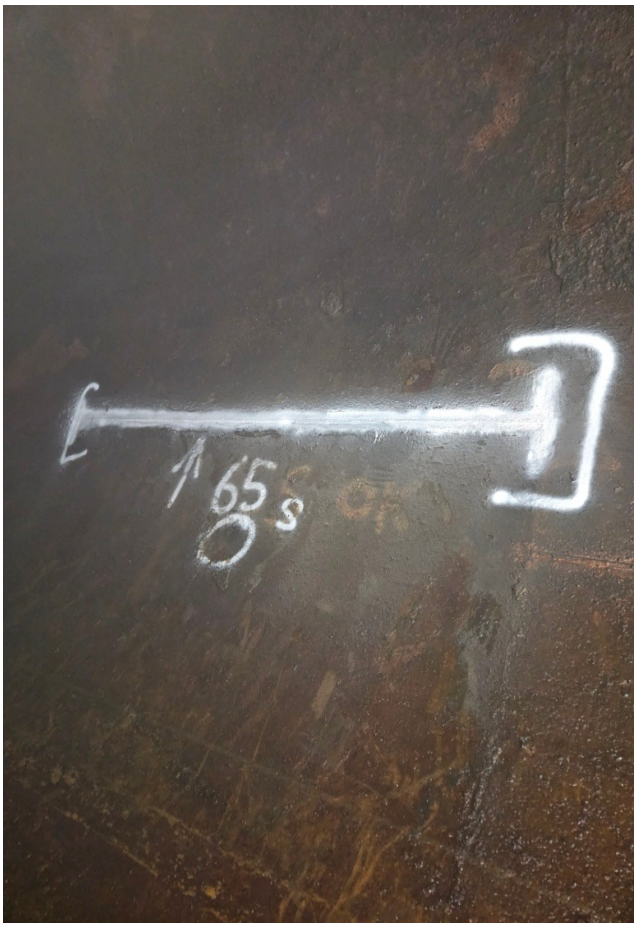


Figure 6 - **Indication #3 -** Can 65S - Location of Indications

Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 7 - **Indication #4 -** Can 71S - Example of Indication - Horizontal Weld



Figure 8 - **Indication #4 -** Can 71s - Location of Indication

Client: Technical Rope & Rescue
Location: Bay d'Espoir - Penstock #3
Magnetic Particle Inspection



Figure 9- **Indication #5 -** Can 75S - Example of Indication - Horizontal Weld



Figure 10 - **Indication #5 -** Can 75S - Location of Indication

APPENDIX D

THICKNESS MEASUREMENTS DATA

Visual Inspections
Radiography & Ultrasonics
Mag & Penetrant Inspections
Eddy Current Testing
Structural Steel & Torque

Eastern Technical Services Ltd.
PO Box 13517, St. John's, NL., A1B 4B8
709-726-4622 27 Austin St. Fax 726-4626

Technical Reports
Engineering Studies
Gas Free Testing
Destructive Testing
Insurance Reports

Report

ETS No.:	24-402-2	Copy:	
Date:	5-9 May 2024	Date Received:	5 May 2024
Client:	Technical Rope & Rescue 1155 Bauline Line Bauline, NL A1K 1E7	Inspected by:	C. Murphy SNT TC-1A: UT, PT and MT Level II CAN/CGSB 48.9712 MT/PT Level II, UT Level I.
Attn:	Todd Legrow		
P.O. No.	2024-0133		
Project:	Bay d'Espoir Hydroelectric Power Station - Penstock #3		
Testing Required:	Ultrasonic Thickness Measurements	Signed:	NDT Inspector

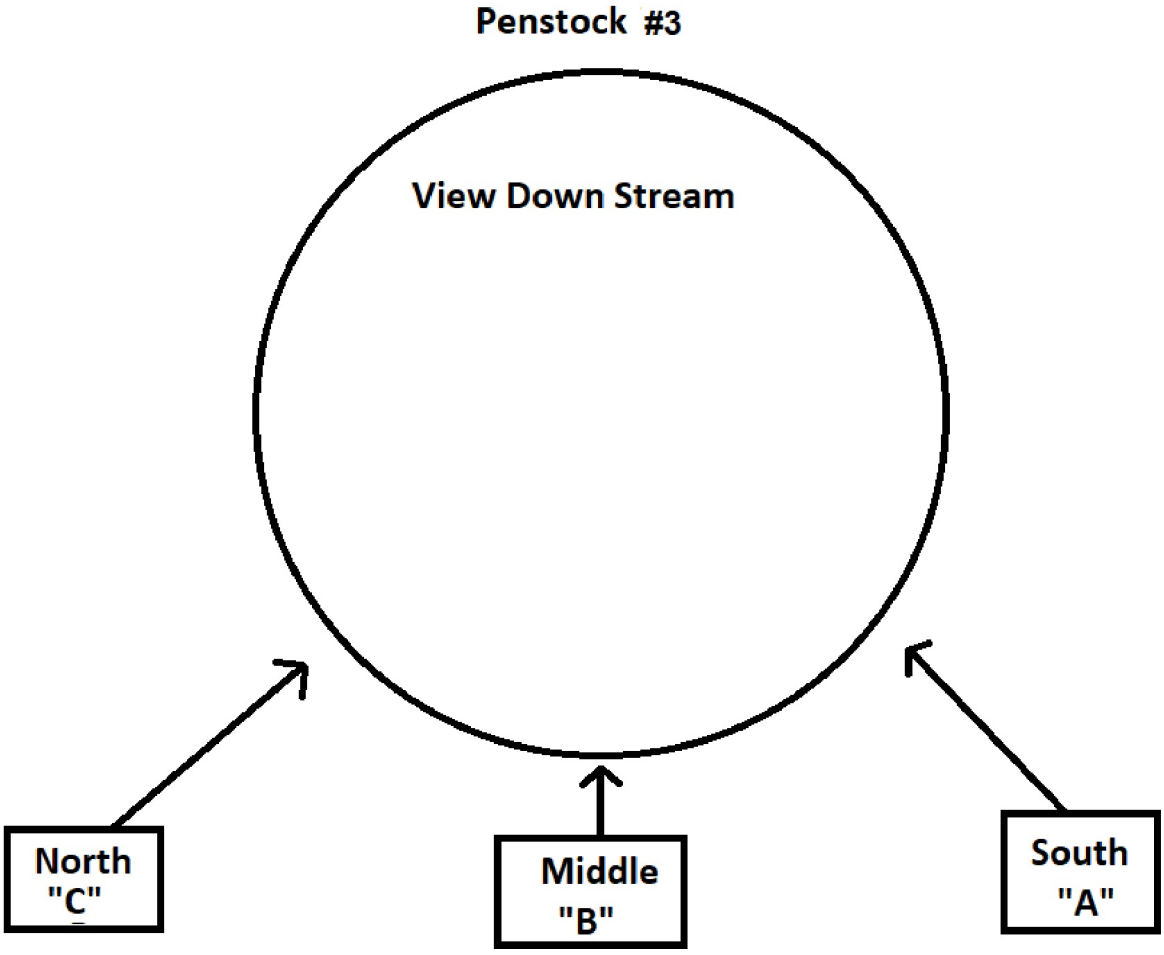
Remarks

As directed, ultrasonic thickness measurements were taken on Penstock #3 in areas requested.
3 readings were taken at each location, readings are shown in mm's on the attached tables.

Equipment Used

GE DMS Go+ digital thickness gauge (S/N GOPLS20050054)
KBA 560 Probe (S/N F08945)
Various calibration blocks & 0.100 to 1.000 " steel step wedge.
Ultragel couplant.

ETS No.: 24-402-2 Date: 5-9 May 2024
Client: Technical Rope & Rescue
Location: Penstock #3
Ultrasonic Thickness Measurements



UTM Data Logger #	Can #	Location ID	Reading (mm)	Reading (mm)	Reading (mm)	Original Thickness (m	Comments
Penstock #1 - (Shot 1: South, Shot 2: Bottom, Shot 3: North)							
1	**4**	**1**	11.9	11.9	11.9	11.1	
1	**4**	**2**	11.9	11.9	11.9	11.1	
1	**4**	**3**	12.0	12.1	11.9	11.1	
2	**14**	**1**	11.3	11.3	11.3	11.1	
2	**14**	**2**	11.3	10.8	10.8	11.1	
2	**14**	**3**	10.3	10.4	10.4	11.1	
3	**24**	**1**	10.5	10.5	10.5	11.1	
3	**24**	**2**	10.2	10.3	10.3	11.1	
3	**24**	**3**	10.9	10.9	10.9	11.1	
4	**34**	**1**	10.5	10.5	10.5	11.1	
4	**34**	**2**	10.9	10.9	10.9	11.1	
4	**34**	**3**	10.8	10.8	10.8	11.1	
5	**44**	**1**	10.3	10.4	10.4	11.1	
5	**44**	**2**	10.7	10.6	10.6	11.1	
5	**44**	**3**	10.4	10.4	10.4	11.1	
6	**55**	**1**	10.6	10.5	10.6	11.1	
6	**55**	**2**	10.6	10.6	10.6	11.1	
6	**55**	**3**	10.5	10.5	10.5	11.1	
7	**65**	**1**	10.5	10.5	10.5	11.1	
7	**65**	**2**	10.4	10.4	10.3	11.1	
7	**65**	**3**	10.5	10.5	10.5	11.1	
8	**75**	**1**	10.3	10.3	10.3	11.1	
8	**75**	**2**	10.4	11.2	10.4	11.1	
8	**75**	**3**	10.4	10.2	10.3	11.1	
9	**85**	**1**	10.4	10.4	10.4	11.1	
9	**85**	**2**	10.3	10.3	10.3	11.1	
9	**85**	**3**	10.5	10.5	10.5	11.1	
10	**95**	**1**	10.3	10.3	10.3	11.1	
10	**95**	**2**	10.6	10.8	10.7	11.1	
10	**95**	**3**	10.4	10.4	10.4	11.1	
11	**105**	**1**	10.0	10.0	10.0	11.1	
11	**105**	**2**	10.4	10.4	10.4	11.1	
11	**105**	**3**	10.2	10.2	10.2	11.1	
12	**115**	**1**	10.2	10.2	10.2	11.1	
12	**115**	**2**	10.4	10.4	10.4	11.1	
12	**115**	**3**	9.9	9.9	9.9	11.1	
13	**125**	**1**	10.2	10.2	10.2	11.1	
13	**125**	**2**	10.3	10.3	10.4	11.1	
13	**125**	**3**	10.3	10.3	10.3	11.1	
14	**134**	**1**	13.8	13.9	13.9	14.2	
14	**134**	**2**	14.0	14.0	14.0	14.2	
14	**134**	**3**	13.9	13.9	13.9	14.2	

15	**144**	**1**	14.1	14.1	14.1	14.2	
15	**144**	**2**	13.9	13.9	13.9	14.2	
15	**144**	**3**	13.8	13.7	13.7	14.2	
16	**154**	**1**	13.5	13.6	13.6	14.2	
16	**154**	**2**	13.8	13.8	13.8	14.2	
16	**154**	**3**	13.6	13.6	13.6	14.2	
17	**164**	**1**	14.1	14.1	14.1	14.2	
17	**164**	**2**	14.3	14.3	14.3	14.2	
17	**164**	**3**	13.8	13.8	13.8	14.2	
18	**173**	**1**	13.8	13.8	13.8	14.2	
18	**173**	**2**	14.1	14.1	14.1	14.2	
18	**173**	**3**	13.7	13.7	13.7	14.2	
19	**180**	**1**	15.8	15.8	15.8	15.8	
19	**180**	**2**	15.7	15.7	15.7	15.8	
19	**180**	**3**	15.0	15.0	15.0	15.8	
20	**190**	**1**	15.4	15.4	15.4	15.8	
20	**190**	**2**	15.4	15.4	15.4	15.8	
20	**190**	**3**	15.4	15.4	15.4	15.8	
21	**200**	**1**	16.7	16.7	16.7	17.2	
21	**200**	**2**	16.9	16.9	16.9	17.2	
21	**200**	**3**	16.4	16.4	16.5	17.2	
22	**209**	**1**	14.9	14.9	14.9	15.9	
22	**209**	**2**	15.0	14.9	14.9	15.9	
22	**209**	**3**	14.3	14.3	14.3	15.9	
23	**219**	**1**	16.1	16.0	16.0	15.9	
23	**219**	**2**	15.5	15.5	15.5	15.9	
23	**219**	**3**	15.5	15.5	15.5	15.9	
24	**229**	**1**	18.1	18.1	18.1	19.1	
24	**229**	**2**	18.7	18.7	18.7	19.1	
24	**229**	**3**	18.1	18.1	18.1	19.1	
25	**239**	**1**	21.2	21.2	21.2	20.6	
25	**239**	**2**	21.9	21.9	21.9	20.6	
25	**239**	**3**	21.6	21.6	21.6	20.6	
26	**250**	**1**	16.5	16.5	16.5	17.9	
26	**250**	**2**	16.7	16.7	16.8	17.9	
26	**250**	**3**	16.9	16.9	16.9	17.9	
27	**260**	**1**	18.1	18.1	18.1	18.8	
27	**260**	**2**	17.9	17.9	17.9	18.8	
27	**260**	**3**	17.8	17.8	17.8	18.8	
28	**270**	**1**	18.8	18.8	18.8	21.1	
28	**270**	**2**	18.8	18.8	18.8	21.1	
28	**270**	**3**	18.6	18.6	18.6	21.1	
29	**280**	**1**	20.1	20.1	20.1	21.7	
29	**280**	**2**	19.7	19.7	19.7	21.7	
29	**280**	**3**	19.4	19.4	19.4	21.7	
30	**290**	**1**	21.5	21.5	21.5	22.3	
30	**290**	**2**	20.9	20.9	20.9	22.3	
30	**290**	**3**	20.5	20.5	20.5	22.3	
31	**301**	**1**	21.3	21.3	21.3	23.0	
31	**301**	**2**	22.2	22.2	22.2	23.0	
31	**301**	**3**	21.2	21.2	21.3	23.0	

32	**311**	**1**	21.8	21.8	21.8	23.6	
32	**311**	**2**	22.5	22.5	22.5	23.6	
32	**311**	**3**	21.8	21.8	21.8	23.6	
33	**320**	**1**	22.5	22.5	22.5	24.9	
33	**320**	**2**	23.6	23.6	23.6	24.9	
33	**320**	**3**	22.0	22.0	22.0	24.9	
34	**334**	**1**	24.6	24.7	24.7	26.0	
34	**334**	**2**	25.4	25.4	25.4	26.0	
34	**334**	**3**	24.2	24.2	24.2	26.0	
35	**339**	**1**	24.6	24.6	24.6	26.0	
35	**339**	**2**	24.7	24.7	24.7	26.0	
35	**339**	**3**	25.0	25.0	25.0	26.0	
36	**349**	**1**	25.7	25.7	25.7	26.9	
36	**349**	**2**	25.5	25.5	25.5	26.9	
36	**349**	**3**	25.4	25.4	25.4	26.9	
37	**359**	**1**	26.7	26.7	26.7	27.8	
37	**359**	**2**	27.5	27.5	27.5	27.8	
37	**359**	**3**	26.0	26.0	26.0	27.8	
38	**365**	**1**	27.5	27.5	27.5	30.3	
38	**356**	**2**	26.9	27.3	28.1	30.3	
38	**365**	**3**	26.7	26.7	26.7	30.3	

APPENDIX E

PENSTOCK EVALUATION CALCULATIONS

TABLE 1 - FULL SUPPLY LEVEL (FSL)
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf	Project No:	2670043	
Normal pond EL=	597	feet	Date:	2024-06-07	
Joint Efficiency=	0.7		By:	NPT	
D_1 ID=	17.00	feet	Checked		
D_2 ID=	15.25	feet			
D_3 ID=	13.50	feet			

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	11.9000	0.4685	0.5000	-6.3%			17000					
4-1			2	11.9000	0.4685	0.5000	-6.3%			17000					Start A285 Steel
			3	11.9000	0.4685	0.5000	-6.3%			17000					
			4	11.9000	0.4685	0.5000	-6.3%			17000					
4-2	26.25	8.50	5	11.9000	0.4685	0.5000	-6.3%	0.4685	555.2042	17000	3943.1	0.23	5633.1	0.33	
			6	11.9000	0.4685	0.5000	-6.3%			17000					
			7	12.0000	0.4724	0.5000	-5.5%			17000					
4-3			8	12.1000	0.4764	0.5000	-4.7%			17000					
			9	11.9000	0.4685	0.5000	-6.3%			17000					
			1	11.3000	0.4449	0.4375	1.7%			17000					
14-1			2	11.3000	0.4449	0.4375	1.7%			17000					
			3	11.3000	0.4449	0.4375	1.7%			17000					
			4	11.3000	0.4449	0.4375	1.7%			17000					
14-2	117.17	8.50	5	10.8000	0.4252	0.4375	-2.8%	0.4055	554.8161	17000	4598.0	0.27	6568.5	0.39	
			6	10.8000	0.4252	0.4375	-2.8%			17000					
			7	10.3000	0.4055	0.4375	-7.3%			17000					
14-3			8	10.4000	0.4094	0.4375	-6.4%			17000					
			9	10.4000	0.4094	0.4375	-6.4%			17000					
			1	10.5000	0.4134	0.4375	-5.5%			17000					
24-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.2000	0.4016	0.4375	-8.2%			17000					
24-2	182.92	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4016	553.9701	17000	4736.2	0.28	6766.0	0.40	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.9000	0.4291	0.4375	-1.9%			17000					
24-3			8	10.9000	0.4291	0.4375	-1.9%			17000					
			9	10.9000	0.4291	0.4375	-1.9%			17000					
			1	10.5000	0.4134	0.4375	-5.5%			17000					
34-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.9000	0.4291	0.4375	-1.9%			17000					
34-2	222.67	8.50	5	10.9000	0.4291	0.4375	-1.9%	0.4134	549.7298	17000	5054.2	0.30	7220.3	0.42	
			6	10.9000	0.4291	0.4375	-1.9%			17000					
			7	10.8000	0.4252	0.4375	-2.8%			17000					
34-3			8	10.8000	0.4252	0.4375	-2.8%			17000					
			9	10.8000	0.4252	0.4375	-2.8%			17000					
			1	10.3000	0.4055	0.4375	-7.3%			17000					
44-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.4000	0.4094	0.4375	-6.4%			17000					
			4	10.7000	0.4213	0.4375	-3.7%			17000					
44-2	372.67	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.4055	533.7287	17000	6896.5	0.41	9852.1	0.58	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.4000	0.4094	0.4375	-6.4%			17000					
44-3			8	10.4000	0.4094	0.4375	-6.4%			17000					
			9	10.4000	0.4094	0.4375	-6.4%			17000					
			1	10.6000	0.4173	0.4375	-4.6%			17000					
55-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.6000	0.4173	0.4375	-4.6%			17000					
			4	10.6000	0.4173	0.4375	-4.6%			17000					
55-2	482.92	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.4134	521.9679	17000	8022.6	0.47	11460.9	0.67	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
55-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.5000	0.4134	0.4375	-5.5%			17000					
65-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.4000	0.4094	0.4375	-6.4%			17000					
65-2	582.33	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.4055	512.2873	17000	9233.6	0.54	13190.8	0.78	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
65-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.3000	0.4055	0.4375	-7.3%			17000					
75-1			2	10.3000	0.4055	0.4375	-7.3%			17000					
			3	10.3000	0.4055	0.4375	-7.3%			17000					
			4	10.4000	0.4094	0.4375	-6.4%			17000					
75-2	682.42	8.50	5	11.2000	0.4409	0.4375	0.8%	0.4016	503.7399	17000	10264.9	0.60	14664.1	0.86	
			6	10.4000	0.4094	0.4375	-6.4%			17000					
			7	10.4000	0.4094	0.4375	-6.4%			17000					
75-3			8	10.2000	0.4016	0.4375	-8.2%			17000					
			9	10.3000	0.4055	0.4375	-7.3%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
85-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.4000	0.4094	0.4375	-6.4%			17000					
			4	10.3000	0.4055	0.4375	-7.3%			17000					
85-2	782.00	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4055	495.2353	17000	11092.2	0.65	15846.0	0.93	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
85-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.3000	0.4055	0.4375	-7.3%			27000					
95-1			2	10.3000	0.4055	0.4375	-7.3%			27000					Start G40.8B Steel
			3	10.3000	0.4055	0.4375	-7.3%			27000					Allowable stress = 27000ksi for
			4	10.6000	0.4173	0.4375	-4.6%			27000					Thickess ≤ 0.625"
95-2	882.00	8.50	5	10.8000	0.4252	0.4375	-2.8%	0.4055	486.6950	27000	12023.1	0.45	17175.8	0.64	
			6	10.7000	0.4213	0.4375	-3.7%			27000					
			7	10.4000	0.4094	0.4375	-6.4%			27000					
95-3			8	10.4000	0.4094	0.4375	-6.4%			27000					
			9	10.4000	0.4094	0.4375	-6.4%			27000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	10.0000	0.3937	0.4375	-10.0%			27000					
105-1			2	10.0000	0.3937	0.4375	-10.0%			27000					
			3	10.0000	0.3937	0.4375	-10.0%			27000					
			4	10.4000	0.4094	0.4375	-6.4%			27000					
105-2	982.00	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.3937	478.1548	27000	13342.6	0.49	19060.8	0.71	
			6	10.4000	0.4094	0.4375	-6.4%			27000					
			7	10.2000	0.4016	0.4375	-8.2%			27000					
105-3			8	10.2000	0.4016	0.4375	-8.2%			27000					
			9	10.2000	0.4016	0.4375	-8.2%			27000					
			1	10.2000	0.4016	0.4375	-8.2%			27000					
115-1			2	10.2000	0.4016	0.4375	-8.2%			27000					
			3	10.2000	0.4016	0.4375	-8.2%			27000					
			4	10.4000	0.4094	0.4375	-6.4%			27000					
115-2	1081.17	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.3898	469.6857	27000	14437.7	0.53	20625.3	0.76	
			6	10.4000	0.4094	0.4375	-6.4%			27000					
			7	9.9000	0.3898	0.4375	-10.9%			27000					
115-3			8	9.9000	0.3898	0.4375	-10.9%			27000					
			9	9.9000	0.3898	0.4375	-10.9%			27000					
			1	10.2000	0.4016	0.4375	-8.2%			27000					
125-1			2	10.2000	0.4016	0.4375	-8.2%			27000					
			3	10.2000	0.4016	0.4375	-8.2%			27000					
			4	10.3000	0.4055	0.4375	-7.3%			27000					
125-2	1181.33	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4016	461.1312	27000	14954.7	0.55	21363.8	0.79	
			6	10.4000	0.4094	0.4375	-6.4%			27000					
			7	10.3000	0.4055	0.4375	-7.3%			27000					
125-3			8	10.3000	0.4055	0.4375	-7.3%			27000					
			9	10.3000	0.4055	0.4375	-7.3%			27000					
			1	14.1000	0.5551	0.5625	-1.3%			27000					
144-1			2	14.1000	0.5551	0.5625	-1.3%			27000					
			3	14.1000	0.5551	0.5625	-1.3%			27000					
			4	13.9000	0.5472	0.5625	-2.7%			27000					
144-2	1324.92	7.63	5	13.9000	0.5472	0.5625	-2.7%	0.5394	432.9938	27000	12056.4	0.45	17223.4	0.64	
			6	13.9000	0.5472	0.5625	-2.7%			27000					
			7	13.8000	0.5433	0.5625	-3.4%			27000					
144-3			8	13.7000	0.5394	0.5625	-4.1%			27000					
			9	13.7000	0.5394	0.5625	-4.1%			27000					
			1	13.8000	0.5433	0.5625	-3.4%			27000					
173-1			2	13.8000	0.5433	0.5625	-3.4%			27000					
			3	13.8000	0.5433	0.5625	-3.4%			27000					
			4	14.1000	0.5551	0.5625	-1.3%			27000					
173-2	1578.58	7.63	5	14.1000	0.5551	0.5625	-1.3%	0.5394	368.0576	27000	16830.0	0.62	24042.8	0.89	
			6	14.1000	0.5551	0.5625	-1.3%			27000					
			7	13.7000	0.5394	0.5625	-4.1%			27000					
173-3			8	13.7000	0.5394	0.5625	-4.1%			27000					
			9	13.7000	0.5394	0.5625	-4.1%			27000					
			1	15.8000	0.6220	0.6250	-0.5%			27000					
180-1			2	15.8000	0.6220	0.6250	-0.5%			27000					
			3	15.8000	0.6220	0.6250	-0.5%			27000					
			4	15.7000	0.6181	0.6250	-1.1%			27000					
180-2	1650.33	7.63	5	15.7000	0.6181	0.6250	-1.1%	0.5905	354.5476	27000	16278.5	0.60	23255.0	0.86	
			6	15.7000	0.6181	0.6250	-1.1%			27000					
			7	15.0000	0.5905	0.6250	-5.5%			27000					
180-3			8	15.0000	0.5905	0.6250	-5.5%			27000					
			9	15.0000	0.5905	0.6250	-5.5%			27000					
			1	15.4000	0.6063	0.6250	-3.0%			25000					Allowable stress = 25000ksi for
190-1			2	15.4000	0.6063	0.6250	-3.0%			25000					0.625"< Thickess ≤ 1.0"
			3	15.4000	0.6063	0.6250	-3.0%			25000					
			4	15.4000	0.6063	0.6250	-3.0%			25000					
190-2	1740.83	7.63	5	15.4000	0.6063	0.6250	-3.0%	0.6063	356.5789	25000	15722.8	0.63	22461.2	0.90	
			6	15.4000	0.6063	0.6250	-3.0%			25000					
			7	15.4000	0.6063	0.6250	-3.0%			25000					
190-3			8	15.4000	0.6063	0.6250	-3.0%			25000					
			9	15.4000	0.6063	0.6250	-3.0%			25000					
			1	16.7000	0.6575	0.6875	-4.4%			25000					
200-1			2	16.7000	0.6575	0.6875	-4.4%			25000					
			3	16.7000	0.6575	0.6875	-4.4%			25000					
			4	16.9000	0.6654	0.6875	-3.2%			25000					
200-2	1814.17	7.63	5	16.9000	0.6654	0.6875	-3.2%	0.6457	344.8753	25000	15482.8	0.62	22118.3	0.88	
			6	16.9000	0.6654	0.6875	-3.2%			25000					
			7	16.4000	0.6457	0.6875	-6.1%			25000					
200-3			8	16.4000	0.6457	0.6875	-6.1%			25000					
			9	16.5000	0.6496	0.6875	-5.5%			25000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	14.9000	0.5866	0.5990	-2.1%			24000					Start "HSB50" Steel
209-1			2	14.9000	0.5866	0.5990	-2.1%			24000					
			3	14.9000	0.5866	0.5990	-2.1%			24000					
			4	15.0000	0.5905	0.5990	-1.4%			24000					
209-2	1895.83	7.63	5	14.9000	0.5866	0.5990	-2.1%	0.5630	331.8418	24000	18674.4	0.78	26677.8	1.11	
			6	14.9000	0.5866	0.5990	-2.1%			24000					
			7	14.3000	0.5630	0.5990	-6.0%			24000					
209-3			8	14.3000	0.5630	0.5990	-6.0%			24000					
			9	14.3000	0.5630	0.5990	-6.0%			24000					
			1	16.1000	0.6339	0.6250	1.4%			24000					
219-1			2	16.0000	0.6299	0.6250	0.8%			24000					
			3	16.0000	0.6299	0.6250	0.8%			24000					
			4	15.5000	0.6102	0.6250	-2.4%			24000					
219-2	1996.00	7.63	5	15.5000	0.6102	0.6250	-2.4%	0.6102	315.8558	24000	18267.4	0.76	26096.2	1.09	
			6	15.5000	0.6102	0.6250	-2.4%			24000					
			7	15.5000	0.6102	0.6250	-2.4%			24000					
219-3			8	15.5000	0.6102	0.6250	-2.4%			24000					
			9	15.5000	0.6102	0.6250	-2.4%			24000					
			1	18.1000	0.7126	0.7500	-5.0%			24000					
229-1			2	18.1000	0.7126	0.7500	-5.0%			24000					
			3	18.1000	0.7126	0.7500	-5.0%			24000					
			4	18.7000	0.7362	0.7500	-1.8%			24000					
229-2	2093.17	7.63	5	18.7000	0.7362	0.7500	-1.8%	0.7126	300.3436	24000	16506.4	0.69	23580.6	0.98	
			6	18.7000	0.7362	0.7500	-1.8%			24000					
			7	18.1000	0.7126	0.7500	-5.0%			24000					
229-3			8	18.1000	0.7126	0.7500	-5.0%			24000					
			9	18.1000	0.7126	0.7500	-5.0%			24000					
			1	21.2000	0.8346	0.8125	2.7%			24000					Location at reducer d/s of surge tower. Design thickness indicates 13/16" (0.8125") per drawing F-2106-C 1.
239-1			2	21.2000	0.8346	0.8125	2.7%			24000					
			3	21.2000	0.8346	0.8125	2.7%			24000					
			4	21.9000	0.8622	0.8125	6.1%			24000					
239-2	2170.50	6.75	5	21.9000	0.8622	0.8125	6.1%	0.8346	288.0016	24000	12994.6	0.54	18563.7	0.77	
			6	21.9000	0.8622	0.8125	6.1%			24000					
			7	21.6000	0.8504	0.8125	4.7%			24000					
239-3			8	21.6000	0.8504	0.8125	4.7%			24000					
			9	21.6000	0.8504	0.8125	4.7%			24000					
			1	16.5000	0.6496	0.6720	-3.3%			24000					
250-1			2	16.5000	0.6496	0.6720	-3.3%			24000					
			3	16.5000	0.6496	0.6720	-3.3%			24000					
			4	16.7000	0.6575	0.6720	-2.2%			24000					
250-2	2270.00	6.75	5	16.7000	0.6575	0.6720	-2.2%	0.6496	272.1220	24000	17554.1	0.73	25077.3	1.04	
			6	16.8000	0.6614	0.6720	-1.6%			24000					
			7	16.9000	0.6654	0.6720	-1.0%			24000					
250-3			8	16.9000	0.6654	0.6720	-1.0%			24000					
			9	16.9000	0.6654	0.6720	-1.0%			24000					
			1	18.1000	0.7126	0.7060	0.9%			24000					
260-1			2	18.1000	0.7126	0.7060	0.9%			24000					
			3	18.1000	0.7126	0.7060	0.9%			24000					
			4	17.9000	0.7047	0.7060	-0.2%			24000					
260-2	2373.33	6.75	5	17.9000	0.7047	0.7060	-0.2%	0.7008	255.6306	24000	17098.1	0.71	24425.8	1.02	
			6	17.9000	0.7047	0.7060	-0.2%			24000					
			7	17.8000	0.7008	0.7060	-0.7%			24000					
260-3			8	17.8000	0.7008	0.7060	-0.7%			24000					
			9	17.8000	0.7008	0.7060	-0.7%			24000					
			1	18.8000	0.7402	0.7390	0.2%			24000					
270-1			2	18.8000	0.7402	0.7390	0.2%			24000					
			3	18.8000	0.7402	0.7390	0.2%			24000					
			4	18.8000	0.7402	0.7390	0.2%			24000					
270-2	2478.42	6.75	5	18.8000	0.7402	0.7390	0.2%	0.7323	238.8600	24000	17166.5	0.72	24523.6	1.02	
			6	18.8000	0.7402	0.7390	0.2%			24000					
			7	18.6000	0.7323	0.7390	-0.9%			24000					
270-3			8	18.6000	0.7323	0.7390	-0.9%			24000					
			9	18.6000	0.7323	0.7390	-0.9%			24000					
			1	20.1000	0.7913	0.7980	-0.8%			24000					
280-1			2	20.1000	0.7913	0.7980	-0.8%			24000					
			3	20.1000	0.7913	0.7980	-0.8%			24000					
			4	19.7000	0.7756	0.7980	-2.8%			24000					
280-2	2578.50	6.75	5	19.7000	0.7756	0.7980	-2.8%	0.7638	222.8900	24000	17192.5	0.72	24560.8	1.02	
			6	19.7000	0.7756	0.7980	-2.8%			24000					
			7	19.4000	0.7638	0.7980	-4.3%			24000					
280-3			8	19.4000	0.7638	0.7980	-4.3%			24000					
			9	19.4000	0.7638	0.7980	-4.3%			24000					
			1	21.5000	0.8465	0.8290	2.1%			24000					
290-1			2	21.5000	0.8465	0.8290	2.1%			24000					
			3	21.5000	0.8465	0.8290	2.1%			24000					
			4	20.9000	0.8228	0.8290	-0.7%			24000					
290-2	2675.25	6.75	5	20.9000	0.8228	0.8290	-0.7%	0.8071	210.1067	24000	16825.9	0.70	24037.1	1.00	
			6	20.9000	0.8228	0.8290	-0.7%			24000					
			7	20.5000	0.8071	0.8290	-2.6%			24000					
290-3			8	20.5000	0.8071	0.8290	-2.6%			24000					
			9	20.5000	0.8071	0.8290	-2.6%			24000					
			1	21.3000	0.8386	0.8540	-1.8%			24000					
301-1			2	21.3000	0.8386	0.8540	-1.8%			24000					
			3	21.3000	0.8386	0.8540	-1.8%			24000					
			4	22.2000	0.8740	0.8540	2.3%			24000					
301-2	2785.75	6.75	5	22.2000	0.8740	0.8540	2.3%	0.8346	200.9142	24000	16657.0	0.69	23795.6	0.99	
			6	22.2000	0.8740	0.8540	2.3%			24000					
			7	21.2000	0.8346	0.8540	-2.3%			24000					
301-3			8	21.2000	0.8346	0.8540	-2.3%			24000					
			9	21.3000	0.8386	0.8540	-1.8%			24000					

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	21.8000	0.8583	0.8790	-2.4%			24000					
311-1			2	21.8000	0.8583	0.8790	-2.4%			24000					
			3	21.8000	0.8583	0.8790	-2.4%			24000					
			4	22.5000	0.8858	0.8790	0.8%			24000					
311-2	2886.50	6.75	5	22.5000	0.8858	0.8790	0.8%	0.8583	192.5328	24000	16541.3	0.69	23630.4	0.98	
			6	22.5000	0.8858	0.8790	0.8%			24000					
			7	21.8000	0.8583	0.8790	-2.4%			24000					
311-3			8	21.8000	0.8583	0.8790	-2.4%			24000					
			9	21.8000	0.8583	0.8790	-2.4%			24000					
			1	22.5000	0.8858	0.9290	-4.6%			24000					
320-1			2	22.5000	0.8858	0.9290	-4.6%			24000					
			3	22.5000	0.8858	0.9290	-4.6%			24000					
			4	23.6000	0.9291	0.9290	0.0%			24000					
320-2	2977.25	6.75	5	23.6000	0.9291	0.9290	0.0%	0.8661	184.9833	24000	16696.8	0.70	23852.6	0.99	
			6	23.6000	0.9291	0.9290	0.0%			24000					
			7	22.0000	0.8661	0.9290	-6.8%			24000					
320-3			8	22.0000	0.8661	0.9290	-6.8%			24000					
			9	22.0000	0.8661	0.9290	-6.8%			24000					
			1	24.6000	0.9685	0.9790	-1.1%			24000					
334-1			2	24.7000	0.9724	0.9790	-0.7%			24000					
			3	24.7000	0.9724	0.9790	-0.7%			24000					
			4	25.4000	1.0000	0.9790	2.1%			24000					
334-2	3118.50	6.75	5	25.4000	1.0000	0.9790	2.1%	0.9528	173.2327	24000	15611.8	0.65	22302.6	0.93	
			6	25.4000	1.0000	0.9790	2.1%			24000					
			7	24.2000	0.9528	0.9790	-2.7%			24000					
334-3			8	24.2000	0.9528	0.9790	-2.7%			24000					
			9	24.2000	0.9528	0.9790	-2.7%			24000					
			1	24.6000	0.9685	0.9790	-1.1%			24000					
339-1			2	24.6000	0.9685	0.9790	-1.1%			24000					
			3	24.6000	0.9685	0.9790	-1.1%			24000					
			4	24.7000	0.9724	0.9790	-0.7%			24000					
339-2	3168.67	6.75	5	24.7000	0.9724	0.9790	-0.7%	0.9685	169.0599	24000	15509.2	0.65	22156.0	0.92	
			6	24.7000	0.9724	0.9790	-0.7%			24000					
			7	25.0000	0.9842	0.9790	0.5%			24000					
339-3			8	25.0000	0.9842	0.9790	0.5%			24000					
			9	25.0000	0.9842	0.9790	0.5%			24000					
			1	25.7000	1.0118	1.0250	-1.3%			24000					
349-1			2	25.7000	1.0118	1.0250	-1.3%			24000					
			3	25.7000	1.0118	1.0250	-1.3%			24000					
			4	25.5000	1.0039	1.0250	-2.1%			24000					
349-2	3256.00	6.75	5	25.5000	1.0039	1.0250	-2.1%	1.0000	155.3017	24000	15503.7	0.65	22148.1	0.92	
			6	25.5000	1.0039	1.0250	-2.1%			24000					
			7	25.4000	1.0000	1.0250	-2.4%			24000					
349-3			8	25.4000	1.0000	1.0250	-2.4%			24000					
			9	25.4000	1.0000	1.0250	-2.4%			24000					
			1	26.7000	1.0512	1.0610	-0.9%			24000					
359-1			2	26.7000	1.0512	1.0610	-0.9%			24000					
			3	26.7000	1.0512	1.0610	-0.9%			24000					
			4	27.5000	1.0827	1.0610	2.0%			24000					
359-2	3353.75	6.75	5	27.5000	1.0827	1.0610	2.0%	1.0236	130.6980	24000	15989.5	0.67	22842.2	0.95	
			6	27.5000	1.0827	1.0610	2.0%			24000					
			7	26.0000	1.0236	1.0610	-3.5%			24000					
359-3			8	26.0000	1.0236	1.0610	-3.5%			24000					
			9	26.0000	1.0236	1.0610	-3.5%			24000					
			1	27.5000	1.0827	1.1520	-6.0%			24000					
365-1			2	27.5000	1.0827	1.1520	-6.0%			24000					
			3	27.5000	1.0827	1.1520	-6.0%			24000					
			4	26.9000	1.0591	1.1520	-8.1%			24000					
365-2	3459.17	6.75	5	27.3000	1.0748	1.1520	-6.7%	1.0512	102.0542	24000	16526.8	0.69	23609.7	0.98	
			6	28.1000	1.1063	1.1520	-4.0%			24000					
			7	26.7000	1.0512	1.1520	-8.8%			24000					
365-3			8	26.7000	1.0512	1.1520	-8.8%			24000					
			9	26.7000	1.0512	1.1520	-8.8%			24000					

Equations:

1.Pressure: $P = h\lambda_w = \frac{h * 62.4 pcf}{144 in/ft}$

2. Hoop Stress: $\sigma_h = \frac{Pr}{et}$

3. Allowable Stress: $S_A = \min(\frac{F_u}{2.4}, \frac{F_y}{1.5})$

4. Stress Ratio: $\frac{\sigma_h}{S_A}$

5. Percent Section Loss in Thickness $\frac{(Original\ Section\ Thickness) - (Thickness\ Reading)}{(Orignal\ Section\ Thickness)}$

Minimum Wall Thickness	
All	0.3898
17dia	0.3898
15.25dia	0.5394
13.5dia	0.6496

Steel Tensile and Yield Strengths:			
F_{y_A285}=	26	ksi	
F_{u_A285}=	50	ksi	
$F_{y\_G40.8B\_1}$=	40	ksi	Thickess ≤ 0.625"
$F_{y\_G40.8B\_2}$=	38	ksi	0.625"< Thickess ≤ 1.0"
$F_{y\_G40.8B\_3}$=	36	ksi	1.0"< Thickess ≤ 1.5"
$F_{U\_G40.8B}$=	65	ksi	
F_{y_HSB50}=	Unknown		
F_{u_HSB50}=	Unknown		

Allowable Stresses:			
F_{all_A285}=	17	ksi	
$F_{all\_G40.8\_1}$=	27	ksi	Thickess ≤ 0.625"
$F_{all\_G40.8\_2}$=	25	ksi	0.625"< Thickess ≤ 1.0"
$F_{all\_G40.8\_3}$=	24	ksi	1.0"< Thickess ≤ 1.5"
$F_{all\_HSB\_50}$=	Unknown		

TABLE 2 - TRANSIENT
PENSTOCK 3 THICKNESS MEASURMENTS AND STRESSES

Unit weight of water=	62.4	pcf	Project No:	2670043	
Normal pond EL=	597	feet	Date:	2024-06-07	
Joint Efficiency=	0.7		By:	NPT	
D_1 ID=	17.00	feet	Checked		
D_2 ID=	15.25	feet			
D_3 ID=	13.50	feet			

Can #	Distance From Fwd Edge of Can 1 (Ft)	Radius (ft)	Reading Number	Thickness Reading (mm)	Thickness Reading (in)	Design Plate Thickness (in)	%Change in Material	Min Thickness (in)	C.L. EL. (ft)	Allowable Steel Stress[3] (psi)	Base Material		At Joints		Notes
											Stress (psi)[2]	Stress Ratio[4]	Stress (psi)[2]	Stress Ratio[4]	
			1	11.9000	0.4685	0.5000	-6.3%			17000					
4-1			2	11.9000	0.4685	0.5000	-6.3%			17000					Start A285 Steel
			3	11.9000	0.4685	0.5000	-6.3%			17000					
			4	11.9000	0.4685	0.5000	-6.3%			17000					
4-2	26.25	8.50	5	11.9000	0.4685	0.5000	-6.3%	0.4685	555.2042	17000	5126.1	0.30	7323.0	0.43	
			6	11.9000	0.4685	0.5000	-6.3%			17000					
			7	12.0000	0.4724	0.5000	-5.5%			17000					
4-3			8	12.1000	0.4764	0.5000	-4.7%			17000					
			9	11.9000	0.4685	0.5000	-6.3%			17000					
			1	11.3000	0.4449	0.4375	1.7%			17000					
14-1			2	11.3000	0.4449	0.4375	1.7%			17000					
			3	11.3000	0.4449	0.4375	1.7%			17000					
			4	11.3000	0.4449	0.4375	1.7%			17000					
14-2	117.17	8.50	5	10.8000	0.4252	0.4375	-2.8%	0.4055	554.8161	17000	5977.4	0.35	8539.1	0.50	
			6	10.8000	0.4252	0.4375	-2.8%			17000					
			7	10.3000	0.4055	0.4375	-7.3%			17000					
14-3			8	10.4000	0.4094	0.4375	-6.4%			17000					
			9	10.4000	0.4094	0.4375	-6.4%			17000					
			1	10.5000	0.4134	0.4375	-5.5%			17000					
24-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.2000	0.4016	0.4375	-8.2%			17000					
24-2	182.92	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4016	553.9701	17000	6157.0	0.36	8795.8	0.52	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.9000	0.4291	0.4375	-1.9%			17000					
24-3			8	10.9000	0.4291	0.4375	-1.9%			17000					
			9	10.9000	0.4291	0.4375	-1.9%			17000					
			1	10.5000	0.4134	0.4375	-5.5%			17000					
34-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.9000	0.4291	0.4375	-1.9%			17000					
34-2	222.67	8.50	5	10.9000	0.4291	0.4375	-1.9%	0.4134	549.7298	17000	6570.5	0.39	9386.4	0.55	
			6	10.9000	0.4291	0.4375	-1.9%			17000					
			7	10.8000	0.4252	0.4375	-2.8%			17000					
34-3			8	10.8000	0.4252	0.4375	-2.8%			17000					
			9	10.8000	0.4252	0.4375	-2.8%			17000					
			1	10.3000	0.4055	0.4375	-7.3%			17000					
44-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.4000	0.4094	0.4375	-6.4%			17000					
			4	10.7000	0.4213	0.4375	-3.7%			17000					
44-2	372.67	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.4055	533.7287	17000	8965.4	0.53	12807.7	0.75	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.4000	0.4094	0.4375	-6.4%			17000					
44-3			8	10.4000	0.4094	0.4375	-6.4%			17000					
			9	10.4000	0.4094	0.4375	-6.4%			17000					
			1	10.6000	0.4173	0.4375	-4.6%			17000					
55-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.6000	0.4173	0.4375	-4.6%			17000					
			4	10.6000	0.4173	0.4375	-4.6%			17000					
55-2	482.92	8.50	5	10.6000	0.4173	0.4375	-4.6%	0.4134	521.9679	17000	10429.4	0.61	14899.1	0.88	
			6	10.6000	0.4173	0.4375	-4.6%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
55-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.5000	0.4134	0.4375	-5.5%			17000					
65-1			2	10.5000	0.4134	0.4375	-5.5%			17000					
			3	10.5000	0.4134	0.4375	-5.5%			17000					
			4	10.4000	0.4094	0.4375	-6.4%			17000					
65-2	582.33	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.4055	512.2873	17000	12003.6	0.71	17148.0	1.01	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
65-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.3000	0.4055	0.4375	-7.3%			17000					
75-1			2	10.3000	0.4055	0.4375	-7.3%			17000					
			3	10.3000	0.4055	0.4375	-7.3%			17000					
			4	10.4000	0.4094	0.4375	-6.4%			17000					
75-2	682.42	8.50	5	11.2000	0.4409	0.4375	0.8%	0.4016	503.7399	17000	13344.3	0.78	19063.3	1.12	
			6	10.4000	0.4094	0.4375	-6.4%			17000					
			7	10.4000	0.4094	0.4375	-6.4%			17000					
75-3			8	10.2000	0.4016	0.4375	-8.2%			17000					
			9	10.3000	0.4055	0.4375	-7.3%			17000					
			1	10.4000	0.4094	0.4375	-6.4%			17000					
85-1			2	10.4000	0.4094	0.4375	-6.4%			17000					
			3	10.4000	0.4094	0.4375	-6.4%			17000					
			4	10.3000	0.4055	0.4375	-7.3%			17000					
85-2	782.00	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4055	495.2353	17000	14419.9	0.85	20599.8	1.21	
			6	10.3000	0.4055	0.4375	-7.3%			17000					
			7	10.5000	0.4134	0.4375	-5.5%			17000					
85-3			8	10.5000	0.4134	0.4375	-5.5%			17000					
			9	10.5000	0.4134	0.4375	-5.5%			17000					
			1	10.3000	0.4055	0.4375	-7.3%			27000					Start G40.8B Steel
95-1			2	10.3000	0.4055	0.4375	-7.3%			27000					Allowable stress = 27000ksi for
			3	10.3000	0.4055	0.4375	-7.3%			27000					Thickess ≤ 0.625"
			4	10.6000	0.4173	0.4375	-4.6%			27000					
95-2	882.00	8.50	5	10.8000	0.4252	0.4375	-2.8%	0.4055	486.6950	27000	15630.0	0.58	22328.6	0.83	
			6	10.7000	0.4213	0.4375	-3.7%			27000					
			7	10.4000	0.4094	0.4375	-6.4%			27000					
95-3			8	10.4000	0.4094	0.4375	-6.4%			27000					
			9	10.4000	0.4094	0.4375	-6.4%			27000					

			1	10.0000	0.3937	0.4375	-10.0%			27000					
105-1			2	10.0000	0.3937	0.4375	-10.0%			27000					
			3	10.0000	0.3937	0.4375	-10.0%			27000					
			4	10.4000	0.4094	0.4375	-6.4%			27000					
105-2	982.00	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.3937	478.1548	27000	17345.3	0.64	24779.0	0.92	
			6	10.4000	0.4094	0.4375	-6.4%			27000					
			7	10.2000	0.4016	0.4375	-8.2%			27000					
105-3			8	10.2000	0.4016	0.4375	-8.2%			27000					
			9	10.2000	0.4016	0.4375	-8.2%			27000					
			1	10.2000	0.4016	0.4375	-8.2%			27000					
115-1			2	10.2000	0.4016	0.4375	-8.2%			27000					
			3	10.2000	0.4016	0.4375	-8.2%			27000					
			4	10.4000	0.4094	0.4375	-6.4%			27000					
115-2	1081.17	8.50	5	10.4000	0.4094	0.4375	-6.4%	0.3898	469.6857	27000	18769.1	0.70	26813.0	0.99	
			6	10.4000	0.4094	0.4375	-6.4%			27000					
			7	9.9000	0.3898	0.4375	-10.9%			27000					
115-3			8	9.9000	0.3898	0.4375	-10.9%			27000					
			9	9.9000	0.3898	0.4375	-10.9%			27000					
			1	10.2000	0.4016	0.4375	-8.2%			27000					
125-1			2	10.2000	0.4016	0.4375	-8.2%			27000					
			3	10.2000	0.4016	0.4375	-8.2%			27000					
			4	10.3000	0.4055	0.4375	-7.3%			27000					
125-2	1181.33	8.50	5	10.3000	0.4055	0.4375	-7.3%	0.4016	461.1312	27000	19441.1	0.72	27773.0	1.03	
			6	10.4000	0.4094	0.4375	-6.4%			27000					
			7	10.3000	0.4055	0.4375	-7.3%			27000					
125-3			8	10.3000	0.4055	0.4375	-7.3%			27000					
			9	10.3000	0.4055	0.4375	-7.3%			27000					
			1	14.1000	0.5551	0.5625	-1.3%			27000					
144-1			2	14.1000	0.5551	0.5625	-1.3%			27000					
			3	14.1000	0.5551	0.5625	-1.3%			27000					
			4	13.9000	0.5472	0.5625	-2.7%			27000					
144-2	1324.92	7.63	5	13.9000	0.5472	0.5625	-2.7%	0.5394	432.9938	27000	15673.3	0.58	22390.5	0.83	
			6	13.9000	0.5472	0.5625	-2.7%			27000					
			7	13.8000	0.5433	0.5625	-3.4%			27000					
144-3			8	13.7000	0.5394	0.5625	-4.1%			27000					
			9	13.7000	0.5394	0.5625	-4.1%			27000					
			1	13.8000	0.5433	0.5625	-3.4%			27000					
173-1			2	13.8000	0.5433	0.5625	-3.4%			27000					
			3	13.8000	0.5433	0.5625	-3.4%			27000					
			4	14.1000	0.5551	0.5625	-1.3%			27000					
173-2	1578.58	7.63	5	14.1000	0.5551	0.5625	-1.3%	0.5394	368.0576	27000	21879.0	0.81	31255.7	1.16	
			6	14.1000	0.5551	0.5625	-1.3%			27000					
			7	13.7000	0.5394	0.5625	-4.1%			27000					
173-3			8	13.7000	0.5394	0.5625	-4.1%			27000					
			9	13.7000	0.5394	0.5625	-4.1%			27000					
			1	15.8000	0.6220	0.6250	-0.5%			27000					
180-1			2	15.8000	0.6220	0.6250	-0.5%			27000					
			3	15.8000	0.6220	0.6250	-0.5%			27000					
			4	15.7000	0.6181	0.6250	-1.1%			27000					
180-2	1650.33	7.63	5	15.7000	0.6181	0.6250	-1.1%	0.5905	354.5476	27000	21162.0	0.78	30231.4	1.12	
			6	15.7000	0.6181	0.6250	-1.1%			27000					
			7	15.0000	0.5905	0.6250	-5.5%			27000					
180-3			8	15.0000	0.5905	0.6250	-5.5%			27000					
			9	15.0000	0.5905	0.6250	-5.5%			27000					
			1	15.4000	0.6063	0.6250	-3.0%			25000					Allowable stress = 25000ksi for
190-1			2	15.4000	0.6063	0.6250	-3.0%			25000					0.625"< Thickess ≤ 1.0"
			3	15.4000	0.6063	0.6250	-3.0%			25000					
			4	15.4000	0.6063	0.6250	-3.0%			25000					
190-2	1740.83	7.63	5	15.4000	0.6063	0.6250	-3.0%	0.6063	356.5789	25000	20439.7	0.82	29199.5	1.17	
			6	15.4000	0.6063	0.6250	-3.0%			25000					
			7	15.4000	0.6063	0.6250	-3.0%			25000					
190-3			8	15.4000	0.6063	0.6250	-3.0%			25000					
			9	15.4000	0.6063	0.6250	-3.0%			25000					
			1	16.7000	0.6575	0.6875	-4.4%			25000					
200-1			2	16.7000	0.6575	0.6875	-4.4%			25000					
			3	16.7000	0.6575	0.6875	-4.4%			25000					
			4	16.9000	0.6654	0.6875	-3.2%			25000					
200-2	1814.17	7.63	5	16.9000	0.6654	0.6875	-3.2%	0.6457	344.8753	25000	20127.7	0.81	28753.8	1.15	
			6	16.9000	0.6654	0.6875	-3.2%			25000					
			7	16.4000	0.6457	0.6875	-6.1%			25000					
200-3			8	16.4000	0.6457	0.6875	-6.1%			25000					
			9	16.5000	0.6496	0.6875	-5.5%			25000					
			1	14.9000	0.5866	0.5990	-2.1%			24000					Start "HSB50" Steel
209-1			2	14.9000	0.5866	0.5990	-2.1%			24000					
			3	14.9000	0.5866	0.5990	-2.1%			24000					
			4	15.0000	0.5905	0.5990	-1.4%			24000					
209-2	1895.83	7.63	5	14.9000	0.5866	0.5990	-2.1%	0.5630	331.8418	24000	24276.8	1.01	34681.1	1.45	
			6	14.9000	0.5866	0.5990	-2.1%			24000					
			7	14.3000	0.5630	0.5990	-6.0%			24000					
209-3			8	14.3000	0.5630	0.5990	-6.0%			24000					
			9	14.3000	0.5630	0.5990	-6.0%			24000					
			1	16.1000	0.6339	0.6250	1.4%			24000					
219-1			2	16.0000	0.6299	0.6250	0.8%			24000					
			3	16.0000	0.6299	0.6250	0.8%			24000					
			4	15.5000	0.6102	0.6250	-2.4%			24000					
219-2	1996.00	7.63	5	15.5000	0.6102	0.6250	-2.4%	0.6102	315.8558	24000	23747.6	0.99	33925.1	1.41	
			6	15.5000	0.6102	0.6250	-2.4%			24000					
			7	15.5000	0.6102	0.6250	-2.4%			24000					
219-3			8	15.5000	0.6102	0.6250	-2.4%			24000					
			9	15.5000	0.6102	0.6250	-2.4%			24000					
			1	18.1000	0.7126	0.7500	-5.0%			24000					
229-1			2	18.1000	0.7126	0.7500	-5.0%			24000					
			3	18.1000	0.7126	0.7500	-5.0%			24000					
			4	18.7000	0.7362	0.7500	-1.8%			24000					
229-2	2093.17	7.63	5	18.7000	0.7362	0.7500	-1.8%	0.7126	300.3436	24000	21458.4	0.89	30654.8	1.28	
			6	18.7000	0.7362	0.7500	-1.8%			24000					
			7	18.1000	0.7126	0.7500	-5.0%			24000					
229-3			8	18.1000	0.7126	0.7500	-5.0%			24000					
			9	18.1000	0.7126	0.7500	-5.0%			24000					
			1	21.2000	0.8346	0.8125	2.7%			24000					Location at reducer d/s of surge
239-1			2	21.2000	0.8346	0.8125	2.7%			24000					tower. Design thickness indicates
			3	21.2000	0.8346	0.8125	2.7%			24000					13/16" (0.8125") per drawing F-2106-C
			4	21.9000	0.8622	0.8125	6.1%			24000					1.
239-2	2170.50	6.75	5	21.9000	0.8622	0.8125	6.1%	0.8346	288.0016	24000	16893.0	0.70	24132.8	1.01	
			6	21.9000	0.8622	0.8125	6.1%			24000					
			7	21.6000	0.8504	0.8125	4.7%			24000					
239-3			8	21.6000	0.8504	0.8125	4.7%			24000					
			9	21.6000	0.8504	0.8125	4.7%			24000					

			1	16.5000	0.6496	0.6720	-3.3%			24000				
250-1			2	16.5000	0.6496	0.6720	-3.3%			24000				
			3	16.5000	0.6496	0.6720	-3.3%			24000				
			4	16.7000	0.6575	0.6720	-2.2%			24000				
250-2	2270.00	6.75	5	16.7000	0.6575	0.6720	-2.2%	0.6496	272.1220	24000	22820.3	0.95	32600.5	1.36
			6	16.8000	0.6614	0.6720	-1.6%			24000				
			7	16.9000	0.6654	0.6720	-1.0%			24000				
250-3			8	16.9000	0.6654	0.6720	-1.0%			24000				
			9	16.9000	0.6654	0.6720	-1.0%			24000				
			1	18.1000	0.7126	0.7060	0.9%			24000				
260-1			2	18.1000	0.7126	0.7060	0.9%			24000				
			3	18.1000	0.7126	0.7060	0.9%			24000				
			4	17.9000	0.7047	0.7060	-0.2%			24000				
260-2	2373.33	6.75	5	17.9000	0.7047	0.7060	-0.2%	0.7008	255.6306	24000	22227.5	0.93	31753.5	1.32
			6	17.9000	0.7047	0.7060	-0.2%			24000				
			7	17.8000	0.7008	0.7060	-0.7%			24000				
260-3			8	17.8000	0.7008	0.7060	-0.7%			24000				
			9	17.8000	0.7008	0.7060	-0.7%			24000				
			1	18.8000	0.7402	0.7390	0.2%			24000				
270-1			2	18.8000	0.7402	0.7390	0.2%			24000				
			3	18.8000	0.7402	0.7390	0.2%			24000				
			4	18.8000	0.7402	0.7390	0.2%			24000				
270-2	2478.42	6.75	5	18.8000	0.7402	0.7390	0.2%	0.7323	238.8600	24000	22316.5	0.93	31880.7	1.33
			6	18.8000	0.7402	0.7390	0.2%			24000				
			7	18.6000	0.7323	0.7390	-0.9%			24000				
270-3			8	18.6000	0.7323	0.7390	-0.9%			24000				
			9	18.6000	0.7323	0.7390	-0.9%			24000				
			1	20.1000	0.7913	0.7980	-0.8%			24000				
280-1			2	20.1000	0.7913	0.7980	-0.8%			24000				
			3	20.1000	0.7913	0.7980	-0.8%			24000				
			4	19.7000	0.7756	0.7980	-2.8%			24000				
280-2	2578.50	6.75	5	19.7000	0.7756	0.7980	-2.8%	0.7638	222.8900	24000	22350.3	0.93	31929.0	1.33
			6	19.7000	0.7756	0.7980	-2.8%			24000				
			7	19.4000	0.7638	0.7980	-4.3%			24000				
280-3			8	19.4000	0.7638	0.7980	-4.3%			24000				
			9	19.4000	0.7638	0.7980	-4.3%			24000				
			1	21.5000	0.8465	0.8290	2.1%			24000				
290-1			2	21.5000	0.8465	0.8290	2.1%			24000				
			3	21.5000	0.8465	0.8290	2.1%			24000				
			4	20.9000	0.8228	0.8290	-0.7%			24000				
290-2	2675.25	6.75	5	20.9000	0.8228	0.8290	-0.7%	0.8071	210.1067	24000	21873.7	0.91	31248.2	1.30
			6	20.9000	0.8228	0.8290	-0.7%			24000				
			7	20.5000	0.8071	0.8290	-2.6%			24000				
290-3			8	20.5000	0.8071	0.8290	-2.6%			24000				
			9	20.5000	0.8071	0.8290	-2.6%			24000				
			1	21.3000	0.8386	0.8540	-1.8%			24000				
301-1			2	21.3000	0.8386	0.8540	-1.8%			24000				
			3	21.3000	0.8386	0.8540	-1.8%			24000				
			4	22.2000	0.8740	0.8540	2.3%			24000				
301-2	2785.75	6.75	5	22.2000	0.8740	0.8540	2.3%	0.8346	200.9142	24000	21654.0	0.90	30934.3	1.29
			6	22.2000	0.8740	0.8540	2.3%			24000				
			7	21.2000	0.8346	0.8540	-2.3%			24000				
301-3			8	21.2000	0.8346	0.8540	-2.3%			24000				
			9	21.3000	0.8386	0.8540	-1.8%			24000				
			1	21.8000	0.8583	0.8790	-2.4%			24000				
311-1			2	21.8000	0.8583	0.8790	-2.4%			24000				
			3	21.8000	0.8583	0.8790	-2.4%			24000				
			4	22.5000	0.8858	0.8790	0.8%			24000				
311-2	2886.50	6.75	5	22.5000	0.8858	0.8790	0.8%	0.8583	192.5328	24000	21503.7	0.90	30719.5	1.28
			6	22.5000	0.8858	0.8790	0.8%			24000				
			7	21.8000	0.8583	0.8790	-2.4%			24000				
311-3			8	21.8000	0.8583	0.8790	-2.4%			24000				
			9	21.8000	0.8583	0.8790	-2.4%			24000				
			1	22.5000	0.8858	0.9290	-4.6%			24000				
320-1			2	22.5000	0.8858	0.9290	-4.6%			24000				
			3	22.5000	0.8858	0.9290	-4.6%			24000				
			4	23.6000	0.9291	0.9290	0.0%			24000				
320-2	2977.25	6.75	5	23.6000	0.9291	0.9290	0.0%	0.8661	184.9833	24000	21705.9	0.90	31008.4	1.29
			6	23.6000	0.9291	0.9290	0.0%			24000				
			7	22.0000	0.8661	0.9290	-6.8%			24000				
320-3			8	22.0000	0.8661	0.9290	-6.8%			24000				
			9	22.0000	0.8661	0.9290	-6.8%			24000				
			1	24.6000	0.9685	0.9790	-1.1%			24000				
334-1			2	24.7000	0.9724	0.9790	-0.7%			24000				
			3	24.7000	0.9724	0.9790	-0.7%			24000				
			4	25.4000	1.0000	0.9790	2.1%			24000				
334-2	3118.50	6.75	5	25.4000	1.0000	0.9790	2.1%	0.9528	173.2327	24000	20295.4	0.85	28993.4	1.21
			6	25.4000	1.0000	0.9790	2.1%			24000				
			7	24.2000	0.9528	0.9790	-2.7%			24000				
334-3			8	24.2000	0.9528	0.9790	-2.7%			24000				
			9	24.2000	0.9528	0.9790	-2.7%			24000				
			1	24.6000	0.9685	0.9790	-1.1%			24000				
339-1			2	24.6000	0.9685	0.9790	-1.1%			24000				
			3	24.6000	0.9685	0.9790	-1.1%			24000				
			4	24.7000	0.9724	0.9790	-0.7%			24000				
339-2	3168.67	6.75	5	24.7000	0.9724	0.9790	-0.7%	0.9685	169.0599	24000	20162.0	0.84	28802.8	1.20
			6	24.7000	0.9724	0.9790	-0.7%			24000				
			7	25.0000	0.9842	0.9790	0.5%			24000				
339-3			8	25.0000	0.9842	0.9790	0.5%			24000				
			9	25.0000	0.9842	0.9790	0.5%			24000				
			1	25.7000	1.0118	1.0250	-1.3%			24000				
349-1			2	25.7000	1.0118	1.0250	-1.3%			24000				
			3	25.7000	1.0118	1.0250	-1.3%			24000				
			4	25.5000	1.0039	1.0250	-2.1%			24000				
349-2	3256.00	6.75	5	25.5000	1.0039	1.0250	-2.1%	1.0000	155.3017	24000	20154.8	0.84	28792.5	1.20
			6	25.5000	1.0039	1.0250	-2.1%			24000				
			7	25.4000	1.0000	1.0250	-2.4%			24000				
349-3			8	25.4000	1.0000	1.0250	-2.4%			24000				
			9	25.4000	1.0000	1.0250	-2.4%			24000				
			1	26.7000	1.0512	1.0610	-0.9%			24000				
359-1			2	26.7000	1.0512	1.0610	-0.9%			24000				
			3	26.7000	1.0512	1.0610	-0.9%			24000				
			4	27.5000	1.0827	1.0610	2.0%			24000				
359-2	3353.75	6.75	5	27.5000	1.0827	1.0610	2.0%	1.0236	130.6980	24000	20786.4	0.87	29694.9	1.24
			6	27.5000	1.0827	1.0610	2.0%			24000				
			7	26.0000	1.0236	1.0610	-3.5%			24000				
359-3			8	26.0000	1.0236	1.0610	-3.5%			24000				
			9	26.0000	1.0236	1.0610	-3.5%			24000				

			1	27.5000	1.0827	1.1520	-6.0%			24000				
365-1			2	27.5000	1.0827	1.1520	-6.0%			24000				
			3	27.5000	1.0827	1.1520	-6.0%			24000				
			4	26.9000	1.0591	1.1520	-8.1%			24000				
365-2	3459.17	6.75	5	27.3000	1.0748	1.1520	-6.7%	1.0512	102.0542	24000	21484.8	0.90	30692.6	1.28
			6	28.1000	1.1063	1.1520	-4.0%			24000				
			7	26.7000	1.0512	1.1520	-8.8%			24000				
365-3			8	26.7000	1.0512	1.1520	-8.8%			24000				
			9	26.7000	1.0512	1.1520	-8.8%			24000				

Equations:

1.Pressure: $P = h\lambda_w = \frac{h * 62.4pcf}{144in/ft}$

2. Hoop Stress: $\sigma_h = \frac{Pr}{et}$

3. Allowable Stress: $S_A = \min(\frac{F_u}{2.4}, \frac{F_y}{1.5})$

4. Stress Ratio: $\frac{\sigma_h}{S_A}$

5. Percent Section Loss in Thickness $\frac{(Original\ Section\ Thickness) - (Thickness\ Reading)}{(Orignal\ Section\ Thickness)}$

Minimum Wall Thickness	
All	0.3898
17dia	0.3898
15.25dia	0.5394
13.5dia	0.6496

Steel Tensile and Yield Strengths:			
F_{Y_A285}=	26	ksi	
F_{U_A285}=	50	ksi	
$F_{Y\_G40.8B\_1}$=	40	ksi	Thickess ≤ 0.625"
$F_{Y\_G40.8B\_2}$=	38	ksi	0.625"< Thickess ≤ 1.0"
$F_{Y\_G40.8B\_3}$=	36	ksi	1.0"< Thickess ≤ 1.5"
$F_{U\_G40.8B}$=	65	ksi	
F_{Y_HSBSO}=	Unknown		
F_{U_HSBSO}=	Unknown		

Allowable Stresses:			
F_{all_A285}=	17	ksi	
$F_{all\_G40.8\_1}$=	27	ksi	Thickess ≤ 0.625"
$F_{all\_G40.8\_2}$=	25	ksi	0.625"< Thickess ≤ 1.0"
$F_{all\_G40.8\_3}$=	24	ksi	1.0"< Thickess ≤ 1.5"
$F_{all\_HSB\_SO}$=	Unknown		

Schedule 1, Attachment 11

Bay d'Espoir Penstock 3 - Basis of Estimate

Newfoundland and Labrador Hydro

March 5, 2026

Bay d'Espoir Penstock 3

Basis of Estimate

NLH Doc. No. BDE-NLH-29600-ES-BOE-0001-01

Comments: The Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment Basis of Estimate presents the cost estimate and basis for the project, and methodologies used to estimate project elements, including direct costs, indirect costs, escalation and borrowing. This document has been prepared in alignment with AACE International Recommended Practices.	**Total # of Pages (including Cover):**
This document contains confidential and commercially sensitive information. Access to this report and the information contained within is restricted and should only be shared with the written approval of the Manager, Project Controls for Major Projects.	29

B1	05-Mar-2026	Use	Doug Maloney	Tony Scott	Steve Hiscock	Marc Cullen
Revision	**Date (DD-MMM-YYYY)**	**Issue Reason**	**Prepared By Sr. Estimator, Major Projects**	**Approved By Manager, Project Controls, Major Projects**	**Approved by Project Manager, Bay d'Espoir Penstock 3**	**Approved by Program Manager, Major Projects**

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hydro	Bay d'Espoir Penstock 3 Basis of Estimate				
NLH Doc. No.	**BDE-NLH-29600-ES-BOE-0001-01**	**Revision**	**B1**	**Page**	**i**

Additional Approvals

Additional approvals are required for further authorization due to document contents, complexity, prescribed requirements, or multi-departmental involvement.

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Endorsements

Endorsements indicate support or acknowledgement of this document's contents but do not imply formal approval. Endorsements are used to represent subject matter experts who have provided input but do not hold final decision-making authority for this document.

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1.0 Executive Summary

The Bay d'Espoir (BDE) Penstock 3 Section Replacement and Weld Refurbishment Project (Project) has been proposed by Newfoundland and Labrador Hydro (Hydro) as a proactive initiative aimed at maintaining the operational integrity and reliability of one of the facility's key components. Recent inspections of Penstock 3 have revealed continuing signs of wear and stress, which could lead to issues, including potential cracks and corrosion in the longitudinal weld seams, posing a risk to the continued safe operation of the Bay d'Espoir Facility.

The Project involves the replacement of the majority of the 7/16" thick sections of Penstock 3 and the refurbishment of the remaining sections of the penstock.

In addition to the estimated base costs for replacement and refurbishment, Hydro developed estimates for Hydro's project management and owner's cost, escalation, and Interest During Construction (IDC).

The project estimate includes:

- Penstock replacement and refurbishment;
- Equipment and materials;
- Commissioning;
- Engineering, Procurement, and Construction Management (EPCM);
- Owner's cost;
- Contingency;
- Escalation; and
- IDC.

This B1 Revision of the Basis of Estimate includes:

- Adjustments due to learnings and experience with Penstock 1 Section Replacement and Weld Refurbishment;
- Updates to quantities of replacement vs refurbishment scope; and
- Review of Owners Team requirements.

The base cost estimate for the project is [redacted] The estimate is considered commensurate with the requirements of a Class 3 estimate, as per AACE International Recommended Practice No. 69R-12 Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for the Hydropower Industry.

Escalation and IDC were calculated based on a cost profile developed from the project schedule. Contingency was calculated using a Monte Carlo Simulation (MCS) based on a Quantitative Risk Assessment (QRA) process.

A summary of the Total Cost Estimate is given in Table 1.

Table 1: Cost Estimate Summary ($2024)

Component	Estimated Cost
Direct Construction Costs	[redacted]
Hydro's Indirect Costs	
Subtotal Base Cost Estimate	
Project Contingency	
Subtotal Base Estimate (with Contingency)	
Escalation	
Interest during Construction	
Total Cost Estimate (Authorized Budget upon Approval)	**77,462,128**

2.0 Terms and Definitions

The following terms and definitions provide clarity on key terms and concepts used throughout the document.

Term	Definition
AACE	The Association for the Advancement of Cost Engineering. An international industry organization that publishes many Recommended Practices (RPs) to aid in guiding project management professionals in many aspects of project execution. AACE RPs provide useful guidance but are not standards.
BDE	Bay d'Espoir Hydroelectric Generating Facility
CDN	Canadian Dollar
Contingency	An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs.[1]
EPCM	Engineering, Procurement and Construction Management
Escalation	A provision in costs or prices for uncertain changes in technical, economic, and market conditions over time.[2]
FEED	Front-End Engineering Design. It includes sufficient field investigations and engineering to establish a contracting strategy and Class 3 cost estimate.
GBP	Great Britain Pounds

[1] As per AACE RP 10S-90.
[2] As per AACE RP 10S-90.

Hydro	Newfoundland and Labrador Hydro and its affiliates, successors, and assigns.
IDC	Interest During Construction. The cost for the use of capital, sometimes referred to as the time value of money.[3]
MCS	Monte Carlo Simulation
MPMT	Major Projects Management Team
PMT	Project Management Team
PUB	Public Utilities Board
QRA	Quantitative Risk Analysis
USD	United States Dollar

3.0 References

The following is a list of documents that are referenced in this Bay d'Espoir Penstock 3 Basis of Estimate document or are relevant to the subject matter contained within.

Reference	Document Title
AACE RP 10S-90	Cost Engineering Terminology[4]
AACE RP 31R-03	Reviewing, Validating, and Documenting the Estimate[5]
AACE RP 34R-05	Basis of Estimate[6]
AACE RP 69R-12	Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for the Hydropower Industry[7]
AACE RP 137R-25	Owner's Costs: Definition and Considerations for Estimating[8]
BDE-NLH-29600-PM-CHT-0001-01	Project Charter - Bay d'Espoir Penstock 3 Replacement

[3] As per AACE RP 10S-90.
[4] AACE International. (July 24, 2024) Recommended Practice 10S-90, *Cost Engineering Terminology*. <https://www.pathlms.com/aace/courses/2928/documents/3796>.
[5] AACE International. (May 12, 2009) Recommended Practice 31R-03, Reviewing, Validating, and Documenting the Estimate. <https://www.pathlms.com/aace/courses/2928/documents/3815>.
[6] AACE International. (October 5, 2021) Recommended Practice 34R-05, *Basis of Estimate.* <https://www.pathlms.com/aace/courses/2928/documents/3819>.
[7] AACE International. (August 7, 2020) Recommended Practice 69R-12, *Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for the Hydropower Industry*. <https://www.pathlms.com/aace/courses/2928/documents/3852>.
[8] AACE International. (May 13, 2025) Recommended Practice 137R-25, *Owner's Costs: Definition and Considerations for Estimating*. < https://www.pathlms.com/aace/courses/2928/documents/149526>.

Reference	Document Title
BDE-KSG-29600-PM-DSP-0001-01	Decision Support Package: Penstocks 2 & 3 Bay d'Espoir Hydro Site
BDE-KSG-29600-PM-PLN-0002-01	Project Execution Strategy and Plan: Penstock No. 1
BDE-NLH-29600-PL-BOS-0001-01	Bay d'Espoir Penstock 3 Basis of Schedule
BDE-NLH-29600-ES-EST-0001-01	Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment Project Cost Estimate[9]

4.0 Introduction

The Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment Project has been proposed by Newfoundland and Labrador Hydro as a proactive initiative to maintain the operational integrity and reliability of one of the facility's key components. While Penstock 3 has not experienced any ruptures to date, recent inspections have revealed continuing signs of wear and stress, which could lead to issues similar to those encountered with Penstock 1. These issues, including potential cracks and corrosion in the longitudinal weld seams, pose a risk to the continued safe operation of the Bay d'Espoir Facility.

The Project involves the replacement of a majority of the 7/16" thick sections of Penstock 3 and the refurbishment of the remaining sections of the penstock.

Replacement penstock sections will be fabricated and coated off-site. Replacement work includes excavation, demolition and off-site disposal of existing 7/16" thick sections. Earthworks will follow in preparation for the placement of the new penstock sections. Field welding will be required to join the new sections together. Field joints will be coated with an appropriate protective coating system to prevent deterioration.

Refurbishment includes a complete inspection of all weld seams in the refurbishment sections to verify their condition. Any refurbishment work required to return the welds to good condition will be completed. An appropriate protective coating system will be applied to prevent deterioration.

After all replacements and refurbishment are complete, backfill as required will be installed and compacted around the penstock.

It is anticipated that various site infrastructure and construction support activities will be required, such as the creation of laydown areas, construction access routes, and modification of an overhead distribution line adjacent to the work.

Penstock replacement and refurbishment activities comprise the external construction contract.

[9] "Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment Project Cost Estimate", Newfoundland and Labrador Hydro, Rev B0, (Excel support file).

Hydro completed the Owner's Cost estimate, which included Hydro's project management and overhead costs.

The total estimated installed cost for the project is the sum of the external construction contract cost estimate and the Owners Cost estimate. The estimate is considered commensurate with the requirements of a Class 3 cost estimate, according to AACE RP 69R-12.

5.0 Purpose

The purpose of this document is to present the updated capital cost estimate and estimate basis for the Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment, for approval to commence project work, as well as to document the capital cost estimate preparation.

This document has been prepared using AACE RP 34R-05 and AACE RP 31R-03 as a general guide.

6.0 Project Scope

The project scope for Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment consists of the following elements:

6.1 Direct Scope

The direct scope of work includes replacement of the majority of penstock with a wall thickness of 7/16", refurbishment of welds as required on the remaining penstock sections, penstock coating, and earthworks for bedding and protection of the penstock.

- Penstock Section Replacement:
  - Removal and disposal of approximately 327 meters of penstock, the majority of which is 7/16" wall thickness;
  - Fabrication and coating of replacement penstock;
  - Installation of replacement penstock;
  - Field welding of joints between penstock sections;
  - Coating of field welds; and
  - Earthworks.
- Penstock Weld Refurbishment:
  - Refurbishment of the remaining approximately 840 metres of penstock;
  - Inspection of welds in the remaining penstock;
  - Weld repairs as required; and
  - Coating of the remaining penstock.
- Commissioning of Penstock.

6.2 Hydro's Indirect Costs

Hydro's indirect costs include personnel and travel costs for:

- FEED: January 2025 to December 2025;
- Enhanced FEED and Procurement Planning: January 2026 to May 2026;
- Owner's Cost in Project Phase: January 2026 to February 2028; and
- EPCM: January 2026 to February 2028.

7.0 Estimate Methodology

7.1 Direct Scope

The Penstock 3 estimate for direct scope has been adjusted based on a review of construction issues and lessons learned from Penstock 1, scope and quantity differences, and considering appropriate unit rates. Penstock 1 proponent bid pricing has been considered when determining the Penstock 3 estimate.

Examples of adjustments include:

- [redacted]

7.2 Hydro's Indirect Costs

Components of Hydro's indirect costs are described in this section.

Hydro's Owner's team costs are the costs that will be incurred by Hydro directly. These costs were estimated by Hydro's Major Projects Estimator, in collaboration with the project team.

A major element of these costs is the Owner's team itself, the cost of which was developed using the roles required for the project, the estimated amount of time that these roles would be engaged by the project, and applicable labour rates.

Expenses such as travel and accommodation costs are also included.

Hydro's indirect cost estimate includes the following:

- Hydro's Major Projects Management Team (MPMT);
- Hydro's Penstock 3 Project Management Team (PMT);

- Hydro's Project Services Team;
- Hydro's Engineering;
- Hydro's Construction and Commissioning Site Team;
- Hydro Personnel Expenses;
- Sunk Costs;
- Insurance; and
- EPCM Costs.

Hydro's Owner's team activities are divided into three phases:

1) Front-End Engineering Design: January 2025 to December 2025;
2) Enhanced FEED and Procurement Planning: January 2026 to May 2026; and
3) Owner's Cost in Project Phase: January 2026 to February 2028.

7.2.1 Hydro's Major Projects Management Team

The MPMT is responsible for managing and supporting all Major Projects and supporting the BDE Penstock 3 Project Management Team, as opposed to managing specific BDE Penstock 3 Section Replacement and Weld Refurbishment activities.

The Project Manager developed the roster for Hydro's MPMT and assigned hours for each position based on their expected engagement on the project.

Some MPMT roles will not be charged to the project, as they are deemed to be operational charges as per Hydro's finance direction. For example, the Director, Major Projects & Asset Management will primarily work at the portfolio and corporate level and will not charge directly to projects. No costs have been included for this position.

7.2.2 Hydro's BDE Penstock 3 Project Management Personnel

The Project Manager developed the roster for Hydro's BDE Penstock 3 Project Management Personnel and assigned hours for each position based on their expected engagement on the project.

7.2.3 Hydro's Major Projects Department Project Services Personnel

While BDE Penstock 3 Project Management Personnel are responsible for managing the project, the Major Projects Department Project Services Personnel are responsible for managing and providing services such as planning, estimating, cost control, procurement, financial services, and document control for the project.

The hours for Project Services Personnel were estimated based on their expected engagement on the project.

7.2.4 Hydro's Engineering Personnel

The expected level of effort for engineering that will support the BDE Penstock 3 project is based on engineering performing the following tasks for the project:

- Reviewing engineering drawings and other technical documents from the EPCM contractor and suppliers, for acceptance on behalf of Hydro;
- Managing contracts for the procurement of components;
- Answering technical queries; and
- Travelling out of province to Vendor's facilities.

The hours for Hydro's Engineering Personnel were estimated based on their expected engagement on the project.

7.2.5 Hydro's Construction Oversight and Commissioning Site Personnel

The expected level of effort for Hydro's Construction Oversight and Commissioning Site Personnel is based on performing the following tasks at the Bay d'Espoir work site:

- Oversight of construction and commissioning work activities, including the EPCM consultant;
- Provide authority for site decisions;
- Answer site-related queries; and
- Manage the Turnover to Hydro Operations.

The hours for the Construction Oversight and Commissioning Site Personnel were estimated based on their expected engagement on the project.

7.2.6 Hydro Personnel Expenses

Hydro personnel expenses include costs for business travel, safety events, and meetings. The cost for personal protective equipment is not included as a separate cost under expenses because it is included in the hourly rates for both employees and contractors.

Travel expenses, as applied to the Owner's estimated costs, include the following cost types:

- Modes of Transportation: rental cars, fleet vehicles and personal vehicles;
- Meal Per Diems; and
- Accommodations, such as hotels.

Travel expenses include costs for travelling to and from the construction worksite in Bay d'Espoir. The expenses for travelling to and from Bay d'Espoir are for the Hydro Construction and Commissioning Site Team, and periodic meetings and reviews performed by Hydro's PMT and Engineering.

7.2.7 Sunk Costs

Sunk costs for FEED to the end of March 2025 are included in the estimate.

7.2.8 Insurance

An allowance for insurance is included in Owner's Cost in the estimate, based on input from Hydro's Commercial, Treasury, and Risk Departments.

7.2.9 EPCM Costs

The detailed engineering, procurement support, and construction management for the project will be done by an EPCM Consultant chosen by Hydro through a competitive request for proposals. The EPCM Consultant's estimated cost is based on an adjustment to the approved budget for Penstock 1.

7.3 Escalation and IDC

Escalation is "A provision in costs or prices for uncertain changes in technical, economic, and market conditions over time." [10]

IDC is "the cost for the use of capital, sometimes referred to as the time value of money."[11] Hydro has a standard method of calculating IDC, which is applied to capital expenditures. This method was applied to this cost estimate.

The amount of applied escalation and IDC depends on the cost profile and when project expenditures are incurred. The cost profile for each item in the estimate was developed based on the project schedule and distributed monthly across the project timeline.

Escalation was estimated by factoring the estimated costs each year by appropriate escalation factors, and IDC costs were estimated based on the cost profile and the applicable Hydro corporate interest rate, as described in Sections 10.4 and 10.5.

8.0 Design Basis

The objective of the BDE Penstock 3 Section Replacement and Weld Refurbishment project is to maintain the operational integrity and reliability of the penstock.

The project scope has been developed based on a decision support package for Penstocks 2 and 3, issued in November 2021 by Kleinschmidt Associates. Note that the cut at the upper end of the penstock has been moved downstream by 34 meters.

[10] AACE International. (July 24, 2024) Recommended Practice 10S-90, *Cost Engineering Terminology*. <https://www.pathlms.com/aace/courses/2928/documents/3796>.
[11] AACE International. (July 24, 2024) Recommended Practice 10S-90, *Cost Engineering Terminology*. <https://www.pathlms.com/aace/courses/2928/documents/3796>.

The design basis and specifications for Penstock 3 are scheduled for completion in Q3 2026. In the interim, the design basis for Penstock 1 can be considered applicable to Penstock 3.

9.0 Planning Basis

The high-level preliminary project plan for Penstock 3 includes:

- Approval by the PUB in Q2 2026;
- Enhanced FEED from Q1 2026 to Q2 2026; and
- Mobilization, construction, and commissioning from Q2 2027 to Q4 2027.

10.0 Cost Basis

This cost estimate is stated in 2024 dollars, with escalation and IDC calculated based on a cost profile which follows the project plan.

An estimate listing is included in Appendix A.

10.1 Direct Costs

The Penstock 3 estimate for direct scope is based on a review of the approved budget and [redacted] This estimate is largely based on [redacted] with [redacted] where appropriate, based on experience gained from Penstock 1.

10.1.1 Productivity

For the Penstock 3 replacement work, productivity is assumed to be [redacted] This equates to [redacted] productive hours in [redacted] hour shift, allowing for a toolbox meeting, [redacted] paid breaks, [redacted] lunch, and end-of-shift cleanup time. [redacted] per day is assumed.

10.2 Hydro's Indirect Costs

Hydro's indirect costs are made up of components outlined in Section 7.2.

10.2.1 Hydro's Owner's Team

The Project Manager developed the roster for Hydro's Owner's Team and assigned hours for each position based on their expected engagement on the project.

10.2.2 Hourly Rates for Hydro Personnel

All-inclusive hourly rates were used to develop Hydro's project management cost:

- For Hydro employees, corporate hourly rates were used;
- For Contractors, a rate of [redacted] was used for both regular time and overtime; and
- For Hydro's construction consultant, a rate of [redacted] was used.

The totals for Hydro's owner's team wages are [redacted] hours and [redacted]

10.2.3 Hydro Personnel Expenses

For travel and accommodations for in-province trips, 2-, 3-, and 5-day trips were assumed, with the following rates used to estimate costs:

- Accommodations: [redacted]
- Meals: [redacted] and
- Transportation: [redacted]

A summary of Hydro's indirect costs is included in Appendix B.

10.2.4 EPCM Consultant Costs

The cost for EPCM is based on the expected cost for Penstock 3 as part of a site-wide EPCM contract.

10.3 Exchange Rates

The corporate foreign exchange rates as of November 2025 are shown in Table 2. These rates were applied in the estimate as necessary.

Table 2: Foreign Exchange Rates

Currency	Exchange Rate
[redacted]	

The project cost is estimated primarily in Canadian dollars. Foreign exchange exposure is considered to apply primarily to items that may be procured in US dollars.

10.4 Escalation

The estimated escalation cost for this project is approximately [redacted] which is the forecast increase in the estimated project costs beyond 2024.

To estimate cost escalation, an expected committed base cost profile was developed as shown in Table 3.

Table 3: Cost Profile for Escalation Calculation ($ Million)

	2025	2026	2027	2028
Cost	[redacted]			

As per normal Hydro practice, escalation factors provided by Hydro's Financial Department were then applied to the committed costs for the years 2025 to 2028 to predict future escalation.

The escalation factors from the October 2025 Corporate assumptions are shown in Table 4.

Table 4: Escalation Factors[12]

Year	GDP	Hydraulic Plant Construction
2024	[redacted]	
2025		
2026		
2027		
2028		

10.5 Interest During Construction

IDC is the cost of borrowing throughout the duration of the project. The expected annual borrowing rate, at the time of estimate preparation, is [redacted] as per the September 2025 Corporate rate. The estimated cost for IDC for the project is approximately [redacted]

To estimate the IDC, the above annual interest rate was applied to the expected annual cost profile, shown in Table 5.[13]

Table 5: Cost Profile for IDC Calculation ($ Million)

	2025	2026	2027	2028
Cost	[redacted]			

11.0 Allowances

Because the project involves work on an aging penstock, there is a possibility of finding additional welds in need of refurbishment. However, based on initial weld inspections on Penstock 1, the extent of weld refurbishment may be less than originally anticipated. Therefore, an allowance for found work has not been included in the base estimate. The potential for additional weld refurbishment has been identified as a risk and evaluated through the QRA process.

[12] Source: GDP as per The Conference Board of Canada, Canadian - 5 Yr Forecast, Sept 15, 2025. Other factors as per Hydro's Escalation Forecast Methodology.
[13] Note that the cost profile for escalation calculation in Table 3 includes base cost and contingency, while the cost profile for IDC calculation in Table 5 includes base cost, contingency and escalation.

12.0 Contingency

Contingency is defined as "an amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs."[14]

Hydro reviewed the project scope in detail and assigned potential low and high percentages to individual estimate items, as shown in Appendix A. These percentages were then used in a Quantitative Risk Analysis using a Monte Carlo Simulation to develop a contingency value.

Results of the MCS are shown in the cumulative distribution curve for the total base cost in Figure 1.

[14] AACE International. (July 24, 2024) Recommended Practice 10S-90, *Cost Engineering Terminology*. <https://www.pathlms.com/aace/courses/2928/documents/3796>.

[redacted]

The contingency amount for the estimate is the P50 value – base estimate value (not including sunk costs):

Contingency = [redacted]

13.0 Estimate Summary

This cost estimate is stated in 2024[15] dollars, with escalation and IDC calculated based on a cost profile which follows the project plan.

The estimated costs are contained in file BDE Penstock 3 Section Replacement and Weld Refurbishment Estimate Rev1.xlsx

A summary of estimated costs is given in Table 6.

Table 6: Summary of Estimated Costs ($2024)[16]

Component	Estimated Cost
Mobilization, Demobilization, and Facilities Cost	[redacted]
Penstock Replacement	
Penstock Rehabilitation	
Performance Security	
Steel Supply	
External Construction Consultants	
Subtotal Direct Construction Costs	
Owner's Cost	
EPCM Consultant	
Subtotal Indirect Costs	
Subtotal Base (Direct + Indirect) Estimate	
Contingency	
Subtotal Base Estimate (with Contingency)	
Escalation	
Interest during Construction	
Total Cost Estimate (Authorized Budget upon Approval)	**77,462,128**

14.0 Estimate Classification

Cost estimate classification and accuracy are considered to depend on the maturity level of the project definition deliverables. AACE Recommended Practice No. 69R-12 provides guidance for cost estimation

[15] Estimate is based on rates in the Penstock 1 contract, which were based on 2024 dollars.
[16] Numbers made not add due to rounding.

classification for new build Hydro Industry EPC projects. In RP 69R-12, the maturity of the project deliverables is evaluated and used to determine the class of estimate that is applicable, as shown in Figure 3.

Penstock 3 Section Replacement and Weld Refurbishment is a refurbishment project. The design element is significantly less than a new hydropower project, and the project deliverables are somewhat different. Developing an accurate estimate depends on the definition of the scope of the work, understanding the penstock condition, and the specifications used to execute the work. Therefore, the development of deliverables, such as condition assessments and the detailed specifications for procurement and installation, rather than studies and drawings, can improve estimate accuracy.

The maturity of the deliverables for Penstock 3 was evaluated by adapting the deliverables table from the AACE recommended practice to suit a refurbishment project. Because the scope of work is very similar to Penstock 1, many of the deliverables for Penstock 1 can be considered applicable to Penstock 3.

It should be noted that estimate accuracy depends not only on the stage of the design but also on the estimating methods used. In this case, the approved budget values and unit rates for Penstock 1were considered when developing the estimate for Penstock 3.

The maturity of the project deliverables was assessed as shown in Appendix C. The assessed maturity is considered to meet the requirements of a Class 3 estimate.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Figure 2: Cost Estimate Classification Matrix

15.0 Assumptions, Exclusions and Opportunities

The following assumptions, exclusions, opportunities and risks are applicable to the cost estimate.

15.1 Assumptions

The following assumptions apply to the project:

- An adequate labour supply is available.
- [redacted]
- There will be no labour disruptions during the execution of the works.
- Regulatory approvals will be generally granted as assumed in the project schedule.
- [redacted]

15.2 Exclusions

The following items are excluded from the project estimate:

- [redacted]

15.3 Opportunities

Opportunities that may occur include:

- Synergy and sharing of resources with other projects at Bay d'Espoir;

- Improved planning due to prior execution of similar scopes, such as work on Penstock 1; and
- Savings due to utilizing one EPCM contract for all Bay d'Espoir work.

15.4 Risks

Risks that may occur include:

- [redacted]

16.0 Estimating Team

The estimating team consisted of Hydro's Major Projects Team members, who reviewed the scope of work of Penstock 3, the approved budget for Penstock 1, experience on Penstock 1, the estimated costs in the decision support package issued by Kleinschmidt Associates, updated estimate components as required, and estimated Hydro's indirect costs, escalation, and IDC, and prepared the Basis of Estimate.

`

Bay d'Espoir Penstock 3 Section Replacement and Weld Refurbishment

Basis of Estimate

Appendix A: Estimate Summary

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newfoundland labrador hydro	Bay d'Espoir Penstock 3 Basis of Estimate				
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Component	Estimated Cost (2024 $CDN)	Potential Low Range for QRA	Potential High Range for QRA
Mobilization to Site	[redacted]		
Operating and Maintaining Temporary Works Facilities			
Access Road on the North Side of Penstock 3			
Demobilization			
Subtotal: Mobilization, Demobilization, and Facilities			
Penstock Fabrication			
Penstock Delivery to Site			
Existing Penstock Removal and Disposal			
Penstock Installation			
Backfill and Bedding Lump Sum			
An Additional 2 Welds at the Upper End			
Rock Trench Stabilization			
Commissioning			
Subtotal: Penstock Replacement			
Penstock Rehabilitation			
Penstock Interior Coating			
Weld Repair			
Subtotal: Penstock Rehabilitation			
Performance Security			
Steel			
External Construction Consultants			
Subtotal: Direct Construction Costs			
Owner's Cost: FEED			
Owner's Cost: Detailed Design and Procurement			
Owner's Cost: Project Phase			
EPCM			
Subtotal: Hydro's Indirect Costs			
Subtotal: Base Cost Estimate			
Project Contingency			
Subtotal, Base Estimate (with Contingency)			
Escalation			
Interest during Construction			
Total Cost Estimate (Authorized Budget upon Approval)	**77,462,128**		

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Bay d'Espoir Penstock 3

Basis of Estimate

Appendix B: Hydro's Indirect Cost Estimate

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Phase	Component	Hours	Estimated Cost (2024 $CDN)[17]
FEED			
	Hydro MPMT & PMT	[redacted]	[redacted]
	FEED Engineering		
	Travel Allowance		
	FEED Spent to Date		
	Subtotal: FEED		
Detailed Design and Procurement			
	Hydro MPMT & PMT	[redacted]	
	Hydro Engineering Team		
	Travel Allowance		
	Subtotal: Detailed Design and Procurement		
Project Phase			
	Hydro MPMT & PMT	[redacted]	
	Hydro Engineering & Construction Team		
	Hydro Expenses (Travel & Accommodations)		
	Site Vehicles		
	Insurance		
	Internal Construction		
	Subtotal: Owner's Costs in Project Phase		
	EPCM		
	Subtotal: Hydro's Indirect Costs		

[17] Numbers may not add due to rounding.

Bay d'Espoir Penstock 3

Basis of Estimate

Appendix C: Design Maturity Assessment

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newfoundland labrador hydro	**Bay d'Espoir Penstock 3** **Basis of Estimate**				
NLH Doc. No.	**BDE-NLH-29600-ES-BOE-0001-01**	**Revision**	**B1**	**Page**	**C-1**

Category	Deliverable Description	AACE Prescribed Maturity	AACE Prescribed Score Equivalent	Hydro Review Comments	Final Assessed Maturity	NLH Final Assessed Score	Final Score Disparity	FEED Phase % Complete
Scope	Condition Assessment	P	[redacted]	Condition assessment completed by Hatch in 2019. Ongoing annual inspections by Kleinschmidt. Additional inspection is ongoing.	C	[redacted]		
Scope	Project Charter	P	[redacted]	Draft Project Charter has been developed.	C	[redacted]		
Scope	Basis of Design	P	[redacted]	Basis of Design for Penstock 1 is considered applicable. Basis of Design for PS3 is expected by July 2026.	S	[redacted]		
Scope	Decision Support Package	C	[redacted]	Decision Support Package completed	C	[redacted]		
Scope	Site Infrastructure	P/C	[redacted]	Access for can sections and equipment deliveries reviewed as part of Penstock 1 review, considered applicable to Penstock 3. Infrastructure will be shared with other BDE projects.	P	[redacted]		
Strategy	Contracting Strategy	C	[redacted]	Contracting Strategy for Penstock 1 is considered applicable. EPCM contracting strategy is complete.	C	[redacted]		
NR	Environmental Approval	NR	[redacted]	Not required.	NR	[redacted]		
Planning	Lessons Learned Reviews	C	[redacted]	Project execution Lessons Learned for Penstock 1 are applicable to Penstock 3.	P	[redacted]		

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Category	Deliverable Description	AACE Prescribed Maturity	AACE Prescribed Score Equivalent	NLH Review Comments	Final Assessed Maturity	NLH Final Assessed Score	Final Score Disparity	FEED Phase % Complete
Planning	Regulatory Application	C		PUB application in preparation for submission in July/Aug 2025.	P			
Planning	Project Master Schedule	P		Class 3 schedule developed and reviewed by Project Team. Basis of schedule document developed.	C			
Technical Deliverables	Specifications & Drawings	P		Specifications for Penstock 1 are considered applicable.	S/P			
Technical Deliverables	Mitigation Measures (Aquatic, Terrestrial, Avian, Clearing, Heritage, etc.)	P		Mitigation measures for Penstock 1 are considered applicable.	P			
Score								

Letter Code	Description
NR	Not required.
S	Work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion.
P	Work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals.
C	The deliverable has been reviewed, approved, and issued for design, as appropriate.

Schedule 1, Attachment 12

Bay d'Espoir Penstock 3 - Basis of Schedule

Newfoundland and Labrador Hydro

March 4, 2026

Bay d'Espoir Penstock 3

Basis of Schedule

NLH Doc. No. BDE-NLH-29600-PL-BOS-0001-01

Comments: The Bay d'Espoir Penstock 3 Project Basis of Schedule documents the basis and assumptions underpinning the BDE Penstock 3 Project Control Schedule. It documents the initial execution intent, sequence, and assumptions at a point in time.	**Total # of Pages (including Cover):**
This document contains confidential and commercially sensitive information. Access to this report and the information contained within is restricted and should only be shared with the written approval of the Manager of Project Controls for Major Projects.	**27**

Revision	Date (DD-MMM-YYYY)	Issue Reason	Prepared By Project Planner, Major Projects	Approved By Manager, Project Controls, Major Projects	Approved by Project Manager, BDE Penstock 3 Project	Approved by Program Manager, Major Projects
82	04-Mar-2026	Use	Gary Davis	Tony Scott	Steve Hiscock	Marc Cullen

These signatures are required to confirm compliance with Major Projects procedures. This document cannot be finalized or distributed without this approval. Any version of this document without these signatures is not considered final.

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hydro	Bay d'Espoir Penstock 3 Basis of Schedule				
NLH Doc. No.	BDE-NLH-29600-PL-BOS-0001-01	Revision	B1	Page	i

Additional Approvals

Additional approvals are required for further authorization due to document contents, complexity, prescribed requirements, or multi-departmental involvement.

Position	Name	Signature	Date (DD-MMM-YYYY)
Director of Major Projects (Regulated) and Asset Management	John Walsh		5-Mar 2026
Senior Manager, Major Projects Commercial	John Skinner		4-Mar 2026

Endorsements

Endorsements indicate support or acknowledgement of this document's contents but do not imply formal approval. Endorsements are used to represent subject matter experts who have provided input but do not hold final decision-making authority for this document.

Position	Name	Signature	Date (DD-MMM-YYYY)
Team Lead Project Controls Major Projects Management	Bethany Cutler		4-Mar-2026
Lead Engineer, BDE Penstock 1 Project	Kathleen Wadden		4/3/2026

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Attachment 1: Bay d'Espoir Penstock 3 – Project Control Schedule

Attachment 2: Bay d'Espoir Penstock 3 Project Control Schedule – WBS Structure

1.0 Executive Summary

The Bay d'Espoir Hydroelectric Generating Facility ("Bay d'Espoir") produces an average of 2,650 GWh annually, making it the largest hydroelectric generating facility on the Island. The station, from which service began in 1967, relies on penstocks to supply water to each of the generating units. In total, there are currently four penstocks that supply water to seven units, with Bay d'Espoir Powerhouse 1 consisting of six hydro units fed by three penstocks.

Penstock 3 serves as an integral component of Bay d'Espoir Units 5 and 6, which together supply 153 MW of generation and are required for Newfoundland and Labrador Hydro ("NL Hydro") to meet current customer requirements. The penstock has now been in service for approximately 55 years. These are aging assets and as such require regular inspection and maintenance. Extensive investigations and repairs have occurred on all penstocks since 2019.

In 2021, a comprehensive review was conducted by Kleinschmidt Associates. The review concluded that section replacement and weld refurbishment for Penstock 3 ("BDE Penstock 3 Project") would present the greatest level of risk mitigation and provide the highest level of reliability of the available options.

To support this project, NL Hydro has assembled a Project Control Schedule (PCS) to validate and plan a successful life extension campaign that includes activities from the initial engineering, through procurement, construction, and commissioning of Penstock 3. This document provides the basis for the PCS.

2.0 Abbreviations and Definitions

Term	Definition
AACE	The Association for the Advancement of Cost Engineering. An international industry organization that publishes many Recommended Practices (RPs) to aid in guiding project management professionals in many aspects of project execution. AACE RPs provide useful guidance but are not standards.
AFE	Authorization For Expenditure
BDE	Bay d'Espoir Hydroelectric Generating Facility.
BOS	Basis of Schedule. A companion document to the Control Schedule (CS) that explains, in narrative form, the Control Schedule as well as the various assumptions made in developing the schedule and planning the project. The Basis of Schedule is sometimes called the CSBD or SBM.
CPM	Critical Path Method. A project scheduling technique used to identify the longest sequence of dependent activities (the critical path) that determines the shortest possible project duration. CPM helps prioritize tasks, manage resources, and assess the impact of delays on overall project completion.
CS	Control Schedule. See Project Control Schedule (PCS).

Term	Definition
CSBD	Control Schedule Baseline Document. See Basis of Schedule (BOS).
EPCM	Engineering, Procurement, Construction Management. A project delivery model where the consultant provides engineering design, procures materials and equipment, and manages construction activities on behalf of NL Hydro.
FEP	Front-End Planning. A stage in project planning that includes project execution planning, environmental management planning, FEED, supply chain management planning, and construction planning.
FEED	Front End Engineering and Design
NL Hydro	Newfoundland and Labrador Hydro and its affiliates, successors, and assigns.
LTAP	Long Term Asset Planning
LEP	Life Extension Project
LNTP	Limited Notice to Proceed
MP	Major Projects Department of NL Hydro.
P6	Oracle Primavera Project Planner Version 6. The preeminent project planning software application used in North America for large engineering and construction projects. NL Hydro currently uses Release 24 of this application.
PCS	Project Control Schedule. The project schedule, developed at a control level, is used to plan project execution, monitor its performance, and make execution decisions. Also called a Control Schedule (CS).
PUB	Public Utilities Board.
RFP	Request for Proposals.
SBM	Schedule Basis Memorandum. See Basis of Schedule (BOS).
TF	Total Float. A key component of the Critical Path Method (CPM) schedule technique. Total Float is a measurement of how much an activity can be delayed without impacting project completion.
WBS	Work Breakdown Structure

3.0 Reference Documents

The following is a list of documents that either are referenced in this Bay d'Espoir Penstock 3 Basis of Schedule document or are relevant to the subject matter contained within.

Document Reference	Title
AACE RP 38R-06	Documenting the Schedule Basis[1]
AACE RP 91R-16	Schedule Development[2]
AACE RP 37R-06	Schedule Levels of Detail[3]
BDE-NLH-29600-ES-BOE-0001-01	Bay d'Espoir Penstock 3 Refurbishment - Basis of Estimate
BDE-KSG-29600-PM-DSP-0001-01	Decision Support Package: Penstocks 2 & 3 Bay d'Espoir Hydro Site

4.0 Purpose

The purpose of this Basis of Schedule is to document the basis and assumptions underpinning the BDE Penstock 3 Project Control Schedule (PCS). This document, and the PCS, are meant to be complementary and read together.

This Basis of Schedule documents the current execution intent, sequence, assumptions, risks, and opportunities developed during the Front-End Planning (FEP) phase of the project. Further project execution maturity, including design development, authorization timeline changes, execution strategy changes, scope modification, or construction contractor execution optimizations, may require updates of the PCS as well as this Basis of Schedule.

5.0 Schedule Structure

5.1.1 Tools/Applications

The PCS is prepared in Oracle Primavera Version 6, Release 24. Future Contractor and Supplier tools and applications are unknown at this point; however, contractual arrangements will require the use of

[1] AACE International. (June 18, 2009) Recommended Practice 38R-06, *Documenting the Schedule Basis*. <https://www.pathlms.com/aace/courses/2928/documents/3823>.
[2] AACE International. (August 13, 2020) Recommended Practice 91R-16, *Schedule Development*. <https://www.pathlms.com/aace/courses/2928/documents/9508>.
3 AACE International. (March 20, 2010) Recommended Practice 37R-06, Schedule Levels of Detail - As Applied in Engineering, Procurement, and Construction. < https://www.pathlms.com/aace/courses/2928/documents/3822>

industry-typical applications, nominally Oracle Primavera or equivalent. Exceptions to Primavera have to be accepted by NL Hydro. This is a standard approach on major projects to ensure the quality of contractor schedule data.

5.1.2 Schedule Structure

The BDE Penstock 3 PCS, provided as Attachment 1 to this Basis of Schedule, is a Class 3, Level 2 schedule (as per AACE International Recommended Practice 37R-06). It has been built by leveraging both historical data, which includes a recently completed project, Bay d'Espoir Penstock 1 Refurbishment. The PCS contains activities that develop a full project view of the scope, they are categorized as: deliverables for project management, regulatory activities required for project approval, execution activities to forecast engineering, procurement/fabrication, construction and commissioning. These activities track and forecast the project's progression through phases structured to follow the Major Projects Approval Process, illustrated in Figure 1. As this project progresses, and Consultants and Contractors are awarded scopes, the Consultants and Contractors will develop schedules that contain a greater level of detail with more activities. These schedules will then be utilized to update the BDE Penstock 3 PCS, with additional activities added to the PCS as required to accurately represent the forecast for scope completion.

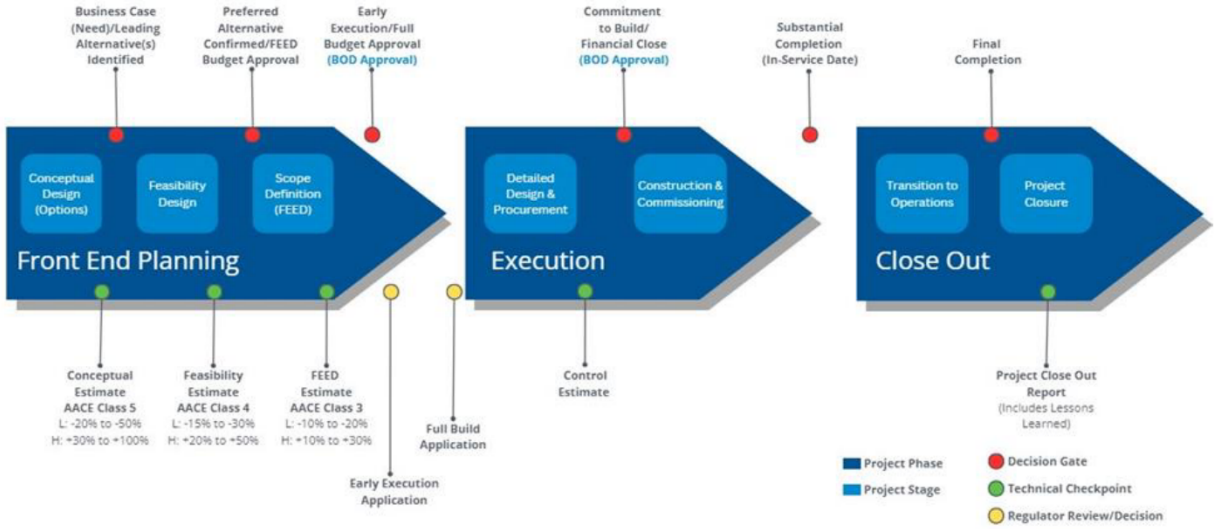

Figure 1: Major Projects Phased Approval Process

This phased definition of the BDE Penstock 3 life cycle has been summarized in the BDE Penstock 3 Project Control Schedule - WBS Structure, provided as Attachment 2 to this Basis of Schedule. Table 1 provides a summary of the Schedule Structure at the Level 1 and Level 2 WBS Level; Figure 2 shows the schedule summarized to the same levels. A full Schedule WBS listing is provided in Attachment 2.

Table 1: Schedule Structure

WBS Level 1	WBS Level 2	Items/Description
Milestones	-	Start and finish milestones marking key project specific activities from the schedule. These will be expanded to include select contractual dates.
FEP	Preparation for Execution	Activities related to the FEP stage of the project. NL Hydro documents and studies. Progressing the project towards Project Sanction and the Execution Phase.
Regulatory and Internal Approvals	Regulatory	Activities related to regulatory approvals and authorizations, such as the Public Utilities Board (PUB) required applications.
	Internal	Activities related to the internal process for approvals, such as "Authorization For Expenditure" (AFE). Required before committing to a purchase / commitment.
Execution	EPCM Contract Support	Activities associated with the selection of the Engineering Procurement Construction Management (EPCM) Consultant.
	Engineering	Activities to reflect the Engineering required to progress the Procurement and Construction items of the project. Activity relationships are logically linked so that schedule updates will show any future impacts.
	Procurement	Activities to forecast the steps and process for the procurement of contracts required to complete the project.
	Construction	For the Construction phase of the project. Currently contains an activity to identify the construction window that the project will utilize.
	Commissioning	Activities to forecast the required steps post Construction that will be required to return Penstock 3 back to an operational state.
Closeout	Closeout	In this schedule, the Execution Phase ends with the "Penstock 3 – Approval of Final Completion Certificate". The Close-Out Phase contains the activities associated with commercial close out,

WBS Level 1	WBS Level 2	Items/Description
		documentation close out (As-Built), lessons learned, and a final "Post Implementation Report."



Figure 2: BDE Penstock 3 Schedule at Level 1 and Level 2 WBS Summary

5.1.3 Calendars

P6 allows for the creation of activity calendars to model various aspects of the work execution. P6 Calendars have several purposes. In the case of the BDE Penstock 3 PCS, they are being used for activity scheduling. The calendars will define when work can take place for an activity, they identify working days and non-working days, such as weekends and statutory holidays. The non-working days can include holiday breaks or periods when work should be avoided, e.g., scheduling in-service commissioning work during the winter readiness period. For this example, a calendar would be used to restrict the work to

occur outside of the winter readiness period when system conditions would allow for such an activity to commence.

For the Bay d'Espoir Penstock 3 Project Schedule, the following calendars, and their use, are described in Table 2.

Table 2: Schedule Calendars

Schedule Calendar	Application
MP – 7 Day Calendar	Reflecting a 7-day work week, also used for any instance where a duration is referred to as "Calendar Days". This is the calendar used for milestones, regulatory activities, procurement activities, and also the construction window.
MP – Internal – 5D x 7.5 hrs	Major Projects Internal (NL Hydro) office execution calendar, reflecting a 5-day work week, with a 7.5-hour working day. [redacted]

5.1.4 Application Specific Calculation Methods

The schedule uses the Retained Logic method of schedule calculation. The Total Float (TF) method is used to determine the project's Critical Path; the criteria used is the default method where TF <= 0 is considered critical. The TF is determined based on the activity predecessor calendar and is calculated as Finish Float.

These are the application's default settings and will be used for schedule management and reporting.

6.0 Schedule Development Basis

The Bay d'Espoir Penstock 3 project is a multi-year, multi-phase project that encompasses several discrete scopes of work that all combine to form the project. The schedule was developed in a manner that allows for a clear logic path to define the forecast date for "Approval of Final Completion Certificate". The schedule development leverages the Bay d'Espoir Penstock 1 Refurbishment and Replacement contractor Project Control Baseline Schedule. The high-level project plan for BDE Penstock 3 includes:

- Approval by the Public Utilities Board (PUB) for the Penstock 3 Early Execution Scope in Q2 2026 (Required for Award of the Steel Supply Contract).
- Approval by the Public Utilities Board (PUB) for the Penstock 3 Full Build Application in Q3 2026
- Initial Engineering design complete in Q2 2026, verification complete (post Geotechnical data) in Q3 2026.
- Steel Contract awarded Q2 2026, with raw steel [redacted]

- [redacted]

Each Sub-Section below provides an overview with a listing of assumptions, issues, risks, and opportunities, by each Phase/Schedule WBS heading of the project.

6.1 Milestones

6.1.1 Overview

This section of the schedule is used to summarize key events and activities for quick reference. The milestones will reflect the dates from the detailed activities in the other phases of the schedule. As these summary milestones reflect the schedule logic, all milestones in this section of the schedule will utilize a 7-day calendar. The listing of milestones will be determined by the BDE Penstock 3 Project Manager. They can be added/modified as required to ensure proper visibility of key events.

There are milestones shown to reference the Bay d'Espoir Unit 8 EPCM contract award. Should the BDE U8 project get approved, the intention is to engage the BDE U8 EPCM Consultant to provide support to the Penstock 3 project[4]. This presents an opportunity to gain synergies across the various BDE facility Major Projects under consideration. A listing of the current milestones is shown in Figure 3.

[4] BDE U8 EPCM Consultant selection process includes the opportunity to support (where needed) the various BDE facility Major Projects under consideration. For the BDE Penstock 3 project, utilizing a site wide Construction Management Consultant would provide synergies.

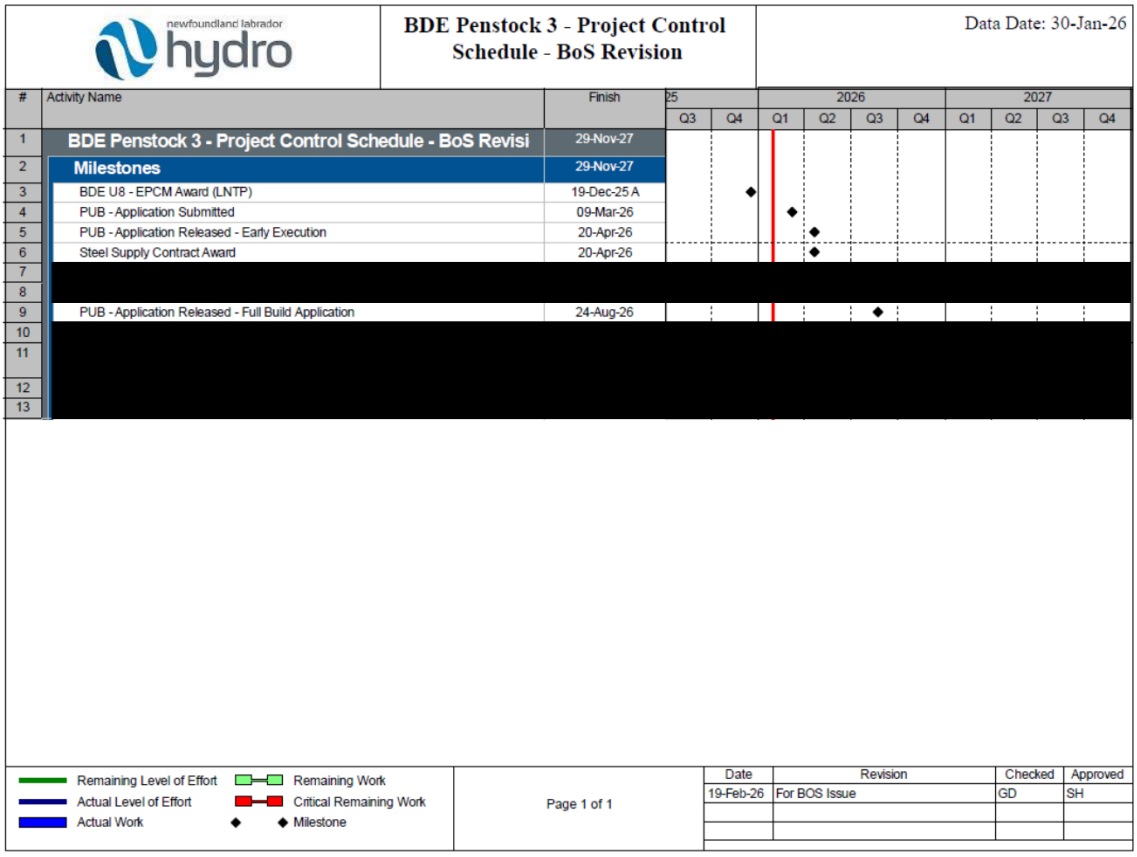

Figure 3: BDE Penstock 3 Schedule Milestone Listing

6.1.2 Assumptions

As the Milestone listing is a summary of details contained in the schedule, there are no schedule assumptions in this section of the schedule.

6.1.3 Risks/Opportunities

As the Milestone listing is a summary of details contained in the schedule, there are no Risks or Opportunities in this section of the schedule.

6.2 Front-End Planning

6.2.1 Overview

The FEP Phase contains the activities associated with the first stages of the project. For the BDE Penstock 3, the FEP phase contains activities that are used to track internal deliverables created by the Major Projects Department. These deliverables are required to provide clarity of scope definition, increase cost and schedule certainty, and to progress the project through to the Execution Phase.

6.2.2 Assumptions

The project scope has been developed based on a 2021 comprehensive review completed by consultant Kleinschmidt Associates ("Kleinschmidt"), which covered the necessary work for Penstocks 1, 2 and 3. The FEP activities are related to the deliverables for cost, schedule, and risk analysis. Durations are based on the experience of the Project Management Team.

6.2.3 Risks/Opportunities

As the FEP stage is well in progress, with all deliverables well defined, there are no significant schedule issues, risks, or opportunities for this stage of work. If there were slight delays in issuing the final FEP deliverables, the schedule has the ability to absorb these changes without affecting overall Project timelines.

6.3 Regulatory

6.3.1 Overview

The BDE Penstock 3 project is subject to PUB review and approval.

6.3.2 Assumptions

The assumptions of the Regulatory phase of the schedule related to the PUB review and approval process are:

- PUB Applications for Penstock 3 Early Execution, and Penstock 3 Full Build Application both submitted in Q1 2026
- PUB Approval of Early Execution in Q2 2026
- PUB Approval of Full Build Application in Q3 2026

As this project is within an existing NL Hydro facility, another assumption is that there are no external government permits associated with this project that would affect the start of construction. Any permits / approvals associated with construction execution will be the responsibility of the construction contractor, under the oversight of the EPCM consultant, and will be planned and obtained in such a time that they will not affect construction / project completion activities.

6.3.3 Risks/Opportunities

6.3.3.1 Risks

Regulatory approvals could take longer than assumed, which could negatively affect the project timeline, including impacting the planned seasonality of the construction work. This, in turn, could have a significant impact on project cost and schedule on this project as well as cascading into the larger Bay d'Espoir refurbishment workplan.

6.3.3.2 Opportunities

If regulatory approvals are granted more quickly than assumed, this may present opportunities. If this were to occur, there would need to be an evaluation as to the potential schedule opportunity that may be gained. As the construction phase of this project is planned to be executed with full consideration of the winter availability period, [redacted]

6.4 AFE Activities

6.4.1 Overview

Before official commitments are made to external parties, NL Hydro internal governance processes require that an Authorization For Expenditure (AFE) are approved following NL Hydro financial authority procedures, and presentation to the Board of Directors as required.

6.4.2 Assumptions

It is the schedule assumption that the preparation of the [redacted] and that all required data is known and available to support the documentation. The review and approval process is also estimated to take [redacted] It is assumed that AFE's will be required before the following commitments are made:

- Phased Array Ultrasonic Testing
- Steel Purchase
- Full Project

Additional AFE's may be required if further commitments must be made prior to full project approval.

6.4.3 Risks/Opportunities

6.4.3.1 Risks

AFE approvals could take longer than assumed, which could negatively affect the project timeline. To mitigate this risk, the timing of preparing the AFE and the approval are sequenced in such a way as to [redacted]

6.4.3.2 Opportunities

The AFE activities define a required internal process. As such, there are no opportunities, from a schedule perspective, to achieve.

6.5 Execution

6.5.1 Overview

The execution phase of the schedule contains activities for EPCM engagement, Engineering, Procurement, Construction, and Commissioning.

EPCM Contract Support:

The activities in this section reflect the effort required to secure an EPCM Consultant. An evaluation was completed to determine whether EPCM support for the Penstock 3 Project should be included in the broader BDE EPCM Consultant RFP; this support was ultimately included. Following this decision, a Scope of Work (SoW) specific to the Penstock 3 Project was issued to define the project-specific EPCM support requirements

Engineering:

The engineering activities reflect the strategy to progress the engineering design, utilizing the Penstock 1 information and adjusting for the Penstock 3 project. Information from a Penstock 3 Phased Array Ultrasonic Testing field investigation, and a Geotechnical field investigation will be used to confirm / finalize the engineering design information which will then be used in the work execution preparation to the completed by the Construction Contractor. The EPCM Consultant will provide engineering support for this project.

Procurement:

The procurement activities reflect the strategy to engage the following contracts:

- Steel Contract to supply the steel to be used by the Construction Contractor for the required replacement sections of Penstock 3.
- Construction contract: to plan, prepare, fabricate penstock sections, and execute for the 2027 execution season works.

Construction:

The construction portion of the schedule is divided into two categories: Fabrication and Site Work. Fabrication activities allow the Construction Contractor to develop shop drawings for the fabrication of the steel penstock sections. There is also [redacted] for the fabrication of the steel sections.

Site Work activities include modifications to the BDE site distribution lines. These lines will need to be raised where they may interfere with Penstock 3 site work. This work is planned to occur during the summer of 2026 as part of the BDE Unit 8 early site work. The schedule also includes an activity within the PCS that serves as a placeholder to represent the required completion window for the construction scope. Once a Construction Contractor has been selected, these construction activities will be further expanded to reflect the contractor's execution strategy and schedule durations.

The current contractor schedule for Penstock 1 is used as a reference to verify that this scope of work can be completed within the planned construction window. Based on lessons learned from the actual execution of Penstock 1, the assumed execution period is now from [redacted]

Commissioning:

There is one, high level commissioning activity in the PCS to reflect the duration to complete the commissioning required with the Penstock 3 refurbishment / replacement. The allotted duration has been updated based on the information from the Penstock 1 project. While commissioning of a penstock is a relatively straightforward process, more detail will be added, as required, once a construction contractor has been selected and they have provided their detailed schedule.

6.5.2 Assumptions

Assumptions for the execution phase will be outlined by each heading of EPCM engagement, Procurement, Engineering, Construction, and Commissioning.

EPCM Contract Support:

The EPCM Contract Support for Penstock 3 scope is included in the overall BDE EPCM contract. The BDE EPCM contracting process has been completed, with a Limited Notice To Proceed (LNTP) issued to Atkins Realis. A kick off meeting has been held, and the EPCM Consultant has started to provide support to Penstock 3 for the engineering design / verification and will provide construction management support at site. The estimated timelines will have to be verified / updated once the EPCM Consultant submits their baseline schedule.

Engineering:

There are a few engineering assumptions for this portion of the schedule. These include:

- Initial engineering support will progress once the EPCM Consultant has been selected and is engaged with a LNTP. This would allow some limited engineering support to be provided before full project approval / release by the PUB.
- The design will be based on an existing engineering design completed for the Penstock 1 project. These projects are similar in overall scope. The penstocks are located next to each other, and design parameters would be consistent, resulting in similar design for the steel bidding process.
- Penstock 3 site specific Phased Array Ultrasonic testing and geotechnical investigation will be completed, with the assumption that [redacted]

Procurement:

There are a few procurement assumptions that are included in the PCS. These include:

- Initial procurement activities (assembly of Scopes of Work, RFP documents, etc.) are dependent on the initial engineering work completed by the EPCM contractor under a LNTP.
- Steel supply is estimated at [redacted]
- Construction contractor would be awarded with sufficient time to allow for the contractor to prepare for site execution (assumed to be [redacted]). This would allow the contractor to prepare workplans, obtain permits, and arrange subcontractors.

Construction:

There are several assumptions that are included for the Construction works. These include:

- All access roads and bridges necessary to bring the equipment to the site are, and will be, in acceptable condition, with no load de-ratings in place.
- Site specific preparation will be executed before commencement of Construction activities.
- Fabrication of steel sections is estimated to be [redacted] in duration, after raw steel is available, and Shop drawings have been approved.
- The planned construction window (assumed as [redacted]) reflects the "Non-Winter Load Period" that would allow for the Penstock 3, and associated generating Units, to be shut down to allow for construction.
- It is assumed that Units 5 and 6 (supplied by Penstock 3) will be able to be taken out of service for the 2027 construction season. While this is the planned approach, this depends upon conditions across the entire electrical generation portfolio.
- The construction window duration is acceptable for the Penstock 3 work to be completed, and returned to operational status.
- Any work planned to be executed on the related turbines or other related assets during the outage for the penstock works will be completed within the time window of the penstock works, and not hamper the penstock construction works.

Commissioning:

The assumptions for the commissioning section of the PCS are:

- Estimated commissioning duration is assumed to take [redacted] Penstock 1 contractor's execution schedule was considered when developing this estimate.
- As this is a penstock refurbishment and replacement project, [redacted] Final commissioning will be completed with a watering up test activity.
- Any [redacted] will be identified and managed so that the effects are reduced, if not eliminated.
- Commissioning tests may be permitted to be performed once the work is completed, even if the work extends into the winter period.

6.5.3 Risks/Opportunities

6.5.3.1 Risks

- Delays to the steel contract procurement could impact the ability to execute the project in the 2027 construction window.
- [redacted]

- Delays to the regulatory process may significantly impact the ability to maintain the schedule, particularly the ability to [redacted] which could have a [redacted] If the approval is delayed such that the planned seasonal construction activities cannot be commenced as scheduled, there is an increased risk of at least a full-year delay. Any such delay could materially affect the overall sequencing of work at the Bay d'Espoir generating station and may give rise to subsequent impacts on other projects.
- [redacted]
- [redacted]

6.5.3.2 Opportunities

Construction Execution is based on the Penstock 1 accepted contractor baseline schedule. Completing the Penstock 1 project in the 2025 construction season could allow for valuable lessons learned which could improve the execution philosophy for Penstock 3. One such lesson learned is [redacted]

7.0 Overarching Critical Path

The overarching critical path for the BDE Penstock 3 project is calculated to occur through the 2027 construction season (which has the basis that Penstock 3 can only be taken off-line during the non-winter load period [redacted]

[redacted]

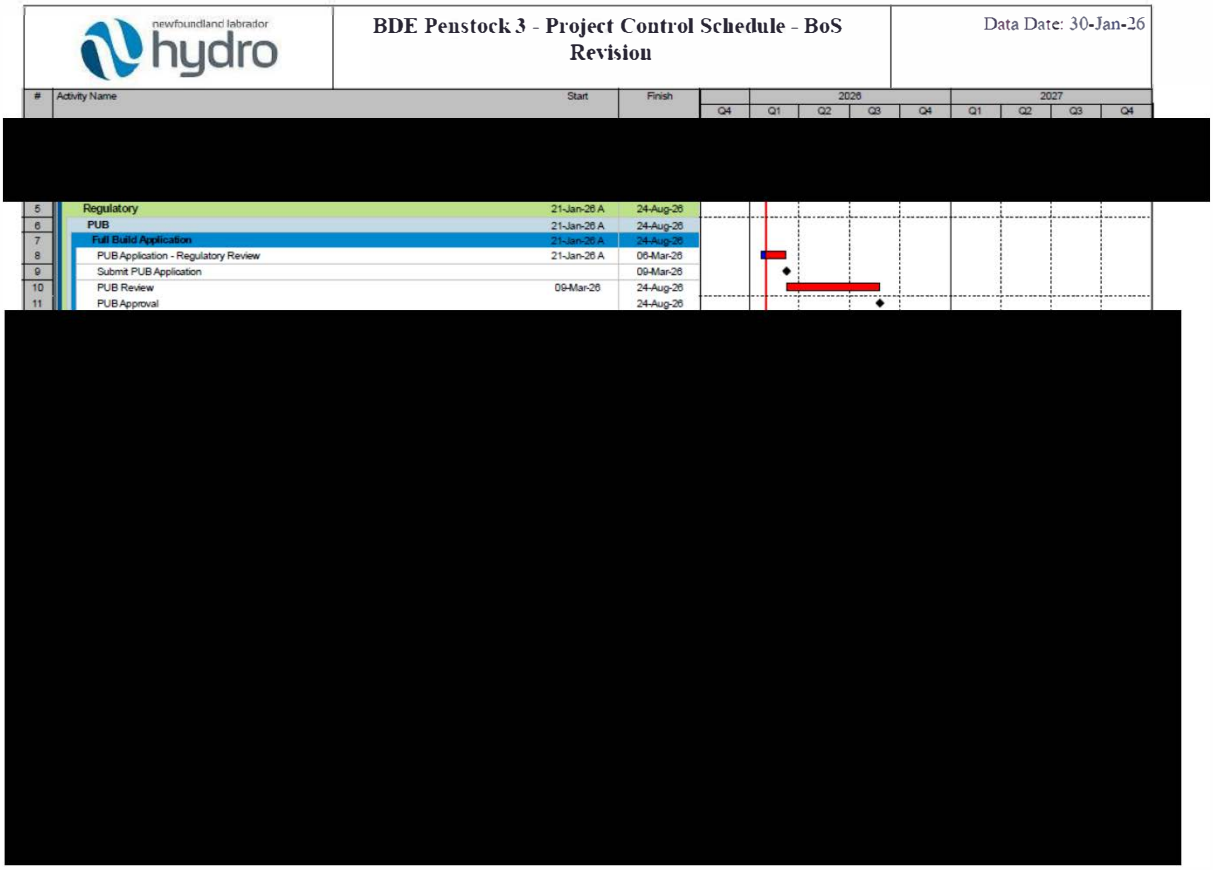

Figure 4: BDE Penstock 3 Project Critical Path

8.0 Schedule Contingency/Schedule Reserve

9.0 PCS Updates/Revisions

The PCS will be updated and revised at key points throughout the project life cycle in accordance with the Major Projects change control process. The following milestones represent known instances when updates to the PCS will occur:

- EPCM Contract Award:
  Upon award, the EPCM Consultant will provide more detailed information to support the engineering review and design of the Penstock 3 scope. The PCS will be updated to reflect contractual milestone dates and revised activity durations.
- Steel Supply Contract Award:
  Steel availability and readiness for shipment to site will represent critical activities. At this stage, the PCS will be updated with contractual milestone dates and revised forecast dates.
- Construction Contract Award:
  Following contract award, the Construction Contractor will submit a detailed schedule outlining the execution strategy. This schedule will be used to update the PCS with increased level of detail.

Additional updates to the PCS may be required as the project progresses; however, such updates will only be permitted through the project's formal change management process and with approval from Senior Management

Bay d'Espoir Penstock 3

Basis of Schedule

Attachment 1: Bay d'Espoir Penstock 3 Project – Project Control Schedule

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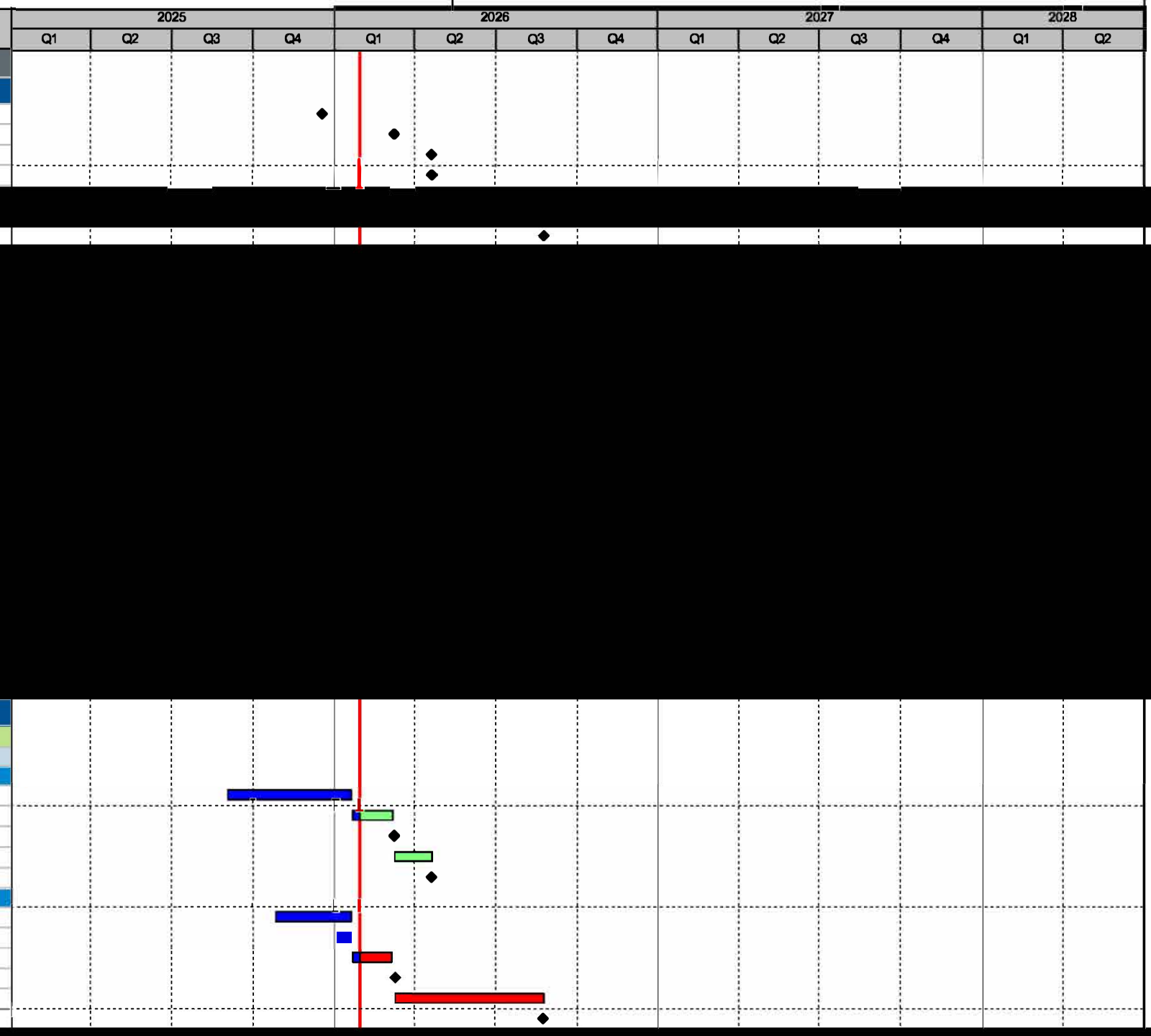
BDE Penstock 3 - Project Control Schedule - BoS Revision

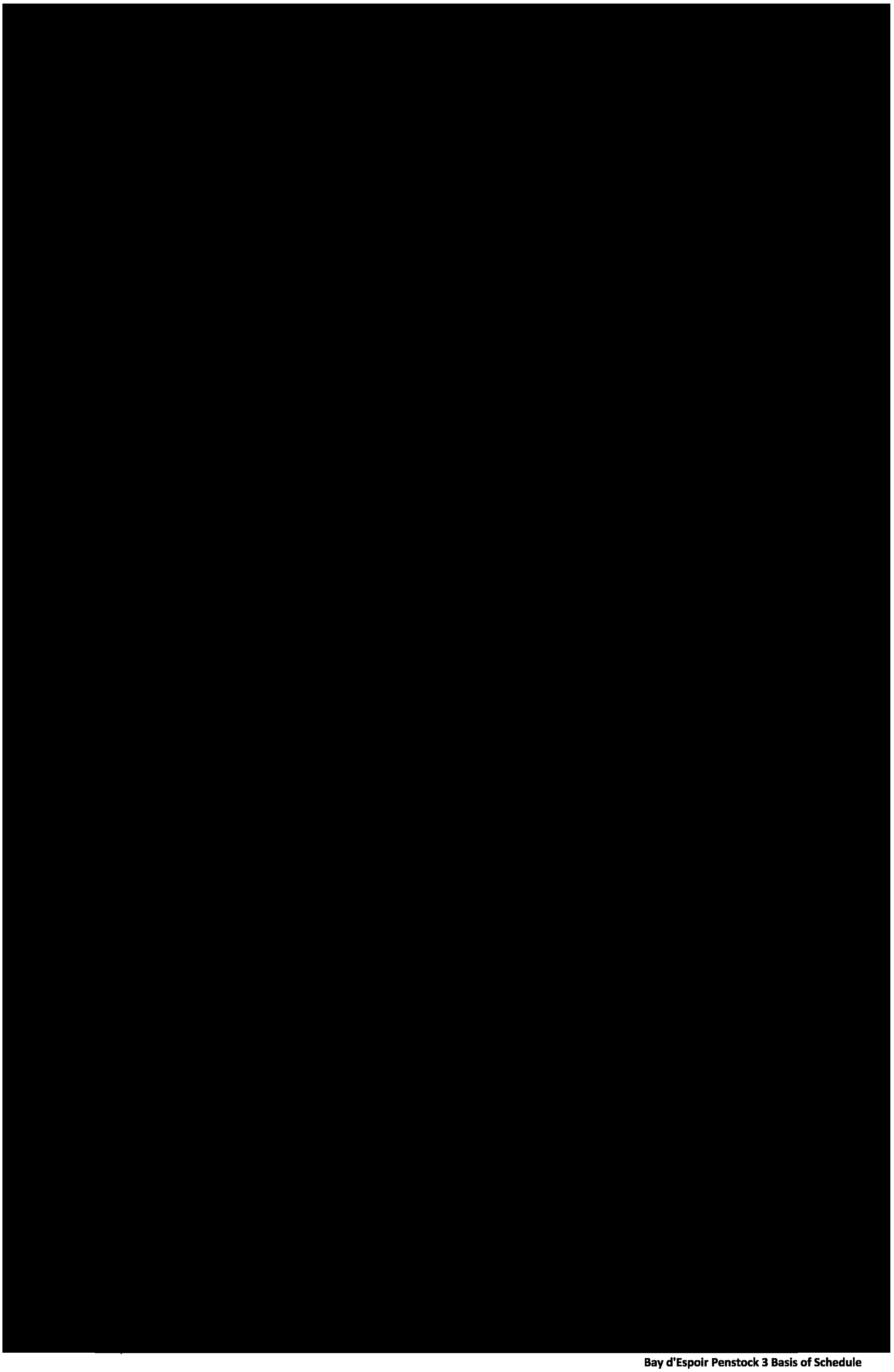
Data Date: 30-Jan-26

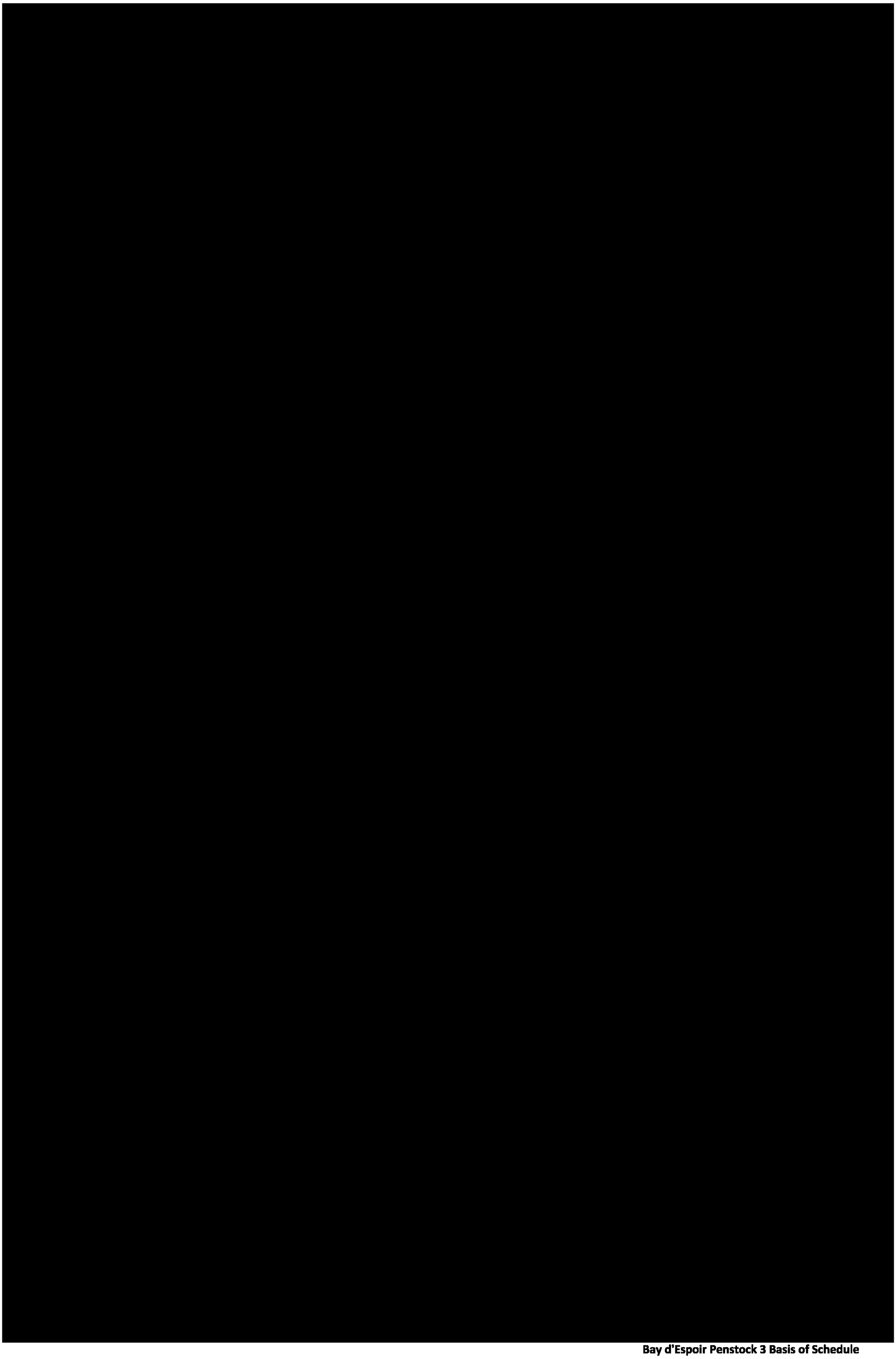
Activity ID	Activity Name	Start	Finish
BDE Penstock 3 - Project Control Schedule - BoS Revision		16-Dec-24 A	30-Mar-28
Milestones		19-Dec-25 A	29-Nov-27
BDE-P3-M1025	BDE U8 - EPCM Award (LNTP)		19-Dec-25 A
BDE-P3-M1012	PUB - Application Submitted		09-Mar-26
BDE-P3-M1055	PUB - Application Released - Early Execution		20-Apr-26
BDE-P3-M1033	Steel Supply Contract Award		20-Apr-26
[redacted]			
BDE-P3-M1022	PUB - Application Released - Full Build Application		24-Aug-26
[redacted]			
Regulatory and Internal Approvals		02-Sep-25 A	08-Sep-26
Regulatory		02-Sep-25 A	24-Aug-26
PUB		02-Sep-25 A	24-Aug-26
Early Execution		02-Sep-25 A	20-Apr-26
A9032	Prepare PUB Early Execution Application	02-Sep-25 A	20-Jan-26 A
A9042	PUB Early Execution Application - Regulatory Review	21-Jan-26 A	06-Mar-26
A9052	Submit PUB Early Execution Application		09-Mar-26
A9062	PUB Review - Early Exectuion	09-Mar-26	20-Apr-26
A9072	PUB Approval - Early Execution		20-Apr-26
Full Build Application		27-Oct-25 A	24-Aug-26
A1180	Prepare PUB Application	27-Oct25 A	20-Jan-26 A
A9012	Review / Update PUB Application with Penstock 1 End of Project Data	05-Jan-26 A	20-Jan-26 A
A1530	PUB Application - Regulatory Review	21-Jan-26 A	06-Mar-26
A1280	Submit PUB Application		09-Mar-26
A1190	PUB Review	09-Mar-26	24-Aug-26
A1200	PUB Approval		24-Aug-26



Remaining Level of Effort
Actual Level of Effort
Actual Work
Critical Remaining Work
Remaining Work
Milestone

Date	Revision	Checked	Approved
19-Feb-26	PCS for BOS Issue	GD	SH





Bay d'Espoir Penstock 3

Basis of Schedule

Attachment 2: BDE Penstock 3 Project Control Schedule – WBS Structure

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	Page 1 of 1	© Oracle Corporation

Schedule 1, Attachment 13

Project Execution Strategy and Plan: Penstock No. 1 Bay d'Espoir Hydro Site

Kleinschmidt Associates

March 2022



PROJECT EXECUTION STRATEGY AND PLAN: PENSTOCK NO. 1

BAY D'ESPOIR HYDRO SITE

FRONT END ENGINEERING AND DESIGN

Prepared for:
Newfoundland and Labrador Hydro

Prepared by:
Kleinschmidt Associates

March 2022

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (NL Hydro) reviewed four options regarding the long-term life extension of Bay d'Espoir Penstocks No. 1, 2, and 3 to provide asset integrity and reliability at best value to rate payers. A decision support package was developed to facilitate NL Hydro's decision-making process for each of the three penstocks regarding which of the four options to advance. The decision support package evaluated the costs, benefits, viability, life expectancy, and risks associated with each option for each penstock. NL Hydro has decided to move forward with Option 3 for each penstock.

Option 3 involves the replacement of the 17-foot diameter section of penstock plus weld refurbishment and recoating of the interior of the smaller diameter sections of the penstock. Welds to be refurbished will be selected after inspection of all welds downstream of the 17-foot diameter section.

This Project Execution Strategy and Plan Report focuses on reviewing or considering items that have significant impacts to the overall schedule and costs associated with refurbishing Penstock No. 1 and outlines an execution plan based on the findings of the review. This report focuses on Penstock No. 1 but due to the refurbishment similarities, proximity, and benefits of back-to-back refurbishment Penstocks 2 and 3 are included in much of the discussion and considerations.

The sequence in which the penstocks are to be refurbished assumes all three (3) penstocks will be refurbished within a three (3) year period and the refurbishment will scheduled sequentially such that no more than a single penstock is out of service at any one time, beginning with Penstock No. 1 and working from right to left across the three (3) penstocks. This would have savings in mobilization and demobilization costs in-between penstocks refurbishments. Having trained and dedicated personnel through all three back-to-back penstocks refurbishments would maximize productivity and consistency. Back-to-back refurbishment would see the project complete in three years which would mitigate risks related cost increases for material and labour, when compared to a schedule that could extend out over eight years if refurbishment is not back-to-back. Back-to-back refurbishment also mitigates the risk of a penstock failure before it is refurbished. However, back-to-back refurbishment is not a requirement, and it is considered acceptable from a risk perspective to spread the refurbishments out with Penstock No. 1

being completed first in the next 2 to 3 years. Spreading the refurbishments out allows greater financial and operational flexibility for NL Hydro.

We have assumed at this point that the work for Penstocks 1, 2 and 3 is completed as a single job and there are shared costs. Due to the amount of weld repairs expected and new penstock being installed it is not practical to expect more than one penstock refurbishment to occur at the same time; however, they can be refurbished sequentially. Refurbishing more than one at a time would also have significant impacts to generation.

Based on the execution strategies and plan outlined in this report, the total refurbishment estimate for Penstock No. 1 is $34.0 Million including contingencies. Although the total schedule for the Penstock No. 1 refurbishment extends 592 days, the unit outage is estimated to be 7 months and is scheduled for the period May to November.

An interesting finding from the studies is that the percentage of weld refurbishment does not have as great an impact on overall project cost as was assumed during earlier phases of this project. Fifty percent of the welds was again assumed to require refurbishment for this study which matches previous estimates and provides good comparison between this estimate and previous estimates. A high-level sensitivity analysis was added to this study that analyzed the costs for 25 percent and 75 percent weld refurbishment. The results show a $375,000 savings at 25 percent, and a $514,000 cost increase if 75 percent of welds require refurbishment instead of 50 percent. These represent between a 1.1 and 1.5 percent cost change for a 25 percent change in the amount of weld refurbishment. We find the cost of mobilizing, getting setup and getting in place has a significant influence on the cost of the weld refurbishment. It is also noted that the expected weld refurbishment is closer to 25 percent based on the quantity and outcomes of previous weld inspections and repairs

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1.0 INTRODUCTION

Newfoundland and Labrador Hydro (NL Hydro) reviewed four options regarding the long-term life extension of Bay d'Espoir Penstocks No. 1, 2, and 3 to provide asset integrity and reliability at best value to rate payers. A decision support package was developed by Kleinschmidt to facilitate NL Hydro's decision-making process for each of the three penstocks regarding which of the four options to advance with. The decision support package evaluated the costs, benefits, viability, life expectancy, and risks associated with each option for each penstock. After review of the options presented within the decision support package, NL Hydro has decided to move forward with Option 3 for each penstock. Option 3 is the option recommended in the decision support package. Option 3 involves the complete replacement of the 5.2 meter (m) diameter section of penstock, weld refurbishment of the smaller diameter sections of the penstocks and coating of the interior surfaces of the entire penstock runs. The extent of weld refurbishment will ultimately be selected after detailed inspection of all welds during execution of the work. Assumptions on the scope of the weld refurbishment effort have been made for quantification purposes in the interim.

The Project Execution Considerations, discussed within Section 2 of this report, outlines high level execution strategies for Penstock No. 1, 2, and 3, as well as synergies and opportunities for cost savings between the initiatives identified. These strategies include fabrication of the replacement section of penstock, coating application and procurement, transportation of penstock cans, local granular material and fill sources, removal and replacement of the penstock, risks, controls, and mitigation.

Utilizing the strategies developed and discussed within the Project Execution Considerations narrative, a Project Execution Plan for Penstock No.1 was developed. The Project Execution Plan, discussed within Section 3.0 of this report, supports the AACE Class 3 cost estimate and supporting Schedule for the planned life extension of Penstock No.1. The Project Execution Plan discusses the estimate classification and assembly methodology, basis of which the schedule and estimate are based upon, assumptions and exclusions within the cost Estimate and supporting Schedule, and risk and opportunities.

The Kleinschmidt Team working to develop the Project Execution Plan consisted of Kleinschmidt Associates providing engineering support and guidance, Chant leading

development of the cost estimate and schedule, and Skarborn Engineering providing guidance and data on weld design and productivity.

References to right and left in this report are from the point of view of someone looking downstream.

2.0 PROJECT EXECUTION CONSIDERATIONS

There are several items and strategies that require consideration when developing a Project Execution Plan. This section of the report outlines high level execution strategies for Penstock No. 1, 2, and 3, as well as synergies and opportunities for cost savings between the initiatives (common elements) identified.

2.1 Execution Sequence

The overarching approach to the delivery of the overall project scope is to complete the work for all three (3) penstocks within a three (3) year period and to schedule the work sequentially such that no more than a single penstock is out of service at any one time, beginning with Penstock No. 1 and working from right to left across the three (3) penstocks. Each construction season will incorporate a May to November timeframe (seven months). It has been assumed that the tendering of the work by NL Hydro would enable the longer lead time requirements of the new 5.2-meter diameter penstock to be addressed in a cost-efficient manner.

It is understood that NL Hydro may choose to space out the refurbishment of the penstocks over a longer period such that the total project would be completed in maybe eight years instead of three with two or three years of no activity in between each penstock refurbishment. Such a strategy can have benefits with regards project financing that is outside our scope to review. Extending the total project timeline can also add flexibility to operations and facility maintenance. Completing each penstock back-to-back focuses resources on BDE for three straight years and will result in delayed maintenance and capital projects at other NL Hydro facilities. There are mobilization/demobilization type costs that will increase if the penstock refurbishments are spaced multiple years apart; and there will also be material and labour cost increases and risk associated with extending the total project timeframe. We estimate the cost difference to be approximately 3 to 5%.

2.2 Site Infrastructure

2.2.1 Potential Camp Location

The proposed campsite is located along Highway 361 at a distance from Intersection G of 8.8 km, as seen in Appendix 1. The camp site was the same as that used by the contractor (RS Lines) to complete the Muskrat Falls Labrador-Island 230 kV transmission line in this area.

The identified property is currently owned by Newfoundland (NFLD) Aqua Services (part of the AKVA Group). The proposed plan is to install a camp that will accommodate 60 people as to not adversely impact the local accommodations capacity and to keep construction personnel away from St. Alban's. The possibility to again utilize the property as a campsite was investigated with the president of NFLD Aqua Services, Mr. Boyd Pack (boydpack@newfoundlandaqua.com). Mr. Pack could not commit to being able to make the site available given the early stage of this project's execution planning, but he did provide some insights into the previous camp installation.

The site previously worked for NFLD Aqua Services simply because at the time they had space available that met RS Line's requirements. The RS Line's camp housed 100 people and arranged/paid for its own electrical hookup, communications, septic, and water services. Aqua Services indicated that if the land was available when needed, they would be willing to also work with NL Hydro in this respect.

2.2.2 Laydown Areas

There is an on-site quarry (designated as Quarry 1) that is owned by NL Hydro east of the intake structures. The quarry is not currently active. This area would serve as a staging/permanent disposal area for the required excavations associated with all the penstock work. The plan also utilizes Quarry 1 as the primary earthmoving equipment yard/maintenance area. The size of the area is approximately 1.3 ha as measured from Google Earth. The cost estimate assumes that grid power is not available at this location and therefore, requiring the use of generators for electricity supply.

An office/fabrication yard area was selected located off Surge Tank Road to the left of Penstock No. 3. The area is approximately 0.5 ha. The cost estimate assumes that grid power connection is available at this location.

For the replacement penstock cans, the base case approach will be delivery from the wharf with any required short-term staging being on the transporters. The staging area (which could double as an offloading area if that became necessary) would be along the right hand side of Penstock No. 1. This area, approximately 0.5 ha, can serve a similar function for the replacement work associated with both Penstock No. 1 and 2.

A corresponding area between Penstock No. 2 and Penstock No. 3 (downstream of the Penstock No. 3 rock cut) would serve a similar function for the replacement of Penstock No. 3. The area does not show on the sketches, but we estimate developing approximately

0.5 ha as well. The cost estimate assumes that grid power connection is available at this location.

A series of small laydown areas is also planned in support of each refurbishment crew immediately adjacent to each of the spring line access portals planned. Each small portal laydown will have space for two (2) crew containers (Sea Cans), generators, welders, and ventilation equipment.

Overall, developing approximately 3 ha of laydown and yard areas is anticipated (including stockpile/disposal areas) most of which will be for the use of all three (3) penstocks.

2.2.3 Hard Faced Wharf

The wharf side fish packing plant in St. Alban's is currently closed (mothballed). The facility is operated by the Barry Group. The wharf itself has a 60 m outside hard face and 40 m inside hard face. Archived photographic evidence indicates the wharf can handle ocean going (deep draft) vessels on both sides – this was confirmed by Redmond King, a former NL Hydro employee who worked on the original construction of the BDE BS in the mid-1960s as a millwright/welder (Horton CBI). Mr. King is familiar with the facility.

It appears the wharf was built to facilitate the original construction of the project fifty years ago as stated in the publication "50 Years Bay d'Espoir Generating Station" (a book prepared by NL Hydro in celebration of the 50th anniversary of the BDE GS). Mr. King reported that half penstock rolled steel sections were delivered from Montreal by ocean going ships to the wharf during the original construction.

The wharf appears to be in good shape. The capacity of the structure is not known while require some further investigation and a cost allocation for upgrades and repairs at the end of the construction period in the estimate. The deck is wide enough to handle an appropriately sized lattice boom crawler crane. The plan is to receive completed penstock cans (5.2 m diameter) and off-loading them at this location.

Mr. Fabien Organ of Barry Group was contacted and Mr. Organ noted the depth of the water is approximately 8 m wharf side. Barry Group doesn't own the facility – it leases the fish packing plant from the Government of NL and as such has use of the wharf.

Ms. Gail Hoskins, Regional Aquaculture Manager, Fisheries and Aquaculture Branch, Department of Fisheries, Forest & Agriculture was also contacted. She noted that the wharf area in St. Alban's consists of a deck area of approximately 10 m x 110 m and another deck area of 11.5 m x 41.025 m. Both wharf sections have 250 mm of concrete for the decking. There is commercial activity from November to June each year whereby access to the wharf could be restricted. The Barry Group has some structures and a trailer on the wharf which may create navigation on the wharf difficult.

The existing buildings of the fish packing plant will need to be modified (partially demolished and perhaps later rebuilt (to be confirmed with the Barry Group) to facilitate the delivery, loading and transportation off the property of fully assembled penstock cans.

It is assumed that each can will be staged on a dedicated fifth wheel trailer on the barge deck, allowing fifth wheel tractors to hitch up and remove the cans across the barge's side ramp onto the St. Alban's wharf deck and take the cans to a storage area near the site. Ship turnaround schedules might involve staging of penstock cans at the wharf (unload the ship as quickly as possible) necessitating additional fish plant demolition/replacement.

There are potential overall cost saving opportunities available if the site infrastructure is planned and developed contemplating the life extension program for all three (3) penstocks, including any required upgrades to the wharf and camp site development infrastructure.

2.3 Qualified Fabricators

The following suppliers were contacted to request budgetary costs to fabricate the new 5.2-m diameter penstock:

- DF Barnes Fabrication, St. John's NL – supplied the steel plate for the emergency repairs of BDE GS Penstock No. 1
- Bell-Camp Manufacture Inc., Ingersoll ON – supplied 305 m long, 2.1-m diameter penstock to OPG's Matabitchuan Penstock Replacement Project
- Northwest Pipe Company, Vancouver WA, USA – provided several cost competitive quotations for Chant's BC and ON projects
- Le Groupe Lar, Métabetchouan-Lac-à-la-Croix, Québec – supplied 10-m diameter penstock to BC Hydro's Site C Clean Energy Project
- RothLochston Company, Paradise NL – completing over ten (10) penstocks replacement for NL Power

At the time of writing, a positive response to the request for budgetary (indicative) quotations and shipment methodologies had been received from Le Groupe Lar as outlined in Appendix 2. This entity planned to manufacture the steel penstocks at their fabrication facility located in Havre-Saint-Pierre, Quebec and then deliver the full section cans to the St. Alban's wharf via a marine vessel. By utilizing Google Maps, the approximate sea-transportation distance is estimated to be 853 km.

Regarding the consideration of any potential cost savings/other project benefits that could be achieved through steel procurement for all three (3) penstocks versus procuring steel for each penstock in separate, standalone contracts, we agree with Le Group Lar's response to this question:

- "There is probably a major impact on the work if NL Hydro wants to proceed with all three (3) penstocks at once since the scale and volume of steel is much bigger; different logistic solutions could be considered. For sure they should expect savings, but it is still very early to commit on the scale of those savings."

Work on developing a high-level fabrication schedule will continue with the companies who respond to inquiries in support of establishing a realistic penstock can procurement timeline.

2.4 Coating Strategy

The scope of Option 3 includes coating of both the replaced and refurbished sections of penstock. Kleinschmidt has proposed two coating product options for the interior coating application:

- A three (3) coat urethane system - Wasser MC-Miozinc, MC Ferrox B and MC Ferrox A.
- A single coat epoxy Cermapure-PL-90 by Induron.

From an application perspective, there is likely a time and cost savings with the single coat product. For the purposes of the cost estimate however, the three-coat urethane system will be utilized. Both approaches require the same surface preparation strategies (SSPC - SP10 Near White Blast Cleaning).

The completed 5.2 m diameter penstock cans will be factory coated. Field coating of the circumferential welds, coating repairs at internal spider contact points and other touch-up type coating effort will be required.

Field coating of the refurbished penstocks using an automated robotic machinery methodology was used assumed in the estimate. A case study entitled "Using Robotics Technology to Reline Large Diameter Piping on Steep Slope", documents a 2016 relining initiative at the Central Arizona Project Mark Wilmer Pumping Plant, as outlined in Appendix 3. This case study presents the state of the art for the use of robotics on steep inclined structures, with 9,800 m^2 of a 3.65 m diameter pipe being relined with a coating in less than 90 days. In this case study, contractor personnel guided and monitored the robotic equipment from inside the pipe while the robots prepared the surface and coated the interior of the pipe structure. The approximate production rates during this project for each robot were as follows:

- Ultra-high pressure water jet robot: 335 m^2 per shift
- Abrasive blast robot: 170 m^2 per shift
- Coating robot: 560 m^2 per shift at 1.524 mm dry film thickness

Attaining the required SSPC - SP10 abrasive blast outcome at this robotic production rate needs to be confirmed.

Regarding the consideration of any potential savings that could be achieved through deferring the coating effort until all three (3) penstocks were replaced/refurbished and available (a single coating mobilization versus three (3) separate coating initiatives), we believe there would be only nominal savings realized and that these would come from reduced mobilization of the robotic equipment and skilled applicators. This saving would be readily offset by the additional work required to provide a suitable environment for coating application after operation for a period and the additional penstock outage required. The coating work could be readily tendered by NL Hydro as a single package independent of the penstock work and then be performed over three (3) years.

2.5 Transportation Requirements and Restrictions

Penstock fabricators were requested to premise their planning and quotations on the supply of completed penstock segments, including interior coating, with a governing length of approximately 15 m. The intent behind this approach is to eliminate longitudinal field shop welding and minimize circumferential field shop and field welds. The major constraints of the approach included overwater shipping costs with premiums associated with bulky dimensional loads, logistics associated with ground transportation and penstock can weight with handling during transport and setting.

The strategy is to have completed penstock cans staged on dedicated fifth wheel trailers and delivered to the designated wharf in St. Alban's, via free on board (FOB) ship or oceanic barge. The sequentially delivered units will be unloaded from the marine vessel using fifth wheel tractors to hook onto the trailers and drive the cans off the barge on to the wharf. From the wharf, the penstock cans will be ground transported over existing roads to alongside the pipe placement crane at site. Alternatively, if the wharf is not available, the trailers could be offloaded at St. Joseph's Cove by beaching the barge and providing a ramp and causeway as was done for Transformer T7 in 2016. The current allowance for St. Albans wharf modifications would be diverted and is expected to cover the costs of this alternative.

The scope of the transportation activity for each penstock is to move approximately 331 m of new 5.2 m diameter steel pipe of various lengths. With some special fabricated segments – transition sections, bends and closure pieces – it is estimated that there will be between 25 and 29 segments per penstock. A 15-m-long penstock will weigh about 11 tonnes without internal spider support or stiffener rings.

The planned penstock transportation route is identified in Appendix 3. The one-way haul distance is 21 km. The selected route will substantively avoid St. Alban's centre by utilizing the Upper Salmon Spillway Access Road, Long Pond Access Road and Air Strip Road. Most of these roads were built for the original construction, ostensibly to avoid a series of unrated bridges. The bridges may have since been upgraded to highway standards between the wharf and BDE GS site. The existing classification of the preferred route can be described as public forestry service. The last 1 km will be on good quality construction type roads but with relatively steep grades.

The forestry road sections will require upgrading (establishment of crowns, rolling surface and drainage improvements) in addition to standard seasonal type maintenance (to be included in the cost estimate). No vertical or horizontal profiling work is anticipated. Some tow/restraint assist for the tractor/transporters is planned and the costs for this work is included in the cost estimate.

Overhead utility plans along the available penstock transportation corridors was a major consideration in selecting the forestry class route over hard surfaced roadways through St. Alban's, which at the time of the original construction of the BDE GS was unelectrified.

Fourteen (14) minor overhead interfaces were identified along the preferred route ranging from overhead guy wires and simple residential services to distribution voltage line crossings requiring raising. Appendix 4 depicts some of the identified overhead interfaces. A mix of permanent and temporary burial/raising solutions has been assumed within the more urbanized reaches of the route. There is one (1) major distribution circuit crossing with multiple circuits and communication wires that will need to be permanently addressed. Some additional non-standard road maintenance/refurbishment at the end of construction work is expected for the urban roadways along with standard seasonal type maintenance which is assumed to be provided by the town of St. Alban's.

Outside of St. Alban's, a medium voltage transmission line crossing, power supply to the Upper Salmon Spillway, has been identified. The contemplated penstock transporters will pass under this crossing, but insulation and a temporary in-bound protection structure is planned. It would appear likely NL Hydro could get a Road Closed – Local Traffic Only designation during penstock hauling operations but piloting the loads will still be required.

We have reached out to the Highway Enforcement with respect to what, if any, permits are required for transporting dimensional loads over the roadways making up the preferred route. While the response to our queries as to permit requirements along the preferred route where not clear, some permitting obligations are expected and allowances for procuring these permits is included in the cost estimate.

The condition of the haul roads and the grades/conditions of site led to the robust approach of using a Cat 769 (or equivalent) off highway tractor and a matching transporter. Cat 769 tractors have about 620 mm of clearance and we are undertaking to have the transporter provide at least the same. Don Anderson Haulage, an expert in the transportation of large dimensional loads, is working with Chant to better define the tractor/transporter solution and associated costs.

2.6 Local Granular Material and Fill Sources

There is an on-site quarry (Q1) that is owned by NL Hydro east of the Intake structures that appears capable of producing all required products including manufactured fines although it is not currently active. Appendix 1 displays the Q1 location. It is planned to utilize this area only for stockpiling/permanent disposal of required excavations and as an equipment maintenance/staging facility.

Any required new or make-up embankment products will be sourced from Q2 (Coast of Bays Contracting quarry) accessed by Surge Tank Road about 3.2 km from Penstock Bridge No. 4. We believe materials sourced from this depot would travel up Airport Road to Intersection C and then across to the intake area for all three (3) penstock initiatives.

We have contacted Coast of Bays Contracting for pricing of the manufactured products (FOB truck in the quarry) required for the work. Prices received from Coast of Bays was compared with our data base for similar types of quarried products.

2.7 Removal and Replacement Plan

A schematic describing the contemplated Penstock No. 1 removal and replacement plan is provided in Appendix 5. The following narrative captures the steps in the plan. Differences in approach necessitated by the physical characteristics of Penstock No. 2 and No. 3 are noted:

a. An existing overhead distribution line network downstream of the common intake structure conflicts with the work necessary for the temporary support of the intake ramp, proposed use of the intake access ramp for construction purposes (access to and from Q1), removal and replacement of all three (3) penstocks and the planned transportation route for penstock delivery to Penstock No. 3. The line's elements requiring relocation and areas necessitating high clearances are illustrated in Appendix 11. The cost of the relocations and clearance improvements (likely performed by NL Hydro crews) is included in the cost estimate. It would seem prudent to undertake the necessary relocations for all three (3) penstocks at the same time.

b. Access from Penstock No. 1 and No. 2 to Q1 will be up/down the existing intake access ramp with left hand travel and loaded vehicles having the right of way. Analysis shows that to perform the required excavation for all three (3) penstocks a temporary excavation support structure will be required at the intake end to preserve the integrity of the existing access ramp (See Appendix 5).

   Access from Penstock No. 3 to and from Q1 will be up/down a temporary construction ramp from Q1 down to the LHS of Penstock No. 3. This ramp will terminate immediately downstream of the end of the Penstock No. 3 rock cut.

   The overall access plan envisions a temporary/permanent crossing of Penstock No. 1 similar in nature to the existing four (4) penstock crossings along Surge Tank Road. The crossing would be downstream of the toe of the reinstated intake ramp embankment after completion of the penstock replacement and backfill in this area).

No such new penstock crossings structures are contemplated for Penstock No. 2 and No. 3.

c. For Penstock No. 1, access development will require having excavators on both sides of Penstock No. 1 in the vicinity of the existing intake ramp embankment toe of slope. The existing penstock would be exposed in this area and a segment of the penstock cut and removed, providing access from the RHS to the LHS of Penstock No. 1. The temporary support of excavation necessary to facilitate the required excavation upstream of this point would then be constructed concurrently with other required excavation/penstock demolition work downstream of this opening (penstock alignment crossing).

   The required excavation for Penstock No. 1 would proceed from the most downstream point of the replacement scope of work and proceed upstream. Natural drainage will be away from the excavation face. Removal of the existing penstock would proceed in the same manner, providing an early upstream open end of the penstock for refurbishment crews. Both the required excavation for the LHS and RHS of Penstock No. 1 will be hauled directly to disposal/stockpile at Q1.

   Cut and demolished sections of Penstock No. 1 will be placed in Q1.

   Penstock No. 2 will proceed in a similar manner to that of Penstock No. 1 utilizing the temporary/permanent crossing installed over Penstock No. 1 as part of the Penstock No. 1 scope of work to access the intake access ramp and ultimately Q1.

   For Penstock No. 3, required excavations will utilize the access ramp/penstock crossing approach described in Item b for access and egress to Q1. At least 65% of the LHS excavation and embankment of Penstock No. 3 will need to be double handled with excavators passing the material to excavators located on the RHS of Penstock No. 3 due to LHS access restrictions.

d. With the installation of the temporary support of excavation complete, installation of the new penstock and backfill for Penstock No. 1 will proceed from the intake thimble connection downstream. A closure section of Penstock No. 1 will be left out in the vicinity of the alignment crossing. As soon as practical the temporary/permanent crossing of Penstock No. 1 will be constructed and commissioned, the Penstock No. 1 upstream closure section installed, and the intake ramp embankment reinstated. The temporary support of excavation will be salvaged for later use on Penstock No. 2. It is anticipated that the temporary support of excavation for Penstock No. 3 will be unique to that installation (new material purchase).

   A second closure section for Penstock No. 1 will be at the most downstream point of the replacement reach.

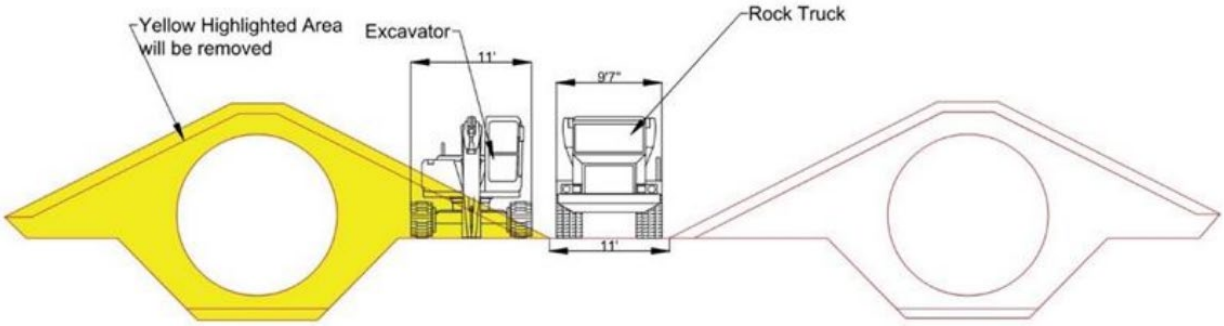
As is the case for Penstock No. 1, there will be an upstream and downstream closure section for Penstock No. 2.

Penstock No. 3 will also require two (2) closure sections, one at the planned interim alignment crossing immediately downstream of the rock cut and a second at the most downstream point of the replacement reach.

e. The approach described above dictates that the first penstock "can" for all three (3) penstocks would be set at the downstream extremity of the intake thimble, and a special dresser type coupler is planned to connect the new and existing penstocks at this point. The intention is to address possible variances in steel chemistry by avoiding direct welding of the new to existing steel penstock sections.

   Closure penstock sections (two (2) each for each penstock) would also have a special dresser type coupler at one end to provide a degree of flexibility in joint orientation and closure width.

f. A size constraint was adopted for excavation and backfill equipment based on the available space between Penstocks No. 1 and No. 2. The below sketch shows the relative scaling of a 30-tonne excavator and 25-tonne articulated rock truck.



g. The required excavation and backfill for the penstocks within the confines of the rock trench sections will need to be performed with small equipment which will have rehandling of materials and slower production rates.

h. Backfill for the area upstream of the end of the rock cut for Penstock No. 3 will be like that of the other penstock rock cut sections, tedious and handled by excavators' multiple times. A crane mounted conveyor, like a cretercrane, would improve material supply logistics and production within the rock cut cross sections. Ultimately the backfill means and methods in this area will depend on the quantities involved, material type and actual dimensions within the rock cut such as the distance between penstock can and rock wall.

i. A primary constructability objective of the penstock replacement work is, to the extent practical, eliminate field welding. This means optimizing, to the maximum practical dimension, the penstock can length. We have set the limiting capacity to "can" length being our ability to set the received "cans" in the trench with a single appropriately sized lattice boom crawler crane.

j. For Penstock No. 1 the penstock "can" placement crane will sit on the RHS of the penstock and penstock "cans" will be delivered under the hook from the intake access road (Intersection C) traveling in a downstream direction. Periodic appropriately sized and constructed crane pads will be required.

k. For Penstock No 2, the setting crane will also sit on the RHS of Penstock No. 1 and reach over Penstock No. 1 to set Penstock No. 2 cans.

   Penstock cans for both Penstock No. 1 and No. 2 will be supplied from the RHS of Penstock No. 1. For Penstock No. 3 the crane will sit along the RHS of Penstock No. 3.

l. For Penstock No. 3, the penstock cans would be delivered utilizing the previously constructed access ramp and exiting the Penstock No. 3 work area by Surge Tank Road. The length of the pre-assembled cans for the rock cut section of Penstock No. 3 will likely be restricted based on crane capacity limited by picking distances and crane dimensional constraints.

m. Salvaged and stockpiled backfill materials will be staged in Q1 and hauled to the penstock embankments using the 25 tonne articulated rock trucks and with similar traffic patterns to the required excavation. New embankment materials for all three (3) penstocks will be sourced from the commercial Q2. Materials will be hauled using the 25 tonne rock trucks circuitously up to the intake area and then in a similar downstream direction, exiting the placement site(s) using Surge Tank Road.

n. The approach taken with respect to the means, methods and sequencing of the penstock cans installation will be to install (spread and compact) the bedding materials with a vertical overbuild and then cut into the compacted foundation providing a defined, compacted shape to receive the cans.

   Temporary alignment docks will be used to assist in the setting and matching of sequential penstock units. Once positioning of a penstock can has been completed and the joint secured, the embankment under the circumferential weld will be excavated and access to the outside of the joint established. A ceramic backer plate will be installed on the exterior of the joint below the spring line with welding accomplished from the interior of the penstock. A ceramic backer plate will be installed along the interior of the joint above the spring line with welding accomplished from the outside. This approach will maximize productivity for the circumferential joint welding activity and avoid the necessity for overhead welding.

Foundation reinstatement below the circumferential joints will be completed after removal of the ceramic backer plates and finishing of the exterior weld presentation. Backfilling of the excavated personnel access will be accomplished by traditional means and methods, including the use of sluicing placement techniques as required to obtain a satisfactory product.

2.8 Disposal Plan

Penstock demolition will be delivered using hydraulic excavators with shears and scissor attachment to cut the pipe. It is expected some cutting will be required for dental crossing removals and connection pieces. Excavators will punch and compress the penstock sections which will be loaded onto rock trucks and staged/disposed of (buried) in Q1. .

The demolished penstock material will be left in Q1. Final disposal will be by others.

2.9 Risks, Controls, and Mitigation

Identified risks and the corresponding control and mitigations measures are summarized in Table 2.1.

Table 2.1 Risks, Controls, and Mitigation

Risk No.	Description of Risk	Mitigation Strategy
1	Excessive premiums (costs) associated with marine shipment of bulky, dimensional loads.	See Alternative Execution Strategy narrative – Section IV herein.
2	Delays in fabrication and delivery of the penstock cans.	Due diligence and prudency in selecting fabricator and provision of adequate lead time for delivery. Detailed timely shop drawing review and approval. Factory presence of NL Hydro. These are zero to little cost mitigation strategies.
3	Shipment of the penstock sections using just in time approach – issues with specials – out of order delivery; dimensional errors in cans that arrive at site	See Risk No. 2.
4	Losses in roundness during multiple handling and transport efforts	Engineered internal support system, factory installed lifting lugs and purpose-built transportation cradles/transporters.

Risk No.	Description of Risk	Mitigation Strategy
5	Penstock can hoist related risks – at fabricator's facility, sea vessel loading, unloading at receiving wharf, staging at the wharf/transporter loading, staging at site, placement at site.	Multiple handling/lifting efforts difficult to avoid but detailed planning should optimize these interfaces. Adopt policy of engineered lifts for each piece (approximately 25 – 29 pieces) and for each pick.
6	Compaction of penstock bedding – effectiveness of compaction efforts/sluicing operations at circumferential weld locations.	Perform mock-ups with destructive testing of compaction results to determine optimum approach. Aggressive QC by contractor and QA (well researched/written specification and QC audit) by NL Hydro.
7	Quality of grade control for penstock saddles and intermediate backfill shaping	Survey verification and template for penstock can foundation backfill shape.
8	Quality of shop welding	Utilize a 3rd party weld inspector and conduct regular inspections throughout the fabrication process.
9	Quality of field welding	Utilize a 3rd party weld inspector and have a well-integrated quality management system throughout the project. Welding refurbishment should be separated from coating application. The contractor should be certified in CSA W47.1 DIV 1 & 2.
10	Quality of field coating	It was identified that the coating application will need close monitoring and a well-defined heightened quality assurance and control processes in place to decrease the risk of adhesion or coating thickness issues. Due to the nature of this type of application where moisture cured urethanes or other coating types may need to be tested in this type of humid environment, well-defined processes must be in place to decrease the risk of potential future coating repairs.
11	Confined space risks	Robust confined space assessments (avoidance of confined spaces whenever practical), adequate ventilation/air exchange and emergency response plans, trained response personnel, suitable response equipment and staging of mock drills.[1]

Risk No.	Description of Risk	Mitigation Strategy
12	Bulk commodity prices - steel	NL Hydro providing adequate lead time to fabricators to conduct a global procurement approach to steel supply.

Notes:

1. On October 2, 2007, nine industrial painters were recoating a portion of penstock at the Cabin Creek hydroelectric station, Georgetown, CO, USA. Inside the confined area, 15-foot diameter penstock, the workers used a highly flammable solvent to clean their equipment, which filled the tunnel with flammable vapor. The vapor ignited Despite lengthy rescue attempts five workers were asphyxiated as smoke slowly filled the tunnel.

3.0 PROJECT EXECUTION PLAN - PENSTOCK NO. 1

The Project Execution Plan supports the AACE Class 3 cost estimate (Estimate) for the planned life extension of Penstock No. 1. The breakdown of the Estimate is detailed in Appendix 6. The Project Execution strategy narrative discussed in Section 2.0 of this report outlined high level execution strategies for Penstock No. 1, No. 2, and Penstock No. 3 as well as synergies/opportunities for cost savings between the three (3) initiatives. The following sections discuss constructability, planning, and the cost estimate for the selected Option 3 penstock life extension strategy and associated scope of work for Penstock No. 1 only.

The main components constructing the Work Breakdown Structure (WBS) of which the schedule and cost estimate is based upon is as follows:

- Section 1000 - Site Preparation
- Section 2000 - Penstock Replacement
- Section 3000 - Penstock Refurbishment
- Section 4000 - Site Finalization
- Section 9000 - Standard 28 Site Indirect and General Condition Accounts

3.1 Estimate Classification and Assembly Methodology

The context of the Cost Estimate (referred to herein as the Estimate) is to assess and assemble the construction costs for the Work from the perspective of an at-risk general contractor operating under a standard form of design-bid-build contract (Stipulated Price CCDC 2 (Fixed Price) or equivalent) directly with NL Hydro. The Estimate assumes that a single multi-discipline general contractor (or combination of general contractor with specialty subcontractors) will be awarded the entire Penstock No. 1 project. NL Hydro's internal costs, including but not limited to the costs of other supporting entities within the NL Hydro project delivery team (owner's engineer, owner representative, specialty QA testing and commissioning related activities or entities), are not included in the Estimate.

The Estimate is based on the marked-up drawings as presented in Appendix 7.

Based on AACE Recommended Practice 69R-12: Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Hydropower Industry, a Class 3 cost estimate is appropriate when:

- The maturity level of project definition deliverables (expressed as a percentage of complete definition) is in the 10% to 40% range, and
- The intended End Usage (purpose) of the Cost Estimate is for budget authorization or control.

The expected accuracy range of a Class 3 Cost Estimate is:

- Low: -10% to -20%
- High: +10% to +30%

The state of technology, availability of applicable reference cost data and other risks affect the expected accuracy range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of P50 contingency for a given scope.

A Class 3 cost estimate is compiled using assembly level line items and semi-detailed unit costs. It is our opinion that preparation of a Class 3 cost estimates is both possible and appropriate for this assignment. Correlation of cost estimates with past cost experience is a vital component of an effective high confidence cost estimating process. An important aspect of this correlation is translating past productivities to the actual context of the Project being estimated. Chant's primary reference projects for the Estimate include OPG's Matabitchuan Penstock Replacement project and Nipissing Penstock Replacement cost estimate (as prepared by Chant) together with the Box Canyon Hydroelectric Project. Data sheets for each of these projects are included in Appendix 18.

We have assumed a progressive labour environment in compiling the Estimate, meaning a unionized setting with non-restrictive manning stipulations, workable jurisdictional conditions, personnel having an average level of relevant experience with effective, experienced direct supervision and management team. The context of the Estimate is "realistically aggressive".

Note: *For clarity, any reference to a Unit Rate within this report is referring to a factored historic production per unit of measure (such as person-hours/m^2), Unit Price to a plugged*

number based on factored cost experience or subcontractor/supplier quotations and Unit Cost means cost estimate developed costs per unit of measure for a given activity.

3.2 Planning and Schedule Basis

The Construction Schedule that has been developed as a part of the AACE Class 3 Estimate has been produced through the means of Microsoft Project. The schedule, as provided in Appendix 8, is displayed as a Gantt chart. Total schedule duration for the replacement and refurbishments of Penstock No.1 is 592 days, starting in April of 2024 and ending in November of 2025. The following items are important premises of which the Estimate Plan is based upon:

- Productivities selected for the Estimate reflect the work being undertaken in a unionized, multi-trade environment as described in Section 3.1 of this report – Estimate Classification and Assembly Methodology.
- As the work will be delivered during a unit outage, the Estimate's schedule calendar is premised on working seven (7) days per week and ten (10) hours per day. Staff and craft personnel will rotate on 14 days in and 7 days out basis.
- The unit outage is scheduled for the period May to November (7 months).
- Given the relative size of the host community, and the need to provide approximately 8,250 person-days of accommodation over seven (7) months for contractor personnel only, a construction camp is contemplated.
- As requested by penstock fabricators, one (1) year lead-time (from Notice to Proceed to first delivery) is required to cost effectively procure the steel (likely from the global steel markets) and fabricate the new 5.2 m diameter penstock. This duration assumes the timely approval by NL Hydro of the fabricators shop drawings.
- The Estimate's plan is to have preassembled, and factory coated penstock cans delivered by ocean going barge to the existing wharf in St. Alban's. The NL Department of Fisheries, Forest & Agriculture has indicated that there is ongoing commercial fishery activity from November to June of each year whereby access to the wharf could be restricted for non-fishery related activities. The Estimate contemplates a total of six (6) days of wharf side activity during two (2) periods approximately four (4) weeks apart to take place in mid-June and again mid-July. It would seem reasonable that this limited interface with normal commercial operations of the wharf facility is manageable.

- With the completion of site preparation activities, penstock replacement work will proceed simultaneously with the work of inspecting and repairing of circumferential and longitudinal welds for the section of penstock to be refurbished. Coating the interior of the refurbished penstock and coating touch-up work for the replaced penstock section will be the last permanent works activity. The Work's critical path runs through refurbished penstock related activities, including temporary hatch closure related work.
- The penstock will be watered up in November.

3.3 Cost Basis

The Cost Estimate has been assembled in constant 2021 CAD dollars. The means and methods used for determining mark-ups, material, labour, equipment, and plug pricing are discussed throughout the following sections of this report.

3.3.1 General and Administrative Expenses and Profit

The Contractor's mark-up (corporate overhead recovery at 6% and profit at 15%) is imputed at twenty-one percent (21%) of Total Cost (direct and site indirect costs) excluding contingency based on forecasted local contractor's capabilities and availabilities, the tender's timing, and the implementation schedule (Spring 2025 start of construction).

3.3.2 Labour Rates

The site craft (manual) person-hours performed on the project will be dominated by the Millwright trade. As such, we have used the rate of Millwright Journeyman, effective May 1, 2021, to April 30, 2022, as the average project labour rate, for the purposes of the Class 3 estimate preparation. The rationality of this approach to labour costs in the context of the Work was confirmed with a local general contractor as a conformation of government and union mandated undertakings within the province.

The average fully burdened craft rate used in the Estimate is $59.88. In addition, based on the agreement between NL Hydro and Local 1615 of the International Brotherhood of Electrical Workers, Operations Unit, effective April 1, 2019 - March 31, 2022, the Estimate also reflects the following:

- Room and Board - $122 per day, where applicable. The Estimate includes a cost of $150 per person-day of camp stay. Use of the camp by construction workers is mandatory (no opt-out provision).

- Shift Differential - $2.00 per hour between 1600 hrs to 0800 hrs, if applicable
- Overtime Rule: Monday to Friday – 1.5 times the base rate for the first 2 hrs of overtime then 2 times the base rate thereafter based on daily rates. Saturday, Sunday, and Holidays the rate is 2 times the base rate.

3.3.3 Equipment Rates

Equipment rates are premised on the latest version of the Newfoundland Equipment Rental Schedule as published by the Government of Newfoundland and Labrador – Department of Transportation and Infrastructure Highway Design and Construction Division, effective August 19, 2020, as provided in Appendix 9.

If an equipment rate could not be found in the Rental Schedule, our own internal equipment rates were used. In three (3) different cases of highly specialized equipment pieces, hourly rates were developed, as summarized in Appendix 10. The three (3) specialized units and the off the shelf purchase price for each unit are as follows:

- Automated robotic hydro blasting/coating unit: $ 83,000/each
- Automated robotic abrasive blasting unit: $160,000/each
- Dehumidifier: $ 70,000/each

3.3.4 Material and Commodity Pricing

The most significant material procurement item within the Estimate is the 5.2 m diameter replacement section of steel penstock.

Le Groupe Lar (LGL) is an experienced hydromechanical fabricator located in Quebec. In the last 5 to 7 years, they have supplied seven (7) draft tube cones to the Keeyask Project located in Manitoba, designed, supplied, and installed 5.6 m diameter steel penstocks for Hydro-Quebec's Romaine 3 generating station, and are currently fabricating and installing the 10.0 m diameter steel penstock elements for the Site C Clean Energy Project, located in BC. LGL's fabrication facility is located in Havre-Saint-Pierre on Quebec's North Shore and has an annual fabrication capacity of approximately 200,000 person-hours.

LGL provided a conceptual program and budgetary price for the supply, fabrication, and delivery of the 5.2 m replacement section of penstock for BDE. Their plan is to fabricate the penstocks at the Havre-Saint- Pierre fabrication facility (the scope of work represents about 25,000 person-hours or less than 15% of their available annual capacity) and then

deliver assembled and coated sections (30 individual cans) to the St. Alban's wharf FOB a chartered marine vessel. Their complete quotation is provided in Appendix 2.

Three (3) important considerations with respect to the LGL proposal are as follows:

- The individual penstock cans will be shipped (two barge trips), saddled, and mounted onto individual transportation trailers. Unloading of the vessel at St. Alban's will be by fifth wheeling the individual penstock sections from the vessel to the wharf deck and local staging areas while awaiting being moved to the site.

  The Estimate includes:

  - Transportation costs for returning the trailers to LGL after both the first and second shipment to St. Alban's, and
  - Costs to investigate, design and modify to suit the wharf facility (including existing buildings) to accommodate the off-loading at the wharf and the eventual restoration of all altered works.
- An issue was raised during the Risk Management Workshops, held in February and March of 2022, regarding the way the end sections of the rolled plates are managed. The rolling process typically leaves the first 100 mm (plus or minus) of the rolled section flat (no curve). This can result in a stress concentration within the circumference of the assembled penstock can. LGL has advised that with the current proposed thickness of plate, they normally would not trim this flat/uncurved length. However, for thicker plate it is their common practice to trim the flat section. Their current quote does not include this trimming, but if required, it can be readily incorporated into the fabrication process. It is unclear at this time if the trimming is required and will need to be investigated during final design. The penstock manufacturer estimated the trimming cost to be approximately 3% to 5% of the manufacturers cost for the cans.
- LGL was not familiar with the specified coating and after discussions with LGL, we have added $200,000 to the coating proposal to bring it compliant with the requirements of the Work.

Two (2) other germane comments arising from our market outreach efforts for the fabrication of the 5.2 m diameter replacement penstock:

- DF Barnes Fabrication (Barnes), St. John's, NL (the steel plate supplier for previous Penstock No. 1 repair work) believes the replacement penstock would be best fabricated in a temporary construction yard near the site, which is consistent with the means and methods deployed for the original construction of the penstocks. Barnes budgetary price for the supply and installation of the penstock components

using this approach was $6.5 million higher than that currently reflected in the Estimate. This approach would require the incorporation into the delivery plan of significantly more field or field shop welding than currently planned (increased quality risk). Transportation of rolled plate sections would offer more flexibility than that of assemble penstock cans. The camp size would double to accommodate the extra labour required for fabrication. This approach would add stress on the schedule and add extra risks related to quality of field work versus shop work.

Note to Reader: Within the current context of the project, Chant believes the adopted means, methods, and sequencing of the work (delivery of assembled and coated penstock cans) is the most cost-efficient approach and provides a robust solution to project quality objectives.

- RothLochston, Paradis, NL, is not able to accommodate the 5.2 m diameter of the replacement penstock at their on-island fabrication facility.

Coast of Bays Contracting Ltd is providing new bedding and processed embankment materials including Granular A, Granular B, ¾" Clear Stone and Coarse Gravel from its commercial operation in quarry Q2. Their quotation includes transportation to the point of placement.

K&D Pratt has provided costs for the Wasser penstock coating products.

The two (2) 5.2 m diameter compression style (mechanical) closure couplings have been supplied by Tyton Femadics.

3.3.5 Project Site Indirect Costs

Significant site indirect expense items (other than non-manual staff) include mobilization/demobilization expenses, temporary utilities and services, temporary construction, staff and craft living out and travel costs, craft incidental and scheduled overtime, quality testing services, and miscellaneous other project support equipment costs. The costs of layout survey, third party QA/QC, and the design of temporary work (excepting the detailed design of the support of excavation structures which have been included as a Direct Cost) are also considered as site indirect expenses.

The applicable period for most variable site indirect costs has been taken as eight (8) months.

The site indirect cost items, OH-01 to OH-28, are outlined in section 9000 of the Estimate, attached as Appendix 6. An overview of key inputs to the site indirect cost estimate are as follows:

- OH-01 Mobilization: Mobilization of equipment and materials (materials which are not purchased FOB jobsite) are included in this account. Local mobilization costs (heavy equipment, scaffolding and miscellaneous loads) are premised on a freight distance of 600 km (St. John's to BDE).
- OH-02 Project Staff: The total craft (manual) person-hours (PHs) are approximately 60,000. The total staff PHs (management, administration, construction engineering and supervision) has been calculated based on a staff/craft ratio of 1:3. This equates to 20,000 staff PHs providing on average of 8.5 FTE (Full Time Equivalent) non-manual personnel during the construction period, including staff on rotation. Staff salary rates are on average $3,400/week for the planned work week/rotation program and are based on our recent cost experience.
- OH-03 Site Offices: This account includes the costs associated with the setup of two (2) wash car trailers, four (4) lunch/foremen office trailers, two (2) main office trailers and fifteen (15) tool cribs/containers.
- OH-04 Utilities: Included in this account is the electrical connection to the Sites permanent power supply for the trailers, a small prefabrication shop and yard lighting in the office/laydown area, adjacent of Surge Tank Road, left of Penstock No. 3. Site distribution within the office/laydown area is included, however, electrical consumption costs are not included in the Estimate. All other site electrical supply and lighting (general area and work location specific) is provided by field generators.
- OH 05 Temporary Construction: This account includes the following:
    - $40,000 for a temporary fabrication shop (200 m^2 including tooling);
    - $20,000 for personnel access stairs in/out of the temporary refurbishment hatches and over Penstock No. 1;
    - $30,000 for an equipment maintenance working slab in Q1;
    - $30,000 for a temporary fuel depot in Q1; and
    - $2,000 for project signs.

    There is a $150,000 budget for costs associated with renting of the St. Alban's wharf, altering, and then restoring some of the existing buildings (including alteration/restoration of the fish processing plant), wharf access roadway improvements, and certain immediate area utility relocation work. Also included is a modest damages allowance for the property of others.

The 21 km access road from the wharf to the site will be upgraded at a cost of $378,000. This cost estimate was generated by assuming that 50% of the 8 m wide road surface will receive on average 75 mm of Granular A to manage as a running surface. No horizontal or vertical profile or drainage improvements are planned along this route.

- OH-06 Transportation: Not used.
- OH-07 Office Supplies: The costs included in this account are calculated as a function of the staff PHs used on the project. A standard base rate of $500 per staff person per month is reflected.
- OH-08 Safety and Security: Safety supplies and safety awards are calculated as a function of the PHs required by the Work. A rate of $1.00 per PH for safety supplies and meetings and a rate of $0.50 per PH for safety awards, have been used to calculate this cost. Fire protection costs (in this case fire extinguishers) at $3,800 are also included in this account.
- OH 09 Employee Expenses: This account includes employee expenses associated with robotics training for certain manual and non-manual personnel. Also included is $4,000 for miscellaneous meals and entertainment. Regional rotational travel expense for four (4) non-manual and four (4) key manual personnel (twelve (12) rotational trips each) is included.
- OH 10 Contract Services: $5,000 for Public Relations and $12,000 for drone flights are included in this account.
- OH 11 Employee Subsistence: All contractor staff and craft will be housed (no opt out) in a temporary construction camp. Based on similar project experience, we have included a $150 per camp person-day as a reasonable forecast in the camp costs.

  The total PHs of craft and staff plus the truck drivers for penstock transportation/shuttle service are approximately 75,000, which requires the camp provide 7,500 person days. In addition, we have added 5% for miscellaneous unaccounted for vendors and visitors, 3% for miscellaneous workers and a 2% for contingency, bringing the total to 8,250 person days.
- OH 12 Winter/Summer Protection: Not used.
- OH 13 QA/QC: QA/QC staff and associated expenses are part of the OH 02 and other indirect cost accounts. Operation specific QC costs (NDT for welding outcomes for example) are included as a direct cost.

- OH 14 Non-Productive Labour: Experience indicates that 3% of total craft person hours should be included in a cost estimate for like work as **unscheduled** or incidental overtime. The **scheduled** overtime cost is based on working 70 hours per week and paying 94 hours (36% more on regular pay).
- OH 15 Contingencies: We have included an allowance of $30,000 to repair incidental damage to the penstock refurbishment sections during removal of embankment materials from above the spring line and excavation below the spring line for selected exterior welding repairs. All other project contingencies are addressed in the Risk/Opportunity Analysis.
- OH 16 Demobilization: Costs for demobilization of the contractor's plant and equipment are included in this account.
- OH 17 Finance: Not Used
- OH 18 Survey: The Estimate assumes third part survey services will be provided for the setting of temporary benchmarks (transferred from permanent benchmarks) and the primary layout of the new penstock. Secondary layout (for individual can setting) will be by the contractor's personnel or crews. The supply of primary site survey control is by others. Field marked prints depicting as-built conditions (where different from Issued for Construction drawings) and for refurbished welds will be provided by the contractor to NL Hydro. The provision of Owner's primary survey control (primary benchmarks) and QA survey is not included in the cost estimate.
- OH 19 Pre-construction Survey: Not Used
- OH 20 Maintenance: Costs for the maintenance of site access roads, assess ramps and laydown areas has been included in this account.
- OH 21 Small Tools: Not Used. A small tool allowance has been included for each person-hour of manual craft labour in the direct cost portion of the Estimate.
- OH 22 Traffic Control: Not Used
- OH 23 Consultant / Engineering: Included in this account is the design related costs for distribution line relocation in the vicinity of the upper reaches of Penstock No. 1, the wharf assessment and remedial work design (if any) for that facility.
- OH 24 Equipment Hours Balance: Not Used
- OH 25 Insurance: A budget for insuring outside rented equipment has been provided in this account.
- OH 26 Design/Build Engineering: Not Used

- OH 27 Project Equipment: This account includes the full-time costs associated with the ownership and operation of:
    - Two (2) telehandlers;
    - Eight (8) pickups;
    - One (1) job bus; and
    - One (1) standby emergency response vehicle.

  Besides the above full-time equipment, this account also includes:
    - Five (5) 150 kW generators for 6 months;
    - One (1) 150 kW generator for 1.5 months;
    - One (1) Cat 980 Loader for 4 months;
    - One (1) 300-ton crawler crane for 3 months; and
    - Two light towers in Q1 (run two hours per day).

  The cost of providing rigging supplies to crews is also included in this account.
- OH 28 Project Hourly Labour: The one (1) 300-ton crane operator and one (1) loader operator have the same labour hours as their equipment. The working hours of the bus driver are calculated based on two hours per day.

3.3.6 Project Direct Costs

Sections 1,000 through 4,000 of the cost Estimate (Appendix 6) outline the project direct costs including Site Preparation, Penstock Replacement, Penstock Refurbishment, and Site Finalization.

Section 1000 – Site Preparation

100 Silt Fence:

Silt fence will be supplied and installed along both sides along the penstock replacement and refurbishment sections. The Unit Rate of 0.153 PH/m includes maintenance during construction.

200 Site Access:

10 Permanent Bridge for Penstock No. 1:

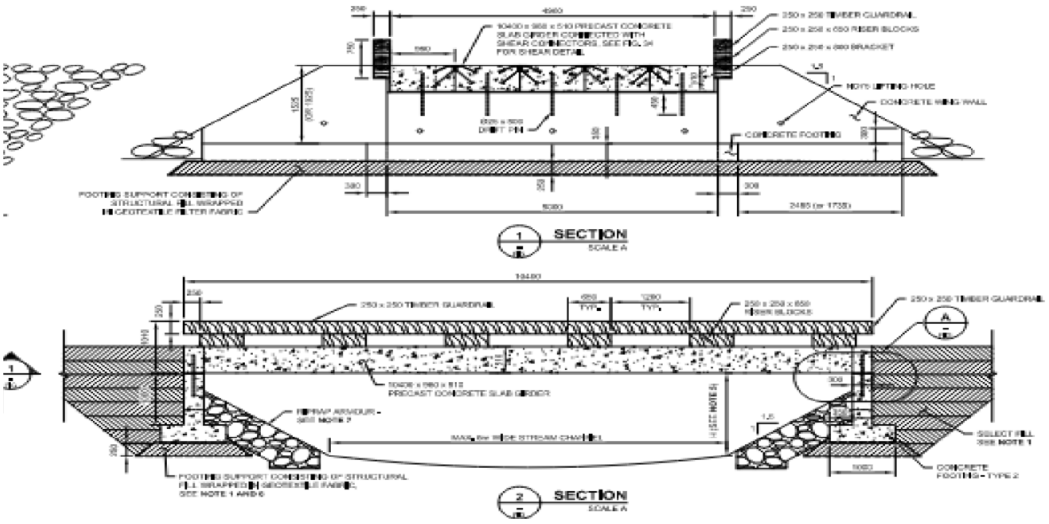


Figure 3.1 Permanent Bridge for Penstock No. 1

Figure 3.1 is provided from a reference project. The structure has been scaled to an eight (8) m span and five (5) m width. The cost estimate is based on using precast concrete abutments and deck girders, with timber blocking supporting wheel rails. The required structure excavation and backfill work has been included in the penstock earthworks, and the 300-ton crawler crane to set the structural elements is included in the indirect costs. Crews will take five (5) days to install the bridge. The bridge will stay in place (permanent) for future work associated with Penstock No. 2.

20 Access Road from Penstock No. 1 Site to Q1: This access road linking the Penstock No. 1 site to Q1 is approximately 1,300 long and 5 m wide. It is assumed that an average thickness of 75 mm of Granular A material will be placed on largely existing roadway subbase and/or base coarse. The material is intended to upgrade the road's running surface.

30 Distribution Line Relocation:

01 Intake Distribution Line Relocation:

Power to the existing common intake structure and the intake structure for Penstock No. 4 is supplied from the switchyard through an overhead distribution line (at 4.8 kV it appears) that runs along the south side of Penstock No.1. There

are six (6) wood poles, two (2) sets of 3-phase pole mounted transformers and one (1) branch circuit (to the Intake for Penstock No.4) located in the vicinity of the Penstock No. 1 replacement area. The existing power supply configuration needs to be relocated (with adequate clearances provided) to allow for the efficient and safe transportation of penstocks elements and materials for Penstock No. 1 (and ultimately Penstocks No. 2 and No. 3).

The Estimate reflects the costs for the power supply relocation plan detailed in Appendix 11. The objective of the relocation effort is to reuse existing transformers to the extent practical and to provide a minimum ground clearance of 12.2 m across access roadways planned to be used for penstock can transport. In addition to the existing plant in the immediate vicinity of Penstock No. 1. a power line crossing of the intake access road to the south of the dam will also be raised with the use of two (2) new 40 feet wood poles. The revised configuration has been constructed in such a manner as to be considered as being the replacement permanent power supply to all four (4) intakes.

Permanent material costs of the relocation work are approximately $68,800. This activity will take line crews ten (10) days in total as follows:

- Remove first six (6) wood poles – 2 days
- Erect five (5) wood poles and two (2) steel poles – 2 days
- Install 3-phase pole mounted transformers – 2 days
- String conductors – 2 days
- Intake structure connection and cabling – 1 day
- Commissioning – 1 day

Costs for temporary power during the change over has not been included.

<u>02 Haul Route Distribution Line Relocations:</u>

Penstock sections arriving at the St. Alban's wharf will be transported overland to the construction site. The route starts from the wharf and initially passes over 1.7 km of paved road on Highway 361. The penstock units will then turn left onto Long Path Road and the Upper Salmon Access Road before turning right onto Long Pond Access Road, and right again onto Air Strip Road. This route was largely constructed for the original construction program to avoid a series of unrated

bridges along the original alignment of Highway 361 between the wharf and site. While the bridges have been upgraded since the time of original construction, the electrification of St. Alban's in the interim and the resulting plethora of distribution and communication crossing along the Highway 361 route now prohibit its use for assembled penstock can transport.

The total height of the penstock cans and trailer is approximately 6.4 m (21 ft) assuming a trailer (including transportation saddle) height of 1.2 m (4 ft) plus the penstock diameter of 5.2 m (17 ft). Fourteen (14) overhead utility lines crossings (power lines and communication lines) along the preferred penstock can transportation route have been identified. Seven (7) of these crossings are along the Highway 361 segment (within St. Alban's) as shown in Appendix 4. The distribution line voltage is typically 8 kV in this area. Note that NL Hydro requires that equipment and loads be kept at least 3 m (10 feet) away from power lines with voltages up to 69 kV.

The following approach was utilized to address the overhead distribution plant challenges for the purpose of the cost estimate.

> 001 Powerline Higher than Truck Load: If the power lines are higher than the loaded penstock can and the free clearance is less than 3 m, the Estimate reflects adding conductor insulation to prevent electrical flashovers between live conductors and penstock cans (wrapping insulation jackets on the power line bare conductors, and/or adding insulation jackets on top of the truckload before crossing under the power lines – Option 1 is preferred). All modifications to the power lines will be restored to the original state after the completion of construction. Based on the site visit observation, Chant estimates that seven (7) of the fourteen (14) crossings fall into this category of passage resolution.
>
> Construction material costs have been estimated at $3,000 for each crossing modification. The activity is anticipated to take crews seven (7) days for installation and seven (7) days for removal/restoration.
>
> 002 Powerline Relocation: If the available clearance under power lines is less than that of penstock cans, the power supply will be rerouted from overhead to the ground. The scope of work includes disconnecting the overhead

power lines, connecting appropriately rated power cables, running the power cables down along the wood poles and across the surface of the roadway utilizing a heavy-duty cable protection system (up to 36 tonnes per axle that allows traffic to pass over the cable) for the duration of the penstock transportation period. After the completion of penstock can transportation, the power lines will be restored to their original state.

Construction material costs are estimated at $10,300 per ground mounted crossing modification. The activity is anticipated to take crews a total of seven (7) days for installation and seven (7) days for restoration. The use of taller poles was considered but ground crossing is believed to better remove the hazard.

003 Communication Line Relocation: There are seven (7) underbuilt communication lines that must also be addressed along the preferred penstock transportation route. The Estimate reflects handling these lines in a similar manner to that described in Section 002 - Powerline Relocation. Construction material costs for each communication relocation is estimated at $3,900 per crossing modification. This activity is anticipated to take crews seven (7) days for installation and seven (7) days for restoration.

004 Line Crossing Monitoring: A line crew will travel with the penstock can convoys to monitor the transportation operation. Included in this activity is the supply, installation, maintenance and removal of public and worker awareness safety signs and barriers around the modified crossings. The Estimate reflects fifteen (15) days of activity for this crew.

300 Laydown Area:

10 Clearing and Grubbing: This account includes the cost of clearing and grubbing the Office/Laydown staging Area (4,000 m^2). Clearing materials will be pushed and stockpiled neatly along the bush line. This area is contemplated for use for all three (3) penstock life extension projects.

20 Laydown Area Topping: This account includes the costs for the supply and placement of an average of 75 mm thick Granular A for the Penstock No. 1 staging area, office/laydown area and approximately 35% of the required area of Q1 (no

plating or yard development expenses for areas under disposal or utilized for temporary stockpiles of rock cover and common fill).

Section 2000 – Penstock Replacement

100 Earthwork:

10 Temporary Intake Embankment Shoring: As identified in section 2.7 – Removal and Replacement Plan, a temporary support of excavation shoring system is required to allow penstock excavation, attachment to an existing intake steel collar protruding from the concrete encasement of the intake and penstock backfill downstream of the common intake structure. The shoring system selected is of a soldier pile and lagging type. The single 8 m span across the top of Penstock No. 1 will require steel lagging. The two sides, at 12 m, will utilize more traditional timber lagging. Crews will take five (5) days to install and a similar time to remove the system. The required excavation and backfill activities have been included in the penstock earthwork operations.

20 Removal of Existing Penstock Embankment Materials: These materials will be loaded and hauled to Q1 with two (2) excavators and four (4) articulated off-highway trucks at a combined productivity of 100 m^3/hour. The excavated materials will be selectively excavated and separated into stockpiles in Q1 as either rock protection over the penstock (rock spall) or for future use as common fill.

30 Demolition of the 5.2 m (17') Diameter Penstock: For the bulk of the demolition work for the existing penstock, a hydraulic excavator will cut, clamp and punch penstock components (with the help of tank cutter and hydraulic thumb attachments). The demolished penstock pieces will be loaded, hauled, and disposed of in Q1. A Unit Rate of 6 PHs/tonne of penstock has been used in the Estimate. There is some risk that the exterior coating has a tar component that may require treatment and extra disposal costs.

35 Engineered Cut: Two (2) engineered cuts of the existing penstock are required, one at the intake point of connection (old to new) and one at the downstream end of the replacement sections (again, old to new). The Unit Rate for these engineered cuts is 2.78 PHs/circumferential m of cut.

40 Backfill:

01 Coarse Gravel Backfill: A placement productivity rate of 60 m^3/hour for the placement of the coarse gravel surrounding the Granular A bedding is used in the Estimate.

02 Bedding Material: The total neat line quantity of the Granular A bedding materials is 2,200m3, 90% of which can be compacted using ride on vibratory compactors. The balance will require hand compaction.

001 Roller Compaction: With the assistance of an excavator, a bulldozer and a compactor, the crew will place Granular A at 60 m^3/hour.

002 Hand Compaction: The quantity includes 10% of the bedding material bedding or 218 m3, backfill of penstock welding connection trenches at 150 m^3 and bridge structural backfill at 108 m^3. With the assistance of an excavator and three plate tampers, the six (6) person crew will place Granular A at 18 m^3/hour, including the installation of the required geotextiles.

003 Purchase Material: The Granular A will be delivered to the point of placement at $24.05/tonne by Coast of Bays Contracting. A 10% loss factor is reflected in the Estimate. The purchase price of geotextiles is $0.87/$m^2$ with again a 10% loss factor (predominately overlap) included in the Estimate.

03 Granular B Material: The total quantity of the Granular B embedment materials is 3,415 m^3, 85% of which can be compacted by ride on vibratory compactors. The balance will be compacted manually.

001 Roller Compaction: With the assistance of an excavator, a bulldozer and a compactor, the crew will place Granular B at 60 m^3/hour.

002 Hand Compaction: With the assistance of an excavator and three plate tampers, the six (6) person crew will place Granular B at 18 m^3/hour.

003 Purchase Material: The Granular B will be delivered to the point of placement at $23.10/tonne by Coast of Bays Contracting. A 10% loss factor is reflected in the procured quantity.

04 Common Fill: The total quantity of the common fill materials is 7,200 m^3. 85% of this quantity will be tracked packed with a Cat D6 dozer and the balance placed and compacted manually.

001 Load and Haul: Common fill for the Penstock No. 1 will reuse the required excavation material previously stockpiled in Q1. The required excavation for Penstock No. 1 totals 13,700 m^3. The common fill embankment quantity is 7,200 m3 and the required rock cover (in lieu of topsoil and seeding) is 2,600 m^3. There should be ample suitable common fill materials available from the required excavations to satisfy the common fill requirements. Common fill will be loaded in Q1 with an excavator and hauled with articulated off-highway haul units.

002 Track Compaction: With the assistance of an excavator and a Cat D6 bulldozer common fill near and over the penstock will be placed and track packed at 80 m^3/hour.

003 Hand Compaction: With the assistance of an excavator, a six (6) person labour crew using handheld compaction equipment will hand place common fill immediately adjacent the penstock can at 18 m^3/hour.

05 Rock Spalls: The required 2,600 m^3 of rock spall (surface protection) material will be loaded by an excavator in Q1, hauled using articulated rock trucks and placed with a Cat D6 bulldozer and excavator at 80 m^3/hour.

50 Pipe:

01 203 mm Pipe Drain: This drainpipe type will be used in penstock rock cut sections. The Unit Rate of 0.4 PHs/m represents the installation of the drainpipe product only. Supply and placement of granular backfill material is included in Item 40 Backfill.

02 150 mm Perforated PVC Pipe: This drainpipe type will be placed on both sides of the replacement penstock in the bedding material. The Unit Rate of 0.4 PHs/m represents the installation of the drainpipe product only. Supply and placement of granular backfill material is included in Item 40 Backfill.

60 Crane Pads: The penstock cans will be set using a 300-ton conventional lattice boom crawler crane. This unit will require suitable working platforms from which to make its engineered picks for Penstock No. 1 (note that Penstock No. 2 will utilize the same crane pads). It is anticipated that five (5) crane pads will be required based on the dimensions of the crane and topography of the site. The five (5) crane pads will require a total of approximately 90 m3 of high-quality granular materials. In addition to the semi-permanent granular base embankments, one (1) set of wooden crane matts will be supplied and reused as work progresses from crane pad to crane pad.

200 Penstock Replacement:

10 Supply and Delivery of Steel Penstock: After consultation with a transportation professional, we have developed and costed a land transportation plan, as described in Appendix 12. The supply of the new steel penstock is described, and costs presented, in section 3.3.4 Material and Commodity Pricing of this report.

In summary, the objective of the wharf side operations will be to limit the dockage time of the marine delivery vessel. Penstock cans will be shipped from the fabricator trailer mounted and as such conventional highway type tractors will offload the cans and stage them in the vicinity of the wharf. Once the vessel is unloaded, the penstock cans (two at a time is planned) will be overland transported to the penstock can staging area (in the required order) adjacent to Penstock No. 1. The staging area is within reach of the placing crane.

20 Unload, Hoist and Align Steel Penstock: After penstock bedding materials have been placed and compacted to grade, a shallow trench will be excavated at the location of the penstock can-to-can connection points (the cost of this operation has been included in the penstock earthworks items) to allow for personnel access to the outside of the circumferential joint for performance of connection welding related activities.

The penstock cans will be installed progressing from upstream (leaving a closure section at the intake) to downstream (leaving a closure section at the connection of replacement to refurbishment sections). The placing crane will hoist penstock cans from their trailers/saddles and directly set the units on the bedding materials.

Precast concrete blocks with steel anchors will be placed on both sides of the cans for the first two (2) sections (2 blocks on each side per can) along the setting alignment to prevent the penstock rolling sideways or sliding downstream because of vibrations from heavy equipment circulation or severe weather events (flooding).

The Estimate reflects crews setting and aligning one (1) penstock can in a ten (10) hour day.

The total costs of the contemplated can anchoring system and precast concrete blocks as described above is approximately $10,000.

30 Spider Removal:

01 Spider Removal: The replacement penstock is 331 m in length and our working plan is thirty (30) individual penstock pieces. On average, each can will come from the fabricator with two (2) sets of factory-installed cross style and one bicycle-wheel style internal bracing. This equates too ninety (90) sets of spiders. It is thought that the bicycle style bracing will be at the upstream end of the individual penstock cans. The sixty (60) sets of cross style braces will be removed immediately after penstock can alignment is complete. The bicycle style internal bracing will be removed after penstock backfilling operations are substantially finished.

While it will be necessary to install backer plates on the upper half of the penstock, actual internal penstock welding operations are restricted to below the spring line of the penstock. Working around the bicycle style brace (one per penstock) should not present a significant adverse welder production impediment. It is believed that the benefit of retaining some internal bracing will assist in preserving penstock roundness through completion of backfilling operations.

The Estimate reflects the use a JLG bucket lift (rubber track with four stabilized legs) for internal access for spider removal. The spider legs will be disconnected, cut into manageable pieces, and removed from the penstock. The Estimate reflects a Unit Rate of two (2) sets of spiders removed per crew day.

02 Spider Disposal: Allow to dispose thirty (30) loads of steel spiders in Q1 with a productivity of two (2) loads/excavator hour.

40 Install New Penstock:

01 Welding: The Estimate reflects the use of a Flux Cored Arc Welding (FCAW) process with external welding gas supply for the circumferential welding of the penstock cans. Advice from an industry expert has indicated that the gas-shielded approach will provide better overall results than a self-shielded methodology as it provides a higher deposition rate and has a higher overall efficiency factor compared to the self-shielded approach.

The new penstock installation requires full penetration butt joint field welds along the circumference joints. The total quantity of deposition metal is 419 kg. Gas-shielded wire (1.1 mm diameter) costs $2.75/kg and the Estimate reflects a 10% waste factor for this consumable. The anticipated FCAW deposition rate at 230 - 280 Amperes for flat, horizontal, and overhead welding is 3.674 kg/PH. The deposition rate at 150 – 220 Amperes for vertical up welding is 2.994 kg/PH. These Unit Rates have been vetted through industry experts.

The blended rate for these activities in the Estimate is 3.334 kg/PH (arc time only). The FCAW efficiency factor is typically in the order of 30% (actual arc time over welder's total time). This factor considers the following items:

- Preparing surface for welding;
- Positioning;
- Tacking;
- Preheating;
- Changing electrodes;
- Chipping slag;

- Moving from one location to another;
- Unionized labour force;
- Supervision quality; and
- Incidental breaks.

The Estimate reflects a 25% efficiency factor based on the site conditions, such as, access and the requirement of working from scaffolding or work platforms. The net is a welding productivity of 0.83 kg/PH.

The Estimate also reflects the use of ceramic backing bars for the circumferential joint welding activity to minimize back gouging and rewelding. Ceramic backing bars require less effort to remove after welding than the effort need to remove steel backing bars.

The selected welding crew consists of seven (7) manual (craft) personnel including one (1) non-working foreman and six (6) welders. Converting the 0.83 kg/PH to 1.2 PHs/kg and factoring in the non-working foreman results in a Unit Rate of 1.45 PHs/kg. The scaffolding and access crew (separate activity in the Estimate) will supply, install, maintain, and remove enough mobile scaffolding to facilitate the interior and exterior welding efforts.

02 NDT Testing: Prescriptive Non-Destructive Testing (NDT) is required for all permanent welds and after the removal of any temporary welds on the permanent works. Permanent welds include penstock circumferential joints, maintenance hole connections and welding associated with the special purpose closure can couplings. Temporary welds include penstock alignment dogs, spiders, and scaffolding anchor points.

The NDT welding inspection includes 100% Visual Testing (VT) by a qualified inspector and 100% Magnetic Particle (MP) testing. The Estimate has used a blended productivity of 4.6 m of weld/PH.

50 Tie-in: The new penstock installation approach contemplates two (2) tie-in connections: one (1) at the intake and a second at the downstream transition from replacement to refurbishment. The Estimate reflects having the joint between new and old steel a compression (mechanical) type connection. The mechanical type of connection addresses the risk of variable steel grades between old and new

penstock and offers a higher fit up tolerance for one end of the closure cans. Based on the weight of the couplers, each unit will take a crew three (3) days to install.

60 Scaffolding Support: Scaffolding is required to support several new penstock related activities: removal of spiders, tie-in work and circumferential welding (interior and exterior). The scope of the scaffolding work includes the initial setup, moving, maintenance and dismantling of the internal mobile scaffolding and the exterior system scaffolding components a total of thirty (30) times. The Estimate reflects a total of 1,500 PHs to complete the required scaffolding works and $96,000 for system rental expense (four (4) months).

70 Field Coating: The DuraShield 210 coating will be applied on the circumference joints on both interior and exterior surfaces after field welding is completed. The scope of work includes abrasive blasting, spraying on of the coating and inspection.

Appendix 13 indicates a reasonable productivity of blended manual blasting and coating of 20 m^2/crew-hour. To address the manual only nature of the interior/exterior circumferential joints of the penstock, the very small areas for blasting/coating to repair the factory installed coating in the vicinity of the spider (crosses and bicycle type) legs and access constraints, a Unit Rate of 11.43 m^2/crew hour is used in the Estimate.

300 Maintenance Hole: Three (3) maintenance holes are assumed to be required in the penstock replacement section. The installation including setting, alignment and welding will take a crew one (1) day each.

400 Penstock Valve Tree: It is assumed that there would be three pressure transducers routed to house data acquisition instrumentation. The Estimate reflects an allowance for a subcontractor to supply and install Ashcroft pressure transducers (Model K1, 0-300 PSI) with four (4) spare parts for a total cost of $50,000.

Section 3000 – Penstock Refurbishment

The penstock refurbishment scope of work includes the 4.6 m (15.3 ft) diameter section and 4.1 m (13.5 ft) diameter section. Together the total length of refurbished penstock is approximately 762 m (2,500 ft).

The weld repair quantity reflected in the Estimate is based on the following assumptions:

- 50% of welds need to be refurbished
- 70% of welds require full depth refurbishment
    - Full depth welds have been assumed to have a depth equal to the full penstock wall thickness and will require access to both the interior and exterior weld locations.
- 30% of welds require shallow depth refurbishment
    - Shallow welds were assumed to have depth equal to half of the penstock thickness and do not require access to both the interior and exterior weld locations.
- 10% of penstock length from the switchyard to the powerhouse needs to be repaired (exterior access not feasible).

100 Temporary Personnel Access:

10 Open Hatches: The Estimate contemplates establishing five (5) temporary openings in the existing penstock to facilitate five (5) crews working simultaneously. This is a schedule related requirement. The planned hatch dimension is 1.5 m in wide and between 2.1 m and 2.3 height (from spring line to top of penstock). The cutting/torching quantity is approximately 10.5 m/hatch).

Hatches will be cut out using guided oxy-acetylene torches. The cut steel pieces will be salvaged to reuse for closing the hatch at the end of the refurbishment effort. The selected Unit Rate of cutting/torching in for this work is 2.778 PHs/m.

15 Fifth Hatch Earthwork: One planned hatch (the 5th) is located immediately upstream of the powerhouse, between the powerhouse and the switchyard. The scope of work for this activity includes providing access to the penstock spring line in the vicinity of the hatch (which will require vacuum truck style excavation means and methods and a temporary support of excavation installation).

20 Reclose Hatches: The edges of each hatch closure piece, and each hatch opening will have any irregularities removed/repaired and be provided with the required bevels. The salvaged hatch opening pieces will be welded back into place from the exterior of the penstock with the support of interior mounted ceramic backing bars. The same Unit Rate of 1.75 PHs/kg as used for the new penstock welding is included in the Estimate.

30 Temporary Weather Enclosure: The scope of work for this activity includes the supply, installation, and removal of six (6) weather enclosures: five (5) for the temporary hatches and one (1) to seal the opening at the upstream end of the refurbishment section to avoid weather from entering the penstock. The Estimate contemplates 15 PHs to construct the enclosure works for each of the six (6) openings.

200 Air Ventilation

10 Supply, Install and Remove: The provision of adequate air ventilation is essential for the types of construction activities contemplated for inside the penstock. Five (5) identical integrated diesel-powered ventilation systems are planned. It is anticipated that these systems will require one (1) day in total to install and remove.

20 Air Ventilation Maintenance: This activity includes all costs associated with operating the five (5) diesel-powered ventilation systems. A full-time maintenance person (single shift for 5 months) is included.

300 Earthwork

10 Excavation: The existing penstock embarkment will be initially excavated down to the spring line on both sides of the penstock in all areas (except under the switchyard). Excavation below the spring line will be dependent on the requirements of exterior access for weld repairs on an area-by-area basis.

01 Machine Excavation: This activity includes two (2) excavators and three (3) articulated off-highway haul units at a productivity of 60 m^3/hour. The selectively excavated materials will be hauled to stockpile in Q1.

02 Manual Excavation: The scope of work includes the removal of materials immediately adjacent the penstock and selected excavation below the spring line of the penstock as required. The quantities are calculated such that approximately 30% of the total manual excavation quantity (1,635 m^3) is below the spring line. The Estimate reflects a Unit Rate of 1.0 m^3/PH with the support of small excavation equipment for this activity.

20 Backfill:

01 Machine Backfill: The common backfill materials will be loaded and hauled from Q1 to the penstock embankment at 60 m^3/hour with the three (3) articulated off-highway units and compacted track packed using a Cat D6 or equivalent dozer.

02 Manual Backfill: The Estimate reflects utilizing Granular A for all manually placed backfill. Crew productivity is 18 m^3/hour (3.0 m^3/PH).

400 Crack Mapping: The crack mapping process is intended to identify the weld repair locations along the penstock sections to be refurbished. An initial thorough cleaning inside of the entire penstock is thought appropriate compared to cleaning the weld lines only. The high-pressure water blasting activity will start at the upstream end washing/flushing debris downward (towards the fifth hatch). An appropriately sized water treatment plant will be installed at a suitable location behind the powerhouse to collect the resulting brown water and treat the effluent before discharging to existing surface water drainage infrastructure via settlement and coagulant methodologies.

10 Hydro Blasting: The Estimate contemplates the use of mobile robotic machines with rotating high pressure water jets to complete the initial cleaning. A manual cleaning activity will follow the robotic effort. The Unit Rate of the robotic activity is set at 0.11 PHs/m^2. This Unit Rate was scaled, utilizing the information presented within Appendix 3.

20 Water Treatment Plant: The Estimate reflects a subcontractor supplying, installing, maintaining, and removing a water treatment plant for $100,000.

30 Visual and MP Inspection: The objective of the inspection effort is to conduct a thorough visual inspection of the hydro blasted surface under good lighting. For areas of uncertainty, Magnetic Particle (MP) inspection will further help identify problematic weld cracking. The depth of the cracks (and further repair decisioning) will be established during the weld groove preparation process.

The Estimate reflects a level of effort the equivalent of 1800 PHs to complete the visual and MP inspection activity.

500 Welding: The weld repair/replacement quantity is based on the welding assumptions previously established within this Section. The same FCAW process with gas-shielded wire as selected for the new penstock field welding will be used for the refurbishment work. Arc air gouging to remove either full depth or half depth cracks has been utilized in the Estimate.

A full depth crack at a longitudinal joint will be treated as J-joint weld (prequalified by CSA W59). A half depth groove is prepared with a single 45° bevel angle and a square end (no bevel) on the opposite side. Back gouging is required for the other half depth to attain the full penetration butt joint weld. Half depth crack repair will follow the same approach but without back gouging.

A full depth crack at a circumferential joint will be treated as U-joint weld with a 20° groove. Back gouging is required for the other half depth to complete the full penetration butt joint weld. Half depth crack repair will follow the same process but without back gouging.

Preheating the weld surface is required to remove moisture or condensation before welding. An oxy-acetylene torch is generally used for this purpose. Each welder will be equipped with a tempil stick or infrared thermometer so they can ensure the metal surface is heated to at least 50°C (122°F) at one half a minute after removal of heat source. Preheating will be to 100°C (212°F) if there is moisture clearly present.

The blended deposition Unit Rate of the FCAW process is 1.50 PHs/kg. This blended Unit Rate is intended to address all weld positions (flat, horizontal, overhead, and vertical up) and is based on an efficiency factor of 25% as rationalized in Section 200 - Penstock Replacement.

600 Welding NDT Testing: This Non-Destructive Testing (NDT) activity includes 100% Visual Testing (VT) and 100% Magnetic Particle (MP) testing. The Unit Rate at 0.219 PHs/m has been vetted by Chant's industry expert.

700 Scaffolding Support:

10 Interior Scaffolding: Stand-alone interior scaffolding systems will be used to provide work platforms for crack mapping, weld repairs and final inspection. The scaffolding systems will be mobile and adjustable to adapt to variable penstock slopes. They will be secured with locked wheels and a mechanical anchoring

mechanism to prevent undesirable sliding downward or other movements. The Estimate reflects twenty (20) such scaffolding systems, ten (10) dedicated units for the welding crews and ten (10) units for the welding inspectors. Interior mobile scaffolding systems will only require initial assembly and final disassembly but do attract some modest maintenance and moving expenses. The Estimate includes 260 PHs of craft labour and a rental cost at $3,000/month for each system.

20 Exterior Scaffolding: The exterior scaffolding system is required to facilitate exterior weld repairs and inspections. Welding locations can potentially be anywhere on the penstock and as such the exterior scaffolding system must be able to accommodate a variety of weld repair location scenarios. The Estimate contemplates having twenty (20) pre-assembled exterior systems each capable of providing access to the entire upper half of the penstock (spring line to spring line), with again, ten (10) units for the welding crews and ten (10) units for the welding inspectors.

The exterior scaffolding activity will require a full-time scaffolding crew on site throughout the refurbishment duration. The Estimate includes 280 PHs of craft labour and a rental cost at $3,000/month for each system.

800 Interior Coating:

10 Robotic Abrasive Blasting: The crew and equipment for this activity includes:

- A five (5) person crew
- Electric winch (tying off the robot)
- Dust collector (removing airborne debris)
- Rubber tracked outrigger equipped JLG bucket lift (inspection platform)
- Dehumidifier (reducing moisture in the penstock during/after blasting)

The productivity of the robotic abrasive blasting equipment is 20.90 m^2/crew-hour as indicated in Appendix 3. Blasting medium consumption has been estimated using a kg/m^2 rate obtained from an abrasive blasting advisor with a 10% waste factor added.

20 Robotic Coating: The robotic coating crew is like that of the abrasive blasting crew except a different type of robotic equipment is deployed. The productivity of the robotic coating is anticipated to be 23.33 m^2/crew-hour as described in Appendix 3.

30 Isolation Bulkheads: The blasting and coating operations will be performed in isolated sections of the penstock attained through the use of five (5) temporary rigid bulkheads. The Estimate includes 75 PHs to fabricate, install and remove each bulkhead, and material costs (lumber and plywood) of $2,500 each. Each bulkhead will be equipped with personal doors and utility ports.

900 Coating Test: QC testing is required after coating of the penstock. Included as the contractor's responsibility is the performance of Holiday and thickness testing. The Estimate contemplates a two-person crew of inspectors with rubber tracked/outrigger equipped JLG bucket lift for fifteen (15) days to perform this activity.

Section 4000 – Site Finalization

100 Wet Commissioning: A pressure test of the new penstock section is referenced in Kleinschmidt's 2670034_001RP_Decision Support Package Penstock 1 Report FINAL Rev1. Typically, a pipeline pressure test requires the installation of engineered bulkheads at each end, filling the pipe with water, then application and maintenance of an internal pressure for a specified period. This is a very significant activity for this diameter and length of penstock. The Estimate includes a five (5) person crew for five (5) days only to assist NL Hydro with the watering up of both the new and refurbishment penstocks.

200 Silt Fence Removal: Silt fencing has been removed at a Unit Rate of 0.05 PHs/m.

300 Staging Area Restoration: The office/yard staging area (4,000 m^2) has been restored by returning the grubbing and topsoil from peripheral stockpiles to the surface area then raking out oversized clearing debris.

400 Staging Area Hydroseeding: The office/yard staging area will be hydroseeded at $3.00/$m^2$.

3.4 Assumptions

Key assumptions reflected within the described AACE Class 3 cost estimate include are summarized in Table 3.1.

Table 3.1 Cost Estimate Key Assumptions

No.	Assumption
1.	The contracting model is design-bid-build, that contractors responding to the RFP will be reasonably aggressive and that given the time of year will have high quality staff becoming available and can bring key, proven craft people to the Work.
2.	There is no material leakage form the Intake gate for Penstock No. 1 and what leakage that does occur will be addressed by NL Hydro immediately downstream of the gate.
3.	Detailed crack mapping has only been performed from inside the penstock.
4.	The Flux Cored Arc Welding (FCAW) process with external welding gas supply has been utilized for all permanent welding. Responding contractors may prefer to utilize the more expensive SMAW approach. This has been identified as a risk item.
5.	For the penstock refurbishment, it is assumed that only existing welds will be inspected and repaired. No repairs to the steel plate are contemplated.
6.	The existing wharf at St. Alban's can be utilized (with the relatively nominal modifications as described in the Basis of Estimate) to unload by truck legal highway type loads (individual trailer mounted penstock cans).
7.	The selected penstock can fabricator has advised that with this thickness of plate they normally would not trim the 100 mm (+/-) of flat/uncurved length inherent in the plate rolling process – for thicker plate it is their common practice. Their current quote does not include this trimming (but if required, it can be readily incorporated into the fabrication process). An add-on price for trimming would be 3 to 5% of the material and be required based on final design.
8.	Three (3) spider arrangements have, on average, been provided for each penstock can element (total 30 elements). Detailed design of lifting stresses might indicate an average of four (4) spiders is more appropriate. This has been addressed as a risk item.
9.	Waste factors have been applied and included in the Estimate for permanent material procurement based on Chant's experience.
10.	Both interior and exterior coatings for the new penstock sections will be factory coated with DuraShield 210 from LifeLast as specified by KAI. However, the supplier does not have experience with this coating system and the quoted price is based on SP-6 preparation with a two (2) layer epoxy paint. An adjustment was made to the quotation by Chant to reflect the specified coating system.
11.	The scope of work for the refurbishment section is premised on assumptions established with the knowledge and understanding of NL Hydro.
12.	NL Hydro is accepting of the concept of robotic abrasive cleaning and coating application methods that have been utilized in the Estimate.
13.	In lieu of the topsoil and vegetation cover on the completed penstock backfill, recovered rock protection (referred to as rock spall) will be supplied and placed over the penstock.
14.	Three (3) penstock maintenance holes and one (1) valve tree are assumed for the penstock replacement section.

3.5 Exclusions

Exclusions pertaining to the Estimate and schedule are presented in Table 3.2.

Table 3.2 Exclusions

Item	Exclusion
1.	No NL Hydro costs of any kind have been incorporated into the Estimate. Owner costs typically include but are not limited to project management costs, owner's overheads – direct and indirect, owner's contingency, construction management, design engineering (design and resident engineer functions during construction) for the permanent works, interest expense during construction and other matters of like import.
2.	Permanent power where used (limited) will be provided at no cost to the contractor.
3.	Costs and time for weld X-Ray testing or ultrasonic testing are not included.
4.	The drainage system shown on the drawings is simplistic and contains no details with respect to cleanouts, person-holes, seepage measurement devices and discharge strategies. Only the drainage works explicitly indicated on the drawings and as described in the Basis of Estimate are included.
5.	The detailed design of the permanent bridge for Penstock No. 1 immediately downstream of the intake structure is by NL Hydro.
6.	For the penstock refurbishment section, no exterior coating has been included.
7.	Disposal of the demolished penstock sections off site is not included
8.	All permits (other than transportation permits as indicated in the Basis of Estimate) and taxes are excluded.

3.6 Cost Summary

A summary of each major cost category within the Class 3 AACE Cost Estimate are presented in Table 3.3. These categories include site direct costs, site indirect costs, and markups which include Bonds and insurance, and contractor overhead and profit.

As discussed within section 3.3.6 – Site Direct Costs, site direct cost includes items such as the penstock replacement and penstock refurbishment. A cost breakdown of these cost can be found in sections 1000 through 4000 of the Cost Estimate, attached as Appendix 6. The total site direct cost was estimated to be $17,407,239, which corresponds to approximately 51% of the total estimated cost. The largest direct cost item was determined to be item 2000-200 – Penstock Replacement, at a total cost of $8,794,554. This item includes the supply, delivery, and installation of the new section of penstock. The cost of this item corresponds to approximately 26% of the total estimated cost.

The project indirect costs include site overhead items such as mobilization, utilities and services, and safety and security. A detailed description of the site indirect cost is discussed in section 3.3.5 – Site Indirect Cost. A breakdown of the indirect cost is included in section 9000 of the cost Estimate and include items OH-01 through OH-28. The indirect cost total was estimated to be $7,356,265, which is approximately 22% of the total estimated cost. The largest indirect cost is item OH-27 – Project Equipment, at a total cost of $1,766,577. As discussed in section 3.3.5 – Site Indirect Cost, item OHO-27 include the full-time costs associated with the ownership and operation of project equipment.

Markup costs include bond and insurance costs, and general overhead and profit. The highest cost item for this category is general overhead and profit at a cost of $5,200,335 corresponding to approximately 15% of the overall estimated cost. A general overhead and profit percentage of 21% was applied to the subtotal estimate cost to estimate the overhead and profit cost.

A contingency analysis is provided within the Class 3 AACE Cost Estimate, attached as Appendix 6. A total estimated contingency cost of $3,893,000 was determined in the analysis. This cost corresponds to approximately 11% of the total cost or 13% of the subtotal cost (total cost not including contingency).

Table 3.3 Summary of Costs

Item	Description	Subtotal
Site Direct Cost:		
1000	Site Preparation	$782,823
2000	Penstock Replacement	$10,685,988
3000	Penstock Refurbishment	$5,859,494
4000	Site Finalization	$78,934
	Direct Cost Total	**$17,407,239**
Site Indirect Cost:		
9000	Site Overhead	$7,356,265
	Indirect Cost Total	**$7,356,265**
Markup:		
	Bond & Insurance	$132,868
	General Overhead & Profit	$5,200,335
	Markup Total	**$5,333,203**
	Sub Total	**$30,096,707**
	Contingency	**$3,893,000**
TOTAL		**$33,990,000**

The total cost is approximately $10M less than the Class 4 estimate in the options report. The construction means and methods of the current cost estimate uses shop fabricated larger penstock cans resulting in much less field welding. A quotation from a reputable vendor for supply of penstock cans F.O.B. wharf in St. Alban's was used for this estimate and not available in the Class 4. Robotic cleaning and coating used in this estimate reduced schedule and labour required for those tasks compared to the Class 4. The means and methods for the Class 3 type estimate developed for this report is more detailed than the previous Class 4 estimate and ultimately resulted in a reduced opinion of cost.

3.7 Schedule Summary

The schedule was created via MS Project and is displayed as a Gantt chart. The overall project duration was estimated to be 592 days, starting in April of 2024, and ending in November of 2025. The construction schedule is broken into seven main structures including the following:

1. Supply and Delivery of Steel Penstock and Heavy Equipment (85 days)
2. Site Preparation (24 days)
3. Penstock Replacement (156 days)
4. Penstock Refurbishment (183 days)
5. Wet Commissioning (5 days)
6. Staging Area Restoration and Hydroseeding (4 days)
7. Silt Fence Removal (3 days)

The items listed overlap and are not intended to be additive. The activity with the longest duration is the refurbishment of the existing penstock. The refurbishment will occur simultaneously with the penstock replacement activities. Both tasks will commence once the site preparation activities are completed. The unit outage is estimated to be 7 months and is scheduled for the period May to November.

The detailed project schedule displayed is provided in Appendix 8 of this report.

3.8 Risks and Opportunities

A short-form quantitative contingency analysis has been performed to assess the total construction contingency a contractor would likely include in the Estimate. The premise of this assessment is from the perspective of a contractor being reasonably aggressive in a competitive tendering environment.

The quantitative analysis has been assembled through a risk identification and quantification process, the development and costing of risk mitigation strategies where applicable and establishment of a probability of occurrence for each mitigated risk with quantification of outcome scenarios.

One of the more material assumptions is the extent and nature of the refurbishment work scope in general, and the extent to which existing welds will need to be repaired and/or replaced. Chant undertook a simple sensitivity analysis as to the potential cost impacts that will arise from a material departure from the base case assumption with respect to the percentage of existing welds that will ultimately need to be replaced. The findings of this analysis are presented in Table 3.4.

Table 3.4 Findings of Sensitivity Analysis Percentage of Existing Welds to be Replaced

Scenario	% of Welds Requiring Refurbishment	Weld Weight (kg)	Total Welding and Inspection Related Costs	Cost Differential from Base Case
Base Case	50%	6,627	$818,000	-
Less	25%	3,532	$444,000	374,000
More	75%	10,596	$1,332,000	514,000

3.9 Recommendations

The following recommendations are provided after considering the Estimate and Schedule provided within this report. The recommendations as discussed below have potential to produce overall project cost savings.

- With the long lead time associated with the steel procurement and fabrication of the new 5.2 m diameter penstock and its value, NL Hydro may consider having an independent tender for supply and delivery of the new elements of Penstock No. 1. Furthermore, all fabricators contacted indicated that purchasing the required

new elements for all three (3) penstocks with delivery over three (3) years would result in and overall aggregated saving.

- The specified coating material for the new penstock is DuraShield 210 from LifeLast. The fabricator utilized for this project, a major supplier of embedded and non-embedded parts to the hydropower industry in North America, was not familiar with this product. It would seem prudent to review coating options with possible fabricators to ensure availability and familiarity.
- The cost/benefit of having a cathodic protection system warrants a detailed review.

4.0 DESIGN CRITERIA DISCUSSION

This Design Criteria defines the applicable design parameters for the penstock refurbishment design, and relevant specifications, industry codes and standards.

4.1 Standards, Codes, and Guidelines

The rehabilitation of Penstock No. 1 shall comply with the most current version of applicable Canadian codes, standards, and guidelines. The following codes, standards, and guidelines shall be utilized throughout the design and construction phases of this project:

4.1.1 National Building Code of Canada

The National Building Code of Canada (NBCC) shall be used to determine the dead, live, wind, snow, and all other applicable loads acting upon the penstock and supporting infrastructure for the purpose of the design of the new 17-ft diameter section of penstock. Structural loading of the remaining sections of the penstock will be analyzed using NBCC to aid in the design of the backfill material supporting the buried penstock.

4.1.2 ASCE 79 – Steel Penstocks, 2nd Ed., 2012.

The American Society of Civil Engineers Manual of Practice 79 (ASCE 79) shall be used to aid in determining the allowable stress intensity acting on the penstock and the required thickness of the new steel penstock section. The manual will be referenced to aid in determining allowable hoop stresses from internal loads such as water pressure.

4.1.3 CSA S16 – Design of Steel Structures

The Canadian Standards Association (CSA) Standard S16 shall be used in the design of all structural steel elements of the project such as the manhole access hatch in the new 17-ft diameter section of penstock.

4.1.4 AWWA M11, Steel Pipe – A Guide for Design and Installation.

The American Water Works Association Manual No.11 (AWWA M11) shall be used in the design of the new 17-ft diameter section of penstock. The internal, external, and vacuum penstock pressures along with the allowable buckling pressures will be calculated utilizing

AWWA M11. Furthermore, the Manual will be referenced for installation processes and techniques for the construction phase of this project, including shipping and handling.

4.1.5 AISI Steel Penstocks and Tunnel Liners, Steel Plate Engineering Data, Vol.4, 1st Ed.

The American Iron and Steel Institute (AISI) Steel Penstocks and Tunnel Liners, Steel Plate Engineering Data will be referenced for the determination of the water hammer surge pressure for which the new 17-ft diameter section of penstock shall be designed.

4.1.6 ASME Boiler & Pressure Vessel Code VIII, Div. 1, 2004

The ASME Boiler & Pressure Vessel Code VIII, Div. 1 shall be utilized in determination of materials, specifications, fabrication, required inspection and testing. The code shall be referenced in determining the allowable vacuum pressures within the penstock and the required ventilation to accommodate the vacuum pressures.

4.1.7 CSA W59 – Welded Steel Construction

CSA W59 shall be referenced for the design and specification of all welded steel.

Determination of steel material properties, electrodes, preparation of material, sequencing, and other pertinent information in relation to welded steel will be determined from this standard.

4.1.8 CSA W47.1 – Certification of Companies for Fusion Welding of Steel

The CSA W47.1 certification of Companies for Fusion Welding of Steel shall be required for any contractor performing the fusion of metals throughout the construction phase of this project. The intent of this certification is to ensure quality control of any welding.

4.1.9 CSA C22 – Canadian Electrical Code

CSA C22 shall be referenced for the design of the new pressure transducer instrumentation system and all other supporting electrical equipment.

4.2 Material Properties

4.2.1 Steel Properties

The steel grade for the new penstock construction was given consideration as it is a critical part to the longevity and constructability of the new penstock. ATSM A516 Grade 70 Steel was chosen for a few reasons including availability, weldability, strength, and cost. A516 is a commonly used grade of steel for pressure vessels as it provides a high tensile strength to cost ratio. It is generally considered to be readily available for construction and finding a source of steel should not be an issue. The metal type chosen is considered a weldable material commonly used for pressure vessels which is required as this is a new build penstock which requires extensive fitting and welding.

4.2.2 Soil Properties

Penstock Bedding Material
The penstock bedding material is to be a stiff, well graded structural fill with the following properties as a guideline. See specification 31 00 00 for more details on earthwork and material requirements.

a) Penstock Bedding Material
    i) Unit Weight of Soil = 19 kN/m^3
    ii) Relative Compaction = 95% for bedding/structural fill
    iii) Minimum Coefficient of Friction = 0.25
    iv) Bearing Capacity = 72 kN/m^2

Common Fill Material

The native backfill will be excavated from the penstock and stored on site for backfill once the new penstock is constructed. The backfill shall be free from large boulders or rocks that may damage the penstock. The large rocks shall be removed prior to backfilling against the penstock

a) Common Backfill
    i) Unit Weight of Soil = 19 kN/m^3
    ii) Relative Compaction = 85% for common fill
    iii) Coefficient of Friction = 0.25
    iv) Bearing Capacity = 58 kN/m^2

v) Native soils may be reused as common backfill provided that their classification and gradation meet the U.S. Army Corps of Engineers Frost Design Soil Classification of F1 or F2.

vi) F3 and F4 soil may not be reused within 1.3m of finished grade.

vii) Large stones, rocks and boulders shall be removed from common backfill prior to installing against

viii) The re-use and placement of frost susceptible soils and/or hazardous soils shall be approved by the OWNER'S REPRESENTATIVE. Large stones, rocks and boulders shall be removed from common backfill prior to installing against penstock.

4.3 Instrumentation Requirements

Instrumentation plays an important role in monitoring the long-term health of any penstock and can provide early indications of developing issues. For this project we are recommending pressure transducers to monitor internal penstock pressure upstream and downstream of the surge tank, and drainage monitoring that can detect penstock leakage before a failure occurs.

4.3.1 Existing Conditions

Pressure Transducer System

The existing pressure transducer system installed on Penstock No. 1 consists of multiple **Ashcroft Model K1, 0-300 PSI** pressure transducers installed along the length of the penstock. The system was implemented in 2018 for the purpose of a condition assessment of each of the penstocks located at the BDE Site. The pressure data is collected via removable storage media located in the No.2 Surge Tower House. The data is then extracted from the data logger and reviewed with a software package. Currently, NL Hydro has experienced multiple pressure transducer failures due to freezing during cold weather events. The transducers are encased in a corrugated galvanized steel pipe with fiberglass insulation.

Drainage Monitoring System

There is uncertainty surrounding the condition, reliability, and layout of the existing drainage system beneath penstock #1. The existing design drawings dated August 1965 depict 6 in perforated drainpipes beneath the penstock.

4.3.2 Rehabilitation

Pressure Transducer System

As a part of the rehabilitation efforts for penstock #1, various options will be explored to update the existing pressure transducer system. The option considered for this report will be replacing the existing transducers immediately upstream and downstream of the surge towers. Three transducers are estimated, and the transducers will be new Ashcroft Model K1, 0-300 PSI pressure transducers, if required, and will be heated during the winter months via heat trace. The existing pressure transducer encasements will be removed and replaced with a more permanent encasement compared to the existing protection. The encasement will be watertight and insulated to protect the transducer from the external elements. The pressure transducer system will be integrated with NL Hydro's existing internal data collection system so that the data can be logged and then trended. Real time monitoring data acquisition systems will also be explored during the design phase of this project.

Drainage Monitoring System

A new drainage system will be installed beneath the new 17 ft diameter section of penstock as a part of the rehabilitation efforts. The new section of drainage system will consist of approximately two 6in perforated PVC pipes and will drain to the stream located to the right for Penstock No. 1, while looking downstream. Flow discharging from the drainage system outlet will be monitored via a new monitoring weir, or a flow monitor, which will be determined during the design phase. The new drainage system will not be integrated with the existing drainage system as the condition of the existing system is unknown and considered unreliable.

Monitoring of the water drainage below the penstock is important as it can provide insight to whether there are any minor leaks below grade, which otherwise would go unnoticed without the drainage system being in place. Furthermore, a functioning drainage system will help prevent any potential washout of the penstock bedding material, which can lead to undue stresses occurring in the penstock, and ultimately lead to failure.

4.4 Structural Load Cases

4.4.1 Design Summary

The primary loading on the penstock is the hoop stresses resulting from a watered pressurized penstock. Static pressure is the pressure resulting from an open system with the internal pressure equal to the gross hydraulic head. A dynamic load was considered which assumes the system experience a surge pressure resulting from the rapid closing of the wicket gates in an emergency shutdown or test. Other loading considered consists of axial loading due to thermal expansion, thrust forces due to bends throughout the pipe and external loading such as deadloads and soil backfill. For the axial expansion forces, the temperature change for the steel was assumed to be +/- 20 degrees Celsius. As for the thrust forces due to bends throughout the pipe, the requirement of external thrust restraints in the form of thrust blocks shall be determined in the final design phase. At this stage, the bends of the new 17'-0" penstock was assumed to match the existing. Additional loading such as vehicular traffic may be considered later after discussions with the client take place on whether it is of use to thicken a couple cans to allow for traffic to travel over the penstock in one or two dedicated locations.

4.4.2 General Buried Penstock

a) Hoop Stress Check (Pipe Bursting):
   i) Static Pressure @ Max. Operating Headpond = 400.54 kPa (Calculated at EL.465' and at maximum Headpond EL. 597')
   ii) Surge Pressure @ Max. Operating Headpond = 520.70 kPa (Calculated at EL.465' and at maximum Headpond EL. 597')

   Note: Approximately a 128 ft difference in head exists between the ends of the penstock. Also, the maximum possible headpond is 599.5 ft

b) Axial Force
   i) The axial force due to thermal expansion to be evaluated based on a +/- 10-degree temperature swing over the entire length of the pipe for normal operation and a +/- 20-degree extreme dewatered scenario.

c) Minimum Thickness for Shipping and Handling Requirements
   i) The minimum thickness to meet shipping and handling requirements.

4.4.3 Empty Buried Penstock

a) Penstock Buckling (Bending)

   i) Evaluate external loading and vacuum pressure on an empty pipe.

      (1) Steel Dead Load = 13.98kN/m (7/16" Thick Plate)

      (2) Soil Dead Load = 89.79 kN/m based on Depth of Soil Cover = 0.9 m, Saturated Soil = 18.85 kN/m^3

   ii) Determine the Maximum Allowable Vacuum Pressure = 4.29 kPa

4.4.4 Combined Loading

a) Combined hoop, bending and thermal.

4.4.5 Thrust Resistance

a) Horizontal Bend (1A) – 26.16 Degrees

   i) Evaluate the soil friction resistance at the bend with a full penstock and water hammer.

   ii) Assume only the self-weight of the steel pipe, the water weight from a full pipe and 900 mm of soil cover contributing to the frictional resistance between the soil and penstock.

b) Vertical Bend (1A) – 6.65 Degrees

   i) Evaluate the soil friction resistance at the bend with a full penstock and water hammer.

   ii) Assume only the self-weight of the steel pipe, the water weight from a full pipe and 900 mm of soil cover contributing to the frictional resistance between the soil and penstock.

c) Vertical Bend (2A) – 6.44 Degrees

   i) Evaluate the soil friction resistance at the bend with a full penstock and water hammer.

   ii) Assume only the self-weight of the steel pipe, the water weight from a full pipe and 900 mm of soil cover contributing to the frictional resistance between the soil and penstock.

d) Vertical Bend (3A) – 5 Degrees

   i) Evaluate the soil friction resistance at the bend with a full penstock and water hammer.

ii) Assume only the self-weight of the steel pipe, the water weight from a full pipe and 900 mm of soil cover contribute to the frictional resistance between the soil and penstock.

e) Vertical Bend (4A) – 8.96 Degrees

i) Evaluate the soil friction resistance at the bend with a full penstock and water hammer.

ii) Assume only the self-weight of the steel pipe, the water weight from a full pipe and 900 mm of soil cover contribute to the frictional resistance between the soil and penstock.

4.5 Specifications

4.5.1 Welding Specifications

Welding is a significant part of the refurbishment work. Consideration was given to how the new sections are welded and how the existing remaining penstock is tested and repaired. Welding mechanism is also important to consider, the welding associated with this project in the cost estimate is flux core welding (FCAW) with a contingent cost set for the use of an alternate more expensive approach such as Shielded Metal Arc Welding (SMAW).

We are expecting many of the welds to be complete penetration welds with access required from both sides. For welds requiring full depth repair, side 1 (exterior of penstock) would be excavated and welded to about half depth then back gouge from Side 2 to sound metal and complete the weld repair. Weld shape on both sides would be U-shape with a 3/16" radius at the bottom and a 45-degree groove angle.

We are expecting some partial depth cracking that will be excavated to create a U-formed shape with a 3/16" radius at the bottom and a 45-degree groove angle. These welds would be repaired from inside the penstock for a partial depth repair and not require excavation to expose the exterior of the penstock.

For the welding of the new 17'-0" diameter penstock section, full depth penetration double beveled weld with a 45-degree groove angle. This requires access from both sides. A backer plate will be installed to contain the weld material during the welding process.

Instances of partial depth cracking from both sides may be encountered, detailed inspection processes will be required to determine the location. These types of cracking shall be treated as a full penetration weld repair. Initial inspection will take place from the interior of the penstock. Inspecting the inside only will mean that some cracks which have initiated on the outside may be missed, these would eventually extend to the inside. Periodic visual inspections would identify these, at which time they would be repaired. To inspect the joint from the outside would be ideal, but the cost is prohibitive due to overburden removal and replacement. The primarily location of full depth cracking is seen in the existing 17'-0" diameter section due to the large diameter and thin can thickness. This section is being replaced and welded from both sides which should mitigate the majority of weld failures seen in the lifespan of this penstock.

See Appendix 15 for the weld specification.

4.5.2 Fabrication Specifications

The fabrication of the new 17 ft diameter section of penstock will be a significant part of the refurbishment effort. Consideration was given to what materials are to be used in the fabrication of the new section of penstock, and the materials to be used for the rehabilitation of the 15.25 ft and 13.5 ft diameter sections of the penstock. Consideration was also given to how the penstock is to be fabricated. The intent of the fabrication specification is to ensure the appropriate materials and elements are utilized to maintain cost effectiveness and durability of the penstock.

The new section of penstock will be constructed from ASTM A516 Grade 70 steel, or an approved equivalent. ASTM A516 Grade 70 steel is plate rolled and commonly found in the construction of pressure vessels. This grade of material was chosen as it is a cost-effective option in comparison to a higher grade of steel, while still maintaining durability.

See Appendix 16 for the Fabrication specification.

4.5.3 Installation Specifications

Consideration was given to the installation procedures of the new 17 ft section of penstock, and the rehabilitation of the remaining sections. The purpose of the installation specification is to ensure materials are handled and installed appropriately, the correct materials and process are utilized, and to ensure that quality control and quality assurance is maintained throughout the construction phase of the project.

Quality assurance is a major component of the installation specification. Quality assurance is maintained by contractor qualification such as the CSA W47.1 Certification of Companies for Fusion Welding of Steel and having an experienced contractor that has project experience of similar or greater complexity. Quality control of the project is maintained via inspection and testing of the materials. Some of the major components of this project that will undergo periodic inspection and testing include the penstock surface coatings, field welds, and the compaction of the backfill.

Since welding is a major element of the refurbishment effort, all welding procedures will be submitted to the engineer for approval. Furthermore, as mentioned above, the contractor will be required to have the CSA W47.1 Certification of Companies for Fusion Welding of Steel. The intent of both of the above requirements is to ensure that the field welds are of a high quality and will not require any rework due to installation error.

Guidance plating is planned around the circumference at the ends of the new cans. This plating is intended to facilitate fitting and aligning each can to the next during installation.

Grading of the bedding material and achieve proper compaction is also a significant consideration during installation.

See Appendix 17 for the Installation Specification.

4.6 Environmental, Health and Safety requirements

4.6.1 Environmental Requirements

Environmental Site Plans shall be developed in accordance with the Environmental Protection Act and the Department of Environment and Climate Change, Newfoundland and Labrador.

Extensive site works will be required to remove and replace the 17-ft diameter section of Penstock No. 1 including:

- Temporary site access roads for large vehicles and equipment
- Temporary drainage or portable pumps to divert water away from the construction site
- Construction of storage areas for fuel, equipment, and materials
- Excavation to expose the buried 17-ft section of Penstock No. 1

- Removal of the existing 17-ft section of penstock, scrap metal and disposal
- Removal and replacement of penstock bedding materials
- Welding of the new 17-ft sections of penstock
- Refurbishment of existing welds in the remaining section of penstock
- Sandblasting of the existing penstock interior surface
- Recoating of the existing penstock interior surface
- Site restoration

Dust from the temporary access roads must be controlled to improve air quality and visibility. Good housekeeping practices should be used to control litter at the site. Garbage shall be disposed of offsite by waste management services including scrap metal or other waste materials. Hazardous waste shall be disposed of according to manufacturer recommendations and Newfoundland and Labrador Environmental Guidelines and Standards.

Refueling procedures for large equipment and trucks shall be implemented along with an environmental monitoring plan to monitor fuel spills and storage. Applications to the Department of Environment are required for the establishment of fuel caches at remote sites and will be needed for refueling protocols. As per the Guidelines for Drum-Based Petroleum Products Storage and Operation at Remote Sites, drums and tanks must be registered with secondary containment and prefilled drums shall not be refilled on site. Section 8.1 of the Environmental Protection Act requires all releases of contaminants into the environment to be reported.

The interior surface of existing penstock will be sandblasted and recoated to prevent further corrosion and will require the implementation of quality assurance and quality control procedures for the application of paint. The manufacturers recommendations and Safety Data Sheets for the paint shall be available and kept with the stored product.

Monitoring systems must be implemented for storm water drainage such as testing for water quality or sediment release. Temporary silt fencing or other shall be used to control soil erosion and sediment release.

Animal or plant species at risk in the area shall be identified and appropriate measures implemented to reduce environmental impacts to the surrounding area.

A final restoration plan for the site shall be developed by the contractor and approved by NL Hydro.

4.6.2 Health and Safety Requirements

Newfoundland and Labrador Occupational Health and Safety Regulations will govern Health and Safety requirements at the Bay d'Espoir Hydro Site. The project will require multiple crews to complete site works, to install the new penstock sections and to complete weld refurbishments for the remaining penstock.

A detailed site Health and Safety plan will need to be developed for the penstock refurbishment project including, but not limited to the following:

1. *General Site Safety* – A site orientation including instructions for visitors, workers and staff shall be provided before entry to the site. Appropriate signage will be used to identify any site restrictions and provide traffic control. An increase in vehicular traffic such as heavy equipment, trucks, public vehicles can pose a risk for accidents and the necessary controls shall be used to direct traffic to appropriate areas of the site. Lay down areas or material storage areas shall be monitored, locked or fenced in. Emergency evacuation details and site supervision contact information shall be posted in areas where required. The site will be equipped with the necessary facilities for workers for taking lunch breaks such as screened shelters or other. Emergency first aid facilities shall be required along with wash stations and eye wash stations. General safety orientation shall include heat and cold stress, injury prevention and COVID-19 protocols.
2. *Emergency Evacuation/Fire* – The health and safety plan must include written procedures for evacuating the site due to fire, flooding, or other.
3. *Training* – Workers shall have the appropriate training and certification to carry out the required tasks. Each worker shall wear the appropriate personal protective equipment (PPE) including hard hat, safety glasses, steel toe boots, high visibility clothing and gloves. Specialized PPE such as welding gear and respirators for recoating procedures will be required and documented in the Job Hazard Assessment.
4. *Permitting* - Work permits for lock out tagout, hot work, confined spaces, live equipment, working at heights, lifting operations, excavation, equipment refueling, and location of buried services will be obtained if required.
5. *Penstock Access/Egress* – Safety training such as confined space and fall arrest will be completed in accordance with the Newfoundland and Labrador Occupational Health and Safety requirements. Suitable access and egress of the penstock must

comply with confined space regulations and require detailed work procedures, qualified personnel, and a written emergency rescue evacuation plan. The need for fall arrest equipment will be evaluated for the steeper sections of the existing penstock. The penstock must be well-ventilated for the work to be completed inside the penstock and air quality conditions shall be re-evaluated during welding and painting procedures. Scaffolding shall be erected by qualified personnel and tagged if in good working order.

6. *Welding* – Welding safety procedures shall be implemented in accordance with CSA W117.2 Safety in Welding, Cutting and Allied Processes which "*provides minimum requirements and recommendations to protect persons who work in an environment affected by welding, cutting, and allied processes from illness and injury, and to prevent damage to property arising from the installation, operation, and maintenance of equipment used in these processes.*" The procedures shall include the type of welding procedure, equipment, and PPE requirements. The areas where welding will be performed shall be well ventilated and free of ignition sources. Respirators will be required if appropriate ventilation cannot be achieved.
7. *Excavations* –A worker shall not enter an excavation of more than 1.22 meters deep unless slopes safely graded at 2H:1V or slopes secured by shoring or sheet piles. An excavation plan shall be submitted noting location of drains, underground conduits, cables or other. The excavations shall be completed to expose the 17-ft diameter section of penstock for removal.
8. *Lifting/Rigging* – Lifting sections of penstock or other materials will require determination of the safe working load. The safe working load is the load a crane or hoist can safely lift including factors such as wind, extreme temperatures, and load sail area. Qualified personnel will oversee lifting operations and will require the development of detailed safe work practices and procedures for each lift.
9. *Job Hazard Assessments (JHA)* - A pre-project plan should be completed to identify the hazards of the work and should be included in written safe work practices. The JHA must be completed daily and accessible at the job site. The Field Crew Leader is to discuss the site-specific hazards of each job prior to the start of work each day with everyone on site and make modifications to the Job Hazard Assessment if conditions change such as the addition of a new crew member or change in weather

5.0 REFERENCES

Chant Limited. (2021). *Bay d'Espoir Hydroelectric Generating Station, Life Extension of Penstock No.1 Cost Estimate*. Aurora, ON.

Chant Limitied. (2021). *Project Execution Strategy, Bay d'Espoir Hydroelectric Generating Station, Life Extension of Penstock No.1, No.2, and No.3*. Aurora, ON.

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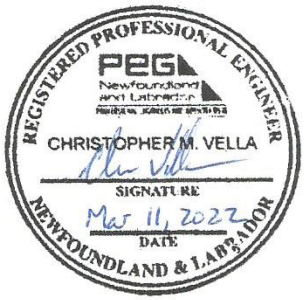
REPORT SIGNATURE PAGE

KLEINSCHMIDT ASSOCIATES CANADA INC.



Chris M. Vella, P.Eng.
Senior Structural Engineer

CMV:SCB



APPENDIX 1

BDE SITE OVERVIEW

Appendix 2 – Chant Site Visit Notes

Amendment Measured Road Distances

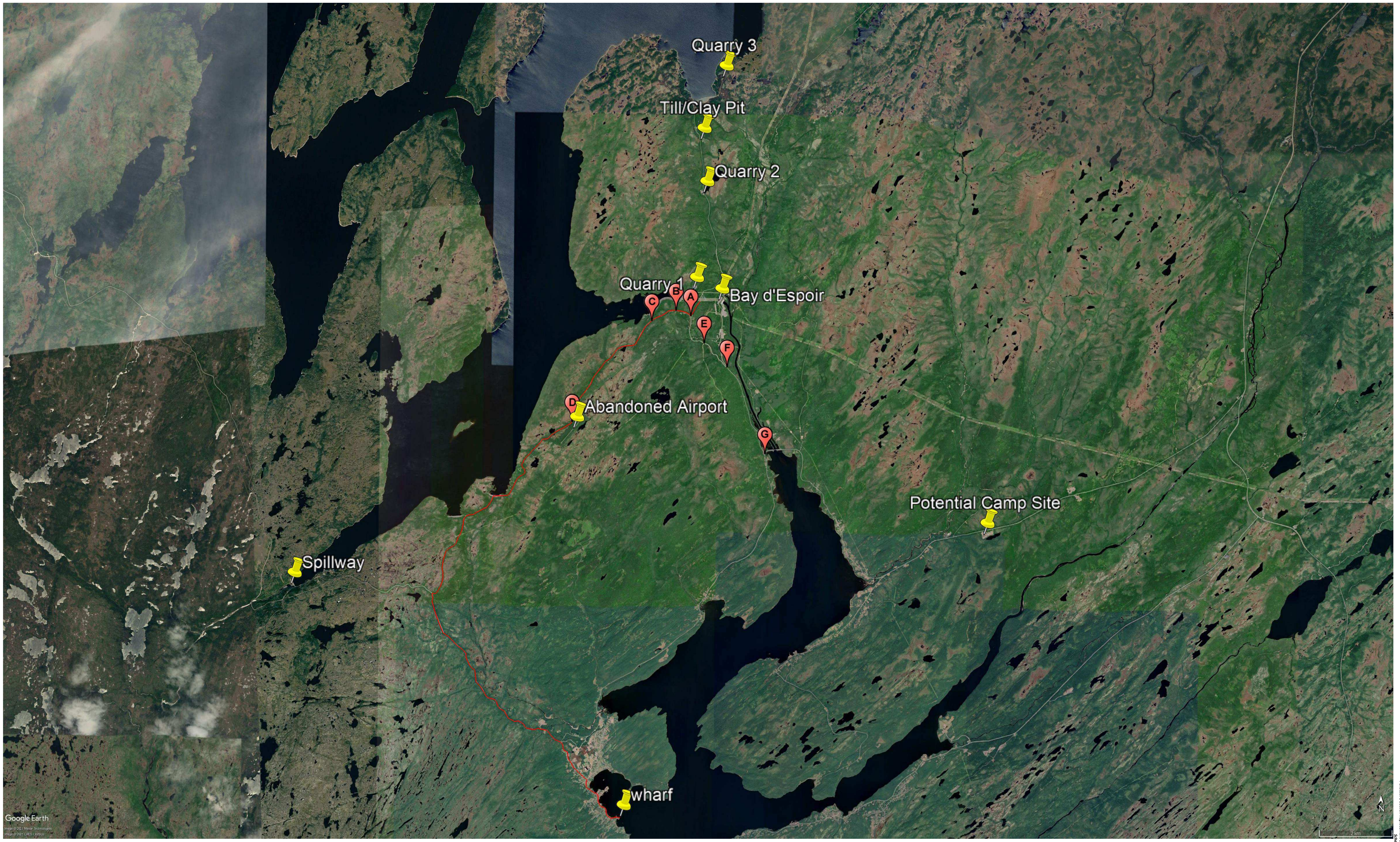
On-Site Road Distances				
Segment		**Odometer**	**Distance (km)**	
	Intersection A	593.5		Intersection Airport Road with Surge Tank Road
			0.6 km	Point A1 is Intersection with ramp to Surge Tanks – ramp is 150 m each way
	Point A2			Bridge Penstock No. 2
			0.2 km	
	Point A3			Bridge Penstock No. 4
			0.8 km	
	Point A4			Turned right at intersection and proceeded to locked gate
	Intersection A	597.0		
			0.4	
	Intersection B	597.4		Intersection with first access to Penstock ROW – 0.2 km to gate
			0.9	
	Intersection C	598.3		Intersection with access road to Right Abutment of Main Dam
			0.2	
	Right Abutment	598.5		Right Abutment of Main Dam
			0.3	
	Intersection C	598.8		
			3.7	Adjusted by (0.4 km) to reflect passing Intersection (0.2 km), turning around and returning to intersection (0.2 km)
	Intersection D	602.9		150 m from Intersection D to centerline of existing airport runway each way or 0.3 km
			0.3	
	Intersection D	603.2		
			3.6	
	Intersection C	606.8		
			0.8	
	Intersection B	607.6		
			0.4	
	Intersection A	34.0		

Appendix 2 – Chant Site Visit Notes

			0.7	
	Twin Culverts	33.3		
			0.3	
	Intersection E	33.0		Intersection of Airport Road and Vista Road
	Vista Road	n/a	1.7	✓
	Intersection E	33.0		
			1.0	
	Intersection F	32.0 613.7		Intersection PP Access Road with Airport Road
			0.5 km	✓
	Guard House	614.2		
			0.6 km	✓
	Intersection F	614.8		
			2.7 km	✓
	Intersection G	617.5 632.8		Intersection of PP Access Road with Highway 361
			11.3 km	
	St. Alban's Inn	644.1		

Notes:

1. The distance between the top of the Intake Ramp to Q2 is approximately 0.6 km.
2. The distance between Bridge No. 4 on the Surge Tank Access Road and the Coast of Bays Contracting quarry is 3.2 km.
3. The distance between Bridge No. 4 and the upper limits of the till deposit is 4.9 km.


Quarry 3
Till/Clay Pit
Quarry 2
Quarry 1
Bay d'Espoir
A
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Abandoned Airport
Potential Camp Site
Spillway
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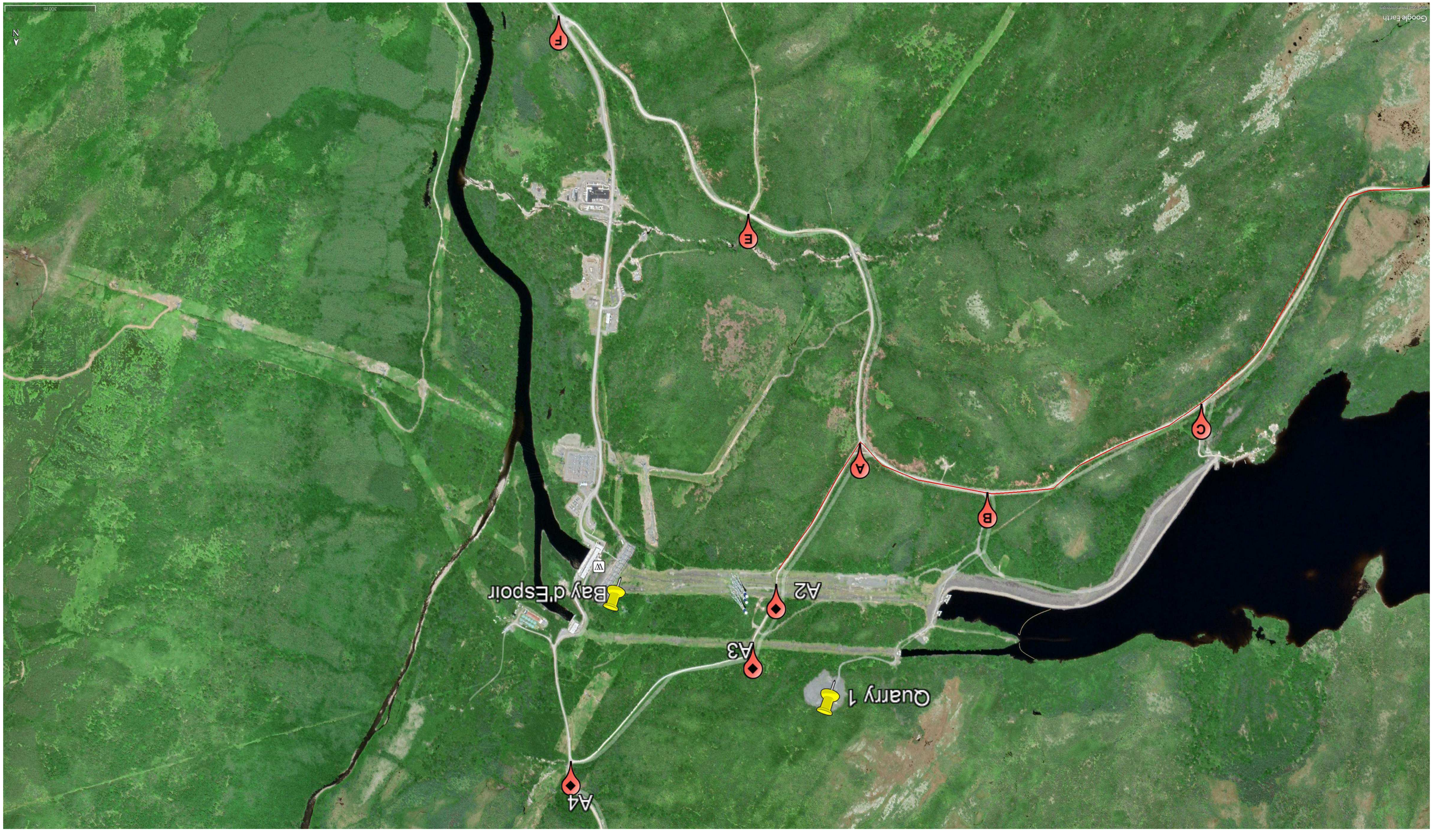
300 m
N
Google Earth
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A2
Bay d'Espoir
A3
Quarry 1
A4

APPENDIX 2

LE GROUPE LAR PENSTOCK QUOTATION

Métabetchouan-Lac-à-la-Croix, December 13th, 2021

Chant Limited
226 Edward St.
Aurora, ON
L4G 3S8

To the intention of Mr. Gabriel Nobre, PMP

Subject : **Bay d'Espoir penstock replacement feasibility study**
***LAR* Ref. #11774**

Mister Nobre,

Following your request, it is our pleasure to submit you our BUDGET price for the Fabrication and Delivery of the penstock for the Bay d'Espoir Penstock feasibility study:

Our BUDGET Price for the penstock : 5'906'400.00 $CAD
Our BUDGET Price for the transport: 1'385'500.00 $CAD (highly variable)

Our pricing is based on your documents and email sent from 2021-11-16 to 2021-11-29 and our experience on the fabrication and delivery of similar penstocks.

Our transport pricing is based on prices we received for barge transport in 2016. Penstock sections with their trailers can be loaded on the barge. To be discussed.

Technical clarifications:

- 3 maintenance holes included (ref. email sent on 2021-11-29);
- 1 "bicycle wheel" (cross bracing) per penstock section;
- 2 cross (X-brace) per penstock section
  NOTE: The bicycle wheel's end of a penstock section is considered the rigid end of the section and the cross end is considered the adapting end. This way, when penstocks sections are field mated, fabrication tolerances are governed by the bicycle end.
- 2 saddles per penstock section
- 4 lifting lugs per penstock section
- Coating: SP-6 preparation with a 2 layers epoxy paint, your specified paint spec will be more expensive, but we do not have enough reference to consider it in our budget.
- No anchors included
- No expansion joint included;
- No concrete injection hole included;
- Total steel weight considered of 1'036'950lbs (471'340kg)
- No design engineering included, only fabrication drawings

1760, ROUTE 169, MÉTABETCHOUAN-LAC-À-LA-CROIX (QUÉBEC) G8G 1B1
TÉLÉPHONE (418) 349-2875. TÉLÉCOPIEUR (418) 349-8415
Courriel : info@lar.qc.ca – site internet : www.lar.qc.ca

Métabetchouan-Lac-à-la-Croix, December 13th, 2021

- All taxes extra.
- **Budget Price valid for 30days;**
- Steel Price considered @ 1.40$CAN/lbs (extremely variable these days!)
- Transport CPT as per incoterms 2020 (on vessel at Saint Alban's Wharf);
- Insurance requirements to be confirmed;
- No penalty or LD's is considered in this offer;
- Base Warranty of 12month included, but specific project warranty to be confirmed.
- No Bonding or Letter of Credit Included.
- No financing fees included as a neutral cash flow along the project duration has been considered. Payment terms might have an impact on overall price.
- No holdback considered.

Best regards,

Alexis Gauthier, Eng.
Heavy Mechanical Work Sales Manager
+1-418-719-5072
agauthier@lar.qc.ca

APPENDIX 3

USING ROBOTICS TECHNOLOGY TO RELINE LARGE DIA. PIPING REFERENCE

RECLAMATION
Managing Water in the West

Using Robotics Technology to Reline Large Diameter Piping on Steep Slope

Research and Development Office
Science and Technology Program
(Final Report) ST-2018-8107-01 8540-2018-50



U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

September 2018

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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13. SUPPLEMENTARY NOTES		
14. ABSTRACT ***(Maximum 200 words)*** This report documents a demonstration at the Central Arizona Project's Mark Wilmer Pumping Plant where the contractor used robotic equipment to reline the 12-foot diameter discharge tube with slopes up to a 77 percent grade. The work consisted of approximately 105,000 square feet of surface area and was completed in less than three months. This is the first known relining project to use robotics on a steep slope.		
15. SUBJECT TERMS Robotics technology, Relining infrastructure, Automation, Large diameter pipes, Coatings		

16. SECURITY CLASSIFICATION OF: Unclassified			**17. LIMITATION OF ABSTRACT** U	**18. NUMBER OF PAGES** 24	**19a. NAME OF RESPONSIBLE PERSON** Allen Skaja
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S Standard Form 298 (Rev. 8/98)
P Prescribed by ANSI Std. 239-18

BUREAU OF RECLAMATION

Research and Development Office
Science and Technology Program

Materials and Corrosion Laboratory, 86-68540

(Final Report) ST-2018-8107-01 8540-2018-50

Using Robotics Technology to Reline Large Diameter Piping on Steep Slope

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Acronyms and Abbreviations

Bureau of Reclamation, Reclamation

CTE	Coal tar enamel
DFT	Dry film thickness
Ft	Feet
Hrs	Hours
ID	Inner diameter
LF	Linear feet
LC	Lower Colorado
N/A	Not applicable
R&D	Research and Development
S&T	Science and Technology
SF	Square feet

Executive Summary

Penstocks, discharge tubes, and outlet works relining projects are dangerous due to the nature of the work, i.e., confined spaces, non-level footing, and steep slopes. In 2007, fire broke out inside of the penstock at the Cabin Creek powerplant during relining application. Five people on the painting crew died. There were a number of contributing factors that caused the accident:

- Poor safety plan for working in permit required confined space
- Lack of Emergency Response plan
- Use of highly flammable solvent for cleaning equipment that produced flammable atmosphere

Advancements in robotics relining jobs are changing the way contractors conduct business by increasing production rates, lowering costs, and reducing worker exposure to harmful chemicals. The potential safety improvements are further magnified by this new opportunity to minimize the number of employees in the permit required confined space. The benefits are safer work environments, reduced liability, shorter downtimes, and reduced cost.

This case study documents a 2016 relining project at the Central Arizona Project Mark Wilmer Pumping Plant. This work demonstrated the state of the art for the use of robotics on steep inclined structures, with the 105,000 total square feet (SF) of the 12-foot diameter pipe being relined in less than 90 days. Contractor personnel guided and monitored the robotic equipment from inside the pipe while the robots prepared the surface and relined the structure. The physical labor required by employees was reduced significantly because the robots did the majority of the work. The approximate production rates during this project for each robot are as follows:

- Ultra-high pressure water jet robot: 100 linear feet (LF) (3,600 SF) per shift
- Abrasive blast robot: 50 LF (1,800 SF) per shift
- Coating robot: 150 LF (6,000 SF) per shift at 60 mils dry film thickness

The next step is to develop an autonomous (person free) robot that is controlled or monitored from outside the confined space work environment. A new research proposal has been submitted to help the technology advance. These advancements could allow for the application of a wider variety of coating systems where safety and health concerns currently preclude their use.

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Background

The majority of the world's penstocks, discharge tubes, and outlet works were originally lined with coal tar enamel (CTE). In most cases, CTE provided an extremely long service life exceeding 50 years [1]. CTE eventually requires replacement requiring these water agencies to reline their infrastructure [2]. Traditional rehabilitation procedures include manually abrasive blast cleaning and applying the new coating, i.e., relining, using mobile scaffolding, which is extremely dangerous on steep inclined surfaces. Work is extremely challenging and slow due to laborers doing the manual labor, resulting in long outages for the facility, and often high opportunity costs as a result of forgoing power generation. Furthermore, the success and quality of the relining work is highly dependent upon the skills of the applicators.

Health and safety considerations for coating in confined spaces improved as a result of the 2007 Cabin Creek accident where a fire broke out inside of a penstock and five workers died [3]. A number of contributing factors that caused the accident:

- Poor safety and rescue plans for working in permit required confined space
- Flammable atmosphere due to use of solvents for cleaning equipment, which was exacerbated by including a large volume of these flammables within the pipe

Since the Cabin Creek fire, Reclamation and other agencies gained interest in using robotics technology for relining projects in penstocks and similar features. BC Hydro and Reclamation wrote reviews highlighting the benefits of robotics technology for use in their agencies [4] [5]. In addition to an estimated 37 percent savings by using robotics technology, Reclamation can benefit from:

- Safer application methods, exposure conditions, and reduced liability
- Higher quality end products resulting in fewer holidays
- Shorter outage times to complete work
- Reduced labor costs, resulting in overall lower project costs
- Utilizing robotic equipment on pipes up to 32-foot inner diameter (ID)

Contractors began using robotics for relining pipelines around 2009 [6]. Almost all of those relining jobs were on minimally inclined surfaces. Some examples of the production rates, shown as square feet (SF) and outage durations are shown in table 1. The primary benefit for these jobs were the reduced outage time and reduced number of outages. In 2016, a contractor relined a discharge tube with areas as high as 77% slope using robotics. This advancement has allowed for almost any relining pipe project to be completed using robotics at an increase production rate.

Table 1. Examples of projects completed using robotics on minor slopes [6]

Project	Project Year(s)	Scope	Duration	Area (SF)
Western Electric Power Coop.	2013, 2014, 2015	Remove existing scale, abrasive blast, reline	50 days per unit	110,000 SF 130,000 SF 130,000 SF
Midwestern Electric Utility	2014-2015	Abrasive blast, reline	110 days	160,000 SF
Southwestern Electric Utility	2009, 2010, 2012, 2014	Remove cement mortar lining, abrasive blast, reline	40 days per unit	60,000 SF 53,000 SF 60,000 SF 50,000 SF

Central Arizona Project Demonstration

The Mark Wilmer Pumping Plant, built in 1981, is located on the south side of Lake Havasu, Arizona. The discharge tubes were originally coated with coal tar enamel. The service life was 35 years, which is on the short end for coal tar enamel. The existing coal tar enamel was in very poor condition shown in Figure 1. It was uncertain why the coal tar enamel failed prematurely when two miles away the coal tar enamel in the Parker Dam penstocks is 80 years old and still in excellent condition.

In 2016 and 2017, the two 12-foot diameter, 2600-foot long discharge pipes were relined. The total surface area per discharge tube was 105,000 SF. The CAP was limited to a 90 day outage from June 1 to August 30. There was an 824-foot change in elevation with slopes ranging from 16% to 77%. Figure 2 shows the terrain of the buried twin barrel discharge tubes, with three staging and access areas to the pipes. The fourth access point is inside the pumping plant. There were approximately 900 linear feet (LF) between access points and all blast media and coating materials were delivered to the robotic equipment via hoses. The contractor used a winch system anchored inside the discharge tube to control the robot at a given rate on the steep inclines as seen in Figure 3.



Figure 1. Existing condition of coal tar enamel, large areas of damaged coating.



Figure 2. Site and terrain conditions at the Mark Wilmer Pumping Plant discharge tubes; access points and staging areas are circled in red.



Figure 3. Electronically controlled winch system to allow the robot to work on steep inclines.

Water Jetting Robot

Severely degraded coal tar enamel is easily removed by water jetting methods, and a water jetting robot was used to remove coal tar enamel. Dust levels were significantly reduced, and the coating was removed without having the workers wear respirators. The workers use rope access equipment for safety, and eliminating the need for supplied air respiratory protection prevented the risk of entanglement with the rope access lines. Figure 4 show the water jetting robot at work removing the coal tar enamel. An average production rate of 3600 SF per 8-hour work shift was achieved for this job. The humidity levels were high while the water jetting procedure were conducted and caused instantaneous flash rusting of the steel surface. Once the water jetting robot was far enough into the penstock, the contractor ran the abrasive blast robot behind it. Bulkheads were used to isolate sections of the discharge tube to control the environmental conditions to prevent flash rusting of freshly blast cleaned steel.



Figure 4. Water jetting robot removing existing coal tar enamel.

Abrasive Blast Cleaning Robot

The abrasive blast cleaning robot was used to obtain a white metal blast with a 3 mil profile as seen in Figure 5. Coal slag blast media was used for cleaning. The media travelled through a 3-inch blast hose to the robot, where it splits off into three smaller 1.5-inch diameter hoses. The average production rate for this job was 1800 SF per 8-hour shift. These production rates were lower than prior work on minimally inclined surfaces. Generally, abrasive blast cleaning is always the slowest process in recoating or relining, so it is the rate limiting step. The faster the abrasive blasting, the faster the entire job is completed. The robotic process is continuous and only stops when the abrasive blast pot needs to be refilled. This is significantly more efficient than manually cleaning on a steep slope. In addition, less abrasive is wasted due to a continuous process than a manual process. Figure 6 shows a close-up of the surface of the blasted steel. The metal loss areas look like alligator skin due to the degradation pattern of the coal tar enamel. The flash rusting of the white metal blast was prevented by using dehumidification equipment and blowing in dry air into the pipe. This was a requirement because many LF can be coated in a

single day. Once the abrasive blast cleaning robot was far enough along in the pipe, the coating robot was used to apply the lining to the blasted areas.



Figure 5. Abrasive blast cleaning robot achieving a white metal blast.

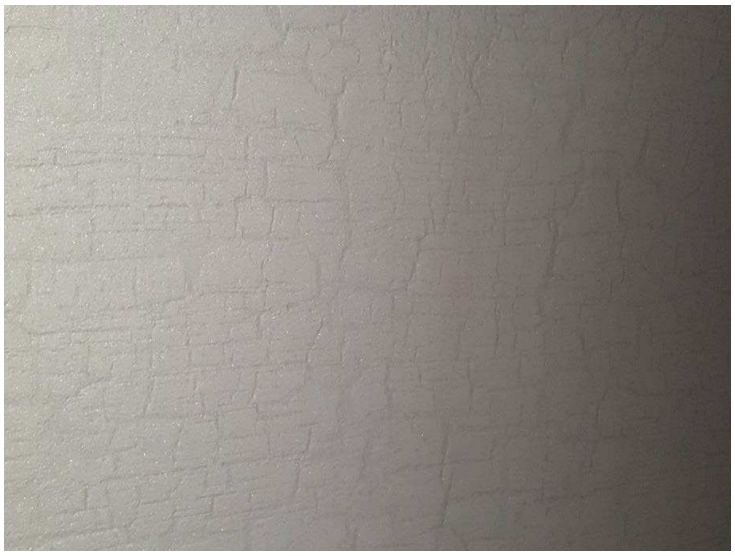

Figure 6. Steel surface after abrasive blast cleaned, notice the metal loss has an alligator pattern.

Coating Robot

The coating robot was the most critical piece of equipment for this work. The contractor has developed their own robotic sprayer that meets their requirements, as seen in Figure 7. Coating material is pumped from a trailer using a plural component pump, as seen in Figure 8. The coating is pumped through heated dual plural component lines until about 20 feet from the robot, where it goes through a mixing blocks to a single whip hose that feeds the robot, as seen in Figure 9. The contractor used solvent-free coatings and replaces the mixing blocks and whip hose after each work stoppage exceeding the material pot life. This eliminated the use of any solvents in the confined space, thus greatly reducing the flammability hazard.

The average production rate was 6,000 SF per 8-hour shift applied at 60 mils dry film thickness (DFT). This equates to 150 LF of 12-foot diameter pipe, and four 55-gallon drums of coating material applied. Compared to conventional application methods, the robot provided high production rates with better quality control. Figures 10 and 11 show the final product and coating appearance. Notice no sags, runs, drips, or similar undesirable features and a uniform coating thickness. The one year inspection showed no signs of wear or defects.



Figure 7. Coating application robot set up.



Figure 8. Plural component pump trailer that pumps the materials through the heated hoses to the coating robot.



Figure 9. Dual heated plural component hose bundles for feeding the coating robot with material to apply.



Figure 10. Final coating inspection after curing.



Figure 11. Close-up of final coating appearance.

Robotics Compared to Traditional Methods

Table 2 compares the Mark Wilmer project to the Flatiron Penstocks that Reclamation relined in 2010. The projects provide for a good comparison with some change to the outage duration, the steepness of the incline, and the diameter. On other relining jobs, such as Grand Coulee, Hoover, and Glen Canyon, the scaffolding costs were as much as 45 percent of the contract costs due to accessibility issues and steep inclines [7]. Fortunately, scaffolding was not required at Flatiron so the costs are more appropriate for comparison to the CAP project completed with robotic equipment.

Table 2. Comparison of the robotics vs. manual application

Facility	Diameter (ft)	Length (ft)	Area (SF)	Outage	Hours (hrs) per day	Incline
Mark Wilmer Discharge Tube (robot applied)	12	2,600	105,000	90 days (June 1, 2016-Aug. 30, 2016)	16 (2 shifts)	16-77%
Flatiron Penstock (manual application)	6	5,800	110,000	180 days (Oct. 1, 2010-Mar. 1, 2011)	12 (1 shift)	8-33%

An accurate cost comparison is not readily available due to construction during a recession, special equipment requirements, inflation, and other project differences. A detailed cost benefit analysis will be completed in the next couple of years comparing Flatiron and Mark Wilmer. Additional similar robotics projects will be added to the economics study as information becomes available.

The contractor at Flatiron utilized manual, traditional methods and took the approach of abrasive blast cleaning and coating in the same day to prevent flash rusting. The contractor had two workers abrasive blasting for 8 hrs per day, followed by 2-3 hrs for clean-up, then coating application for a total of about 12 hrs of work per day. The average production rate was 1,300 SF per 12 hrs. This contractor abrasive blast cleaned the coal tar enamel from the surface rather than use water jetting. The LF production rate was approximately 60-80 feet, resulting in a coating termination between each day's work at these intervals. Some application defects witnessed were, runs, sags, overspray, disbondment due to recoat window issues, and stalactites. There were also weather delays due to the time of year.

Table 3 directly compares typical daily production rates for various tasks. The robotic application took about a third of the operation time compared to manual methods. Note the total work days is based on actual production, and doesn't account for days when there is mobilization or other delays in production. It should also be noted that multiple robots can be working simultaneously in multiple locations within the pipe, whereas the manual operation is normally done in localized sections of pipe. The crew size remained the same for both the robotics and manual approaches. However, the tasks and physical labor for workers was significantly reduced because the robot performs the majority of the work.

Table 3. Typical production rates for robotic equipment vs. manual

Facility	Water Jetting (SF/hr)	Abrasive blast cleaning (SF/hr)	Coating Application (SF/hr)
Mark Wilmer Discharge Tube (robot applied)	450	225	750
Flatiron Penstocks (manual application)	N/A	108	108

The contractor also has additional benefits from using robotic equipment:

- Reduced exposure to hazardous conditions or materials in confined spaces
- Reduced cost of personal protective equipment due to reduced usage
- Reduced number of employees in confined space using ropes access equipment
- Improved surface cleanliness consistency and coating thickness control
- Fewer coating holidays occur, resulting in less touch-up work
- Reduced blast media and coating material wastage
- Reduced fuel consumption due to faster production rates
- Faster return to service, moving onto next job
- Reduced fatigue of employees

Conclusions

Advancements in relining jobs completed with robotic equipment are changing the way contractors conduct business by increasing production rates, lowering costs, and reducing worker exposure to harmful chemicals. The potential safety improvements are further magnified by this new opportunity to minimize the number of employees in the permit required confined space. The benefits are safer work environments, reduced liability, shorter downtimes, and reduced cost.

As contractors fine tune their robotic operations, the production rates may get even faster. Multiple robots can work simultaneously, and larger jobs may be completed with compressed schedules. The cost to recoat may be lowered as time progresses and contractors become even more efficient in operating the robotic equipment.

The next step in this technology is to develop an autonomous (person free) robot that is controlled or monitored from outside the confined space work environment. A new research proposal has been submitted to help the technology advance by building collaborations, sharing ideas, and investigating autonomous applications. These advancements could allow the application of a wider variety of coating systems where safety and health concerns currently preclude their use.

References

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[2] A. Skaja, "Coal Tar Repair Guide," 5840-2017-047 Materials and Corrosion Laboratory Bureau of Reclamation, Denver, 2017.

[3] US Chemical Safety and Hazard Investigation Board, "Xcel Energy Hydroelectric Plant Penstock Fire," US Chemical Safety and Hazard Investigation Board, 2010.

[4] S. Drexel, "State of Technology Report: The Use of Robotic Technology for Penstock Recoating," BC Hydro Report No TR00764.01-R2, Vancouver, 2015.

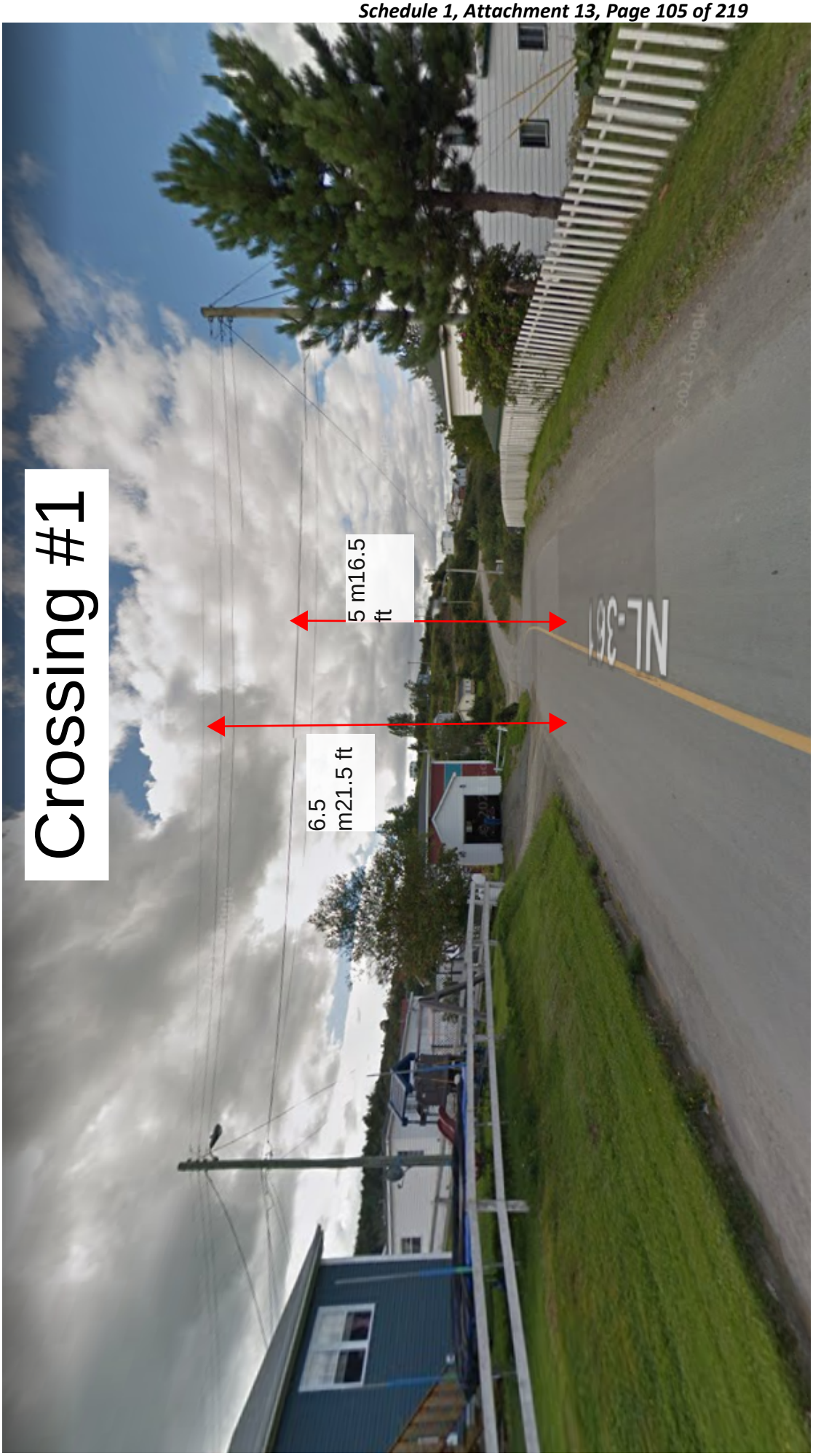
[5] D. Good, "Viability of Computer/ Robotic Controlled Penstock Coating Removal and Application," Bureau of Reclamation ST-2016-4047-01, Denver, 2016.

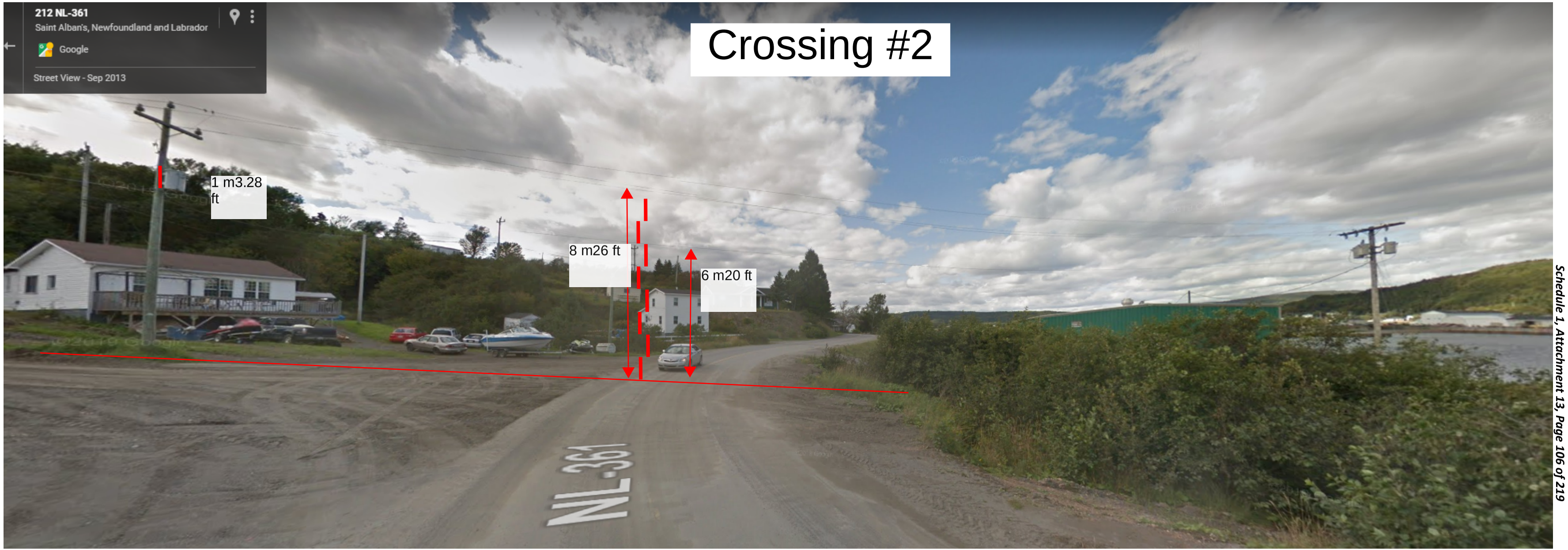
[6] J. Chism, "Development and Use of Robotic Equipment for Large Diameter Pipe Recoating," in *Pipelines 2017*, Phoenix, 2017.

[7] B. o. R. L. C. D. Office, "Drawing 45-301-9012, Hoover Power Plant, Interior Penstock Coatings Work Plan," Boulder City NV, 2009.

APPENDIX 4

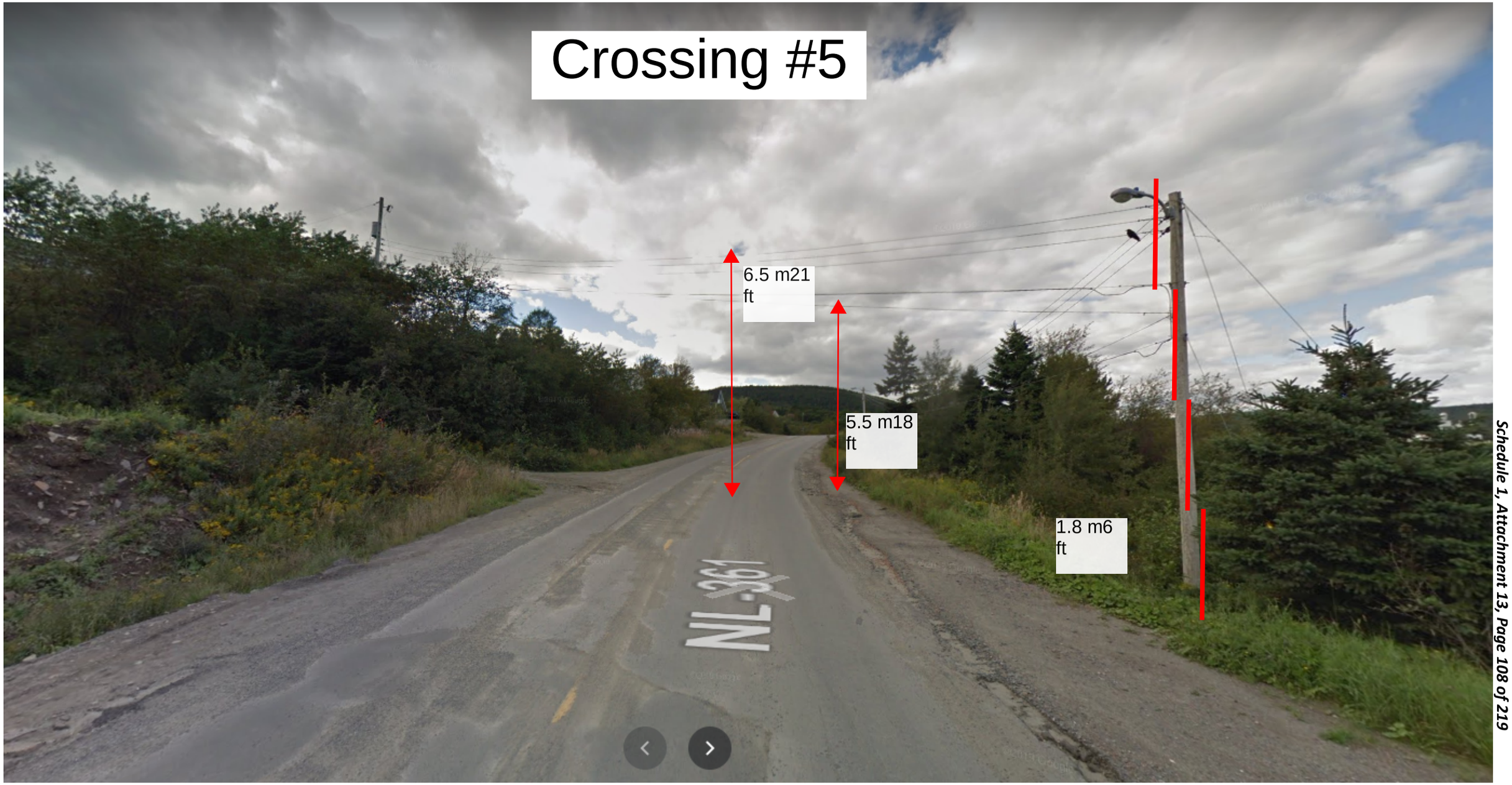
POWERLINE CROSSINGS


Crossing #1
5 m16.5 ft
6.5 m21.5 ft
NL-361

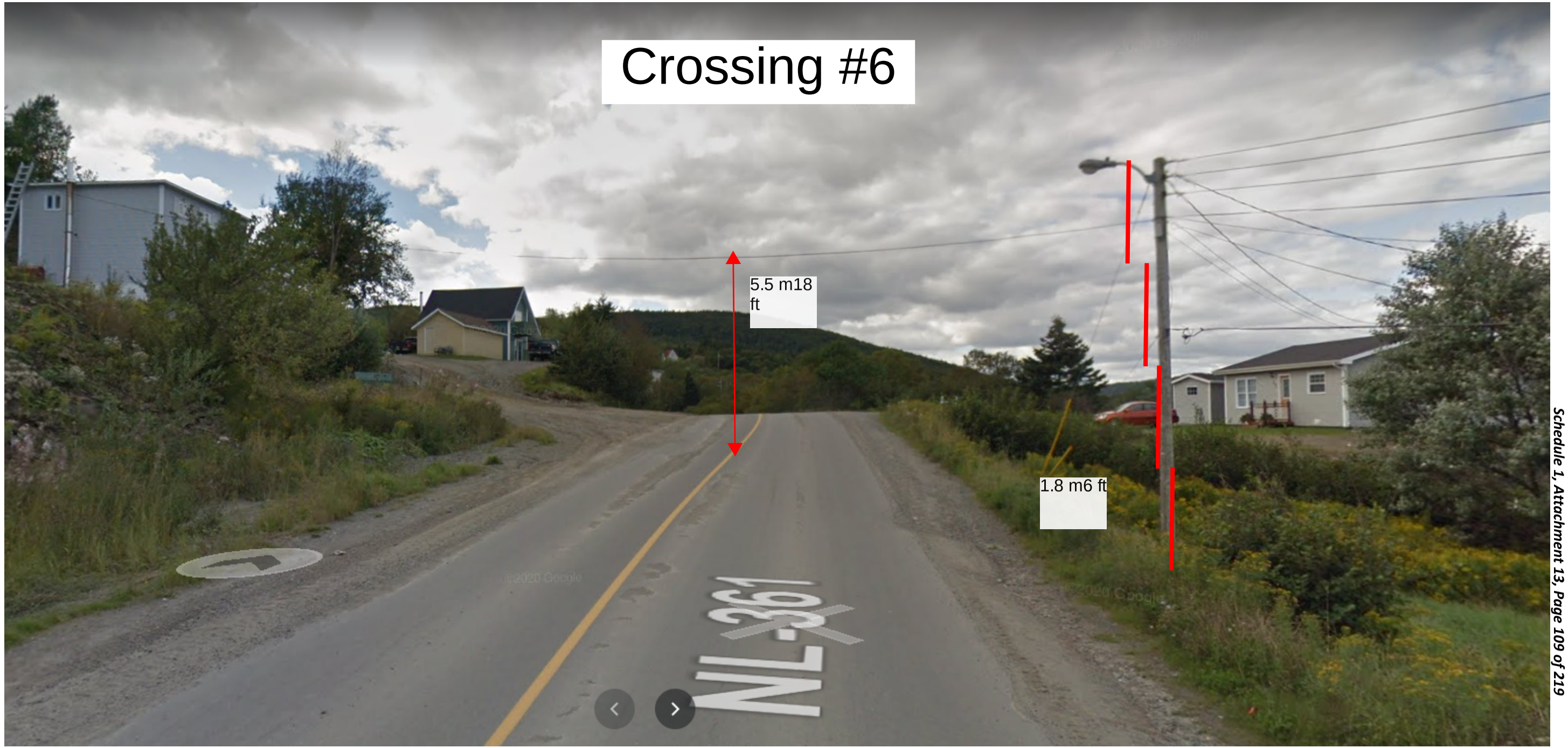

212 NL-361
Saint Alban's, Newfoundland and Labrador
Google
Street View - Sep 2013
Crossing #2
1 m3.28 ft
8 m26 ft
6 m20 ft
NL-361

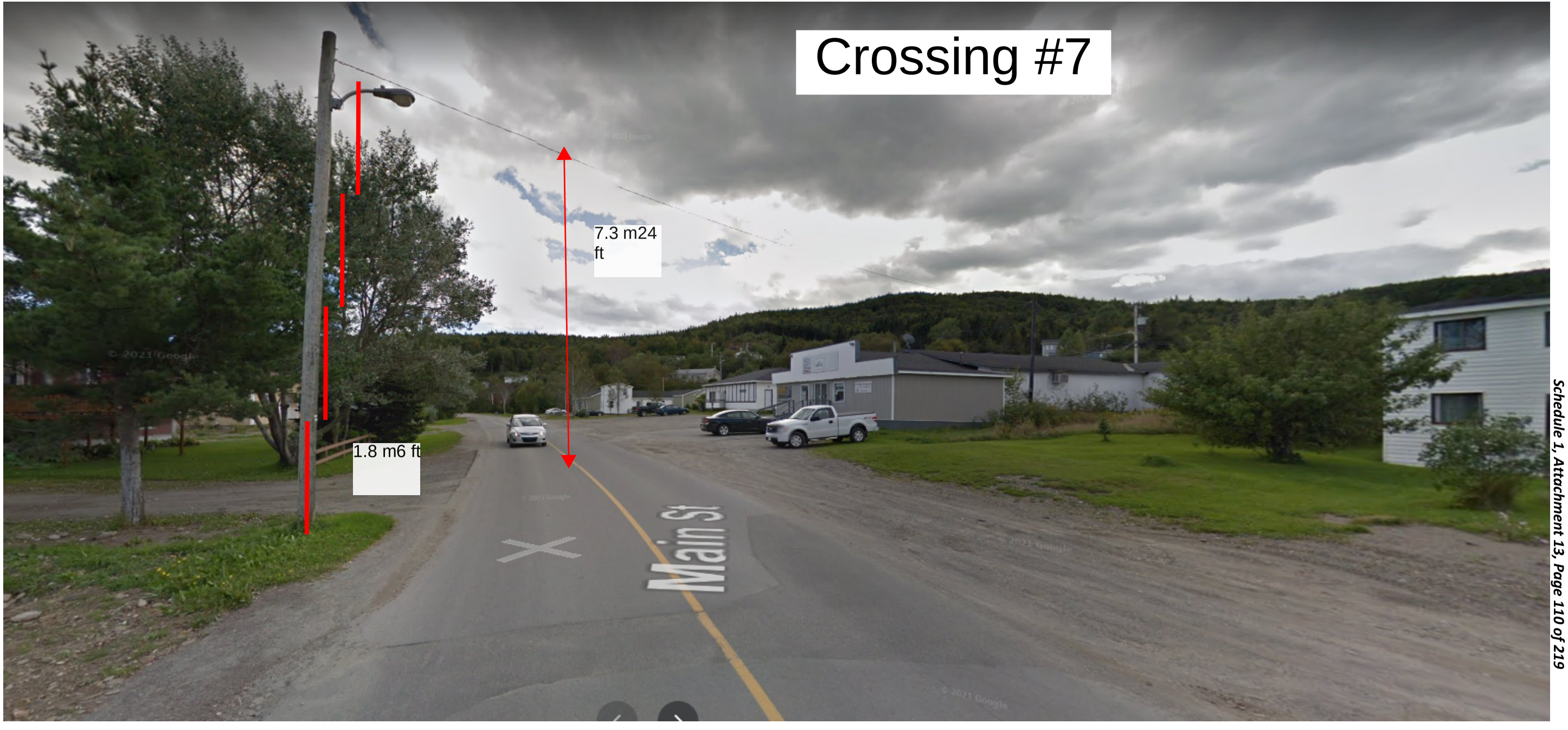

foundland and Labrador
013
7 m23 ft
6 m20 ft
3.5
m11.5 ft
NL-361
Crossing #3 and #4

Crossing #5



Crossing #6

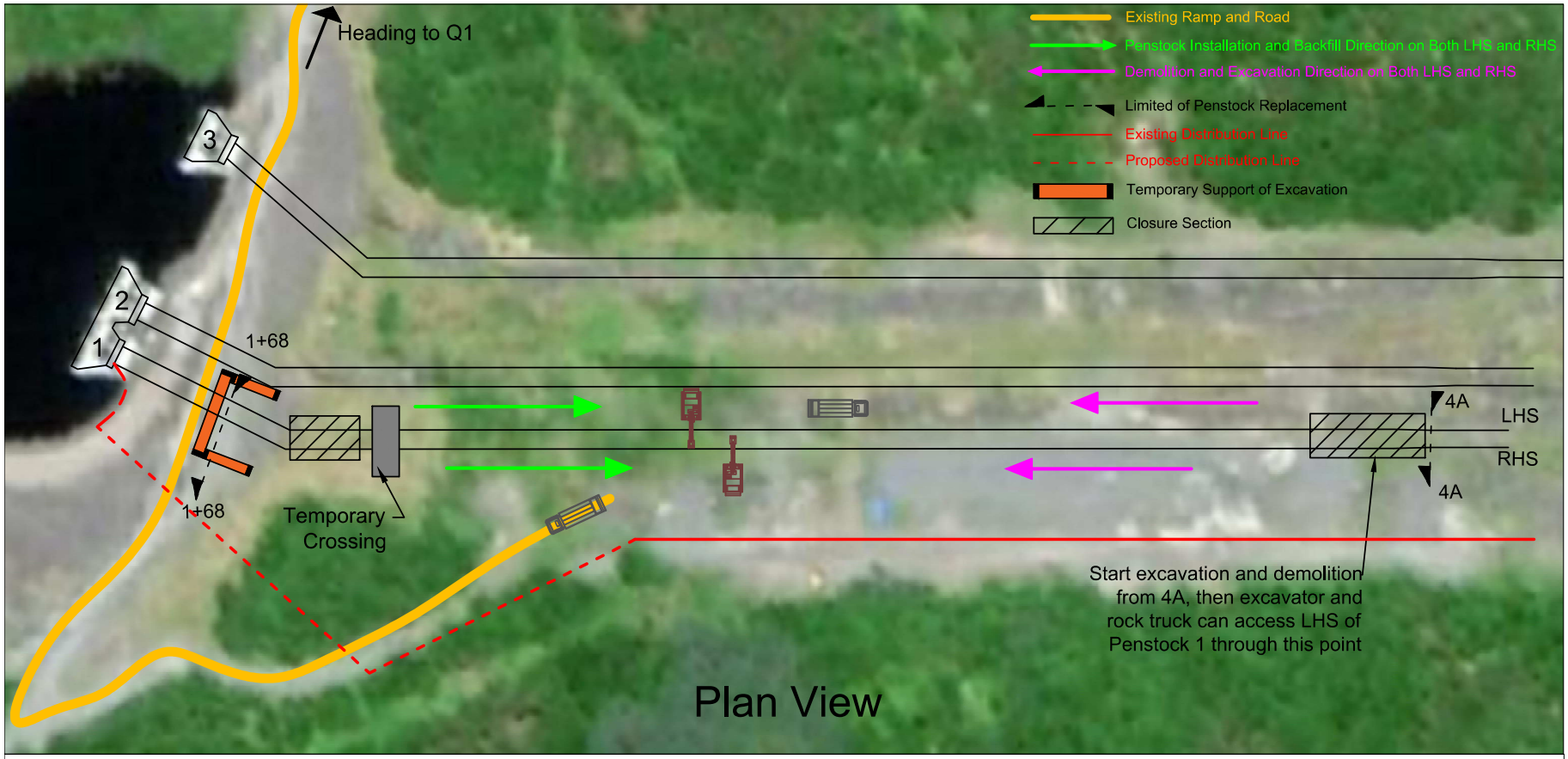


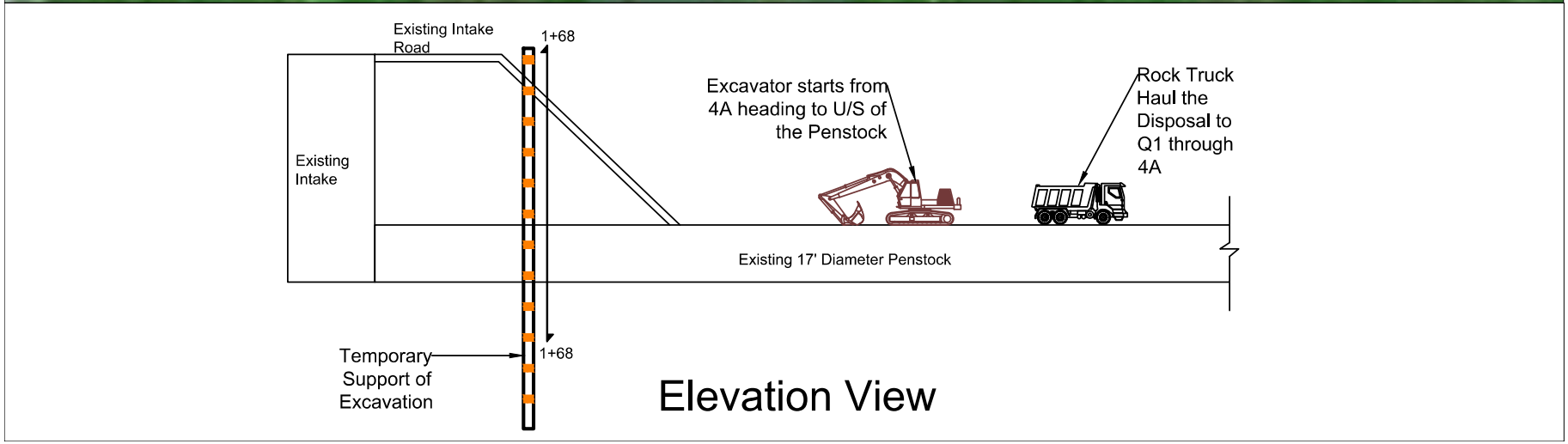

Crossing #7
7.3 m24 ft
1.8 m6 ft
Main St

APPENDIX 5

PENSTOCK NO.1 REPLACEMENT PLAN

Penstock 1 Replacement Plan





APPENDIX 6

AACE CLASS 3 COST ESTIMATE

CHANT LIMITED

Bay d'Espoir Hydroelectric Generating Station - Life Extension of Penstock No. 1

Cost Estimate

Item Code	Description	Quantity	Unit	Subtotal
Site Direct Cost				
1000	Site Preparation	1	LS	$ 782,823
2000	Penstock Replacement	1	LS	$ 10,685,988
3000	Penstock Refurbishment	1	LS	$ 5,859,494
4000	Site Finalization	1	LS	$ 78,934
Site Indirect Cost				
9000	Site Overhead	1	LS	$ 7,356,265
Markup				
	Bond and Insurance	1	LS	$ 132,868
	General Overhead and Profit	1	LS	$ 5,200,335
	Subtotal Price	**1**	**LS**	**$ 30,096,707**
	Contingency	**1**	**LS**	**$ 3,893,000**

Total Price **$ 33,990,000**

Markup Summary

Estimate: 210201 - Bay d'Espoir Penstock No. 1 Life Extension

Currency: Canada

	Rate	Applied Amount	Amount	% Total Price	% Cost	% Direct Cost	% Total Labor	% Total Equip
Grand Total Price			30,096,705					
General Overhead and Profit	21.00%		5,200,335	17.28%	20.89%	29.87%	87.21%	108.67%
Grand Total Cost			24,896,370					
Bonding (per 1,000 Project Cost)			68,577	0.23%	0.28%	0.39%	1.15%	1.43%
Performance and L&M	8.00	8,572,138	68,577	0.23%	0.28%	0.39%	1.15%	1.43%
Insurance (per 1,000 Project Cost)			64,291	0.21%	0.26%	0.37%	1.08%	1.34%
Insurance	7.50	8,572,138	64,291	0.21%	0.26%	0.37%	1.08%	1.34%
Total Escalated Cost			24,763,502	82.28%	100.00%	142.26%	415.30%	517.49%
Total Margins (% Project Cost)			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Project Cost			24,763,502	82.28%	100.00%	142.26%	415.30%	517.49%
Total Construction Cost			24,763,502	82.28%	100.00%	142.26%	415.30%	517.49%
Total Labor			5,962,739	19.81%	24.08%	34.25%	100.00%	124.60%
Total Equipment			4,785,356	15.90%	19.32%	27.49%	80.25%	100.00%
Total Job Material			436,300	1.45%	1.76%	2.51%	7.32%	9.12%
Total Permanent Material			10,371,534	34.46%	41.88%	59.58%	173.94%	216.73%
Total Permanent Process Equipment			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Subcontract			552,300	1.84%	2.23%	3.17%	9.26%	11.54%
Total Cash Allowance			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Plug			2,655,272	8.82%	10.72%	15.25%	44.53%	55.49%
Total Indirect Cost (I)			7,356,265	24.44%	29.71%	42.26%	123.37%	153.72%
Total Labor			2,545,415	8.46%	10.28%	14.62%	42.69%	53.19%
Total Equipment			1,756,577	5.84%	7.09%	10.09%	29.46%	36.71%
Total Job Material			399,000	1.33%	1.61%	2.29%	6.69%	8.34%
Total Permanent Material			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Permanent Process Equipment			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Subcontract			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Cash Allowance			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Plug			2,655,272	8.82%	10.72%	15.25%	44.53%	55.49%
Total Direct Cost (D)			17,407,237	57.84%	70.29%	100.00%	291.93%	363.76%
Total Labor			3,417,324	11.35%	13.80%	19.63%	57.31%	71.41%
Total Equipment			3,028,779	10.06%	12.23%	17.40%	50.80%	63.29%
Total Job Material			37,300	0.12%	0.15%	0.21%	0.63%	0.78%
Total Permanent Material			10,371,534	34.46%	41.88%	59.58%	173.94%	216.73%
Total Permanent Process Equipment			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Subcontract			552,300	1.84%	2.23%	3.17%	9.26%	11.54%
Total Cash Allowance			0	0.00%	0.00%	0.00%	0.00%	0.00%
Total Plug			0	0.00%	0.00%	0.00%	0.00%	0.00%

Risk/Opportunity Analysis

BDE Life Extension of Penstock 1

New Penstock Fabricated on Field					
New penstock fabricated on field $15.5 million (DFBarnes)	$ 6,500,000	1	LS	$	6,500,000
Our Estimate S&I new penstock $9 million					
Total Estimate				**$**	**6,500,000**
Occurrence probability					**0%**
Risk Contingency Estimate (factored with probability)				**$**	**-**
Design Development					
Total Construction Cost Increase 10%	$ 30,000,000	10%		$	3,000,000
				$	-
Total Estimate				**$**	**3,000,000**
Occurrence probability					**50%**
Risk Contingency Estimate (factored with probability)				**$**	**1,500,000**
SMAW Welding Method Instead of FCAW					
Welding productivity double, welding cost increases	$900,000	100%		$	900,000
Total Estimate				**$**	**900,000**
Occurrence probability					**30%**
Risk Contingency Estimate (factored with probability)				**$**	**270,000**
Labour Productivity					
20% less production due to inclement weather	$5,700,000	20%		$	1,140,000
Total Estimate				**$**	**1,140,000**
Occurrence probability					**60%**
Risk Contingency Estimate (factored with probability)				**$**	**684,000**
Steel Price Increase					
New penstock price increase 20%	$7,500,000	20%		$	1,500,000
Total Estimate				**$**	**1,500,000**
Occurrence probability					**50%**
Risk Contingency Estimate (factored with probability)				**$**	**750,000**
Traditional Blasting and Coating Methods					
If Robotic methods do not work, manual operations will apply					
Manual operation will triple costs of robotic operations	2	times	$970,000	$	1,940,000
Total Estimate				**$**	**1,940,000**
Occurrence probability					**30%**
Risk Contingency Estimate (factored with probability)				**$**	**582,000**
Bicycle Spiders in New Penstock					
One more bicycle spider per can may required to supply	30	Can	$5,000	$	150,000
Associated costs of removal and coating	30	Can	$2,100	$	63,000
Total Estimate				**$**	**213,000**
Occurrence probability					**50%**
Risk Contingency Estimate (factored with probability)				**$**	**106,500**
TOTAL CONTINGENCIES ESTIMATE (Note: Excluding Bonds, Insurance and Contractor Mark Up)				**$**	**3,893,000**

Estimate Line Detail

Estimate: 210201 - Bay d'Espoir Penstock No. 1 Life Extension

Currency: Canada

Grand Total Price:												**30,096,705**
	Overhead & Profit (%)									20.89		5,200,335
Grand Total Cost												**24,896,370**
Margin												132,868
	Bonding (per 1,000)									2.77		68,577
	Insurance (per 1,000)									2.60		64,291
Total Project Cost												**24,763,502**
Total Construction Cost												**24,763,502**
Total Indirect Costs (I)										29.71		7,356,265
Total Direct Costs (D)										70.29		17,407,237

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
10000	**BDE Hydroelectric GS Penstock 1**	**1.00**	**LS**		**74,352**	**5,962,739**	**4,785,356**	**436,300**	**10,371,534**		**3,207,572**	**24,763,502**
					74,351.54	5,962,739.22	4,785,356.42	436,299.65	10,371,534.50		3,207,572.00	24,763,501.78
1000	Site Preparation	1.00	LS		4,051	242,570	109,488		430,764			782,822
					4,050.94	242,569.99	109,488.17		430,763.54			782,821.70
100	Silt Fence	2,100.00	M		321	19,239	5,462		15,200			39,901
					0.15	9.16	2.60		7.24			19.00
	Crew:Qty= 2,100.000 M, Prod=26.14 M/hour (261.44 M/ day), 0.153MH/M, 6.54 M/MH, 80.33 hour (8.03 days)											
	Miscellaneous Crew	*1.00*	*EA*	*307.52*								
	Craft	4.0		59.88		19,239						
	Small Tools & Supplies	4.0		3.00			964					
	0.8 CY (0.6 m3) Backhoe Loader (Case 580)	1.0		44.59			3,582					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			917					
	Tensar Fencing & T Posts	2,310.0	LM	6.58					15,200			
200	Site Access	1.00	LS		3,588	214,867	87,267		347,648			649,782
					3,588.30	214,867.40	87,266.90		347,648.02			649,782.32
10	Permanent Bridge of Penstock 1	1.00	LS		400	23,952	1,771		122,592			148,315
					400.00	23,952.00	1,770.50		122,592.00			148,314.50
	Crew:Qty= 1.000 LS, Prod=0.02 LS/hour (0.20 LS/ day), 400.000MH/LS, 0.00 LS/MH, 50.00 hour (5.00 days)											
	Rigging Permanent Bridge	*1.00*	*EA*	*514.45*								
	Craft	8.0		59.88		23,952						
	Small Tools & Supplies	8.0		3.00			1,200					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			571					
	Timber Blocking and Guardrail	0.3	MBF	5,600.00					1,792			
	Precast Footing Concrete	45.4	m3	2,000.00					90,800			
	Precast Girder	12.0	M3	2,500.00					30,000			
20	Access Road from Site to Q1	1,288.00	M		48	2,892	5,000		27,256			35,149
					0.04	2.25	3.88		21.16			27.29
	Crew:Qty= 483.000 M3, Prod=50.00 M3/hour (500.00 M3/ day), 0.100MH/M3, 10.00 M3/MH, 9.66 hour (0.97 days)											
	Access Road from Site to Q1	*1.00*	*EA*	*817.04*								
	Craft	5.0		59.88		2,892						
	Small Tools & Supplies	5.0		3.00			145					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			913					
	260 Hsp Grader (Cat 14M)	1.0		118.00			1,140					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			2,096					
	15 Ton (16.7 tonne) Compactor 84" (Cat 563)	1.0		61.75			597					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			110					
	Granular A	1,131.0	Tonne	24.10					27,256			

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
30	Distribution Line Relocation	1.00	LS		3,140	188,023	80,496		197,800			466,319
					3,140.00	188,023.20	80,496.00		197,800.00			466,319.20
01	Intake Distribution Line Relocation	1.00	LS		740	44,311	19,995		68,800			133,106
					740.00	44,311.20	19,995.00		68,800.00			133,106.20
	Crew:Qty= 1.000 LS, Prod=0.01 LS/hour (0.10 LS/ day), 740.000MH/LS, 0.00 LS/MH, 100.00 hour (10.00 days)											
	Intake Distribution Line Relocation	*1.00*	*EA*	*643.062*								
	Craft	7.4		59.88		44,311						
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	0.2		217.00			4,340					
	Post Hole Auger	0.2		23.00			460					
	Bucket Truck up to 65 ft (20m)	2.0		47.27			9,454					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,141					
	38 Ton (35 tonne) Boomtruck	0.2		119.00			2,380					
	Small Tools & Supplies	7.4		3.00			2,220					
	Overhead Conductor	1,000.0	m	52.00					52,000			
	Wood Pole Transmission Hardware	7.0	ea	1,000.00					7,000			
	Wood Pole Class III 61 ft (18.5m)	7.0	ea	1,400.00					9,800			
02	Hauling Road Distribution Line Relocation	1.00	LS		2,400	143,712	60,501		129,000			333,213
					2,400.00	143,712.00	60,501.00		129,000.00			333,213.00
001	Powerline Higher than Truck Load	7.00	EA		700	41,916	16,933		20,000			78,849
					100.00	5,988.00	2,419.00		2,857.14			11,264.14
	Crew:Qty= 7.000 EA, Prod=0.05 EA/hour (0.50 EA/ day), 100.000MH/EA, 0.01 EA/MH, 140.00 hour (14.00 days)											
	Powerline Higher than Truck Load	*1.00*	*EA*	*420.35*								
	Craft	5.0		59.88		41,916						
	Bucket Truck up to 65 ft (20m)	2.0		47.27			13,236					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,597					
	Small Tools & Supplies	5.0		3.00			2,100					
	Conductor Protection	1.0	LS	20,000.00					20,000			
002	Powerline Relocation	7.00	EA		700	41,916	16,933		72,000			130,849
					100.00	5,988.00	2,419.00		10,285.71			18,692.71
	Crew:Qty= 7.000 EA, Prod=0.05 EA/hour (0.50 EA/ day), 100.000MH/EA, 0.01 EA/MH, 140.00 hour (14.00 days)											
	Powerline Relocation	*1.00*	*EA*	*420.35*								
	Craft	5.0		59.88		41,916						
	Bucket Truck up to 65 ft (20m)	2.0		47.27			13,236					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,597					
	Small Tools & Supplies	5.0		3.00			2,100					
	Cable Protection	1.0	LS	12,000.00					12,000			
	Overhead Conductor	1.0	LS	35,000.00					35,000			
	Cable	1.0	LS	25,000.00					25,000			
003	Communication Line Relocation	7.00	EA		700	41,916	16,933		27,000			85,849
					100.00	5,988.00	2,419.00		3,857.14			12,264.14
	Crew:Qty= 7.000 EA, Prod=0.05 EA/hour (0.50 EA/ day), 100.000MH/EA, 0.01 EA/MH, 140.00 hour (14.00 days)											
	Communication Line Relocation	*1.00*	*EA*	*420.35*								
	Craft	5.0		59.88		41,916						
	Bucket Truck up to 65 ft (20m)	2.0		47.27			13,236					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,597					
	Small Tools & Supplies	5.0		3.00			2,100					
	Cable Protection	1.0	LS	12,000.00					12,000			
	Communication Cable	1.0	LS	15,000.00					15,000			

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
004	Line Crossing Monitoring	15.00	Day		300	17,964	9,702		10,000			37,666
					20.00	1,197.60	646.80		666.67			2,511.07
	Crew:Qty= 15.000 Day, Prod=0.10 Day/hour (1.00 Day/ day), 20.000MH/Day, 0.05 Day/MH, 150.00 hour (15.00 days)											
	Install Survey Monitoring Pins in Structures	*1.00*	*EA*	*184.44*								
	Craft	2.0		59.88		17,964						
	Bucket Truck up to 65 ft (20m)	1.0		47.27			7,091					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,712					
	Small Tools & Supplies	2.0		3.00			900					
	Safety Fence and Sign	1.0	LS	10,000.00					10,000			
300	Laydown Area	1.00	LS		141	8,463	16,759		67,916			93,138
					141.34	8,463.14	16,759.17		67,915.73			93,138.04
10	Clearing and Grubbing of Staging Area	4,000.00	M2		80	4,790	8,711					13,502
					0.02	1.20	2.18					3.38
	Crew:Qty= 4,000.000 M2, Prod=50.00 M2/hour (500.00 M2/ day), 0.020MH/M2, 50.00 M2/MH, 80.00 hour (8.00 days)											
	Clearing and Grubbing	*1.00*	*EA*	*168.77*								
	Craft	1.0		59.88		4,790						
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			7,558					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			913					
	Small Tools & Supplies	1.0		3.00			240					
20	Laydown Area Topping	16,356.00	M2		61	3,673	8,048		67,916			79,636
					0.00	0.22	0.49		4.15			4.87
	Crew:Qty= 16,356.000 M2, Prod=800.00 M2/hour (8,000.00 M2/ day), 0.004MH/M2, 266.67 M2/MH, 20.45 hour (2.04 days)											
	Miscellaneous Crew	*1.00*	*EA*	*573.28*								
	Craft	3.0		59.88		3,673						
	Small Tools & Supplies	3.0		3.00			184					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			1,932					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			4,437					
	15 Ton (16.7 tonne) Compactor 84" (Cat 563)	1.0		61.75			1,262					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			233					
	Granular A	2,818.1	tonne	24.10					67,916			
2000	Penstock Replacement	1.00	LS		13,411	803,036	833,104	12,300	8,597,248		440,300	10,685,988
					13,410.76	803,036.20	833,104.15	12,299.65	8,597,247.63		440,300.00	10,685,987.64
100	Earthwork	1.00	LS		6,421	384,470	740,849	12,300	699,327			1,836,946
					6,420.68	384,470.36	740,849.02	12,299.65	699,326.78			1,836,945.80
	10, 017 M3 of Native Backfill is from 11,310 M3 of Excavation											
10	Supply, Install and Remove Temperary Intake Shoring	1.00	LS		250	14,970	11,779		270,954			297,703
					250.00	14,970.00	11,778.50		270,954.00			297,702.50
	Crew:Qty= 1.000 LS, Prod=0.02 LS/hour (0.20 LS/ day), 250.000MH/LS, 0.00 LS/MH, 50.00 hour (5.00 days)											
	Temperary Intake Shoring	*1.00*	*EA*	*534.97*								
	Craft	5.0		59.88		14,970						
	Pile Auger Drill 22" (550mm) Caisson Drill (Wirth B6)	1.0		217.03			10,852					
	Concrete Transit Mixer 8 CY (6.1m3)	1.0		6.25			313					
	2-CY (1.5m3) Quikrete Bucket (Gravity)	1.0		0.88			44					

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	1/2 Ton Pickup Truck 4x4	1.0		11.41			571					
	Supply H-Piles Shoring	31.3	t	2,200.00					68,794			
	10"x12"x13' Log	60.0	EA	1,000.00					60,000			
	Quikrete	2,000.0	bags	5.08					10,160			
	Steel Stoplog	60.0	tonne	2,200.00					132,000			
20	Removal of Drainage/Embarkment Materials	13,677.00	M3		957	57,329	154,579					211,907
					0.07	4.19	11.30					15.49
	Crew:Qty= 13,677.000 M3, Prod=100.00 M3/hour (1,000.00 M3/ day), 0.070MH/M3, 14.29 M3/MH, 136.77 hour (13.68 days)											
	Removal of Embarkment	*1.00*	*EA*	*1549.37*								
	Craft	7.0		59.88		57,329						
	Small Tools & Supplies	7.0		3.00			2,872					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			12,922					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	2.0		217.00			59,358					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	4.0		142.33			77,866					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,561					
30	Demolition of 5.2 m (17') Dia. Penstock	331.00	M		2,808	168,143	366,070					534,213
					8.48	507.99	1,105.95					1,613.94
	Crew:Qty= 468.000 Tonne, Prod=1.00 Tonne/hour (10.00 Tonne/ day), 6.000MH/Tonne, 0.17 Tonne/MH, 468.00 hour (46.80 days)											
	Demolish Steel Frame	*1.00*	*EA*	*1141.48*								
	Craft	6.0		59.88		168,143						
	Tank Cutter Attachment	1.0		10.21			4,778					
	Hydraulic Thumb Attachment	1.0		8.41			3,936					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	2.0		217.00			203,112					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	2.0		142.33			133,221					
	Acetylene Cutting Torch	3.0		5.17			7,259					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			5,340					
	Small Tools & Supplies	6.0		3.00			8,424					
35	Engineered Cut	2.00	EA		92	5,489	782		2,000			8,271
					45.84	2,744.72	390.84		1,000.00			4,135.56
	Crew:Qty= 33.000 M, Prod=1.08 M/hour (10.80 M/ day), 2.778MH/M, 0.36 M/MH, 30.56 hour (3.06 days)											
	Engineered Cut	*1.00*	*EA*	*205.22*								
	Craft	3.0		59.88		5,489						
	Acetylene Cutting Torch	1.0		5.17			158					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			349					
	Small Tools & Supplies	3.0		3.00			275					
	Steel Cutting Guide	2.0	EA	1,000.00					2,000			
40	Backfill	19,200.00	M3		1,861	111,450	194,122		418,773			724,345
					0.10	5.80	10.11		21.81			37.73
01	Coarse Gravel Backfill	1,527.00	M3		102	6,096	10,094		85,610			101,800
					0.07	3.99	6.61		56.06			66.67
	Crew:Qty= 1,527.000 M3, Prod=60.00 M3/hour (600.00 M3/ day), 0.067MH/M3, 15.00 M3/MH, 25.45 hour (2.55 days)											
	Roller Compaction	*1.00*	*EA*	*636.16*								
	Craft	4.0		59.88		6,096						
	Small Tools & Supplies	4.0		3.00			305					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			2,405					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			5,523					
	15 Ton (16.7 tonne) Compactor 84" (Cat 563)	1.0		61.75			1,572					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			290					

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Coarse Gravel	3,746.6	t	22.85					85,610			
02	Bedding Material	2,179.00	M3		289	17,309	21,270		139,666			178,245
					0.13	7.94	9.76		64.10			81.80
001	Roller Compaction	1,956.00	M3		130	7,808	13,028					20,837
					0.07	3.99	6.66					10.65
	Crew:Qty= 1,956.000 M3, Prod=60.00 M3/hour (600.00 M3/ day), 0.067MH/M3, 15.00 M3/MH, 32.60 hour (3.26 days)											
	Roller Compaction	*1.00*	*EA*	*639.16*								
	Craft	4.0		59.88		7,808						
	Small Tools & Supplies	4.0		3.00			391					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			3,080					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			7,074					
	15 Ton (16.7 tonne) Compactor 84" (Cat 563)	1.0		61.75			2,013					
	Staging Bin	1.0		3.00			98					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			372					
002	Hand Compaction	476.00	M3		159	9,501	8,242					17,743
					0.33	19.96	17.31					37.27
	Crew:Qty= 476.000 M3, Prod=18.00 M3/hour (180.00 M3/ day), 0.333MH/M3, 3.00 M3/MH, 26.44 hour (2.64 days)											
	Handy Backfill	*1.00*	*EA*	*670.95*								
	Craft	6.0		59.88		9,501						
	Small Tools & Supplies	6.0		3.00			476					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			5,738					
	1100 lb (500 Kg) Plate Tamper	3.0		16.75			1,329					
	125 CFM (3.5 m3/min) Diesel Compressor	1.0		15.01			397					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			302					
003	Purchase Material	1.00	LS						139,666			139,666
									139,665.85			139,665.85
	Gran. A	5,599.0	Tonne	24.05					134,656			
	Geotextile Fabric Woven	5,758.5	m2	0.87					5,010			
03	Granular B Backfill	3,415.00	M3		364	21,808	28,056		193,497			243,361
					0.11	6.39	8.22		56.66			71.26
001	Roller Compation	2,903.00	M3		194	11,589	19,191					30,780
					0.07	3.99	6.61					10.60
	Crew:Qty= 2,903.000 M3, Prod=60.00 M3/hour (600.00 M3/ day), 0.067MH/M3, 15.00 M3/MH, 48.38 hour (4.84 days)											
	Exc-B/Fill	*1.00*	*EA*	*636.16*								
	Craft	4.0		59.88		11,589						
	Small Tools & Supplies	4.0		3.00			581					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			4,571					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			10,499					
	15 Ton (16.7 tonne) Compactor 84" (Cat 563)	1.0		61.75			2,988					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			552					
002	Hand Compaction	512.00	M3		171	10,220	8,865					19,085
					0.33	19.96	17.31					37.27
	Crew:Qty= 512.000 M3, Prod=18.00 M3/hour (180.00 M3/ day), 0.333MH/M3, 3.00 M3/MH, 28.44 hour (2.84 days)											
	Handy Backfill	*1.00*	*EA*	*670.95*								
	Craft	6.0		59.88		10,220						

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Small Tools & Supplies	6.0		3.00			512					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			6,172					
	1100 lb (500 Kg) Plate Tamper	3.0		16.75			1,429					
	125 CFM (3.5 m3/min) Diesel Compressor	1.0		15.01			427					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			325					
003	Purchase Material	1.00	LS						193,497			193,497
									193,497.15			193,497.15
	Granular B	8,376.5	Tonne	23.10					193,497			
04	Common Fill	7,179.00	M3		947	56,693	101,879					158,572
					0.13	7.90	14.19					22.09
001	Load and Haul from Q1	7,179.00	m3		359	21,494	58,814					80,308
					0.05	2.99	8.19					11.19
	Crew:Qty= 7,179.000 m3, Prod=80.00 m3/hour (800.00 m3/ day), 0.050MH/m3, 20.00 m3/MH, 89.74 hour (8.97 days)											
	Load and Haul from Q1	*1.00*	*EA*	*894.92*								
	Craft	4.0		59.88		21,494						
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			19,473					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	3.0		142.33			38,317					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,024					
002	Track Compaction	6,102.00	M3		229	13,702	25,315					39,017
					0.04	2.25	4.15					6.39
	Crew:Qty= 6,102.000 M3, Prod=80.00 M3/hour (800.00 M3/ day), 0.038MH/M3, 26.67 M3/MH, 76.28 hour (7.63 days)											
	Exc-B/Fill	*1.00*	*EA*	*511.53*								
	Craft	3.0		59.88		13,702						
	Small Tools & Supplies	3.0		3.00			686					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			7,206					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			16,552					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			870					
003	Hand Compaction	1,077.00	M3		359	21,497	17,750					39,247
					0.33	19.96	16.48					36.44
	Crew:Qty= 1,077.000 M3, Prod=18.00 M3/hour (180.00 M3/ day), 0.333MH/M3, 3.00 M3/MH, 59.83 hour (5.98 days)											
	Handy Backfill	*1.00*	*EA*	*655.94*								
	Craft	6.0		59.88		21,497						
	Small Tools & Supplies	6.0		3.00			1,077					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			12,984					
	1100 lb (500 Kg) Plate Tamper	3.0		16.75			3,007					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			683					
05	Load and Haul Rock Spalls from Q1 to Site	2,550.00	M3		159	9,543	32,823					42,366
					0.06	3.74	12.87					16.61
	Crew:Qty= 2,550.000 M3, Prod=80.00 M3/hour (800.00 M3/ day), 0.063MH/M3, 16.00 M3/MH, 31.88 hour (3.19 days)											
	Load and Haul Rock Spalls	*1.00*	*EA*	*1329.13*								
	Craft	5.0		59.88		9,543						
	Small Tools & Supplies	5.0		3.00			478					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	2.0		217.00			13,834					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	4.0		142.33			18,147					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			364					

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
50	Pipe	1.00	LS		272	16,311	1,439		7,600			25,350
					272.40	16,311.31	1,438.82		7,599.97			25,350.10
01	203mm Drain Pipe	19.00	m		8	455	40		1,600			2,095
					0.40	23.95	2.11		84.21			110.28
	Crew:Qty= 19.000 M, Prod=12.50 M/hour (125.00 M/ day), 0.400MH/M, 2.50 M/MH, 1.52 hour (0.15 days)											
	Placing Pipe	*1.00*	*EA*	*325.81*								
	Craft	5.0		59.88		455						
	Small Tools & Supplies	5.0		3.00			23					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			17					
	203m Drain Pipe	19.0	LM	84.21					1,600			
02	150mm Perforated PVC	662.00	M		265	15,856	1,399		6,000			23,255
					0.40	23.95	2.11		9.06			35.13
	Crew:Qty= 662.000 M, Prod=12.50 M/hour (125.00 M/ day), 0.400MH/M, 2.50 M/MH, 52.96 hour (5.30 days)											
	Placing Pipe	*1.00*	*EA*	*325.81*								
	Craft	5.0		59.88		15,856						
	Small Tools & Supplies	5.0		3.00			794					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			604					
	150mm CSP Perforated Pipe	662.0	m	9.06					6,000			
60	Crane Pad	5.00	EA		180	10,778	12,079	12,300				35,157
					36.00	2,155.68	2,415.84	2,459.93				7,031.45
	Crew:Qty= 150.000 M3, Prod=5.00 M3/hour (50.00 M3/ day), 1.200MH/M3, 0.83 M3/MH, 30.00 hour (3.00 days)											
	Exc-B/Fill	*1.00*	*EA*	*761.92*								
	Craft	6.0		59.88		10,778						
	Small Tools & Supplies	6.0		3.00			540					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			2,834					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			6,510					
	15 Ton (16.7 tonne) Compactor 84" (Cat 563)	1.0		61.75			1,853					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			342					
	Crane Matts	5.0	ea	1,166.00				5,830				
	Gran. A	165.0	M3	39.21				6,470				
200	Penstock Replacement	331.00	M		6,930	414,973	91,370		7,897,911		390,300	8,794,554
					20.94	1,253.69	276.04		23,860.76		1,179.15	26,569.65
10	Supply and Delivery Steel Penstock	1.00	LS						7,491,900		390,300	7,882,200
									7,491,900.00		390,300.00	7,882,200.00
	Penstock Supply FOB Ship at Wharf	1.0	LS	7,491,900.00					7,491,900			
	Penstock Land Transportation Subcontractor	1.0	LS	390,300.00							390,300	
20	Unload, Handle and Alignment Penstock	331.00	LM		1,500	89,826	7,923		10,000			107,749
					4.53	271.38	23.94		30.21			325.53
	Crew:Qty= 331.000 LM, Prod=1.10 LM/hour (11.03 LM/ day), 4.532MH/LM, 0.22 LM/MH, 300.02 hour (30.00 days)											
	Steel Penstock Rigging	*1.00*	*EA*	*325.81*								
	Craft	5.0		59.88		89,826						
	Small Tools & Supplies	5.0		3.00			4,500					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			3,423					
	Anchor System	4.0	EA	500.00					2,000			
	Precast Concrete Blocks	8.0	EA	1,000.00					8,000			

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
30	Spider Removal	1.00	LS		2,295	137,425	41,460		4,656			183,540
					2,295.00	137,424.60	41,459.70		4,656.00			183,540.30
01	Spider Removal	331.00	LM		2,250	134,730	33,503		4,656			172,889
					6.80	407.04	101.22		14.07			522.32
	Crew:Qty= 90.000 Set, Prod=0.20 Set/hour (2.00 Set/ day), 25.000MH/Set, 0.04 Set/MH, 450.00 hour (45.00 days)											
	Spider Removal and inspection	*1.00*	*EA*	*373.85*								
	Craft	5.0		59.88		134,730						
	Small Tools & Supplies	5.0		3.00			6,750					
	Platform Cart	2.0		1.00			900					
	Acetylene Cutting Torch	4.0		6.26			11,268					
	JLG Bucket Lift	1.0		21.00			9,450					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			5,135					
	Tunnel Light Line	32.0	m	103.00					3,296			
	Work Lights	8.0	ea	170.00					1,360			
02	Spider Disposal	30.00	load		45	2,695	7,957					10,652
					1.50	89.82	265.24					355.06
	Crew:Qty= 30.000 load, Prod=2.00 load/hour (20.00 load/ day), 1.500MH/load, 0.67 load/MH, 15.00 hour (1.50 days)											
	Steel Disposal	*1.00*	*EA*	*710.12*								
	Craft	3.0		59.88		2,695						
	Hydraulic Thumb Attachment	1.0		8.41			126					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			3,255					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	2.0		142.33			4,270					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			171					
	Small Tools & Supplies	3.0		3.00			135					
40	Install New Penstock	331.00	LM		714	42,783	9,262		3,776			55,821
					2.16	129.25	27.98		11.41			168.64
01	Welding	419.00	KG		608	36,380	7,942		3,776			48,097
					1.45	86.83	18.95		9.01			114.79
	Crew:Qty= 419.000 kg, Prod=4.83 kg/hour (48.28 kg/ day), 1.450MH/kg, 0.69 kg/MH, 86.79 hour (8.68 days)											
	Welder	*1.00*	*EA*	*510.66*								
	Craft	7.0		59.88		36,380						
	300 Amp Electric Welder	6.0		11.75			6,119					
	Small Tools & Supplies	7.0		3.00			1,823					
	Welding Flux Core Wire	460.9	KG	2.75					1,267			
	Ceramic Backing Bar	634.8	M	1.50					952			
	Argon Gas	130.0	m3	11.97					1,556			
02	NDT Inspection	1.00	LS		107	6,403	1,320					7,723
					106.94	6,403.30	1,320.12					7,723.42
	Crew:Qty= 488.290 M, Prod=9.13 M/hour (91.32 M/ day), 0.219MH/M, 4.57 M/MH, 53.47 hour (5.35 days)											
	Weld Testing	*1.00*	*EA*	*144.45*								
	Craft	2.0		59.88		6,403						
	1/2 Ton Pickup Truck 4x4	1.0		11.41			610					
	Weld Testing Equipment	2.0		3.64			389					
	Small Tools & Supplies	2.0		3.00			321					
50	Tie-in	2.00	EA		420	25,150	1,945		250,000			277,094
					210.00	12,574.80	972.30		125,000.00			138,547.10

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Crew:Qty= 2.000 EA, Prod=0.03 EA/hour (0.33 EA/ day), 210.000MH/EA, 0.00 EA/MH, 60.00 hour (6.00 days)											
	Coupling Installation	*1.00*	*EA*	*451.57*								
	Craft	7.0		59.88		25,150						
	1/2 Ton Pickup Truck 4x4	1.0		11.41			685					
	Small Tools & Supplies	7.0		3.00			1,260					
	Machanical Coupling	2.0	ea	125,000.00					250,000			
60	Scaffolding Support	30.00	EA		1,500	89,820	6,945		96,000			192,765
					50.00	2,994.00	231.50		3,200.00			6,425.50
	Crew:Qty= 30.000 EA, Prod=0.14 EA/hour (1.40 EA/ day), 50.000MH/EA, 0.02 EA/MH, 214.29 hour (21.43 days)											
	Scaffold Up & Down	*1.00*	*EA*	*451.57*								
	Craft	7.0		59.88		89,820						
	1/2 Ton Pickup Truck 4x4	1.0		11.41			2,445					
	Small Tools & Supplies	7.0		3.00			4,500					
	Rent Access Scaffold	4.0	month	24,000.00					96,000			
70	Coating (Field Coating only for welding portion)	715.00	M2		501	29,970	23,836		41,579			95,385
					0.70	41.92	33.34		58.15			133.41
	Crew:Qty= 715.000 M2, Prod=11.43 M2/hour (114.29 M2/ day), 0.700MH/M2, 1.43 M2/MH, 62.56 hour (6.26 days)											
	Blasting and Coating	*1.00*	*EA*	*860.03*								
	Craft	8.0		59.88		29,970						
	100 KW Diesel Generator Set	1.0		27.50			1,720					
	375 CFM (10.6 m3/min) Diesel Compressor	1.0		31.28			1,957					
	Coating Pump	2.0		76.70			9,597					
	Sand Blast Equipment	1.0		88.90			5,562					
	JLG Bucket Lift	1.0		21.00			1,314					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			714					
	1 Ton Flat Bed Truck	1.0		23.50			1,470					
	Small Tools & Supplies	8.0		3.00			1,502					
	Miscellaneous Hardware	1.0	LS	10,000.00					10,000			
	DuraShield 210	113.3	Gallon	278.72					31,579			
300	Maintenance Hole Installation	3.00	EA		60	3,593	885		10			4,488
					20.00	1,197.60	295.00		3.37			1,495.97
	Crew:Qty= 3.200 kg, Prod=0.11 kg/hour (1.07 kg/ day), 18.750MH/kg, 0.05 kg/MH, 30.00 hour (3.00 days)											
	Maintenance Hole	*1.00*	*EA*	*149.26*								
	Craft	2.0		59.88		3,593						
	300 Amp Electric Welder	2.0		11.75			705					
	Small Tools & Supplies	2.0		3.00			180					
	Welding Flux Core Wire	3.7	KG	2.75					10			
400	Penstock Valve Trees	1.00	LS								50,000	50,000
	Penstock Valve Trees	1.0	LS	50,000.00							50,000.00 50,000	50,000.00
3000	Penstock Refurbishment	1.00	LS		39,053	2,338,484	2,052,486	25,000	1,343,523		100,000	5,859,494
					39,052.84	2,338,484.23	2,052,485.99	25,000.00	1,343,523.32		100,000.00	5,859,493.54
100	Temperary Person Access	1.00	LS		611	36,568	26,985		5,456			69,010
					610.69	36,568.38	26,984.90		5,456.24			69,009.52
10	Open Hatch	15.00	tonne		144	8,649	4,232					12,881

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
					9.63	576.62	282.12					858.74
	Crew:Qty= 52.000 m, Prod=2.52 m/hour (25.20 m/ day), 2.778MH/m, 0.36 m/MH, 20.63 hour (2.06 days)											
	Open Hatch	*1.00*	*EA*	*624.24*								
	Craft	7.0		59.88		8,649						
	Acetylene Cutting Torch	6.0		6.20			768					
	Motorized Manlift 30 Ft (9m)	1.0		16.47			340					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			235					
	38 Ton (35 tonne) Boomtruck	1.0		119.00			2,456					
	Small Tools & Supplies	7.0		3.00			433					
15	Fifth Hatch Earthwork	1.00	LS		112	6,707	12,968		2,000			21,674
					112.00	6,706.56	12,967.92		2,000.00			21,674.48
	Crew:Qty= 280.000 M3, Prod=10.00 M3/hour (100.00 M3/ day), 0.400MH/M3, 2.50 M3/MH, 28.00 hour (2.80 days)											
	Equipment Excavation	*1.00*	*EA*	*702.66*								
	Craft	4.0		59.88		6,707						
	Small Tools & Supplies	4.0		3.00			336					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			6,076					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	1.0		142.33			3,985					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			319					
	Vacuum Truck	1.0		80.40			2,251					
	Shoring Protection	1.0	LS	2,000.00					2,000			
20	Reclose Hatch	52.00	m		264	15,823	9,173		1,656			26,652
					5.08	304.29	176.40		31.85			512.55
	Crew:Qty= 151.000 kg, Prod=4.00 kg/hour (40.00 kg/ day), 1.750MH/kg, 0.57 kg/MH, 37.75 hour (3.78 days)											
	Welder	*1.00*	*EA*	*662.15*								
	Craft	7.0		59.88		15,823						
	300 Amp Electric Welder	6.0		11.75			2,661					
	Acetylene Cutting Torch	6.0		5.17			1,171					
	Motorized Manlift 30 Ft (9m)	1.0		16.47			622					
	38 Ton (35 tonne) Boomtruck	1.0		119.00			4,492					
	Small Tools & Supplies	2.0		3.00			227					
	Welding Flux Core Wire	173.7	KG	2.75					478			
	Ceramic Backing Bar	67.6	M	1.50					101			
	Argon Gas	90.0	m3	11.97					1,077			
30	Supply, Installation and Removal of Temporary Weather Enclosure	75.00	M2		90	5,389	612		1,800			7,802
					1.20	71.86	8.16		24.00			104.02
	Crew:Qty= 6.000 EA, Prod=0.20 EA/hour (2.00 EA/ day), 15.000MH/EA, 0.07 EA/MH, 30.00 hour (3.00 days)											
	Erect Miscellaneous Crew	*1.00*	*EA*	*200.05*								
	Craft	3.0		59.88		5,389						
	1/2 Ton Pickup Truck 4x4	1.0		11.41			342					
	Small Tools & Supplies	3.0		3.00			270					
	Purchase Temporary Weather Enclosure	6.0	EA	300.00					1,800			
200	Air Ventilation	1.00	LS		3,211	192,275	533,585	12,500	139,000			877,360
					3,211.00	192,274.68	533,584.91	12,500.00	139,000.00			877,359.59
10	Supply, Install and Remove	1.00	LS		180	10,778	4,948	12,500	139,000			167,227
					180.00	10,778.40	4,948.20	12,500.00	139,000.00			167,226.60
	Crew:Qty= 5.000 Set, Prod=0.25 Set/hour (2.50 Set/ day), 36.000MH/Set, 0.03 Set/MH, 20.00 hour (2.00 days)											

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Air Ventilation Supply, Install and Remove	*1.00*	*EA*	*786.33*								
	Craft	9.0		59.88		10,778						
	1/2 Ton Pickup Truck 4x4	1.0		11.41			228					
	Air Ventilation Units	5.0		43.00			4,300					
	Small Tools & Supplies	7.0		3.00			420					
	Air Isolation Bulkheads	5.0	ea	2,500.00				12,500				
	Air Ventilation Hose and Appliances	5.0	EA	27,800.00					139,000			
20	Air Ventilation Maintainence	1.00	LS		3,031	181,496	528,637					710,133
					3,031.00	181,496.28	528,636.71					710,132.99
	Crew:Qty= 5.000 Month, Prod=0.00 Month/hour (0.03 Month/ day), 606.200MH/Month, 0.00 Month/MH, 3,031.00 hour (151.55 days)											
	Air Ventilation Supply, Install and Remove	*1.00*	*EA*	*234.29*								
	Craft	1.0		59.88		181,496						
	Diesel Air Ventilation	5.0		32.00			484,960					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			34,584					
	Small Tools & Supplies	1.0		3.00			9,093					
300	Earthwork	15,588.00	M3		5,436	325,490	465,649		50,529			841,667
					0.35	20.88	29.87		3.24			53.99
10	Excavation	15,588.00	M3		3,263	195,379	258,071					453,450
					0.21	12.53	16.56					29.09
01	Machine Excavation	13,953.00	M3		1,628	97,476	229,731					327,207
					0.12	6.99	16.46					23.45
	Crew:Qty= 13,953.000 M3, Prod=60.00 M3/hour (600.00 M3/ day), 0.117MH/M3, 8.57 M3/MH, 232.55 hour (23.26 days)											
	Equipment Excavation	*1.00*	*EA*	*1407.04*								
	Craft	7.0		59.88		97,476						
	Small Tools & Supplies	7.0		3.00			4,884					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			21,971					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	2.0		217.00			100,927					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	3.0		142.33			99,297					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			2,653					
02	Manual Excavation	1,635.00	M3		1,635	97,904	28,339					126,243
					1.00	59.88	17.33					77.21
	Crew:Qty= 1,635.000 m3, Prod=11.00 m3/hour (110.00 m3/ day), 1.000MH/m3, 1.00 m3/MH, 148.64 hour (14.86 days)											
	Manual Excavation	*1.00*	*EA*	*849.34*								
	Craft	11.0		59.88		97,904						
	1200LB (550 kg) Skid Steer Loader (Bobcat 543)	5.0		29.25			21,738					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,696					
	Small Tools & Supplies	11.0		3.00			4,905					
20	Backfill	15,588.00	M3		2,173	130,110	207,578		50,529			388,217
					0.14	8.35	13.32		3.24			24.90
01	Machine Backfill	13,953.00	M3		1,628	97,476	179,268					276,744
					0.12	6.99	12.85					19.83
	Crew:Qty= 13,953.000 M3, Prod=60.00 M3/hour (600.00 M3/ day), 0.117MH/M3, 8.57 M3/MH, 232.55 hour (23.26 days)											
	Track Compaction	*1.00*	*EA*	*1190.04*								
	Craft	7.0		59.88		97,476						
	Small Tools & Supplies	7.0		3.00			4,884					

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			21,971					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			50,463					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	3.0		142.33			99,297					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			2,653					
02	Handy Backfill	1,635.00	M3		545	32,635	28,310		50,529			111,474
					0.33	19.96	17.31		30.90			68.18
	Crew:Qty= 1,635.000 M3, Prod=18.00 M3/hour (180.00 M3/ day), 0.333MH/M3, 3.00 M3/MH, 90.83 hour (9.08 days)											
	Handy Backfill	*1.00*	*EA*	*670.95*								
	Craft	6.0		59.88		32,635						
	Small Tools & Supplies	6.0		3.00			1,635					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			19,711					
	1100 lb (500 Kg) Plate Tamper	3.0		16.75			4,564					
	125 CFM (3.5 m3/min) Diesel Compressor	1.0		15.01			1,363					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,036					
	Gran. A	2,101.0	Tonne	24.05					50,529			
400	Crack Mapping	1.00	LS		2,965	177,531	77,650		11,434		100,000	366,615
					2,964.78	177,531.03	77,650.46		11,434.00		100,000.00	366,615.48
10	Hydro Blasting	1.00	LS		1,165	69,748	63,330					133,078
					1,164.80	69,748.22	63,330.18					133,078.40
	Crew:Qty= 10,489.000 m2, Prod=126.07 m2/hour (1,260.70 m2/ day), 0.111MH/m2, 9.01 m2/MH, 83.20 hour (8.32 days)											
	Robotic Hydro Blasting	*1.00*	*EA*	*1599.5*								
	Craft	14.0		59.88		69,748						
	Winch	3.0		8.30			2,072					
	8" (200mm) Diesel Water Pump 125,000 gph	2.0		24.36			4,054					
	1600 CFM (45.3 m3/min) Diesel Compressor	3.0		84.13			20,999					
	JLG Bucket Lift	1.0		21.00			1,747					
	1/2 Ton Pickup Truck 4x4	2.0		11.41			1,899					
	3000 gal (11,400 litres Watertruck	3.0		41.00			10,234					
	Hydro Blasting and Coating Robot	3.0		75.45			18,832					
	Small Tools & Supplies	14.0		3.00			3,494					
20	Water Treatment Plant	1.00	LS								100,000	100,000
											100,000.00	100,000.00
	Water Treatment Plant	1.0	LS	100,000.00							100,000	
30	Visual and MP Inspection	1.00	LS		1,800	107,783	14,320		11,434			133,537
					1,799.98	107,782.80	14,320.28		11,434.00			133,537.08
	Crew:Qty= 5,980.000 M, Prod=66.45 M/hour (664.45 M/ day), 0.301MH/M, 3.32 M/MH, 90.00 hour (9.00 days)											
	Visual and MP Testing	*5.00*	*EA*	*271.3432*								
	Craft	20.0		59.88		107,783						
	1/2 Ton Pickup Truck 4x4	5.0		11.41			5,134					
	Weld Testing Equipment	10.0		4.21			3,786					
	Small Tools & Supplies	20.0		3.00			5,400					
	Tunnel Light Line	78.0	m	103.00					8,034			
	Work Lights	20.0	ea	170.00					3,400			
500	Weld Repair	6,627.00	KG		9,941	595,237	146,622		43,987			785,846
					1.50	89.82	22.13		6.64			118.58
	Crew:Qty= 6,627.000 kg, Prod=8.00 kg/hour (80.00 kg/ day), 1.500MH/kg, 0.67 kg/MH, 828.38 hour (82.84 days)											

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Welder	*3.00*	*EA*	*298.52*								
	Craft	12.0		59.88		595,237						
	300 Amp Electric Welder	12.0		11.75			116,801					
	Small Tools & Supplies	12.0		3.00			29,822					
	Welding Flux Core Wire	7,289.7	KG	2.75					20,047			
	Argon Gas	2,000.0	m3	11.97					23,940			
600	Welding NDT Testing	2,990.00	M		655	39,210	8,084					47,294
					0.22	13.11	2.70					15.82
	Crew:Qty= 2,990.000 M, Prod=27.40 M/hour (273.97 M/ day), 0.219MH/M, 4.57 M/MH, 109.14 hour (10.91 days)											
	Weld Testing	*3.00*	*EA*	*144.45*								
	Craft	6.0		59.88		39,210						
	1/2 Ton Pickup Truck 4x4	3.0		11.41			3,736					
	Weld Testing Equipment	6.0		3.64			2,384					
	Small Tools & Supplies	6.0		3.00			1,964					
700	Scaffolding Support	1.00	LS		10,800	646,704	63,207		380,000			1,089,911
					10,800.00	646,704.00	63,207.00		380,000.00			1,089,911.00
10	Interior Scaffolding	1.00	LS		5,200	311,376	30,433		260,000			601,809
					5,200.00	311,376.00	30,433.00		260,000.00			601,809.00
	Crew:Qty= 20.000 Set, Prod=0.08 Set/hour (0.77 Set/ day), 260.000MH/Set, 0.00 Set/MH, 260.00 hour (26.00 days)											
	Interior Scaffolding	*5.00*	*EA*	*262.93*								
	Craft	20.0		59.88		311,376						
	1/2 Ton Pickup Truck 4x4	5.0		11.41			14,833					
	Small Tools & Supplies	20.0		3.00			15,600					
	Costomized Anchor	20.0	Set	1,000.00					20,000			
	Rent Access Scaffold	4.0	month	60,000.00					240,000			
20	Exterior Scaffolding	1.00	LS		5,600	335,328	32,774		120,000			488,102
					5,600.00	335,328.00	32,774.00		120,000.00			488,102.00
	Crew:Qty= 20.000 Set, Prod=0.07 Set/hour (0.71 Set/ day), 280.000MH/Set, 0.00 Set/MH, 280.00 hour (28.00 days)											
	Exterior Scaffolding	*5.00*	*EA*	*262.93*								
	Craft	20.0		59.88		335,328						
	1/2 Ton Pickup Truck 4x4	5.0		11.41			15,974					
	Small Tools & Supplies	20.0		3.00			16,800					
	Rent Access Scaffold	4.0	month	30,000.00					120,000			
800	Interior Coating	1.00	LS		5,135	307,505	723,698	12,500	713,117			1,756,820
					5,135.36	307,505.26	723,697.54	12,500.00	713,117.36			1,756,820.16
10	Robotic Abrasive Blasting	10,489.00	M2		2,510	150,269	488,038		164,997			803,304
					0.24	14.33	46.53		15.73			76.59
	Crew:Qty= 10,489.000 m2, Prod=20.90 m2/hour (208.99 m2/ day), 0.239MH/m2, 4.18 m2/MH, 501.90 hour (50.19 days)											
	Robotic Abrasive Blasting	*1.00*	*EA*	*1271.78*								
	Craft	5.0		59.88		150,269						
	Dehumidifier	5.0		93.38			234,337					
	Winch	1.0		8.30			4,166					
	1600 CFM (45.3 m3/min) Diesel Compressor	1.0		84.13			42,225					
	Abrasive Blasting Pot	1.0		6.20			3,112					
	JLG Bucket Lift	1.0		21.00			10,540					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			5,727					

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Dust Collection	1.0		34.64			17,386					
	Abrasive Blasting Robot	5.0		64.96			163,017					
	Small Tools & Supplies	5.0		3.00			7,529					
	Blast Material	131,723.9	kg	1.25					164,997			
20	Robotic 3-Coats	10,489.00	M2		2,251	134,781	232,779		548,120			915,681
					0.21	12.85	22.19		52.26			87.30
	Crew:Qty= 10,489.000 m2, Prod=23.30 m2/hour (233.00 m2/ day), 0.215MH/m2, 4.66 m2/MH, 450.17 hour (45.02 days)											
	Robotic 3-Coats	*1.00*	*EA*	*816.49*								
	Craft	5.0		59.88		134,781						
	Winch	1.0		8.30			3,736					
	1600 CFM (45.3 m3/min) Diesel Compressor	1.0		84.13			37,873					
	JLG Bucket Lift	1.0		21.00			9,454					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			5,136					
	Hydro Blasting and Coating Robot	5.0		75.45			169,827					
	Small Tools & Supplies	5.0		3.00			6,753					
	MC MIOZINC 100	710.0	Gallon	104.06					73,883			
	MC FERROX B 100	710.0	Gallon	68.06					48,323			
	Robot Accessories	5.0	EA	72,000.00					360,000			
	MC Ferrox A Medium Color	570.0	Gallon	115.64					65,915			
30	Isolation Bulkhead	1.00	LS		375	22,455	2,881	12,500				37,836
					375.00	22,455.00	2,880.75	12,500.00				37,835.75
	Crew:Qty= 5.000 EA, Prod=0.07 EA/hour (0.67 EA/ day), 75.000MH/EA, 0.01 EA/MH, 75.00 hour (7.50 days)											
	Isolation Bulkhead	*1.00*	*EA*	*337.81*								
	Craft	5.0		59.88		22,455						
	JLG Bucket Lift	1.0		21.00			1,575					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			856					
	Small Tools & Supplies	2.0		3.00			450					
	Prefabricated Wood Bulkheads	5.0	ea	2,500.00				12,500				
900	Coating Test	10,489.00	M2		300	17,964	7,007					24,971
					0.03	1.71	0.67					2.38
	Crew:Qty= 10,489.000 M2, Prod=69.93 M2/hour (699.27 M2/ day), 0.029MH/M2, 34.96 M2/MH, 150.00 hour (15.00 days)											
	Coating Test	*1.00*	*EA*	*166.47*								
	Craft	2.0		59.88		17,964						
	Winch	1.0		8.30			1,245					
	JLG Bucket Lift	1.0		21.00			3,150					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			1,712					
	Small Tools & Supplies	2.0		3.00			900					
4000	Site Finalization	1.00	LS		555	33,233	33,701				12,000	78,934
					555.00	33,233.40	33,700.70				12,000.00	78,934.10
100	Wet Commissioning	1.00	LS		250	14,970	1,321					16,291
					250.00	14,970.00	1,320.50					16,290.50
	Crew:Qty= 1.000 EA, Prod=0.02 EA/hour (0.20 EA/ day), 250.000MH/EA, 0.00 EA/MH, 50.00 hour (5.00 days)											
	Wet Commissioninng	*1.00*	*EA*	*325.81*								
	Craft	5.0		59.88		14,970						
	1/2 Ton Pickup Truck 4x4	1.0		11.41			571					
	Small Tools & Supplies	5.0		3.00			750					

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
200	Silt Fence Removal	1.00	LS		105	6,287	1,785					8,072
					105.00	6,287.40	1,785.00					8,072.40
	Crew:Qty= 2,100.000 M, Prod=80.00 M/hour (800.00 M/ day), 0.050MH/M, 20.00 M/MH, 26.25 hour (2.63 days)											
	Miscellaneous Crew	*1.00*	*EA*	*307.52*								
	Craft	4.0		59.88		6,287						
	Small Tools & Supplies	4.0		3.00			315					
	0.8 CY (0.6 m3) Backhoe Loader (Case 580)	1.0		44.59			1,170					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			300					
300	Staging Area Restoration	4,000.00	M2		200	11,976	30,595					42,571
					0.05	2.99	7.65					10.64
	Crew:Qty= 4,000.000 M2, Prod=100.00 M2/hour (1,000.00 M2/ day), 0.050MH/M2, 20.00 M2/MH, 40.00 hour (4.00 days)											
	Miscellaneous Crew	*1.00*	*EA*	*1064.28*								
	Craft	5.0		59.88		11,976						
	Small Tools & Supplies	5.0		3.00			600					
	170 Hsp (97 kw) Bulldozer (Cat D6)-22 ton	1.0		94.48			3,779					
	3.0 CY (2.3 m3) Backhoe (Cat 329)-28 tonne	1.0		217.00			8,680					
	25 Ton (23 tonne) Articulated Truck (Volvo A25)	3.0		142.33			17,080					
	1/2 Ton Pickup Truck 4x4	1.0		11.41			456					
400	Staging Area Hydroseeding	4,000.00	m2								12,000	12,000
											3.00	3.00
	Seeding to Slopes	4,000.0	m2	3.00							12,000	
9000	Site Overhead	1.00	LS		17,282	2,545,415	1,756,577	399,000			2,655,272	7,356,265
					17,282.00	2,545,415.40	1,756,577.40	399,000.00			2,655,272.00	7,356,264.80
OH-01	Mobilization	1.00	LS					223,800			25,090	248,890
								223,800.00			25,090.00	248,890.00
001006	Mobilization	1.00	LS					223,800			25,090	248,890
								223,800.00			25,090.00	248,890.00
010	Freight In Heavy Equipment Loads	38.00	EA					91,200				91,200
								2,400.00				2,400.00
	Mob In Heavy Equipment	38.0	EA	2,400.00				91,200				
020	Set Up Equipment	240.00	HR								15,600	15,600
											65.00	65.00
030	Set Up Miscellaneous Items	1.00	LS					9,100				9,100
								9,100.00				9,100.00
	Bucket Lift Modification in Interior Penstock	140.0	Hrs	65.00				9,100				
050	Freight in Misc Loads	45.00	Load					108,000				108,000
								2,400.00				2,400.00
	Misc Loads	45.0	Load	2,400.00				108,000				
060	Unload Freight In	73.00	Load								9,490	9,490
											130.00	130.00
070	Freight In Trailers & Job Shacks	23.00	EA					15,500				15,500
								673.91				673.91
	Mob In Washroom Trailer	2.0	EA	1,000.00				2,000				

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
	Mob In Storage	15.0	EA	500.00				7,500				
	Mob In Lunch Trailers	4.0	EA	1,000.00				4,000				
	Mob In Office Trailers	2.0	EA	1,000.00				2,000				
OH-02	Project Staff	8.00	MO		14,700	999,600						999,600
					1,837.50	124,950.00						124,950.00
001050	Supervisory & Management Staff	294.00	Week		14,700	999,600						999,600
					50.00	3,400.00						3,400.00
020	Project Staff	294.00	Week		14,700	999,600						999,600
					50.00	3,400.00						3,400.00
	General Staff	1.0	EA	3,400.00	294.00	week						
OH-03	Site Offices	8.00	MO								154,100	154,100
											19,262.50	19,262.50
001590	Temp. Trailers (Office, Tool Shack, Sanitation)	8.00	MO								154,100	154,100
											19,262.50	19,262.50
010	Setup Trailers	23.00	EA								34,500	34,500
											1,500.00	1,500.00
020	Trailer Rental	8.00	MO								92,000	92,000
											11,500.00	11,500.00
040	Dismantle Trailer	23.00	EA								27,600	27,600
											1,200.00	1,200.00
OH-04	Utilities & Services	8.00	MO								80,590	80,590
											10,073.75	10,073.75
001026	Communication (radios, etc.)	15.00	SET								2,250	2,250
											150.00	150.00
001510	Utilities Connection Costs	1.00	LS								31,500	31,500
											31,500.00	31,500.00
020	Temporary Power Service	1.00	LS								15,000	15,000
											15,000.00	15,000.00
030	Temporary Power Distribution	1.00	LS								15,000	15,000
											15,000.00	15,000.00
080	Internet Services	1.00	LS								1,500	1,500
											1,500.00	1,500.00
001512	Temp. Utilities (phone & Internet)	8.00	MO								2,400	2,400
											300.00	300.00
001517	Portable Toilets	8.00	MO								24,640	24,640
											3,080.00	3,080.00
010	Drop Off	8.00	EA								1,600	1,600
											200.00	200.00
020	Rent Temporary Toilets	64.00	MO								23,040	23,040
											360.00	360.00
001519	Cell Phone Charges	68.00	MMO								10,200	10,200
											150.00	150.00
001521	Refusal Disposal	8.00	MO								9,600	9,600

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
											1,200.00	1,200.00
OH-05	Temporary Construction	1.00	LS								650,000	650,000
											650,000.00	650,000.00
001543	Project Sign	4.00	EA								2,000	2,000
											500.00	500.00
001550	Temporary Roads	1.00	LS								378,000	378,000
											378,000.00	378,000.00
001560	Temporary Structures	1.00	LS								250,000	250,000
											250,000.00	250,000.00
040	Construct/Remove Temporary Docks/Wharves	1.00	LS								150,000	150,000
											150,000.00	150,000.00
070	Construct/Remove Prefab Shop	200.00	M2								40,000	40,000
											200.00	200.00
080	Mechanical Working Slab in Q1	200.00	M3								30,000	30,000
											150.00	150.00
090	Temperary Fuel Depot	1.00	LS								30,000	30,000
											30,000.00	30,000.00
001561	Job Access Scaffolds/Stairs	10.00	EA								20,000	20,000
											2,000.00	2,000.00
OH-07	Office Supplies	8.00	MO								34,000	34,000
											4,250.00	4,250.00
001020	Office Supplies	68.00	MM								34,000	34,000
											500.00	500.00
OH-08	Safety & Security	1.00	LS								115,200	115,200
											115,200.00	115,200.00
001524	Safety Supplies & Meetings	74,300.00	MH								74,300	74,300
											1.00	1.00
001527	Safety Awards	74,300.00	Manhours								37,150	37,150
											0.50	0.50
001529	Fire Protection	25.00	EA								3,750	3,750
											150.00	150.00
OH-09	Employee Expense	1.00	LS								95,800	95,800
											95,800.00	95,800.00
001064	Travel- From Site to Toronto	96.00	Trip								76,800	76,800
											800.00	800.00
001068	Meals & Entertainment	8.00	MO								4,000	4,000
											500.00	500.00
001070	Blasting and Coating Robot Training	1.00	LS								15,000	15,000
											15,000.00	15,000.00
OH-10	Contract Services	1.00	DAY								17,000	17,000
											17,000.00	17,000.00
070	Public Relations	1.00	LS								5,000	5,000
											5,000.00	5,000.00

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
090	Drone	8.00	MO								12,000	12,000
											1,500.00	1,500.00
OH-11	Employee Subsistence	1.00	LS								1,237,500	1,237,500
											1,237,500.00	1,237,500.00
001075	Camp Day	8,250.00	Camp Day								1,237,500	1,237,500
											150.00	150.00
OH-14	Non Productive Labour	1.00	Week		2	1,391,325						1,391,325
					2.00	1,391,325.00						1,391,325.00
001017	Unscheduled Overtime	1.00	LS		1	107,025						107,025
	Hourly Unscheduled Overtime	1.0	EA	107,025.00	1.00	107,025.00 1.00 hour						107,025.00
001018	Scheduled Overtime	1.00	LS		1	1,284,300						1,284,300
	Hourly Scheduled Overtime	1.0	EA	1,284,300.00	1.00	1,284,300.00 1.00 hour						1,284,300.00
OH-15	Contingencies	1.00	LS								30,000	30,000
											30,000.00	30,000.00
10	Penstcok Damage Repair in Penstock Refurbishment	1.00	LS								30,000	30,000
											30,000.00	30,000.00
OH-16	Demobilization	1.00	LS					175,200			34,992	210,192
								175,200.00			34,992.00	210,192.00
001007	Demobilization	1.00	LS					175,200			24,992	200,192
								175,200.00			24,992.00	200,192.00
010	Load Freight Out	73.00	load								9,490	9,490
											130.00	130.00
10	Load Out Heavy Loads	38.00	EA								4,940	4,940
											130.00	130.00
20	Load Out Misc Loads	35.00	EA								4,550	4,550
											130.00	130.00
020	Freight Out Trailers & Job Shacks	23.00	EA								15,502	15,502
											674.00	674.00
030	Freight Out Heavy Equipment Loads	38.00	EA					91,200				91,200
	Freight Out Equipment	38.0	EA	2,400.00				2,400.00 91,200				2,400.00
050	Freight Out Misc Loads	35.00	EA					84,000				84,000
	Frieght Out Misc Loads	35.0	EA	2,400.00				2,400.00 84,000				2,400.00
001010	Final Cleanup	1.00	LS								10,000	10,000
											10,000.00	10,000.00
OH-18	Layout Survey	1.00	LS								24,000	24,000
											24,000.00	24,000.00
001016	Surveying/Layout	2.00	MO								24,000	24,000
											12,000.00	12,000.00

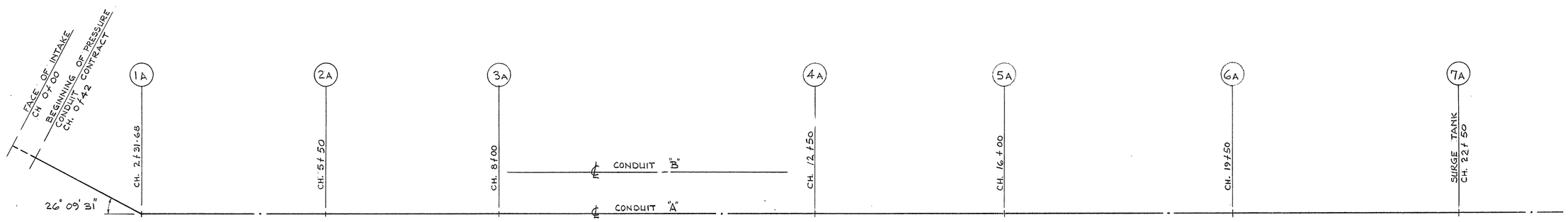
Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
OH-20	Maintenance	1.00	LS								32,000	32,000
											32,000.00	32,000.00
001802	Maintain Access Roads	8.00	MO								32,000	32,000
											4,000.00	4,000.00
OH-23	Consultants/Engineering	1.00	LS								110,000	110,000
											110,000.00	110,000.00
001300	Submittals, As Builts, Manuals	1.00	LS								110,000	110,000
											110,000.00	110,000.00
10	Distribution Line Relocation Design	1.00	LS								60,000	60,000
											60,000.00	60,000.00
20	Wharf Assessment and Design	1.00	LS								50,000	50,000
											50,000.00	50,000.00
OH-25	Bonds & Insurance	1.00	LS								5,000	5,000
											5,000.00	5,000.00
001002	Insurance	1.00	LS								5,000	5,000
											5,000.00	5,000.00
070	Equipment-OSR	1.00	LS								5,000	5,000
											5,000.00	5,000.00
OH-27	Project Equipment	8.00	MO				1,756,577				10,000	1,766,577
							219,572.18				1,250.00	220,822.18
010	Zoom Boom	8.00	MO				258,960					258,960
	Telehandler	2.0	EA	53.95			32,370.00 2,400.00 hour					32,370.00
080	Cranes	8.00	MO				469,440					469,440
	300 Ton Penstock Crane	1.0	EA	521.60			58,680.00 900.00 hour					58,680.00
090	Loader	4.00	MO				155,484					155,484
	6.5 CY (5.0 m3) Loader (Cat 980)	1.0	EA	129.57			38,871.00 1,200.00 hour					38,871.00
100	Pick Up Trucks	8.00	MO				252,576					252,576
	3/4 T Pick Up - Crew 1/2T Pick Up - Staff	2.0 6.0	EA EA	18.39 11.41			31,572.00 2,400.00 hour 2,400.00 hour					31,572.00
110	Ambulance	1.00	EA				73,776					73,776
	Ambulance	1.0	EA	30.74			73,776.00 2,400.00 hour					73,776.00
130	Job Bus	8.00	MO				37,176					37,176
	13 Person Mini Bus	1.0	EA	15.49			4,647.00 2,400.00 hour					4,647.00
170	Hoisting Chains & Slings	1.00	LS								10,000	10,000
											10,000.00	10,000.00

Item	Description	Quantity	UOM	Rate	ManHrs	Labor	Equip	Job Mat	Perm Mat	Mech Elec Eq	Sub/Plug	Total Cost
200	Generators	8.00	MO				505,575					505,575
							63,196.88					63,196.88
	150 KW Diesel Generator Set for Hatches	5.0	EA	53.50			1,800.00 hour					
	150 KW Diesel Generator Set for Penstock Replacement	1.0	EA	53.50			450.00 hour					
230	Light Towers for Q1	480.00	HR				3,590					3,590
							7.48					7.48
	Tower 4-Lights 12 Hsp (8.9 kw)	1.0	EA	7.48			480.00 hour					
OH-28	Project Hourly Labour	1.00	LS		2,580	154,490						154,490
					2,580.00	154,490.40						154,490.40
050	Crane Operator	900.00	HR		900	53,892						53,892
					1.00	59.88						59.88
	Craft	1.0	EA	59.88	900.00 hour							
060	Cat 980 Loader Operator	1.00	LS		1,200	71,856						71,856
					1,200.00	71,856.00						71,856.00
	Craft	1.0	EA	59.88	1,200.00 hour							
070	Bus Driver	480.00	HR		480	28,742						28,742
					1.00	59.88						59.88
	Craft	1.0	EA	59.88	480.00 hour							

APPENDIX 7

SUPPORTING DRAWINGS

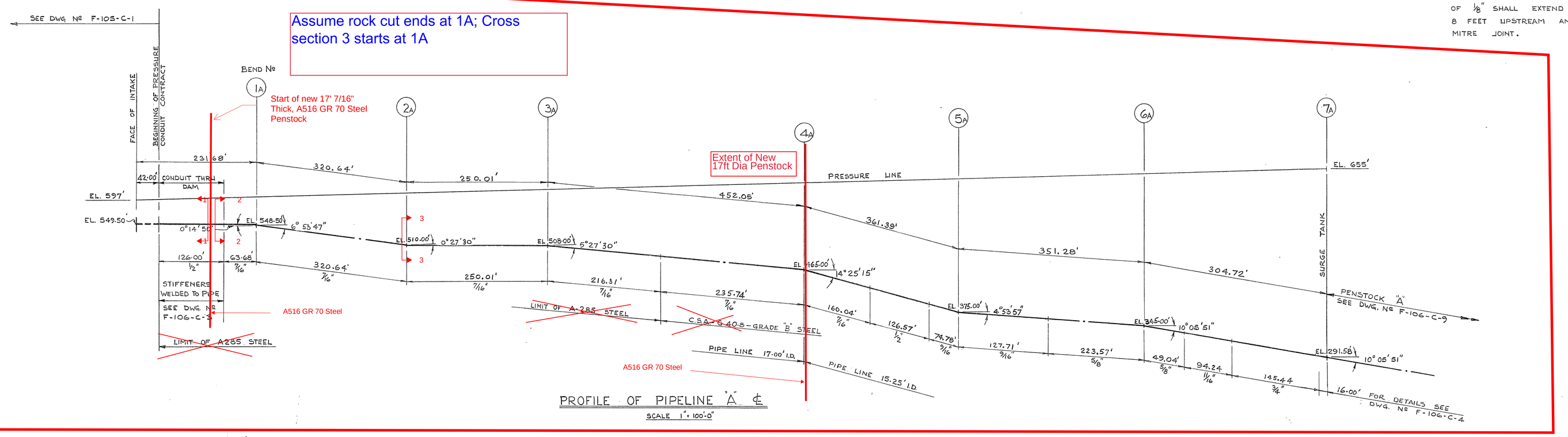
To be used for Class 3 Estimate



PLAN OF PIPELINE "A" ℄

SCALE 1" = 100'-0

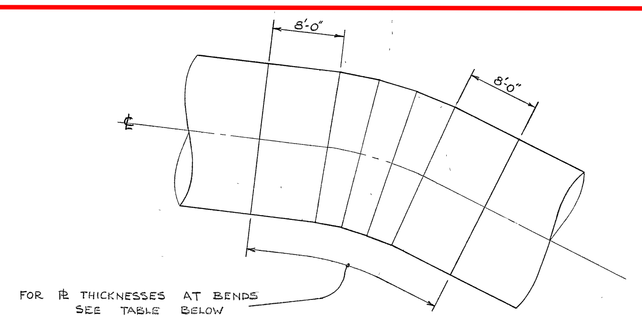
Assume rock cut ends at 1A; Cross section 3 starts at 1A



PROFILE OF PIPELINE "A" ℄

SCALE 1" = 100'-0"

Assume transition piece is required



TYPICAL BEND

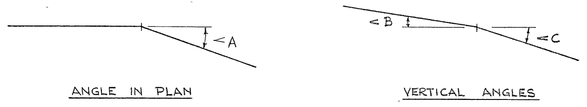
SCALE 1" = 10'-0"

SEE SPEC. M-3116

To be used for Class 3 Estimate

ANGLES & ℔ THICKNESSES AT BENDS

BEND	∠A	∠B	∠C	TRUE ANGLE	℔ THICKNESS
1A	26° 09' 31"	0° 14' 50"	6° 55' 47"	26° 55' 34"	7/16"
2A	——	6° 55' 47"	0° 27' 30"	6° 26' 17"	1/2"
3A	——	0° 27' 30"	5° 27' 30"	5° 00' 00"	1/2"
4A	——	5° 27' 30"	14° 25' 15"	8° 57' 45"	9/16"
5A	——	14° 25' 15"	4° 53' 57"	9° 31' 18"	3/4"
6A	——	4° 53' 57"	10° 05' 51"	5° 11' 54"	13/16"
7A	——	10° 05' 51"	10° 05' 51"	0° 00' 00"	



ANGLE IN PLAN — VERTICAL ANGLES

NOTES

1. THE PRESSURE CONDUITS SHALL BE CALLED "A" AND "B". CONDUIT "A" IS SOUTH OF CONDUIT "B" AND SHALL BE COMPLETED IN 1966. CONDUIT "A" CONSISTS OF PIPELINE "A" AND PENSTOCK "A".
2. THE PIPELINE SHALL BE DESIGNED IN ACCORDANCE WITH SPECIFICATION Nº M-3116 EXCEPT FOR BENDS WHERE ⅛" SHALL BE ADDED TO PLATE THICKNESSES CALCULATED TO RESIST HOOP TENSION PLUS THE EFFECTS OF THE TORUS SHAPE OF BENDS. THIS EXTRA THICKNESS OF ⅛" SHALL EXTEND OVER THE BENDS AND AT LEAST 8 FEET UPSTREAM AND DOWNSTREAM OF THE LAST MITRE JOINT.

F-106-C-3 CONDUITS THROUGH DAM
F-106-C-4 SURGE TANK-DETAILS OF TEES
F-106-C-5 " " " -GENERAL LAYOUT & DETAILS
F-106-C-6 PRESSURE CONDUITS-CLEARING
F-106-C-8 " " " -EXCAVATION & DRAINAGE
F-106-C-9 " " " -PENSTOCK A
F-106-C-10 " " " -PENSTOCK B

OTHER REFERENCES
1. SPECIFICATION No. M-3116

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
5	2-6-68		AS BUILT, FROM FIELD INFORMATION	A.B.	JHM
4	5JAN'67		2 TYP. SECTIONS CHANGED, ONE REMOVED	A.R.	JHM
3	9DEC'66		3 TYPICAL SECTIONS ADDED	A.R.	JHM
2	20SEPT65		REVISED PROFILE & PLATE THICKNESSES	A.R.	JHM
1	AUG 5/65		EL. @ BEND 4 CORRECTED, MINOR REVISIONS	J.P.	JHM

REVISIONS

APPROVED FOR CONSTRUCTION
JUL 16 1965
APPROVED BY: K. C. Brennell
MANAGER ENGINEERING

TRANS'N	ELECT'L	CIVIL
		JHM

PASSED

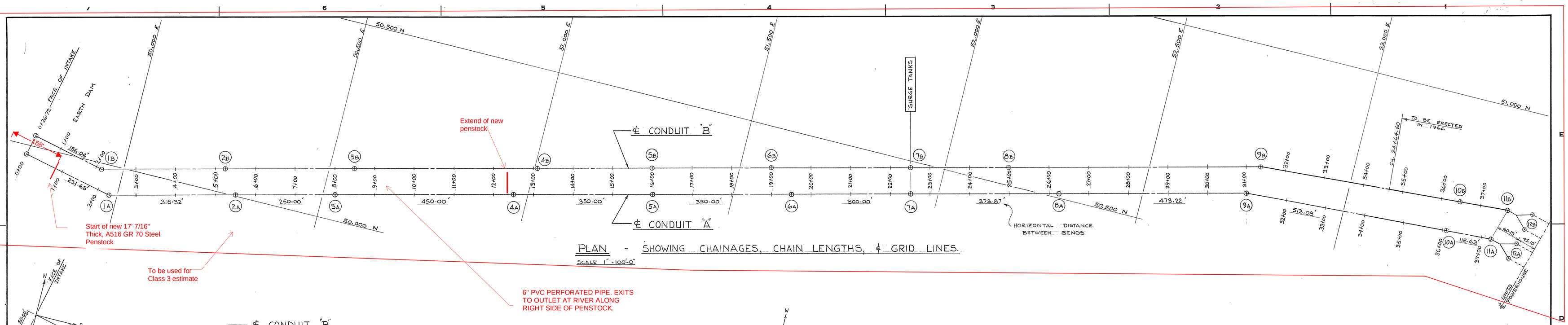
DESIGNED R. MacD.
DRAWN J.P.
CHECKED
RECOMMENDED J.H. Mercer P.Eng.

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERING AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
PLAN & PROFILE PIPELINE "A"

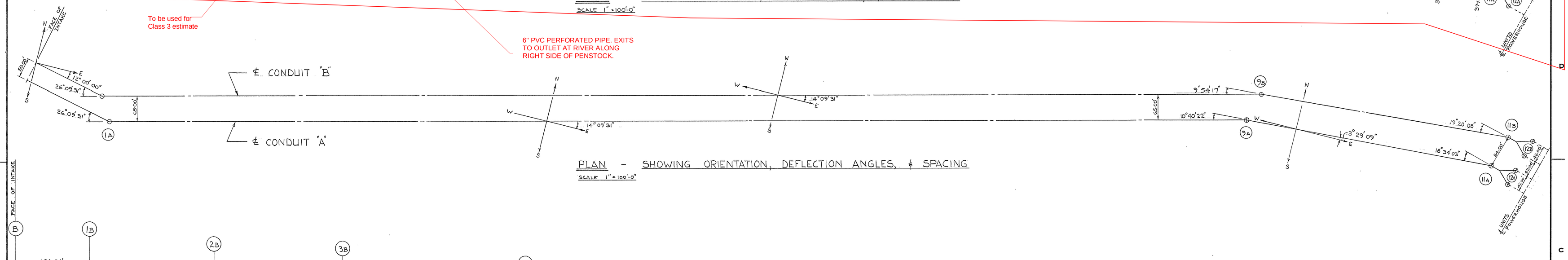
CONTRACT	SCALE	FILE NO.	DATE	DWG NO.	REVISION
	NOTED	PD-11	JULY 16, 1965	F-106-C-7	5

Penstock 3 Section Replacement and Weld Refurbishment Project - 2018
Schedule 1, Attachment 13, Page 13 of 22



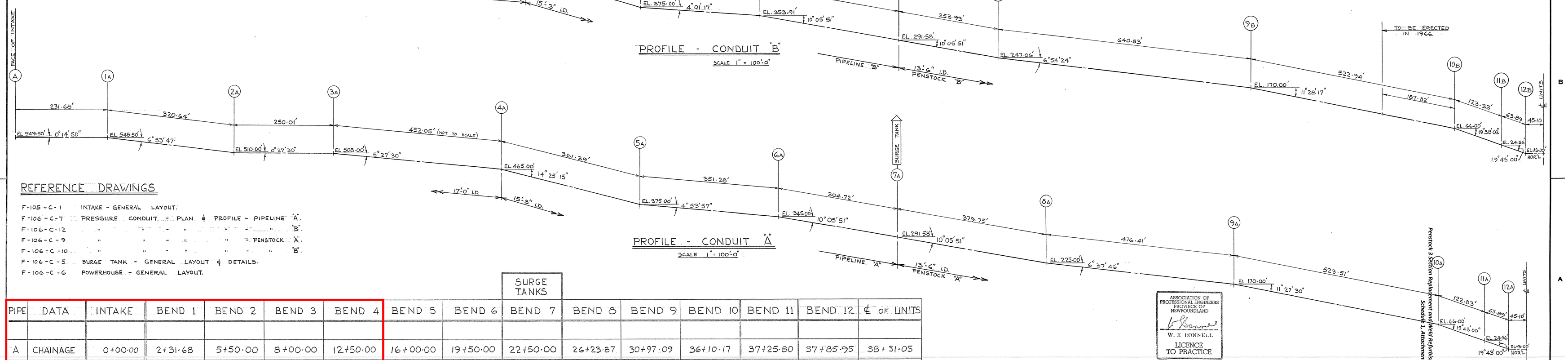
PLAN - SHOWING CHAINAGES, CHAIN LENGTHS, & GRID LINES.

SCALE 1" = 100'-0"



PLAN - SHOWING ORIENTATION, DEFLECTION ANGLES, & SPACING

SCALE 1" = 100'-0"



PROFILE - CONDUIT "B"

SCALE 1" = 100'-0"

PROFILE - CONDUIT "A"

SCALE 1" = 100'-0"

REFERENCE DRAWINGS

F-105-C-1 INTAKE - GENERAL LAYOUT.
F-106-C-7 PRESSURE CONDUIT - PLAN & PROFILE - PIPELINE "A".
F-106-C-12 " " - " " " - " "B".
F-106-C-9 " " - " " " - PENSTOCK "A".
F-106-C-10 " " - " " " - " "B".
F-106-C-5 SURGE TANK - GENERAL LAYOUT & DETAILS.
F-106-C-6 POWERHOUSE - GENERAL LAYOUT.

PIPE	DATA	INTAKE	BEND 1	BEND 2	BEND 3	BEND 4	BEND 5	BEND 6	SURGE TANKS BEND 7	BEND 8	BEND 9	BEND 10	BEND 11	BEND 12	℄ OF UNITS
A	CHAINAGE	0+00.00	2+31.68	5+50.00	8+00.00	12+50.00	16+00.00	19+50.00	22+50.00	26+23.87	30+97.09	36+10.17	37+25.80	37+85.95	38+31.05
A	NORTHING	49,975.55	49,927.38						50,421.08		50,628.28		50,666.51		
A	EASTING	49,754.80	49,981.42						51,938.43		52,759.79		53,387.34		
B	CHAINAGE	0+26.72	2+12.76	5+25.00	8+50.00	13+10.00	16+00.00	19+00.00	22+50.00	25+00.00	31+36.18	36+48.67	37+64.83	38+24.98	38+70.08
B	NORTHING	50,024.46	49,985.78								50,700.98		50,747.62		
B	EASTING	49,765.20	49,947.17								52,782.26		53,409.20		

ASSOCIATION OF PROFESSIONAL ENGINEERS PROVINCE OF NEWFOUNDLAND
W. E. BONNELL
LICENCE TO PRACTICE

NO.	DATE	LOCATION	DESCRIPTION	MADE BY	APPR'D
3	JAN 23/66		I.D.'s INDICATED.	J.P.	J.H.M.
2	OCT. 19/65		STA. B-1B. VERTICAL ANGLE REVISED	J.P.	J.H.M.
1	SEPT. 27/65		PLANS & PROFILES REVISED	J.P.	J.H.M.

REVISIONS

APPROVED FOR CONSTRUCTION
AUG 13 1965
APPROVED BY: W. Bonnell
MANAGER ENGINEERING

TRANS'N	ELECT'L	CIVIL
		J.H.M.

PASSED

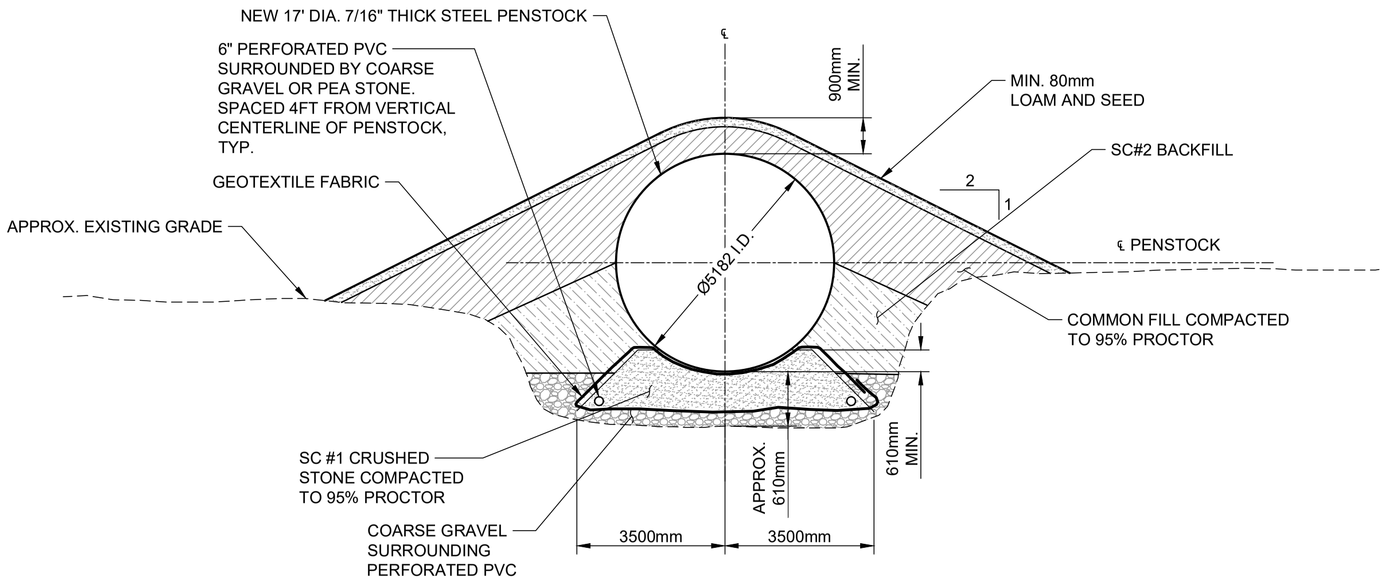
DESIGNED R. MacD.
DRAWN J.P.
CHECKED A.P. H.K.
RECOMMENDED J.H. Mann

NEWFOUNDLAND AND LABRADOR POWER COMMISSION
BAY D'ESPOIR DEVELOPMENT
ENGINEERED AND DESIGN BY
SHAWMONT ENGINEERING NEWFOUNDLAND LIMITED
MONTREAL, QUEBEC

PRESSURE CONDUITS
LAYOUT & LOCATION DATA

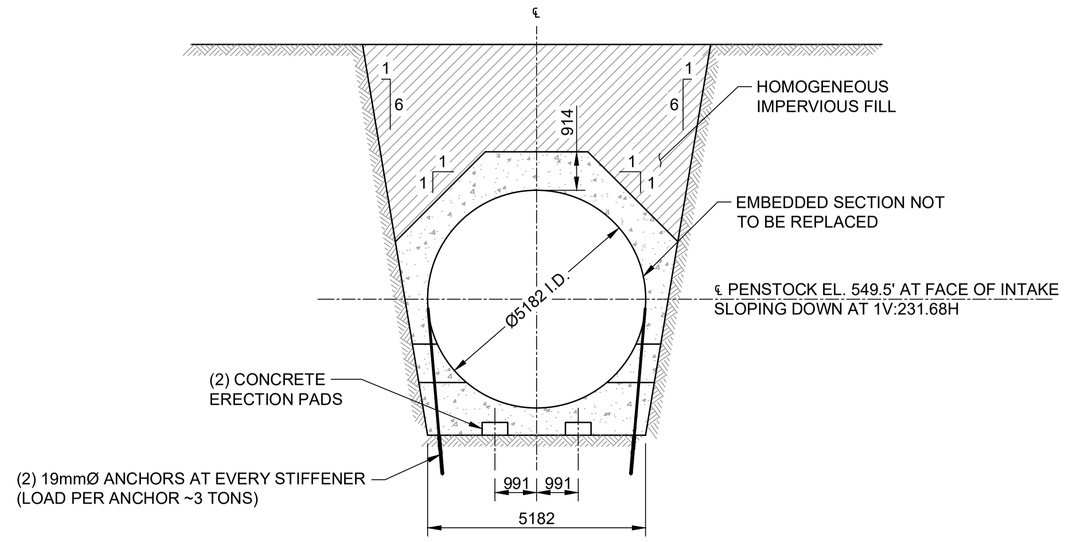
CONTRACT	SCALE	FILE NO.	DATE	DWG. NO.	REVISION
	1" = 100'-0"	PD - 11	SEPT. 27, 1965	F-106-C-11	3

Penstock Section Replacement and Weld Refurbishment - Bay d'Espoir
Schedule 1, Attachment 1.3 Page 139 of 212



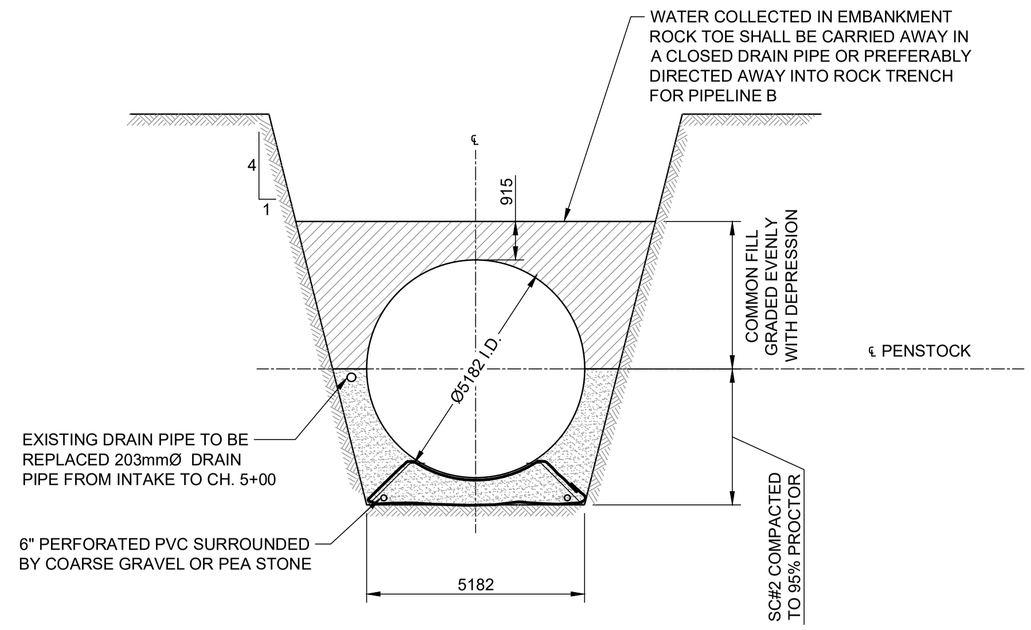
TYPICAL FULLY BURIED SECTION 3

N.T.S.



SECTION THRU PENSTOCK AT INTAKE 1

1:100



TYPICAL THRU ROCK-CUT SECTION 2

1:100

GENERAL NOTES:

SOIL MATERIALS:

A. GENERAL: PROVIDE BORROW SOIL MATERIALS WHEN SUFFICIENT SATISFACTORY SOIL MATERIALS ARE NOT AVAILABLE FROM EXCAVATIONS. REFER TO ATTACHED TABLE 5-3 FROM AWWA M45 FOR CLASSIFICATION DETAILS.

B. AWWA M45 SOIL CLASS I (SC1) MATERIAL IS DEFINED AS CRUSHED STONE AND GRAVEL WITH <15% SAND AND <5% FINES, 100% PASSING 37.5 MM (1.5").

C. AWWA M45 SOIL CLASS II (SC2) MATERIAL IS DEFINED AS GW, GP, SW, SP DUAL SYMBOL SOILS CONTAINING ONE OF THESE DESIGNATIONS SUCH AS GW-GC CONTAINING 12% FINES OR LESS. 100% PASSING 37.5 MM (1.5").

D. PIPE BEDDING SHALL CONSIST OF SC1 MATERIAL COMPACTED TO 95% STANDARD PROCTOR.

E. PIPE STRUCTURAL BACKFILL SHALL CONSIST OF SC2 MATERIAL COMPACTED TO 95% STANDARD PROCTOR.

F. COMMON BACKFILL SHALL BE COMPACTED TO 95% STANDARD PROCTOR.

1. NATIVE SOILS MAY BE REUSED AS COMMON BACKFILL PROVIDED THAT THEIR CLASSIFICATION AND GRADATION MEET THE U.S. ARMY CORPS OF ENGINEERS FROST DESIGN SOIL CLASSIFICATION OF F1 OR F2.

2. F3 AND F4 SOIL MAY NOT BE REUSED WITHIN 1.3M OF FINISHED GRADE.

3. THE RE-USE AND PLACEMENT OF FROST SUSCEPTIBLE SOILS AND/OR HAZARDOUS SOILS SHALL BE APPROVED BY THE OWNER'S REPRESENTATIVE.

G. ACCESS ROAD SHALL BE TOPPED WITH 75MM OF CLASS A UPON COMPLETION OF WORK.

H. AN APPROPRIATELY SIZED GEOTEXTILE MUST BE PLACE BETWEEN SC1 AND SC2 LAYERS TO PREVENT MIGRATION OF FINES. IN ALL CASES, GEOTEXTILE MUST BE PLACED BETWEEN NATIVE SOIL AND EXCAVATED NATIVE SOIL.

I. UNSATISFACTORY SOIL IS MUD, SILT, OR SOIL WHICH CONTAINS DEBRIS, ORGANIC MATERIAL OR FROZEN MATERIAL, OR SOILS WHICH CLEARLY WILL NOT PROVIDE APPROPRIATE SUPPORT.

J. FROST SUSCEPTIBLE SOILS WITHIN 1.3M OF FINISHED GRADE, REGARDLESS OF CONTAMINATION, SHALL BE REMOVED.

	% PASSING			
SIEVE SIZE	SC1	SC2	20mm STONE FILL	CLASS "A"
37.5mm (1 1/2")	100%	100%		
25mm (1")			95-100%	100%
19mm (3/4")			85-100%	95-100%
12.5mm (1/2")				70-90%
9.5mm (3/8")	<25%	50%	0-15%	
4.75mm (No. 4)			0-5%	30-55%
No. 200 (0.75um)	<5%	<12%		6-16%

NOTES:

KA SHEET NUMBER:

DWG #	TITLE

REFERENCE DRAWINGS

REV	DATE	DESCRIPTION	APPROVED
-	11-23-21	CLIENT REVIEW	NS

REVISION HISTORY

Kleinschmidt
888-224-5942
KleinschmidtGroup.com

SITE: BAY d'ESPOIR HYDRO SITE

PROJECT: FRONT END ENGINEERING & DESIGN

PROJECT # 2670-034

TITLE: PENSTOCK NO. 1 CROSS SECTIONS

REV DESCRIPTION: RECORD DRAWING

DESIGNED: CHECKED:

DRAWN: JCH APPROVED:

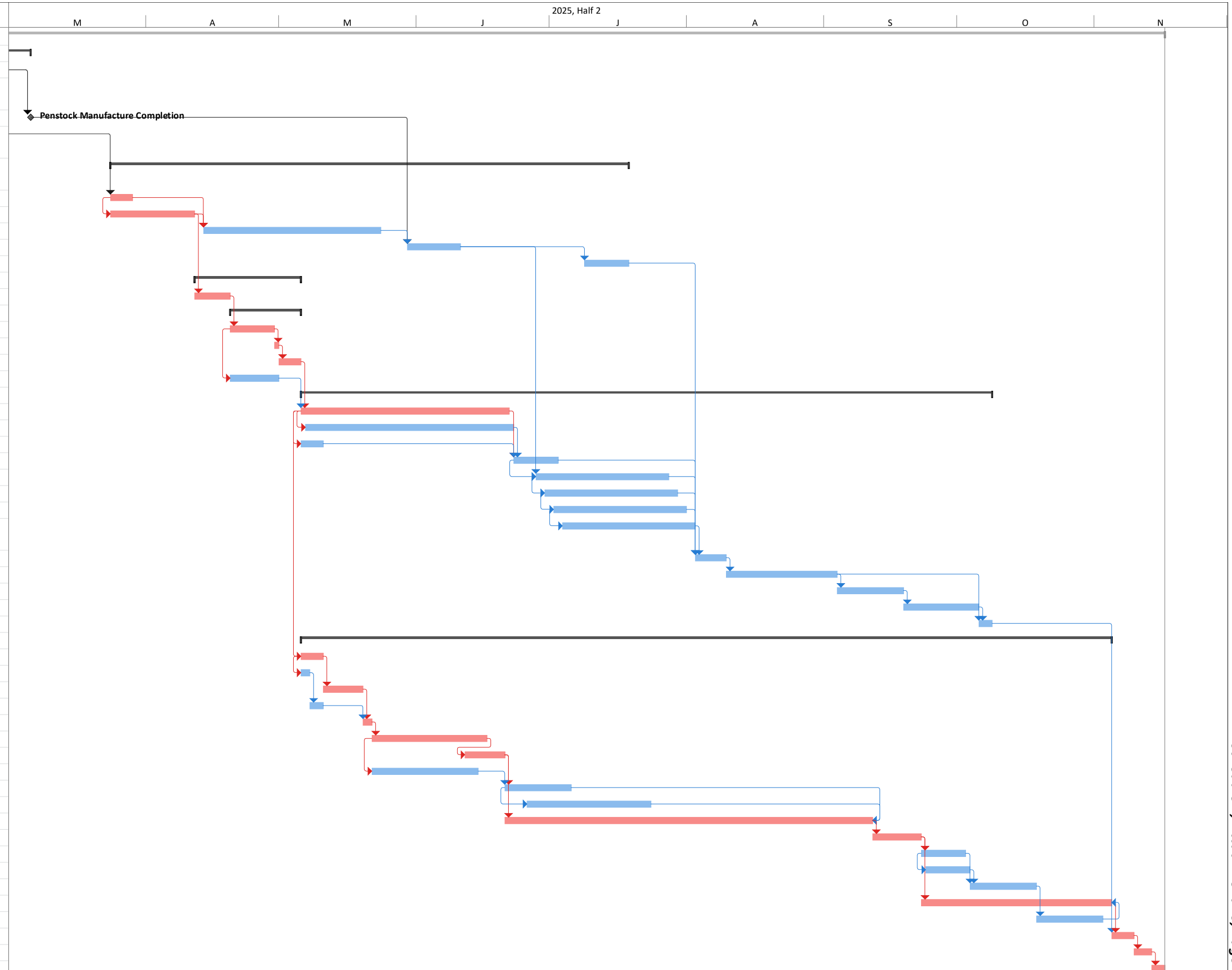
SCALE: AS SHOWN DRAWING NUMBER REVISION

DATE: 10-29-21 -

APPENDIX 8

CONSTRUCTION SCHEDULE

ID	Task Name	Duration	Start	Finish
0	**Bay D'Espoir Penstock Replacement - Option 3**	**592 days**	**Mon 24-04-01**	**Sun 25-11-16**
1	**Milstones**	**240 days**	**Mon 24-04-01**	**Wed 25-03-05**
2	Penstock Manufacture Start	0 days	Mon 24-04-01	Mon 24-04-01
3	Engineering Assessment and Design of Wharf Start	0 days	Mon 24-04-01	Mon 24-04-01
4	Penstock Manufacture Completion	0 days	Wed 25-03-05	Wed 25-03-05
5	Engineering Assessment and Design of Wharf Completion	0 days	Fri 24-06-21	Fri 24-06-21
6	**Supply and Delivery Steel Penstock and Heavy Equipment**	**85 days**	**Mon 25-03-24**	**Fri 25-07-18**
7	Fish Packing Plant Modification	5 days	Mon 25-03-24	Fri 25-03-28
8	Hauling Road Distribution Line Relocation	15 days	Mon 25-03-24	Fri 25-04-11
9	Hauling Road Upgrade	30 days	Mon 25-04-14	Fri 25-05-23
10	Penstock Transportation - First 15 Cans	8 days	Fri 25-05-30	Tue 25-06-10
11	Penstock Transportation - Last 15 Cans	8 days	Wed 25-07-09	Fri 25-07-18
12	**Site Preparation**	**24 days**	**Sat 25-04-12**	**Mon 25-05-05**
13	Silt Fence	8 days	Sat 25-04-12	Sat 25-04-19
14	**Site Access**	**16 days**	**Sun 25-04-20**	**Mon 25-05-05**
15	Intake Distribution Line Relocation	10 days	Sun 25-04-20	Tue 25-04-29
16	Access Road from Site to Q1	1 day	Wed 25-04-30	Wed 25-04-30
17	Permanent Bridge of Penstock 1	5 days	Thu 25-05-01	Mon 25-05-05
18	Laydown Area	11 days	Sun 25-04-20	Wed 25-04-30
19	**Penstock Replacement**	**156 days**	**Tue 25-05-06**	**Wed 25-10-08**
20	Removal of Drainage/Embedment Materials	47 days	Tue 25-05-06	Sat 25-06-21
21	Demolition of 17' Diameter Penstock	47 days	Wed 25-05-07	Sun 25-06-22
22	Temperary Intake Shoring	5 days	Tue 25-05-06	Sat 25-05-10
23	Place Bedding Material	10 days	Mon 25-06-23	Wed 25-07-02
24	Unload,Handle and Alignment Penstock	30 days	Sat 25-06-28	Sun 25-07-27
25	X-Bracing Removal	30 days	Mon 25-06-30	Tue 25-07-29
26	Scaffolding Erecting	30 days	Wed 25-07-02	Thu 25-07-31
27	New Penstock Welding,Manhole Installation, and Welding NDT Test	30 days	Fri 25-07-04	Sat 25-08-02
28	Apply Coating on Welding and Spider Location	7 days	Sun 25-08-03	Sat 25-08-09
29	Backfill of Ganular B and Common fill	25 days	Sun 25-08-10	Wed 25-09-03
30	Bicycle Removal	15 days	Thu 25-09-04	Thu 25-09-18
31	Mechanical Coupling Installation	17 days	Fri 25-09-19	Sun 25-10-05
32	Rock Spalls Installation	3 days	Mon 25-10-06	Wed 25-10-08
33	**Penstock Refurbishment**	**183 days**	**Tue 25-05-06**	**Tue 25-11-04**
34	Water Treatment Plant Buildup	5 days	Tue 25-05-06	Sat 25-05-10
35	Hatches Open	2 days	Tue 25-05-06	Wed 25-05-07
36	Hydro Blasting	9 days	Sun 25-05-11	Mon 25-05-19
37	Temporary Weather Enclosure Installation	3 days	Thu 25-05-08	Sat 25-05-10
38	Air Ventilation and Tunnel Lights Installation	2 days	Tue 25-05-20	Wed 25-05-21
39	Interior Scaffolding Erecting (5 crews)	26 days	Thu 25-05-22	Mon 25-06-16
40	Crack Mapping (5 crews)	9 days	Thu 25-06-12	Fri 25-06-20
41	Excavation Above Spring Line	24 days	Thu 25-05-22	Sat 25-06-14
42	Excavation Manually	15 days	Sat 25-06-21	Sat 25-07-05
43	Exterior Scaffolding Erecting (5 crews)	28 days	Thu 25-06-26	Wed 25-07-23
44	Weld Repair(3 crews)	83 days	Sat 25-06-21	Thu 25-09-11
45	Welding NDT Testing (3 crews)	11 days	Fri 25-09-12	Mon 25-09-22
46	Abrasive Blasting (5 crews)	10 days	Tue 25-09-23	Thu 25-10-02
47	Apply 3-Coating Sytem (5 crews)	10 days	Wed 25-09-24	Fri 25-10-03
48	Coating Testing	15 days	Sat 25-10-04	Sat 25-10-18
49	Backfill	43 days	Tue 25-09-23	Tue 25-11-04
50	Reclose Hatch	15 days	Sun 25-10-19	Sun 25-11-02
51	**Wet Commissioning**	**5 days**	**Wed 25-11-05**	**Sun 25-11-09**
52	**Staging Area Restoration and Hydroseeding**	**4 days**	**Mon 25-11-10**	**Thu 25-11-13**
53	**Silt Fence Removal**	**3 days**	**Fri 25-11-14**	**Sun 25-11-16**



Project: Bay D'Espoir Penstock Re
Date: Fri 21-12-17

Task | Summary | External Milestone | Inactive Summary | Manual Summary Rollup | Finish-only | Critical Split
Split | Project Summary | Inactive Task | Manual Task | Manual Summary | Deadline | Progress
Milestone | External Tasks | Inactive Milestone | Duration-only | Start-only | Critical | Manual Progress

APPENDIX 9

NL EQUIPMENT RENTAL SCHEDULE

FORM 1000

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
Department of Transportation and Works
Highway Design Division

DIVISION 10

NEWFOUNDLAND EQUIPMENT RENTAL SCHEDULE

FORWARD

Rental rates in this schedule include: depreciation, interest, liability insurance, repairs, maintenance, supplies, fuels, lubricants, overhead and profit.

Rates for equipment sizes not shown will be interpolated.

The rental rates stated in this Schedule are Hourly Rates unless indicated otherwise. These rates do not include the operator's wages.

When equipment is rented on an operated basis, the operator's wages will be added to the rental cost. Operator's wages shall be interpreted to mean the basic wage paid the operator plus 35% burden.

The cost of fuel and lubricants supplied by the Department will be deducted from the rental charge at the commercial rate applying in the area.

Rental rates in this Schedule are maximum hourly rates allowed. When equipment is rented for weekly or monthly periods, the Department reserves the right to negotiate rates lower than the hourly rates shown.

Rentals are to be paid for working time only. Lunch hour is not paid as working time. Down time of less than one hour in one shift will not be deducted.

The rental period commences when the unit leaves the owner's premises and shall end on the date of the actual delivery of the unit at the owner's premises or at any other equidistant point, provided transportation conditions are equal and such delivery is requested by the owner. In the case of water transport, the owner will be required to negotiate a rate less than that shown for the period of transport.

Insurance for the unit or units being rented will be the responsibility of the owner.

Machines that may not be represented in this schedule will be subject to rate calculation by the Department.

All rates for equipment rented in Labrador will be increased by 5.8%. This will recognize the different operating conditions associated with work in Labrador.

METRIC CONVERSION			
net flywheel horsepower	X 0.746	- kilowatts	kw
weight (mass)	X 0.45	- kilograms	kg
cubic yards	X 0.7646	- cubic metres	m^3
cubic feet	X 0.028	- cubic metres	m^3
cubic feet per minute (CFM)	X 28.31	- litres/minute	
foot pounds	X 1.355818	- joule	j
feet	X 0.305	- metres	m
inches	X 25.40	- millimetres	mm
ton	X 0.907	- tonne	t
inches	X 2.54	- centimetres	cm
amperes	X NC	- amperes	A
kilowatts (Electric 1,000 watts)	X NC	- kilowatts	kw
gallons - Imperial	X 4.546	- litres	l
NOTE: Model and Specification References are located in the Appendix.			

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SECTION 1 AIR EQUIPMENT AND TOOLS

FORM 1000

1-1 Compressors
1-2 Pneumatic Tools and Accessories
1-3 Jackhammer
1-4 Pavement Breakers
1-5 Grinders
1-6 Blasting Apparatus
1-7 Air Tracks
1-8 Hydraulic Track Drill

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2-2 Distributors
2-3 Pavement Profilers /Cold Planers
2-4 Asphalt Recyclers
2-5 Asphalt Pulverizers/Reclaimers
2-6 Material Transfer Vehicle

SECTION 3 COMPACTION EQUIPMENT
3-1 Rammer Type
3-2 Vibratory Plate Type
3-3 Vibratory Rollers
3-4 Self-Propelled, Tandem Vibrating, Smooth Drums
3-5 Self-Propelled Single Drum, Smooth, Single Drive
3-6 Self-Propelled, Multiple Drum, Smooth for Asphalt or Soils
3-7 Pneumatic Tired
3-8 Steel Wheel - Tandem Smooth Drums for Asphalt
3-9 Self-Propelled, Single Drum, Vibratory, Smooth Drum, Drum Drive

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4-2 Curb – Machines
4-3 Concrete Vibrators
4-4 Concrete Mixers

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5-3 Crawler Mounted - Cable
5-4 Boom Trucks – Hydraulic
5-5 Pile Driving – Diesel Hammer – Open Head
5-6 Pile Driving – Diesel Hammer – Closed Head
5-7 Pile Driving – Vibratory Driver/Extractor

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6-1 Engine Driven

SECTION 7 FLOATS
7-1 Floats with Tractor
7-2 Detachable Gooseneck

SECTION 8 EXCAVATORS
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8-2 Hydraulically Operated, Crawler Mounted
8-3 Telescopic Boom Excavators, Truck Mounted
8-4 Hydraulic Excavator Attachments
8-5 Mini Excavators

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9-2 Articulated
9-3 With Scarifier

SECTION 10 RUBBER TIRED FRONT END LOADERS (4x4)

SECTION 11 CRAWLER TYPE LOADERS

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12-2 Skid Steer Loaders

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13-2 Electric Submersible
13-3 Diaphragm
13-4 Discharge Hoses
13-5 Test/Fire Pump

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SECTION 15 TRACTOR-DOZERS

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16-2 Off Highway Trucks
16-3 Articulated Rock Trucks
16-4 Water Trucks
16-5 Paint Stripers
16-6 Truck Mounted Striper
16-7 Dump Trucks
16-8 Dump Truck/Tag Along Combinations
16-9 Stone Slingers
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17-2 Torch

SECTION 18 MISCELLANEOUS EQUIPMENT
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18-2 Boilers
18-3 Steam Cleaners
18-4 Portable Scales
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18-8 Gas Powered Jackhammers
18-9 Survey Equipment
18-10 Tapping Gear
18-11 Trench Box
18-12 Butt Fusion Machine
18-13 Chain Saw
18-14 Sweepers - Towed or Attachment
18-15 Sweepers - Self Propelled
18-16 Boats
18-17 Outboard Boat Motors

FORM 1000

SECTION 1

AIR EQUIPMENT AND TOOLS

1-1 Compressor (Portable or Self-Propelled)

Rated Litre/Minute	Rated C.F.M.	Rate Per Hour
1700 - 2400	60 - 85	$ 9.25
2450 - 3550	86 - 125	$11.75
3600 - 5000	126 - 180	$17.43
5100 - 7000	181 - 250	$20.62
7140 - 7900	252 - 280	$26.50

Rated Litre/Minute	Rated C.F.M.	Rate Per Hour
17000	600	$48.35
21200	750	$60.75
24000	850	$65.25
25400	900	$69.50

1-2 Pneumatic Tools and Accessories

Rock Drills NOTE: (1) Schedule of rates not including steels or bits. Crawler mounted with hammer off:

Bore - Millimetres	Bore - Inches	Rates Per Hour
82.6 - 101.6	3¼" - 4"	$42.00
108.0 - 127.0	4¼" - 5"	$50.00

Bore - Millimetres	Bore - Inches	Rates Per Hour
133.4 - 152.4	5¼: - 6"	$59.00

1-3 Jackhammer

SIZE - Kilograms	SIZE - Pounds	Rate Per Hour
Up to 27 kg	Up to 60 lbs	$3.75
36 kg	80 lbs.	$4.24

1-4 Pavement Breakers

SIZE - Kilograms	SIZE - Pounds	Rate Per Hour
14 - 18	30 - 40	$3.12
23 - 27	50 - 60	$3.75

SIZE - Kilograms	SIZE - Pounds	Rate Per Hour
32 - 36	70 - 80	$4.25

1-5 Grinders

	Rate Per Hour
Bit Grinders - Bench Type	$2.90
Over 10886	$4.98

	Rate Per Hour
Surface Grinders - 152.4 mm or 6" diameter stone	$2.90

1-6 Blasting Apparatus

	Millimetres	Inches	Rate Per Hour
50 Shot Blaster	10	0.40	$0.49
1,000 Shot Blaster	27	1.06	$1.19

	Millimetres	Inches	Rate Per Hour
Sequential Blaster	142	5.60	$6.23

1-7 Air Tracks, Crawler Mounted, Compressor, Drill Steel, Bits, Hose and Incidental Hardware Included in Rate

Bore		Rate Per Hour
Millimetres	Inches	
Up to 127.0	Up to 5	$119.67
Over 127.0 to 165.1	Over 5 to 6.5	$123.10

Bore		Rate Per Hour
Millimetres	Inches	
Over 165.1 to 177.8	Over 6.5 to 7	$130.18
Over 177.8 to 203..2	Over 7 to 8	$141.87

FORM 1000

1-8 Hydraulic Track Drill, Power Drill Steel and Bit Extra

Millimetres	Rate Per Hour
Up to 127.0 bore	$217.00

SECTION 2

ASPHALT AND BITUMINOUS EQUIPMENT

2-1 Spreaders and Finishers - Crawler or Rubber Tire Mounted

Metres	Feet	Rate Per Hour
Small - basic 2.44m	Small - basic 8'	$91.44
Medium - 3.05m - 4.27m	Medium - 10' - 14'	$117.36

Metres	Feet	Rate Per Hour
Large - 3.05m - 4.88m	Large - 10' - 16'	$167.24
With electric screed control		$15.84

2-2 Distributors - Truck mounted complete with power unit and spray bars

Litres	Imperial Gallons	Rate Per Hour
6819	1500	$69.15
9092	2000	$75.82
11365	2500	$78.10

Litres	Imperial Gallons	Rate Per Hour
13638	3000	$88.24
18184	4000	$93.30

2-3 Pavement Profilers/ Cold Planers (Including replacement teeth)

Cut Width - Centimetres	Cut Width - Inches	Rate Per Hour
Under 30	Under 12	$123.50
30-45	12-18	$194.00
76	30	$238.50
137	54	$385.00

Cut Width - Centimetres	Cut Width - Inches	Rate Per Hour
168	66	$435.00
205-252	81-99	$525.00
253-381	100-150	$625.00

2-4 Asphalt Recyclers

Capacity - tonnes per hour	Rate per Hour
4-9	$33.30

2-5 Asphalt Pulverizers - Reclaimers

Rated kW	Rate per Hour
250	$245.70
325	$289.80
440	$352.25

2-6 Material Transfer Vehicle – Self propelled. min. storage capacity – 9100 kg with conveyor system and either (a) auger system or (b) paddle mixers in the hopper insert

Capacity	Rate per Hour
9100 kg	$218.50

SECTION 3

COMPACTION EQUIPMENT

3-1 Rammer Type

Strokes/Minute	Mass Kilograms	Mass Pounds	Rate Per Hour
300 - 800	Up to 67.5	Up to 150	$8.20
300 - 800	68 - 112.5	151 - 250	$9.35

Strokes/Minute	Mass Kilograms	Mass Pounds	Rate Per Hour
300 - 800	113 - Over	251 - Over	$9.80

FORM 1000

3-2 Vibratory Plate Type - Manually Guided

Mass (kilograms)	Plate Width (millimetres)	Mass (pounds)	Plate Width (inches)	Rate Per Hour
Up to 126	Up to 610	Up to 280	Up to 24"	$8.75
126.5 - 225	457 - 914	281 - 500	18" - 36"	$11.25
225.5 - 360	508 - 813	501 - 800	20" - 32"	$14.25
360.5 & over	508 - 914	801 - over	20" - 36"	$16.75

3-3 Vibratory Rollers - Manually Guided

Drum Length - Centimetres	Drum Length - inches	Rate Per Hour
71.1cm - 76.2cm single drum	28" - 30" single drum	$8.00
38.1cm - 55.9cm tandem drum	15" - 22" tandem drum	$11.25
61.0cm - 66.0cm tandem drum	24" - 26" tandem drum	$13.75

Drum Length - Centimetres	Drum Length - inches	Rate Per Hour
71.1cm - 76.2cm tandem drum	28" - 30" tandem drum	$16.00
81.3cm - 91.4cm tandem drum	32" - 36" tandem drum	$23.00

3-4 Self-Propelled - Tandem Vibrating, Smooth Drums

Drum Length - Centimetres	Kilograms	Inches	Pounds	Rate Per Hour
Up to 106.7	Up to 3175	Up to 42	Up to 7,000	$19.50
109.0 - 139.7	3629 - 5670	43 - 55	8,000 – 12,500	$58.00
142.0 - 185.0	6804 - 10433	56 - 73	15,000 - 23000	$76.00
188.0 - 216.0	10886 – 11,820	74 - 85	24,000 – 26,000	$93.40
216.0 and over	Over 11,820	85 - 90	Over 26,000	$104.25

3-5 Self-Propelled - Single Drum, Smooth, Single Drive

Centimetres	Kilograms	Inches	Pounds	Rate Per Hour
101.6 - 127	2722 - 3269	40 - 50	6000 - 8000	$43.25
129.5 - 152	3856 - 5443	51 - 60	8500 - 12000	$59.00
154.9 - 215	5670 - 9072	61 - 85	12500 - 20000	$72.75
218.4 - 266	9526 - 13608	86 - 105	21000 - 30000	$99.00

3- 6 Self-Propelled - Multiple Drum, Smooth, for Asphalt or Soils

Centimetres	Kilograms	Inches	Pounds	Rate Per Hour
109.0 - 203	3628 - 5440	43 - 55	8000 - 12000	$58.25
152.4 -	5443 - 7258	60 - 80	12000 - 16000	$76.75

3-7 Pneumatic Tired

No of Wheels	Operating Mass - Tonne	Operating Mass - Ton	Rate Per Hour
9 wheel	Up to 8.7	Up to 10	$37.25
9 - 13 wheel	8.7 - 13	10 - 15	$44.25
7 - 9 wheel	14 - 22	16 - 25	$61.75

No of Wheels	Operating Mass - Tonne	Operating Mass - Ton	Rate Per Hour
7 - 9 wheel	23 - 27	26 - 30	$68.50
7 - 9 wheel	28 - 32	31 - 35	$68.50

FORM 1000

3-8 Steel Wheel - Tandem Smooth Drums, for Asphalt, 2 Axles

Working Mass - Tonne	Working Mass - Ton	Rate Per Hour
2.7 - 4.5	3.1 - 5	$38.65
4.6 - 7.2	5.1 - 8	$36.90

Working Mass - Tonne	Working Mass - Ton	Rate Per Hour
7.3 - 10.8	8.1 - 12	$42.90
10.9 - 14.5	12.1 - 16	$48.25

3-9 Self-Propelled, Vibratory, Single Drum, Smooth Drum, Drum Drive

Centimetres	Kilograms	Inches	Pounds	Rates Per Hour
154.9 - 177.8	4990 - 6804	61 - 70	11000 - 15000	$59.00
180.5 - 215.9	6350 - 9752	71 - 85	14000 - 21500	$72.75
180.5 - 215.9	9752 - 11340	71 - 85	21500 - 25000	$85.35

SECTION 4

CONCRETE PLACING EQUIPMENT

4-1 Concrete Saws - Self-Propelled - Single Blade

Kilowatts	Horsepower	Rate Per Hour
13	18	$12.75
22	30	$17.70

Kilowatts	Horsepower	Rate Per Hour
28	37	$17.70
45	60	$23.50

4-2 Curb Machines

	Rate Per Hour
Slip form Curb and Gutter Machine - Fully Automatic	$100.00

4-3 Concrete Vibrators

	Rate Per Hour
Electric	$4.40
Gas	$4.30
Buggy Engine	$7.25

4-4 Concrete Mixers

Capacity – cubic foot	Rate per Hour
3.5	$6.25
6	$11.25
11	$16.75
16	$19.50

4-5 Concrete Pumper Trucks

Pump & Boom included	Tons	Rate Per Hour
Under 28m Boom	Under 92 feet Boom	$175.00
28m Boom	92 foot Boom	$190.00
31m & 32 m Boom	102 and 105 foot Boom	$210.00
36m Boom	118 foot Boom	$233.00
42 m Boom	138 foot Boom	$290.00
52 m Boom	171 foot Boom	$450.00
Extra Pipe/Hose attachment		$10.00

FORM 1000

SECTION 5

CRANES & PILE DRIVING EQUIPMENT

5-1 Mobile or Self-Propelled - Hydraulic

Tonne	Ton	Rate Per Hour
4.5 - 7.3	5 - 8	$63.25
9.07 - 13.6	10 - 15	$89.50
15.5 - 16.3	16 - 18	$96.50
18.1 - 27.2	20 - 30	$123.00

Tonne	Ton	Rate Per Hour
36.3 - 40.8	40 - 45	$157.00
45.3 - 49.9	50 - 55	$203.00
54.4 - 58.9	60 - 65	$219.00

5-2 Truck Mounted - Cable

Tonne	Ton	Rate Per Hour
9.07 - 13.6	10 - 15	$81.00
14.5 - 18.1	16 – 20	$105.00
19.1 – 27.2	21 - 30	$125.75
28.1 - 36.3	31 - 40	$145.00

Tonne	Ton	Rate Per Hour
37.2 - 45.4	41 – 50	$181.50
46.3 - 59.0	51 - 65	$230.00
59.9 - 72.6	66 - 80	$265.00

5-3 Crawler Mounted - Cable

Tonne	Ton	Rate Per Hour
10.9 - 13.6	12 - 15	$75.00
14.5 - 22.7	16 - 25	$95.00
23.6 - 27.2	26 – 30	$120.00
18.1 - 27.2	31 - 40	$145.00
37.2 - 45.4	41 – 50	$165.00
46.3 - 54.4	51 – 60	$200.00

Tonne	Ton	Rate Per Hour
55.3 - 63.5	61 - 70	$220.00
64.4 - 72.6	71 – 80	$240.00
73.5 - 86.2	81 - 95	$270.00
87.1 - 90.7	96 – 100	$280.00
91.6 - 127.0	101 – 140	$320.00
127.9 – 136.1	141 - 150	$345.00

5-4 Boom Trucks - Hydraulic

Tonnes	Rate per Hour
< 8.0	$35.00
8.0 to 11.99	$57.00
12.0 to 17.99	$67.00

Tonnes	Rate per Hour
18.0 to 23.99	$92.00
24.0 and over	$119.00

5-5 Pile Driving Equipment – Diesel Hammer – Open Head

Ft-lbs force	Rate per Hour
9000 -16 000	$31.00
17 000 - 19 000	$36.00
22 000 – 26 000	$40.50
27 000 – 30 000	$50.00

Ft-lbs force	Rate per Hour
31 000 – 39 000	$60.00
40 000 – 59 000	$80.00
60 000 – 82 999	$100.00
84 000 – 100 000	$126.25

5-6 Pile Driving Equipment – Diesel Hammer – Closed Head

Ft-lbs force	Rate per Hour
8000 -10 000	$27.00
15 000 – 21 000	$45.25
26 000 – 31 000	$55.00

Ft-lbs force	Rate per Hour
32 000 – 40 000	$65.00
45 000 – 50 000	$80.00

5-7 Pile Driving Equipment – Driver/Extractor, Vibratory Centrifugal, Including Power Excluding Crane

Driving Force, KN	Rate per Hour
245	$69.05
392	$89.85

Driving Force, KN	Rate per Hour
980	$171.75
1471	$210.65

FORM 1000

637	$118.30

SECTION 6

GENERATORS

6-1 Engine Driven - Gasoline or Diesel - Air or Water Cooled

Description	Rate Per Hour
Less than 3 KW	$4.25
3kW to 3.99kW	$5.25
4kW to 4.99kW	$6.50
5kW to 5.99kW	$7.25
6kW to 6.99kW	$8.75
7kW to 9.99 kW	$11.75

Description	Rate Per Hour
10kW to 14.99kW	$12.75
15kW to 24.99kW	$16.25
25kW to 34.99kW	$18.25
35kW to 39.99kW	$20.25
40kW to 49.99kW	$24.25
50kW to 129.99kW	$27.50

Description	Rate Per Hour
130kW to 149.99kW	$41.75
150kW to 174.99kW	$53.50
175kW and Greater	$79.25

SECTION 7

FLOATS

7-1 **Floats with Tractor - Rigid Gooseneck**

Tonnes	Tons	Rate Per Hour
14.5-18.1 tonnes single axle trailer	16-25 tons single axle trailer	$61.84
23.6-31.7 tonnes tandem axle trailer	26-35 tons tandem axle trailer	$104.92
32.7-40.8 tonnes tandem axle trailer	36-45 tons tandem axle trailer	$115.97
41.7-49.9 tonnes tandem axle trailer	46-55 tons tandem axle trailer and up	$127.52

7-2 Detachable Float – Gooseneck with Tractor

Tonnes	Rate Per Hour
Up to - 36 tonnes	$100.00
42 - 50 tonnes	$112.00

Tonnes	Rate Per Hour
54 tonnes and up	$115.00

SECTION 8

EXCAVATORS

8-1 Hydraulically Operated, Rubber Tired, Four Wheel Drive, Capacity Heaped

Cubic Metres	Cubic Yards	Rate Per Hour
0.38 - 0.56	1/2 - 5/8	$83.00
0.57 - 0.67	3/4 - 7/8	$93.00

8-2 Hydraulically Operated, Crawler Mounted, Capacity Heaped

Cubic Metres	Cubic Yards	Rate Per Hour
.38 - .56	1/2 - 5/8	$88.00
.57 - .75	3/4 - 7/8	$100.00
.76 - 1.13	1 - 1 1/4	$110.00
1.14 - 1.52	1 1/2 - 1 7/8	$155.00
1.53 - 1.89	2 - 2 1/4	$175.00

Cubic Metres	Cubic Yards	Rate Per Hour
1.90 - 2.28	2 1/2 - 2 7/8	$217.00
2.29 - 3.05	3 - 3 7/8	$274.00
3.06 - 3.81	4 - 4 7/8	$337.00
3.82 and over	5 and over	$370.00

FORM 1000

Add 15% for Long Reach & Super Long Reach Boom applications when authorized (rated digging depth over 11.5 meters)

8-3 Telescopic Boom Excavators, Truck Mounted, Capacity Heaped

Cubic Metres	Cubic Yards	Rate Per Hour
to .38	to 1/2	$64.00
.38 - .44	1/2 - 5/8	$95.00
.44 - .57	5/8 - 3/4	$115.50

Cubic Metres	Cubic Yards	Rate Per Hour
.57 - .67	3/4 - 7/8	$134.50
.67 - .76	7/8 – 1	$145.00
.76 – 1.15	1 – 1.5	$160.00

8-4 Hydraulic Excavator Attachments

Hydraulic Breakers

Impact Energy (ft-lb)		Rate Per Hour
Joules	Foot Pounds	
205 - 675	150 - 499	$18.00
676 - 1355	500 - 999	$27.75
1356 - 2710	1000 - 1999	$84.50
2711 - 4065	2000 - 2999	$109.00
4066 - 5422	3000 - 3999	$109.00

Impact Energy (ft-lb)		Rate Per Hour
Joules	Foot Pounds	
5423 - 6778	4000 - 4999	$109.00
6779 - 8134	5000 - 5999	$134.00
8135 - 9490	6000 - 6999	$138.00
>9490	>7000	$140.44

Hydraulic Brush Cutters

Cutting Swath		Rate Per Hour
Millimetres	Inches	
1321	54	$35.00
1676	66	$46.00

Hydraulic Concrete Crushers/Shears

Crushing Force in Tonnes	Rate Per Hour
15 - 30	$26.24
31 - 50	$55.34
51 - 100	$86.11

Crushing Force in Tonnes	Rate Per Hour
101 - 150	$90.75
151 - 200	$109.31

Hydraulic Tamper

Maximum Impulse Force - Kilograms	Rate per Hour
1000 - 2500	$8.41
2501 - 5000	11.14
5001 - 7500	$19.56

Maximum Impulse Force - Kilograms	Rate per Hour
7501 - 10000	$24.26
10001 - 12500	$29.04

8-4 Mini Excavators - Tracked

Operating Weight (kg)	Rate per Hour
Up to 1999	$29.25
2000 to 2999	$37.25

Operating Weight (kg)	Rate per Hour
3000 to 3999	$46.25
4000 and Over	$54.00

SECTION 9

MOTOR GRADERS

9-1 Rigid Frame

Net Engine HP	Rate per Hour
70 to 79	$46.50
80 - 99	$57.00
100 - 125	$67.75
126 - 150	$76.25

Net Engine HP	Rate per Hour
181 - 210	$90.75
211 -245	$101.25
246 -269	$118.00
270 and Up	$170.75

FORM 1000

151 - 180	$84.50		

9-2 Articulated

Net Engine HP	Rate per Hour
Up to 59	$50.00
60 - 79	$55.25
80 - 99	$57.00
100 - 125	$67.75

Net Engine HP	Rate per Hour
126 – 150	$76.25
151 – 180	$84.50
181 – 210	$90.75
211 - 245	$101.25

Net Engine HP	Rate per Hour
246 - 269	$118.00
270 and Up	$170.75

9-3 With Scarifier

Kilograms	Rate per Hour
Up to 10999	$5.50
11 000 - 12 999	$7.50

Kilograms	Rate per Hour
13 000 - 18999	$14.50
19 000 and Over	$20.50

With Vee Plow Add $5.60 Per Hour - With Wing Add $4.40 Per Hour

SECTION 10

RUBBER TIRED FRONT END LOADER (FOUR WHEEL DRIVE)

10-1 Minimum S.A.E. Operating Weight Rating

Minimum Operating Weight kgs	S.A.E. Bucket Sizes (m^3)	Rate Per Hour
Less than 6570	Up to 1.14	$54.00
6570 to 8069	1.15 - 1.52	$58.00
8070 to 9519	1.53 - 1.90	$58.00
9520 to 10879	1.91 - 2.28	$66.75
10880 to 13483	2.29 - 2.67	$86.75
13484 to 14959	2.68 - 3.05	$90.00

Minimum Operating Weight kgs	S.A.E. Bucket Sizes (m^3)	Rate Per Hour
14960 to 18589	3.06 - 3.43	$103.80
18590 to 23119	3.44 - 3.81	$117.15
23120 to 24929	3.82 - 4.19	$137.35
24930 to 26290	4.20 - 4.58	$159.71
More than 26290	4.59 -	$184.95

Attachments - wing add $4.40 per hour
Attachments – shouldering machine add $35.25 per hour
NOTE: "Operating weights will be the final authority on rates to be charged. Additional weight caused by the usage of any form of counter weight devices will not change the rate classification."

SECTION 11

CRAWLER TYPE LOADERS

11-1 Crawler Type Loaders Minimum S.A.E. Operating Weight Rating

Kilograms	Pounds	Rate Per Hour
4536 - 6123	10000 - 13500	$39.83
7484	16500	$48.88
9526	21000	$55.78

Kilograms	Pounds	Rate Per Hour
13608	30000	$76.75
16782	37000	$84.77
19505	43000	$107.89

SECTION 12

FRONT END LOADER / BACKHOE COMBINATION

12-1 Rubber Tired

Kilowatts	Horsepower	Rate Per Hour
23 - 33	31 - 44	$39.47
34 - 48	45 - 65	$44.59
49 - 63	66 - 85	$53.70

Kilowatts	Horsepower	Rate Per Hour
64 - 82	86 - 110	$70.95
83 - 112	111 - 150	$100.15

If backhoe bucket is not required, reduce appropriate loader backhoe rate by 33 1/3%.

FORM 1000

12-2 Skid Steer Loaders Rubber Tired

Rated Operating Capacity	Horsepower	Rate Per Hour
Up to 320 kg	Up to 44	$23.00
321 – 650 kg	49 - 52	$26.75
651 – 850 kg	55 - 65	$28.75

Kilowatts	Horsepower	Rate Per Hour
851 – 1100 kg	57 - 73	$33.50
1101 – 1400 kg	82 - 85	$37.75
1401 kg and up	90 - 94	$43.50

Attachments – Sweeper add $5.50; Asphalt Cold Planer/Milling device add $10.50; Hole Auger (up to 300 mm) add $2.50

SECTION 13

PUMPS

13-1 Centrifugal
Including 6.1m - 20' Suction Hose, 7.6m - 25' Discharge Hose

Millimetres	Inches	Rate Per Hour
50.8mm - gasoline	2" - gasoline	$ 4.13
76.2mm - gasoline	3" - gasoline	$5.52
101.6mm - gasoline	4" - gasoline	$9.92
152.4mm - gasoline	6" - gasoline	$15.30
203.2mm - gasoline	8" - gasoline	$20.35

Millimetres	Inches	Rate Per Hour
76.2mm - diesel	3" - diesel	$5.15
101.6mm - diesel	4" - diesel	$9.92
152.4mm - diesel	6" - diesel	$17.00
203.2mm - diesel	8" - diesel	$21.05
254.0mm - diesel	10" - diesel	$25.85

13-2 Electric Sumbersible Including cable and 7.6 m - 25' discharge hose

Millimetres	Inches	Rate Per Hour
50.8 mm	2"	$3.78
76.2 mm	3"	$6.35
101.6 mm	4"	$12.70

Millimetres	Inches	Rate Per Hour
152.4 mm	6"	$19.09
203.2 mm	8"	$32.51
254.0 mm	10"	$36.00

13-3 Diaphragm - Gasoline portable including 6.1m - 20' suction, 7.6 - 25' discharge hose

Millimetres	Inches	Rate Per Hour
50.8mm	2"	$4.38
76.2mm	3"	$5.62

Millimetres	Inches	Rate Per Hour
101.6mm	4"	$8.00

13-4 Pump Discharge Hoses - for each metre in excess of 7.6m

Millimetres	Inches	Rate Per Hour
50.8mm	2"	$0.02
76.2mm	3"	$0.03
101.6mm	4"	$0.04

Millimetres	Inches	Rate Per Hour
152.4mm	6"	$0.08
203.2mm	8"	$0.13
254.0mm	10"	$0.21

13-5 Test/Fire Pump - Gasoline with attachments

Millimetres	Inches	Rate Per Hour
50.8mm	2"	$6.77

SECTION 14

SNOW CLEARING EQUIPMENT

14-1 Snowblowers, Loader Mounted
NOTE:
1. Hourly rate does not include Carrier

Model	Rate Per Hour

FORM 1000

Vohl DV4000	$148.34
SMI 3200	$91.13
SnoGo MP-3D	$91.13
RPM Tech RPM-227	$148.34

14-2, Plow Trucks

NOTE:

1. Plow trucks are to be complete with a front blade, side wing and a spreader capable of dispensing ice control materials
2. Rate does not include operator

Model	Rate per Hour
Single Axle	$85.00
Tandem Axle	$99.00

SECTION 15

TRACTOR - DOZERS

15-1

NOTE:

1. Tractor-Dozers that have been discontinued or put out of production for 15 years are deleted from the current reference lists.
2. Any crawler Tractor-Dozer not included in these lists will be rated by using a comparable Tractor-Dozer chosen by the Department.
3. The owner shall supply the Department with proof of net kilowatt or net horsepower capacities.
4. Power shift machines are rated by net engine kilowatt or net engine horsepower.

Rates for Tractor, Crawler - Complete with Blade

Kilowatt	Horsepower	Rate Per Hour	Kilowatt	Horsepower	Rate Per Hour
30 - 41	40 - 55	$48.30	102 - 131	136 - 175	$106.39
42 - 52	56 - 70	$48.30	132 - 168	176 - 225	$138.05
53 - 60	71 - 80	$59.67	169 - 254	226 - 340	$177.10
61 - 75	81 - 100	$65.36	255 - 328	341 - 440	$288.50
76 - 101	101 - 135	$88.09			

Hydraulic Ripper - Rear Mounted

Rating	Rate Per Hour	Rating	Rate Per Hour
up to 135 Hp	$18.20	226 to 340 Hp	$36.50
136 to 175 Hp	$25.90	341 to 440 Hp	$52.30
176 to 225 Hp	$31.50		

SECTION 16

TRUCKS

16-1 Pickup Trucks - capacity shown is Gross Vehicle Mass Two Wheel Drive

Kilograms	Pounds	Rate Per Hour	Kilograms	Pounds	Rate Per Hour
2268 - 2812	5000 - 6200	$16.58	3855 - 4175	8500 - 9200	$18.18
2812 - 3810	6200 - 8400	$17.88	4200 - 4536	9300 - 10000	$18.56

Four Wheel Drive - Add $0.45 per hour **Attachments** – Pony utility trailer add $15.50 for tandum; add $19.50 for triaxle trailer

16-2 OFF HIGHWAY TRUCKS

- diesel powered, rear dump, full cab
- capacity shown is "Rated Payload Capacity"

Tonne	Ton	Rate Per Hour	Tonne	Ton	Rate Per Hour
19.0 - 22.7	21 - 25	$117.50	28.1 - 31.8	31 - 35	$170.78
23.6 - 27.2	26 - 30	$149.25	32.7 - 40.8	36 - 45	$197.00

16-3 ARTICULATED ROCK TRUCKS

- diesel powered, rear dump, full cab
- capacity shown is "Rated Payload Capacity"

FORM 1000

Tonne	Ton	Rate Per Hour
19.0 - 22.7	21 - 25	$142.33
23.6 - 27.2	26 - 30	$170.78

Tonne	Ton	Rate Per Hour
28.1 - 31.8	31 - 35	$196.71
32.7 - 40.8	36 - 45	$216.38

16-4 Water Trucks

Hourly truck rates will apply according to manufacturer's GVM rating plus the following: Tank, Water Pump and Spray Bar.

Tank Capacity - Litre	Tank Capacity - Gallons	Rate Per Hour
up to 4541	up to 999	$30.61
4546 - 6814	1000 - 1499	$36.37

Tank Capacity - Litre	Tank Capacity - Gallons	Rate Per Hour
6819 - 9087	1500 - 1999	$41.00

16-5 Paint Stripers

Tank Capacity - Litre	Tank Capacity Gallons	Rate Per Hour
45 - 63 litre hand or self-propelled	10 - 14 gal.	$30.83
67.5 - 81 litre self-propelled	15 - 18 gal.	$53.94

16-6 Truck Mounted Stripers

Rating	Rate Per Hour
28,000 lb to 34,000 lb G V W R	$120.00

16-7 Dump Trucks

Vehicle	Rate Per Hour (Operator Included)
Single Axle Vehicle	$55.00
Tandem Axle Vehicle	$80.00
Tandem - Tandem Vehicle	$98.00

Vehicle	Rate Per Hour (Operator Included)
Tractor Dump Trailer (including Belly Dump)	$110.00
Tractor Only	$75.00

16-8 Dump Truck / Tag Along Combinations

Equipment	Rate Per Hour (Operator Included)
Tandem Axle Dump Truck & Single Axle Tag-along	$82.00
Tandem Axle Dump Truck & Tandem Axle Tag-along	$94.00

Equipment	Rate Per Hour (Operator Included)
Tandem Axle Dump Truck & Tri-axle Tag-along	$101.00
Tandem Axle Dump Truck & Hydroseeder	$92.00

16-9 Stone Slingers

Equipment	Rate Per Hour
Stone Slinger	$56.86

16-10 Stake Body Trucks

Manufacturers GVW - kilograms	Rate Per Hour
Up to 6803	$21.60
6804 to 8844	$31.13
8845 to 13607	$32.50

Manufacturers GVW - kilograms	Rate Per Hour
13608 to 20411	$35.05
Over 20412	$40.25

Attachments Hydraulic boom up to 9t add $15.00
Hydraulic boom over 9t add $22.00

FORM 1000

SECTION 17

WELDING EQUIPMENT

17-1 Arc Welder
Portable Engine Driven (Diesel or Gasoline). Rods Extra.

Amperes	Rate Per Hour
100 - 200	$5.62
200 - 300	$8.25

Amperes	Rate Per Hour
260 - 500	$11.75

17- 2 Torch including Acetylene and Oxygen (rods extra if required)

	Rate Per Day
Torch	$21.66

SECTION 18

MISCELLANEOUS EQUIPMENT

18-1 Air Benders and Cutters
Benders

Description	Rate Per Hour
Large Hand Operated	$1.23
Power Operated	$9.61

Cutters

Description	Rate Per Hour
Hand Operated	$1.23
Power Operated	$8.20

18-2 Boilers - Oil fired, skid mounted

Kilowatts	Horsepower	Rate Per Hour
15	20	$5.50
22	30	$7.50
37	50	$10.75

Kilowatts	Horsepower	Rate Per Hour
75	100	$16.25
112	150	$24.75

18-3 **Steam Cleaners**

Litres	Imperial Gallons	Rate Per Hour
455 - 546	100 - 120	$3.95
682 - 818	150 - 180	$5.06

Litres	Imperial Gallons	Rate Per Hour
1023 - 1137	225 - 250	$10.15

18-4 Portable Scales

Tonne	Metres	Ton	Feet	Rate Per Hour
22.7 - 27.2	7.6m - 2.7m	25 - 30	25' x 9' deck	$13.75
27.2 - 36.3	9.1m - 3.1m	30 - 40	30' x 10' deck	$16.00

Tonne	Metres	Ton	Feet	Rate Per Hour
36.3 - 45.4	12.2m - 3.1m	40 - 50	40' x 10' deck	$18.25

FORM 1000

18-5 Semi-portable Scales

Tonne	Metres	Rates Per Hour
22.7 - 27.1	7.6m x 2.7m	$13.75
27.2 - 36.3	9.1m x 3.1m	$16.00
36.4 - 45.4	12.2m x 3.1m	$18.25

Tonne	Metres	Rates Per Hour
45.5 - 54.4	13.7m x 3.1m	$20.75
54.5 and Greater	15.2m x 3.7m	$22.00

18-6 Melting Kettle (includes propane)

	Rate Per Hour
Trailer Mounted 750 - 825 litres	$24.66
Level and Equipment	$2.71

18-7 Concrete Routers

	Rate Per Hour
Gas Powered 4.5 W	$11.10
Gas Powered 18.5 W	$22.20

18-8 Gas Powered Jackhammers

	Rate Per Hour
Gas Powered Jackhammers	$1.77

18-9 Survey Equipment

	Rate Per Hour
Sewer Lazer	$4.49
Theodolite and Equipment	$2.69

	Rate Per Hour
Level and Equipment	$2.50
Total Station and Equipment	$3.25
GPS Package incl. Rover & Base	$3.25

18-10 Tapping Gear

	Rate Per Hour
Up to 2"	$4.58

18-11 Trench Box

	Rate Per Hour
Standard (4' x 8' x 16')	$3.47

18-12 Butt Fushion Machine

	Rate Per Hour
Up to 14" Gen set N/I	$8.67

18-13 Chain Saw

	Rate Per Day

FORM 1000

All Sizes	$34.00

18-14 Sweepers - Towed or Attachment

Description	Broom Width	Rate Per Hour
Towed - Traction Type	5 - 6 ft (152 - 183 cm) 7 - 8 ft (213 - 244 cm)	$9.75 $11.05
Towed - Separate Engine	5 - 6ft (152 - 183 cm) 7 - 8 ft (213 - 244 cm)	$11.05 $13.00
Attachment - Hydraulic Driven	5 - 6 ft (152 - 183 cm) 7 - 8 ft (213 - 244 cm)	$10.40 $11.70
Attachment - PTO Driven	5 - 6 ft (152 - 183 cm) 7 - 8 ft (213 - 244 cm)	$9.75 $11.05

18-15 Sweepers - Self Propelled

Description	Capacity	Rate Per Hour
Self Loading	$0.8m^3$ (1yd3) $1.5m^3$ (2yd3) $2.5m^3$ (3yd3) $3.1m^3$ (4yd3) $3.8m^3$ (5yd3)	$37.91 $42.78 $48.46 $55.50 $67.15

18-16 Boats

Length	Rate Per Hour
Up to 4.57 m (15 foot)	$3.63
4.88 m (16') to 5.48 m (18')	$4.62
5.79 (19') to 6.40 (21')	$5.44

Manufacturers GVW - kilograms	Rate Per Hour
6.71 m (22') to 7.32 m (24')	$6.31
7.62 m (25') to 8.23 m (27')	$6.96
8.53 m (28') and Over	$7.40

Includes life jackets per each occupant, anchor and safety apparatus per Coast Guard requirements

18-17 Outboard Boat Motor

Horsepower	Rate Per Hour
Up to 10	$4.51
11 to 15	$5.12
16 to 25	$ 5.95
26 to 40	$6.75

Manufacturers GVW - kilograms	Rate Per Hour
41 to 50	$12.20
51 to 70	$13.25
71 to 100	$14.50
101 to 130	$16.00

Includes all special fuels and lubricants

SECTION 19

TRAFFIC CONTROL EQUIPMENT

19-1 Truck Mounted Attenuators

Description	Rate Per Hour
Rated up to 75 km/hr	$6.50
Rated 75 – 100 km/hr	$8.50

19-2 Arrow Boards & Radar Display Signs

Description	Rate Per Hour
Truck Mounted – carrier powered	$5.00
Trailer Mounted – solar power supply	$5.00

FORM 1000

Trailer Mounted – gas power supply	$6.25
Trailer Mounted – diesel power supply	$7.75

19-3 Portable Variable Message Signs

Description	Rate Per Hour
Truck Mounted – carrier powered	$5.00
Trailer Mounted – solar power supply	$9.25
Trailer Mounted – gas power supply	$10.50
Trailer Mounted – diesel power supply	$12.00

TRACTORS - BULLDOZERS - CRAWLERS

POWER RANGE Kw (Hp)	MAKE	MODEL	NET FLYWHEEL ENGINE POWER Kw (Hp)
30-41 (40-55)	KOMATSU	D2OP-6	30 (40)
	KOMATSU	D20A-6	30 (40)
	KOMATSU	D20PL-6	30 (40)
	KOMATSU	D21A-6	30 (40)
	KOMATSU	D21P-6	30 (40)
42-52 (56-70)	J. DEERE	400 G	45 (60)
	CAT	D3	46 (62)
	CAT	D3B	48 (65)
	IHC	TD-7E	48 (65)
	CASE	550	50(67)
	CASE	550G/G LT/LGP	50(67)
	CAT	D3C	52 (70)
	DRESSER	TD-7G	52 (70)
	DRESSER	TD-7H	52 (70)
53-60 (71-80)	CAT	D3C SERIES III	53 (71)
	CASE	850B	54 (72)
	IHC	TD8E	58 (78)
	CASE	650	60 (80)
	CASE	650 G	60 (80)
	CAT	D4E	60 (80)
	CAT	D4C	60 (80)
	DRESSER	TD-8G	60 (80)
61-75 (81-100)	CAT	D4C SERIES III	61 (82)
	CASE	850D	61 (82)
	F-A	8	65 (87)
	F-A	8B	66 (88)
	CASE	850 G	66 (89)
	CASE	850 G LGP	66 (89)
	J. DEERE	650 G	67 (90)
	J. DEERE	650 G SERIES IV	67 (90)
	J. DEERE	650 G LGP SERIES IV	67 (90)
	KOMATSU	D40A-3	67 (90)

POWER RANGE Kw (Hp)	MAKE	MODEL	NET FLYWHEEL ENGINE POWER Kw (Hp)
30-41 (40-55)	KOMATSU	D20PLL-6	30 (40)
	KOMATSU	D21PL-6	30 (40)
	J. DEERE	350C	31 (42)
	CASE	350	34(45)
	CASE	450	40 (53)
42-52 (56-70)	J. DEERE	450G	52 (70)
	J. DEERE	450G LGP / LT	52 (70)
	KOMATSU	D31PLL-18	52 (70)
	KOMATSU	D31-18	52 (70)
	KOMATSU	D31PL-18	52 (70)
	KOMATSU	D31P-18	52 (70)
	KOMATSU	D31P-20	52 (70)
	KOMATSU	D31E-20	52 (70)
53-60 (71-80)	DRESSER	TD-8H	60 (80)
	DRESSER	TD-8H LGP	60 (80)
	J. DEERE	550G	60 (80)
	J. DEERE	550G SERIES IV	60 (80)
	KOMATSU	D37P-2	60 (80)
	KOMATSU	D37E-2	60 (80)
	KOMATSU	D37E-5	60 (80)
	KOMATSU	D37P-5	60 (80)
61-75 (81-100)	KOMATSU	D41P-3	67 (90)
	KOMATSU	D41A-3	67 (90)
	KOMATSU	D39E	67 (90)
	CAT	D5C	67 (90)
	DRESSER	TD-9H	67 (90)
	DRESSER	TD-9H LGP	67 (90)
	CAT	D5C SERIES III XL	68 (91)
	CAT	D5C SERIES III LGP	68 (91)
	CAT	D4H	71 (95)
	CAT	D4H SERIES II	71 (95)

APPENDIX 10

SPECIAL EQUIPMENT RATES

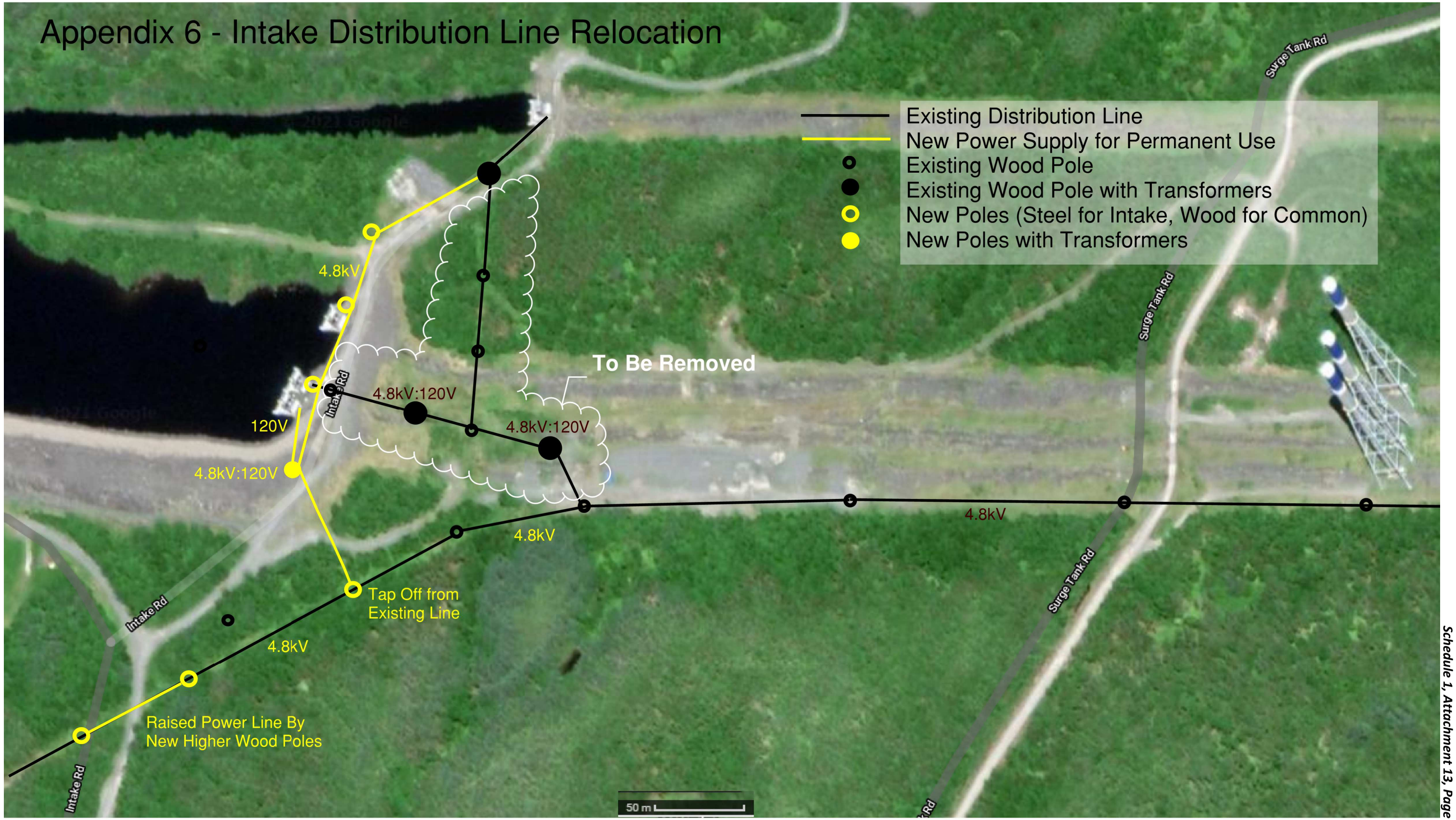
BDE Special Equipment Rates Note: All taxes extra

Quoted Price						Depreciation/Interest on Purchase					Hourly Rates - All Found		
Item	Description	Total Estimated Usage (Hours)	No. of Units Required	Purchase Price	Total Base Purchase Cost	Depreciation Life (Years)	Risidual Value	Interest Expense (8% of Average Value)	Indirect Costs (2% of Purchase Cost)	Total Owners Cost	Hourly Rate of Total Owners Cost	Hourly Rate of Operating Cost per Unit	Total Hourly Rate
1	Automated robotic hydroblasting/coating machinery	1,150	1	$83,000	83,000.00	1	$40,000	4,920.00	1,660.00	$49,580	$43.11	$32.33	$75.45
2	Automated robotic abrasive blasting machinery	2,500	1	$160,000	160,000.00	1	$80,000	9,600.00	3,200.00	$92,800	$37.12	$27.84	$64.96
3	Dehumidifier	500	1	$70,000	70,000.00	1	$35,000	4,200.00	1,400.00	$40,600	$81.20	$12.18	$93.38

APPENDIX 11

INTAKE DISTRIBUTION LINE RELOCATION

Appendix 6 - Intake Distribution Line Relocation



APPENDIX 12

BDE PENSTOCK LAND TRANSPORT

BDE Penstock Land Transport

Penstock Transportation Option 2 (Option 1 utilized crane unloading of the barge and is not used in favor of Option 2)

Costs

Item	Quantity	Unit	$	Unit	Time Period		Total
Mob/Demob	2		15,000.0	$ / Set Mob	1.0	Unit	$ 30,000.00
Trucks	2	un.	5,000.0	$/month	2.0	Month	$ 20,000.00
Trailers	2	un.	5,000.0	$/month	2.0	Month	$ 20,000.00
Repair upon return	1	un	5.0	%	-	Unit	$ 2,000.00
Operator	2	Un	110.00	$/hour	600.0	hours	$ 132,000.00
Fuel Trip	21.6	lt	1.5	l	-	-	$ 986.21
Fuel (others)	-	lt	-	-	-	-	$ 493.11
Permits	30	trips	500.0	$/trip	-	-	$ 15,000.00
Ship at dock	1	un.	50,400.0	$/day	2.0	Extra Days	$ 100,800.00
Ship trailers back to manufacturer	10	loads	1,500.0	$/day	4.0	Day	$ 60,000.00
Ferry	10	loads	450	$/trip	2	times	$ 9,000.00
							$ 390,300.00

Travel Information

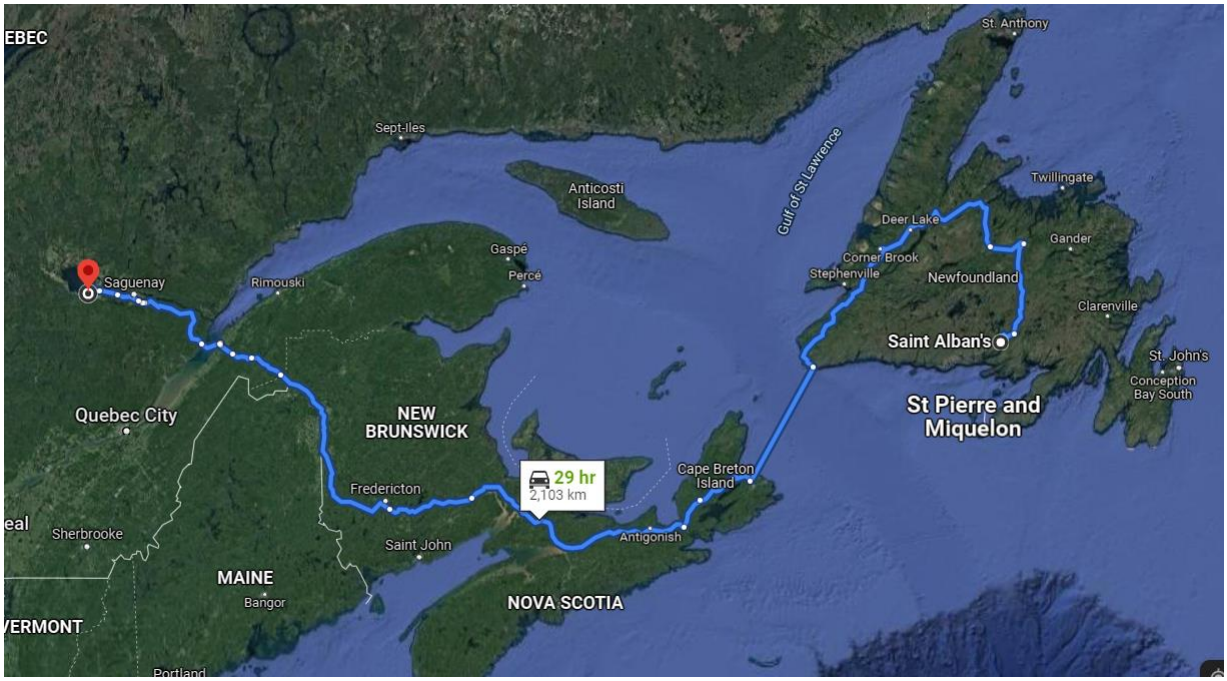
Nr Cans	Km per trip	Round-Trip (km)	Fuel efficiency km per litre (km/l)	Price Fuel ($)	Total Km		Total Cost
30	27	54.0	2.5	1.52	1,620.0		984.96

Penstock Sections Transportation

Option 2 – Penstock sections shipped to wharf by barge already in the trailers.

1. Penstock Sections (Cans) shipped to St Alban's.

   Assumptions:
   - 2 loads with 15 trailers loaded with 1 can each.
   - 4 weeks between loads
2. Unload ship at the wharf.
   - Minimize the dock time
   - No crane is needed
   - 3 days to unload each ship
     i. Move all trailers to the wharf or nearby location
     ii. Release the Ship
3. Ship leaves wharf.
   - Without Trailers
   - Go back to LAR Group.
4. Transport to the site.
   - 2 trucks, 1 trip/day each for 15 cans.
   - 8 days trip
   - Leave the cans in the trailers.
5. Send trailers back to LAR Group (Metabechuan-Lac-la-croix)
   - Hire local freight company.
   - Set 3 trailers for each truck (5 trucks)
   - 5 days to drive back -> 29 hours - 2103km (source: Google Maps)



APPENDIX 13

ROBOTIC COATING APPLICATION – MEANS AND METHODS REFERENCE

Bay D'Espoir Hydroelectric Generating Station Penstock Refurbishment Section

Equipment and Consumables Budget Pricing

Equipment (priced each)		Purchase Option	Rental Option	
Bulk Pot - 4 outlet		$50,000	$2,500	
Air Dryer - 1600		$28,000	$2,200	
Bull Hoses - 100' of 3"		$1,600	$400	
Blast Nozzles		$1,200	$300	
Blast Hose - 600' of 2"		$5,500	$2,000	
1600 CFM Compressor		$250,000	$8,000	
Blast PPE		$4,500	$550	
RIPT - Blast	**	$58,000	$18,000	
RIPT Spare parts kit		$5,500	$5,500	*
20K CFM Dust Collector		$125,000	$7,500	
DC Ducting - 150'		$2,800	$1,800	
Dehu - 5K CFM		$70,000	$5,500	
DH Ducting - 50'	(included)		(Included)	
56 kW Diesel GenSet		$38,000	$3,500	
Diesel Vacuum unit		$187,000	$10,000	
Vac Hose 600'		$7,800	$3,600	
Misc site appliances		$20,000	$5,000	*
RIPT - Paint		$60,000	$18,350	
60:1 Pre-pump and 90:1 Primary Paint Pump		$22,000	$6,000	
Paint consumables		$20,000		n/a
Paint Lines		$15,000		n/a
Inspection Instruments		$6,600		n/a
Site Support/Set-up - plus travel time		$8,500	$8,500	*
Freight		$30,000	$60,000	
Equipment Sub-Total		$1,017,000	$169,200	
Abrasive - GMA - GX2 garnet 264,000 lbs.	***	$118,800	$118,800	
Grand Total		**$1,135,800**	**$288,000**	

*Required with rental option
Pricing in USD and DOES NOT include any sales or use taxes
Most large equipment carries significant lead-times
**will require a winch due to slope of penstock - (unsure of spec/price)
***Approx. 117,200 SF @ 2.25 lbs./SF



BLASTONE®

LARGE INTERNAL PIPE BLAST AND PAINT SYSTEMS

Surface preparation and coating of large pipe or tunnel interiors is always precarious, labour intensive and is typically performed under tight time constraints. BlastOne's RIPT (Robotic Internal Pipe Technology) blast and paint equipment features rotating lances which are adjusted to the size of the pipe/tunnel and move at a set speed.



RIPT-Blast™ unit typically features 3 rotating nozzles which are attached to a self propelled trolley, and move down the pipe at speeds of up to 10 feet (3 metres) per minute. Typical production speeds are significantly higher than manual blasting and this will transfer into more profit for your business.

ROBOTIC INTERNAL PIPEBLAST TECHNOLOGY



Mini Pipeline Blaster

Used for blasting smaller pipes, typically in the gas industry.

Diameter Range
- 2' to 6' / 0.6 m to 1.8 m

Average Blasting Rate*
- 1,500 sqft / 140 m^2 to 2,500 / 232 m^2 per hour

Blast Requirement
- 600-800 cfm

Gas Industry. 2' to 6'

Part Number	Description
IPRIPTA	Mini Pipeline Blaster



Internal Pipeline Blaster

The work horse of the RIPT range, the machine is very versatile and can be used for blasting penstocks, small tunnels, wind towers and other large pipes.

Diameter Range
- 4' to 12' / 1.2 m to 3.6 m

Average Blasting Rate*
- 2,000 sqft / 186 m^2 to 3,000 sqft / 279 m^2 per hour

Blast Requirement
- 1100-1300 cfm

Penstock Industry. 4' to 12'

Part Number	Description
IPRIPTB	Internal Pipeline Blaster



Large Pipeline Blaster

The large RIPT Pipeline Blaster is used in the tunnel and wind tower industry.

Diameter Range
- 6' to 32' / 1.2 m to 9.8 m

Average Blasting Rate*
- 2,000 sqft / 186 m^2 to 3,000 sqft / 279 m^2 per hour

Blast Requirement
- 1100-1300 cfm

Tunnel Industry. 6' to 32'

Part Number	Description
IPRIPTC	Large Pipeline Blaster

*Blasting Rates are a guide and depend on actual site conditions.

ROBOTIC INTERNAL PIPEBLAST TECHNOLOGY

BLASTONE



Mini Pipeline Painting System

Used for painting smaller pipes, typically in the gas industry.

Diameter Range
- 2' to 6' / 0.6 m to 1.8 m

Average Painting Rate*
- Up to 4,000 sqft / 372 m^2 per hour

Paint Requirement
- 40-70 cfm

Gas Industry. 2' to 6'

Part Number	Description
IPRIPT2A	Mini Pipeline Painter



Internal Pipeline Painting System

The work horse of the RIPT range, the machine is very versatile and can be used for painting penstocks, small tunnels, wind towers and other large pipes.

Diameter Range
- 4' to 12' / 1.2 m to 3.6 m

Average Painting Rate*
- 4,000 sqft / 372 m^2 to 5,000 / 465 m^2 per hour

Paint Requirement
- 50-100 cfm

Penstock Industry. 4' to 12'

Part Number	Description
IPRIPT2B	Internal Pipeline Painter
IPRIPT2KB	Internal Pipeline Painter - 2K



Large Pipeline Painting System

The large RIPT Pipeline Painting System is used in the tunnel industry.

Diameter Range
- 6' to 32' 1.2 m to 9.8 m

Average Painting Rate*
- 4,000 sqft / 372 m^2 to 5,000 /465 m^2 per hour

Paint Requirement
- 50-100 cfm

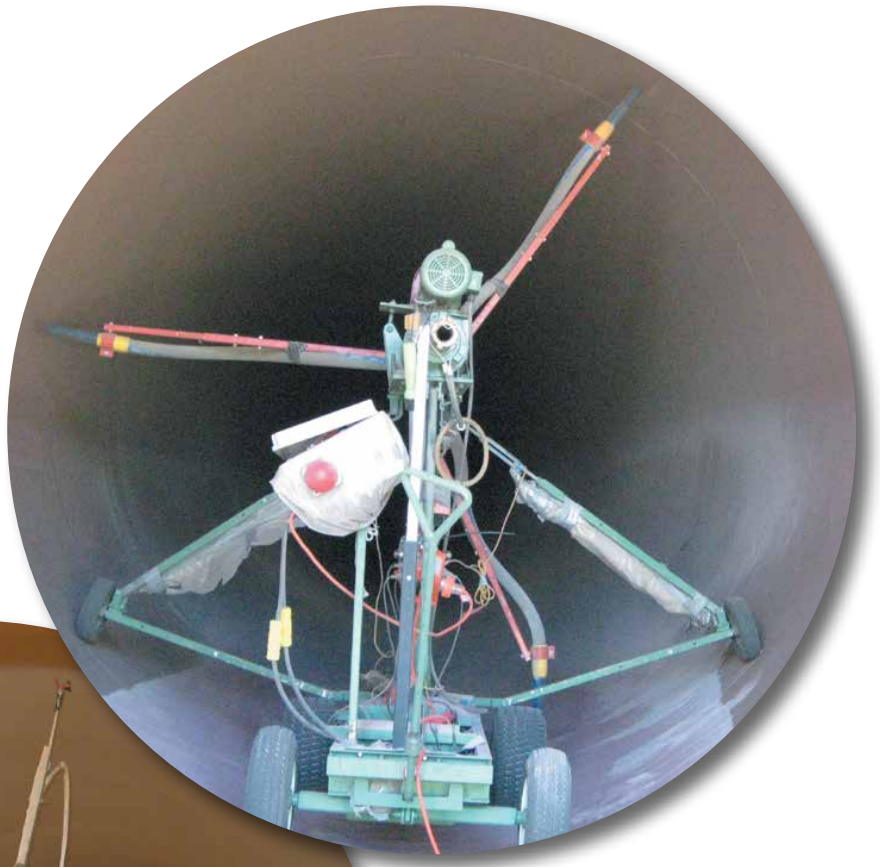
Tunnel Industry. 6' to 32'

Part Number	Description
IPRIPT2C	Large Pipeline Painter

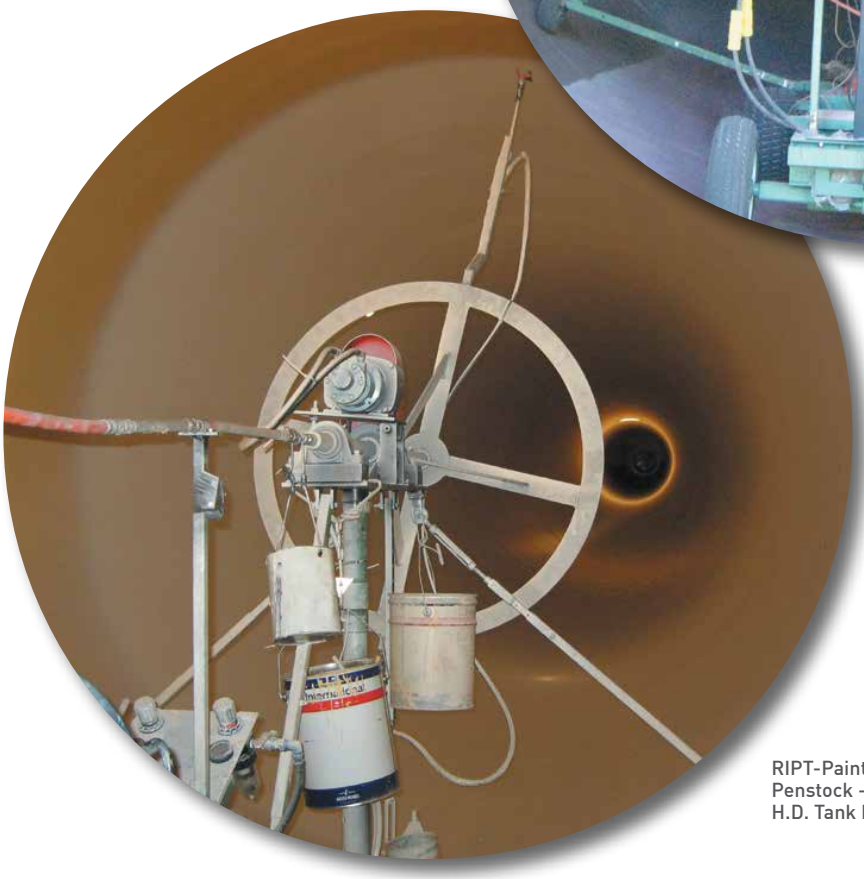
ROBOTIC INTERNAL PIPEBLAST TECHNOLOGY

High Production Blasting and Coating of Pipe Internals

Large pipe projects requiring fast surface preparation and coating of pipe internals require specialized equipment.



RIPT-Blast in action removing 80 Mils (2000 Microns) of old epoxy.



RIPT-Paint in action on a 13ft (4m) diameter Penstock – applying 40 Mils (1000 Microns) of H.D. Tank Liner Coating.

BLASTONE
SUPERIOR PERFORMANCE

BLASTONE INTERNATIONAL

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UNITED KINGDOM
London

AUSTRALIA
Adelaide | Brisbane | Darwin | Mackay | Melbourne | Perth | Sydney

NEW ZEALAND
Auckland | Christchurch

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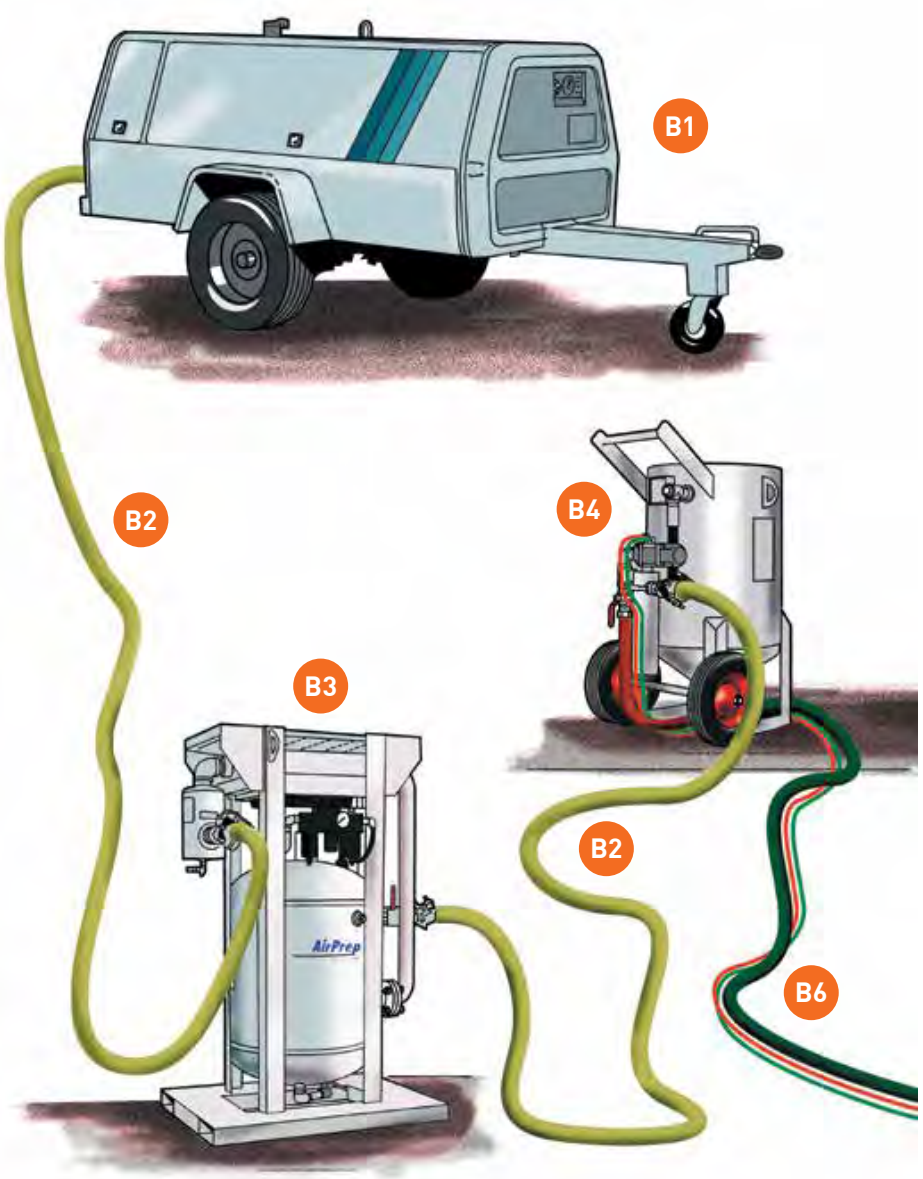
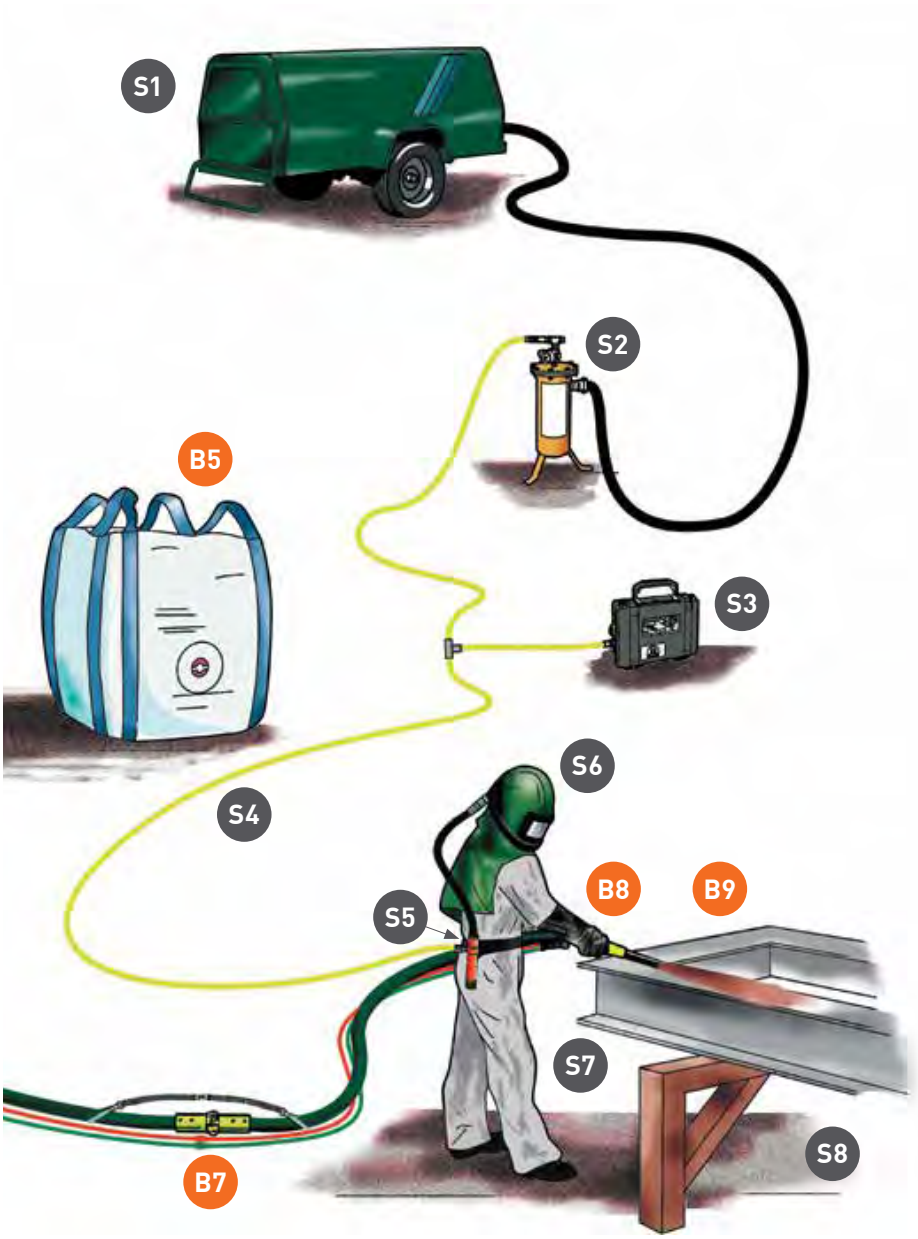
Abrasive Blasting System:

BLAST COMPONENTS	DAILY CHECKLIST	PRE-REQUIREMENTS
B1 Air Compressor	✓	✓
• Fully maintained and serviced		☐
• Capable of 125psi discharge pressure		☐
• Located upwind and away from the blasting area		☐
• High volume output (typically 300+ cfm per nozzle) based on nozzle size requirements plus 50% wear allowance (plus 30 cfm of quality breathing air per operator)	☐	
• High temperature safety cut out	☐	
• Oil and particulate filter separator	☐	
B2 Blast Air Supply Hose		
• Large bore hose (4 times nozzle orifice minimum)		☐
• Large connector fittings with whipchecks and/or safety chains installed		☐
B3 Air Moisture Control		
• Regularly cleaned and maintained		☐
• Compressed air moisture removal system with final moisture separator	☐	
• Large porting	☐	
B4 Blast Machine		
• Remote Control Valve System checked/ maintained		☐
• Abrasive Metering Valve and fittings checked/maintained		☐
• Lid and screen (portable hoppers) fitted		☐
• AS Standard Approved Design	☐	
B5 Blast Abrasive		
• Kept dry and protected		☐
• Small palletized bags or bulk bags		☐
• Safe, approved, productive, abrasive media	☐	
• Free of harmful substances (health or environmental)	☐	
B6 Blast Hose		
• Kept as straight and as short as possible (drawn curved to show perspective) – checked daily for wear or soft spots		☐
• Abrasive resistant hose sized 3–5 times the nozzle orifice	☐	
• Heavy wall hose for extension lengths, Superflex for nozzle end flexibility	☐	
B7 Blast Couplings/Connectors		
• Checked daily for gasket and component wear, and air leaks		☐
• External connectors properly fitted	☐	
• Lockpins and whipchecks installed	☐	
B8 Remote Control Handle		
• Check and maintain for safe operation		☐
• Fast acting, under direct positive control of the operator		☐
• Pneumatic or electric operation	☐	
• Optional abrasive cut off control	☐	
B9 Blast Nozzle		
• Checked routinely for air pressure and liner/ thread wear or damage		☐
• Fast acting, under direct positive control of operator		☐
• Sized to suit air and workpiece requirements	☐	
• Long venturi (and other designs) with durable wear liner	☐	



DISCLAIMER: The above information is only a guide and does not represent nor claim to be either a full or complete or accurate nor an approved or standard method of checking blast cleaning equipment or components. It is the responsibility of the reader and/or users of this information to separately determine and verify each and/or any guideline, regulations, tests, checks, etc. for equipment and/or setup as directed or indicated or required in or by any work specifications and/or standards. BlastOne expressly disclaims any liability for the use or misuse of the above information.

Daily Component Checklist



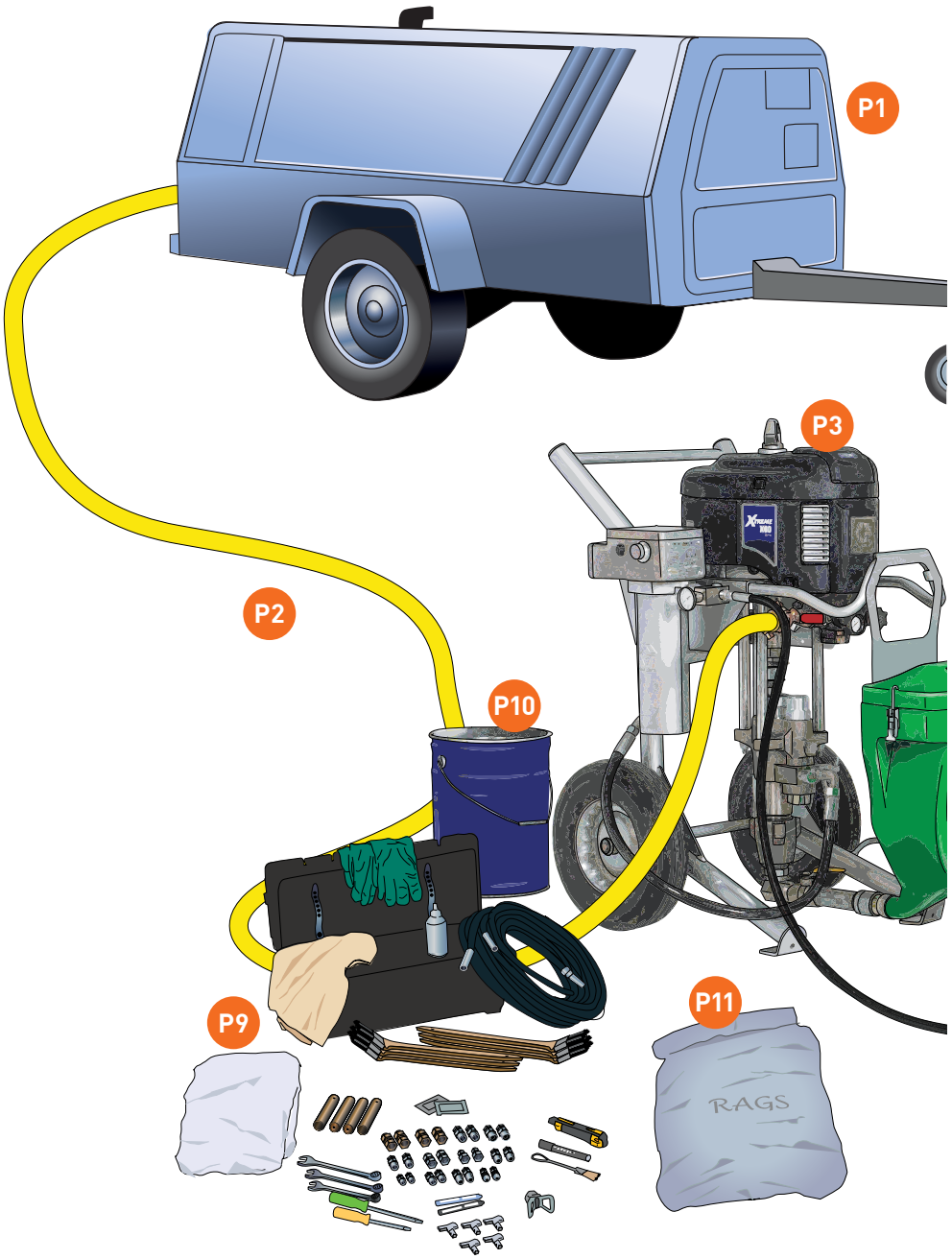
OPERATOR SAFETY COMPONENTS	DAILY CHECKLIST	PRE-REQUIREMENTS
S1 Breathing Air Source	✓	✓
• Checked and maintained on a regular basis		☐
• Located in a clean air atmosphere, upwind and away from the blast area and engine exhaust fumes		☐
• Approved air compressor or dedicated breathing air compressor or air pump or bottled breathing air or other approved supply	☐	
S2 Breathing Air Filter		
• Cartridges require regular programmed replacement		☐
• Filters and regulates the breathing air supply		☐
S3 Carbon Monoxide Monitor or Converter Monitor		
• Checked, tested and calibrated on a routine basis		☐
• Samples air and safeguards against toxic, carbon monoxide gas	☐	
• Ensures carbon monoxide level is below 10ppm (11 milligram/m³) as per AS1715	☐	
S4 Breathing Air Line		
• Fitted with threaded screw-type connector or AS 1715 approved 'Safety Type' coupling with two distinct actions required for disconnection		☐
• AS Standard approved and marked	☐	
S5 Climate Control Tube		
• Air temperature control within 15°C – 25°C range for operator comfort		☐
• Complies with requirements of AS 1715	☐	
S6 Blast Helmet (Respirator)		
• Inspected and maintained for wear and tear to the cape, collar, head gear and visor as per AS 1715 requirements		☐
• Inner lens in place for impact protection		☐
• Supplied with minimum 170 liters/minute breathing quality air as per AS 1715		☐
• Air quality regularly tested and test records maintained as per AS 1715 requirements to check the following levels of contaminants: Oil below 1 milligram/m³, Carbon Monoxide below 10 ppm (11 milligrams/m³), Carbon Dioxide below 800 ppm (1400 milligrams/m³), Oxygen between 19.5 and 22.0%		☐
• Issued on an exclusive use basis (or shared use only with an AS 1715 approved programme for extensive and stringent cleaning, disinfecting, and recording)	☐	
• Earplugs and/or earmuffs essential for hearing protection	☐	
• Optional communication equipment	☐	
• Optional blast light illumination kit	☐	
S7 Other Protective Clothing		
• Leather gloves/gauntlets	☐	
• Blast suit/protective overalls	☐	
• Safety footwear		☐
S8 Work Hazards		
Check, control and eliminate wherever possible:		
• Physical dangers – tripping, falling, crushing		☐
• Toxic substances e.g. lead, arsenic, cyanide, heavy metals, chromates, free silica, etc. present either in the abrasive, the coating, the substrate or the environment		☐

Use this handy reference daily checklist to analyse your key requirements

16

Spray Painting System:

PAINT COMPONENTS	DAILY CHECKLIST PRE-REQUIREMENTS	
P1 Air Compressor	✓	✓
• Fully maintained and serviced		☐
• Capable of 125psi discharge pressure		☐
• Positioned upwind and away from working area		☐
• High volume of breathing air quality if separate dedicated compressor not used	☐	
• High temperature cut out	☐	
• Oil and particulate filter separator	☐	
P2 Paint Air Supply Hose		
• Large bore hose		☐
• Large connector fittings with whipchecks and/or safety chains installed		☐
P3 Paint Pump		
• Fully maintained and serviced on a regular basis		☐
• Check and top up throat seal liquid daily		☐
• Completely cleaned immediately after each operation		☐
• Keep pump 'wet' at all times – leave solvent in pump after use, for long storage periods, use Diesel, Kerosine or Pump Armor		☐
P4 Paint Line		
• Rated pressure must be greater than maximum rated pressure of pump and undamaged	☐	
P5 Paint Line Whip Hose		
• Rated pressure must be greater than maximum rated pressure of pump and undamaged	☐	
P6 Spray Gun		
• Check Spray Gun is clean and fully operational (clean with thinners, etc.)		☐
• Ensure Tip Guard is in place		☐
• Ensure correct tip size is used for product being applied	☐	
• Ensure gun rated pressure is above pump rated pressure	☐	
P7 Reversible Air Drill and Mixer/Stirrer		
• Ensure Air Drill is in good working order		☐
• Mixer/Stirrer is clean and free from contaminants		☐
• For 2 component coatings – 2 Air Drills and Mixer/Stirrers required	☐	
P8 Drum(s) for Mixing Paint		
• Clean straight sided tin(s) for mixing paint	☐	
P9 Painter's Tool Box		
• Contains spares, tools, gloves for mixing, brushes, fittings, etc	☐	
P10 Extra Drum		
• Disposal drum for waste paint and used Thinner residue	☐	
P11 Bag of Rags		
• These are a must for general use and any spills or leaks	☐	



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Daily Component Checklist



OPERATOR SAFETY COMPONENTS	DAILY CHECKLIST ✓	PRE-REQUIREMENTS ✓
S1 Breathing Air Source		
• Checked and maintained on a regular basis		☐
• Located in a clean atmosphere, upwind and away from the working area and engine exhaust fumes		☐
• Approved air compressor or dedicated air compressor or air pump or bottled breathing air or other approved supply	☐	
S2 Breathing Air Filter		
• Cartridges require regular programmed replacement		☐
• Filters and regulates the breathing air supply – ensure in excellent working order		☐
S3 CO Monitor and Alarm		
• Check CO Monitor is active, tested and calibrated on a regular basis		☐
• If audible, check sound level is high enough		☐
• Ensure carbon monoxide level is below 10ppm		☐
S4 Breathing Air Line		
• Fitted with threaded screw-type connector or AS 1715 approved 'Safety Type' coupling with 2 distinct actions required for disconnection		☐
• AS Standard, approved and marked		☐
S5 Climate Control Tube		
• Air temperature control within 60°F - 77°F (15°C - 25°C) range for operator comfort and to comply with requirements of AS 1715		☐
S6 Air Fed Hood		
• Check for air leaks or loose fittings – ensure no breathing air is escaping to atmosphere		☐
• Check for overhead hazards – Optional Hard Hat Compatible hoods are available		☐
• Supplied with minimum 45 gal/minute breathing quality air		☐
• Air quality regularly tested and test records maintained as per AS 1715 requirements to check the following levels of contaminants: Oil below 1 milligram/m³, Carbon Monoxide below 10 ppm (11 milligrams/m³), Carbon Dioxide below 800 ppm (1400 milligrams/m³), Oxygen between 19.5 and 22.0%		☐
• For use in atmosphere not Immediately Dangerous to Life or Health (IDLH)	☐	
• Issued on an exclusive use basis (or shared with an approved programme for extensive and stringent cleaning, disinfecting and recording)	☐	
• Earplugs and/or earmuffs where necessary	☐	
• Communication equipment where necessary	☐	
S7 Other Protective Clothing and Equipment		
• Gloves		☐
• Protective overalls or similar		☐
• Safety Footwear		☐
• Safety Footwear covers		☐
• First Aid Kit		☐
S8 Work Hazards		
• Check, control and eliminate any hazards:		
• Physical dangers – tripping, falling, crushing		☐
• Overspray		☐

Use this handy reference daily checklist to analyse your key requirements

APPENDIX 14

MEASURED ROAD DISTANCES

Chant Site Visit Notes

Measured Road Distances

On-Site Road Distances				
Segment		**Odometer**	**Distance (km)**	
	Intersection A	593.5		Intersection Airport Road with Surge Tank Road
			0.6 km	Point A1 is Intersection with ramp to Surge Tanks – ramp is 150 m each way
	Point A2			Bridge Penstock No. 2
			0.2 km	
	Point A3			Bridge Penstock No. 4
			0.8 km	
	Point A4			Turned right at intersection and proceeded to locked gate
	Intersection A	597.0		
			0.4	
	Intersection B	597.4		Intersection with first access to Penstock ROW – 0.2 km to gate
			0.9	
	Intersection C	598.3		Intersection with access road to Right Abutment of Main Dam
			0.2	
	Right Abutment	598.5		Right Abutment of Main Dam
			0.3	
	Intersection C	598.8		
			3.7	Adjusted by (0.4 km) to reflect passing Intersection (0.2 km), turning around and returning to intersection (0.2 km)
	Intersection D	602.9		150 m from Intersection D to centerline of existing airport runway each way or 0.3 km
			0.3	
	Intersection D	603.2		
			3.6	
	Intersection C	606.8		
			0.8	
	Intersection B	607.6		
			0.4	
	Intersection A	34.0		

			0.7	
	Twin Culverts	33.3		
			0.3	
	Intersection E	33.0		Intersection of Airport Road and Vista Road
	Vista Road	n/a	1.7	✓
	Intersection E	33.0		
			1.0	
	Intersection F	32.0 613.7		Intersection PP Access Road with Airport Road
			0.5 km	✓
	Guard House	614.2		
			0.6 km	✓
	Intersection F	614.8		
			2.7 km	✓
	Intersection G	617.5 632.8		Intersection of PP Access Road with Highway 361
			11.3 km	
	St. Alban's Inn	644.1		

Notes:

1. The distance between the top of the Intake Ramp to Q2 is approximately 0.6 km.
2. The distance between Bridge No. 4 on the Surge Tank Access Road and the Coast of Bays Contracting quarry is 3.2 km.
3. The distance between Bridge No. 4 and the upper limits of the till deposit is 4.9 km.

APPENDIX 15

WELDING SPECIFICATION

SECTION 40 17 26 – STEEL PENSTOCK WELDING

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

A. This specification is for welding of the penstock sections shown on the Project Plans and indicated in this specification. Penstock shall be installed with the appropriate elbows, transitions, all permanent supports including anchor bolts, and all other appurtenances as required to complete the job.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASME BPVC SEC I	(2010) BPVC Section I-Rules for Construction of Power Boilers
ASME BPVC SEC II-C	(2010) BPVC Section II-Materials Part C-Specifications for Welding Rods Electrodes and Filler Metals
ASME BPVC SEC IX	(2010) BPVC Section IX-Welding and Brazing Qualifications
ASME BPVC SEC V	(2010) BPVC Section V-Nondestructive Examination
ASNT SNT-TC-1A	(2016) Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing
AWWA C206	(2017) Field Welding of Steel Water Pipe
CISC G40.20-13	General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel
CISC S16-14, 6-188	(2014) Welded Joints Standard Symbols
CISC S16-14, 6-183	(2014) Welding Terms and Definitions
CSA S16-14	Structural Welding Code - Steel
CSA W47.1	Certification of Companies for Fusion Welding of Steel.
CSA W59	Welded Steel Construction.
CSA W178.2-14	(2016) Certification of Welding Inspectors

29 CFR 1910	Occupational Safety and Health Standards
29 CFR 1926	Safety and Health Regulations for Construction

1.3 SUBMITTALS

Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

A. Fabrication Drawings (including principle dimensions of penstock and supports, manway details, upstream and downstream weldments and support details, connection details, total weight of assembled penstock, and weld details – minimum sizes, lengths, and profiles)

B. Quality Control Manual

C. Certificates

- Welder certifications
- Welding procedures qualification
- Nondestructive examination (NDE) procedures
- NDE personnel certification *
- Inspector certification (CISC W178.2-14)*
- *Submit inspector certification and NDE personnel certification for record.

D. Closeout Submittals

- As-built drawings of penstocks (including exterior dimensions, inside diameter, and other critical dimensions, capacity, weight, and locations of fittings and accessories)
- Weld identifications (including weld maps showing traceability of joint locations)
- NDE results

1.4 QUALITY ASSURANCE

A. Welding

Show location, length, and type of welds, and indicate post-weld heat treatment and nondestructive testing as required.

B. Procedures

Develop and qualify procedures for welding metals included in the work. Do not start welding until welding procedures, welders, and welding operators have been qualified. Perform qualification testing by an approved testing laboratory. Maintain current records of the test results obtained in welding procedure,

welding operator/welder performance qualifications, and nondestructive examination (NDE) procedures. Qualify procedures for making transition welds between different materials or between plates or pipes of different wall thicknesses. Unless otherwise specified, the choice of welding process shall be the responsibility of the Contractor.

1. Previous Qualifications

   Welding procedures, welders, and welding operators previously qualified by test may be accepted for the work without requalification provided that the following conditions are fulfilled:

   a. Copies of welding procedures, procedure qualification test records, and welder and welding operator performance qualification test records are submitted and approved in accordance with the paragraph entitled "Submittals."

   b. Testing was performed by an approved testing laboratory or technical consultant or by the Contractor's approved quality control organization.

   c. The welding procedures, welders, and welding operators were qualified in accordance with CISC S16-14, CWB and CSA W59; and base materials, filler materials, electrodes, equipment, and processes conformed to the applicable requirements of this specification.

   d. The requirements of paragraph entitled "Welder and Welding Operator Performance Qualification" for renewal of qualification were met, and records showing name of employer and period of employment using the process for which qualified are submitted as evidence of conformance.

2. Performance

   The Contractor shall be responsible for the quality of joint preparation, welding, and examination. Clearly identify and record materials used in the welding operations. The examination and testing defined in this specification are minimum requirements; the Contractor may provide additional examination and testing as necessary to achieve the quality required.

C. Welding Procedures Qualification

1. Qualify welding procedures as required in CISC S16-14, CWB and CSA W59. Record in detail and qualify the "Welding Procedure Specifications" for every welding procedure proposed. Describe the type of backing rings or consumable inserts, if used, and, if they are to be

removed, the removal process. Welding procedure qualifications shall be identified individually and referenced on the shop drawings or suitably keyed to the contract drawings.

2. Welding suitability shall be established according to CISC S16-14, CWB and CSA W59. This may require in-place weld tests on a safe area of the structure or samples may need to be obtained.

3. Welding procedures shall be qualified to provide notch tough welds.

D. Welder and Welding Operator Performance Qualification

Qualify each welder and welding operator assigned to work covered by this specification by performance tests using equipment, positions, procedures, base metals, and electrodes or bare filler wires from the same specification, classification, or group number that will be encountered on assignment. Welders or welding operators who make acceptable procedure qualification tests will be considered performance-qualified for the welding procedure used. Determine performance qualification in accordance with CISC S16-14, CWB and CSA W59and as specified.

E. Renewal of Qualification

Requalification of a welder or welding operator shall be required under one or any combination of the following conditions:

1. When a welder or welding operator has not used the specific welding process for a period of 3 months. The period may be extended to 6 months if the welder has been employed on another welding process.

2. There is specific reason to question the welder's ability to make welds that will meet the requirements of the specifications.

3. The welder or welding operator was qualified by an employer other than those firms performing work under this contract and a qualification test has not been taken within the preceding 6 months. Renewal of qualification under this condition need be made on only a single test joint or pipe of any thickness, position, or material to reestablish qualification for any thickness, position, or material for which the welder or welding operator had qualified previously.

4. When a welder or welding operator qualification is renewed, testing shall take place at a location and time disclosed to the Owner at least 7 days in advance such that the Owner is given the opportunity to observe the welder performance testing. The performance test shall be conducted at a facility or certifying entity approved by the Owner. Test coupons shall be examined using RT and accepted according to the

requirements of CISC S16-14 and CSA W59. After completion of the test coupon, all welder performance qualification records shall be submitted to the Owner prior to beginning the work. Certifications may be revoked and retesting of welders can be done at any time based on poor quality of work.

F. Qualification of Inspection and (NDE) Personnel

Qualify inspection and nondestructive examination personnel in accordance with the following requirements:

1. Inspector Certification

   Current CWB certification in compliance with W178.2-14.

2. NDE Personnel Certification Procedures

   Certify NDE personnel and establish a written procedure for the control and administration of NDE personnel training, examination, and certification. Base procedures on appropriate specific and general guidelines of training and experience recommended by ASNT SNT-TC-1A.

3. Welding Procedures and Qualifications

   a. Specifications and Test Results:

      i. Submit copies of the welding procedure specifications and procedure qualification test results for each type of welding required.

      ii. Approval of any procedure does not relieve the Contractor of the responsibility for producing acceptable welds.

      iii. Submit this information on the forms printed in CISC S16-14 and CSA W59.

   a. Certification:

      i. Before assigning welders or welding operators to the work, submit their names, together with certification that each individual is performance qualified as specified.

      ii. Do not start welding work prior to procedure qualification.

iii. The certification shall state the type of welding and positions for which each is qualified, the code and procedure under which each is qualified, date qualified, and the firm and individual certifying the qualification tests.

G. Symbols

Conform to CISC S16-14 and CSA W59.

1. Weld Identifications

Submit written records indicating the location of welds made by each welder or welding operator.

H. Safety

Conform to AWS Z49.1, 29 CFR 1910-SUBPART Q, "Welding, Cutting, and Brazing," 29 CFR 1926-SUBPART J, "Welding and Cutting."

I. Do not store materials in a manner that might cause distortion or damage to materials, members or supporting structures. Repair or replace damaged materials or structures as indicated.

1.5 ENVIRONMENTAL

Do not perform welding when the quality of the completed weld could be impaired by the prevailing working or weather conditions.

1.6 DELIVERY AND STORAGE

Deliver filler metals, electrodes, fluxes and other welding materials to the site in manufacturers' original packages and store in a dry space until used. Label and design packages properly to give maximum protection from moisture and to assure safe handling.

PART 2 – PRODUCTS

2.1 WELDING MATERIALS

A. Comply with CISC S16-14, G40.20-13/G40.21-13 and CSA W59. Welding equipment, electrodes, welding wire, and fluxes shall be capable of producing satisfactory welds when used by a qualified welder or welding operator using qualified welding procedures.

B. Filler material shall meet the same toughness requirements as the base metal and a minimum average value of absorbed energy of 20 ft-lb at 32°F. Charpy V-notch (CVN) specimens shall be prepared according to ASTM A370, CISC

S16-14 and CSA W59.

PART 3 – EXECUTION

Owner's written approval shall be obtained prior to start of welding.

3.1 WELDING

A. Do not deviate from applicable codes, approved procedures, and approved shop drawings. Assign each welder or welding operator an identifying number, letter, or symbol that shall be used to identify his welds. Each welder or welding operator shall apply his mark adjacent to his weld using an approved rubber stamp or felt-tipped marker with permanent, weatherproof ink or other approved methods that do not deform the metal.

B. Weld bevel preparations shall be machined or ground to remove all discoloration if flame or arc cut.

C. Welding sequences shall be planned to reduce residual stresses and distortion.

3.2 WELDING OPERATORS

Perform welding in accordance with qualified procedures using qualified welders and welding operators.

3.3 EXAMINATIONS AND TESTS

TABLE I – MINIMUM NONDESTRUCTIVE EXAMINATION REQUIREMENTS		
Joint Type	*Examinations Required*	*Frequency*
Shop Welds	RT or UT[1]	10%
	MT	100%
Field Welds	MT	100% at each stage

1. UT is acceptable in place of RT only if the full penetration of the weld can be assessed by this method.

A. Visual and nondestructive examinations shall be performed by the Contractor to detect surface and internal discontinuities in completed welds. Visually examine welds. Radiographic (RT), Liquid penetrant (LT), Magnetic particle (MT), or Ultrasonic (UT) examination shall be required as indicated in Table I attached to this section. Random NDE testing shall be performed as specified. When examination and testing indicate defects in a weld joint, a qualified welder shall repair the weld in accordance with the paragraph entitled "Corrections and Repairs" of this section.

B. Visually examine welds.

C. Field welds: 100% of welds shall be inspected as follows:

1. Visual examination of the root.

2. Magnetic particle inspection after the first pass over the root.

3. Magnetic particle inspection after the final weld pass.

D. When examination and testing indicates defects in a weld joint, a qualified welder shall repair the weld in accordance with the paragraph entitled "Corrections and Repairs" of this section.

E. Visual Examination

Visually examine all welds as follows:

1. Before welding -- for compliance with requirements for joint preparation, placement of backing rings or consumable inserts, alignment and fit-up, and cleanliness.

2. During welding -- for conformance to the qualified welding procedure.

3. After welding -- for cracks, contour and finish, bead reinforcement, undercutting, overlap, and size of fillet welds.

F. Nondestructive Examination

NDE shall be in accordance with written procedures. Procedures for radiographic, liquid penetrant, magnetic particle, or ultrasonic tests and methods shall conform to CISC S16-14 and CSA W59. In addition, the written procedures shall include:

1. Timing of the nondestructive examination in relation to the welding operations.

2. Safety precautions.

G. Random NDE Testing

When radiographic examination is required, test a minimum of 10 percent of the total length or number of welds. Randomly select the welds examined but include an examination of welds made by each welding operator or welder. If random testing reveals that a weld fails to meet minimum quality requirements, examine an additional 10 percent of the welds in that same group. If the additional welds examined meet the quality requirements, the entire group of welds represented shall be accepted and the defective welds shall be repaired. If any of the additional welds examined also fail to meet the quality requirements,

that entire group of welds shall be rejected. Remove and reweld rejected welds or examine rejected welds 100 percent and remove and reweld defects.

H. All welding shall be inspected with oversight review by the Owner's authorized representative. Owner's authorized representative must be present to witness all testing and hold points. The contractor shall "hold" fabrication and notify Owner's authorized representative at the following points so that Owner's authorized representative may perform inspections at a minimum:

- At fit up, completion of first pass, and completion of cap pass.
- Prior to any welding on the penstock.
- To witness any NDE
- Surface preparation prior to coating

In addition to the hold points established above, Owner's authorized representative may require additional inspection points due to unforeseen or otherwise unusual conditions or situations. No inspection point shall be bypassed unless specifically directed by Owner's authorized representative in writing.

3.4 ACCEPTANCE STANDARDS

A. Visual

The following indications are unacceptable:

1. Cracks--external surface.

2. Undercut on surface which is greater than 1.00 mm 1/32 inch deep.

3. Lack of fusion on surface.

4. Incomplete penetration.

5. Convexity of fillet weld surface greater than 10 percent of longest leg plus 0.03 inch.

6. Concavity in groove welds.

7. Concavity in fillet welds greater than 1/16 inch.

8. Fillet weld size less than indicated or greater than 1 1/4 times the minimum specified fillet leg length.

B. Other NDE Types (RT, UT, MT, and PT)

Acceptance criteria shall conform to the requirements of CISC S16-14 and CSA W59.

3.5 CORRECTIONS AND REPAIRS

A. Remove defects and replace welds as specified in CISC S16-14 and CSA W59. Repair defects discovered between weld passes before additional weld material is deposited. Wherever a defect is removed, and repair by welding is not required, the affected area shall be blended into the surrounding surface eliminating sharp notches, crevices, or corners. After defect removal is complete and before rewelding, reexamine the area by the same test methods which first revealed the defect to ensure that the defect has been eliminated. After rewelding, reexamine the repaired area by the same test methods originally used for that area. For repairs to base material, the minimum examination shall be the same as required for butt welds. Indication of a defect shall be regarded as a defect unless reevaluation by NDE or by surface conditioning shows that no unacceptable indications are present. The use of foreign material to mask, fill in, seal, or disguise welding defects will not be permitted.

B. Defects shall be documented in a Non-Conformance Report (NCR) and submitted to the Owner. All costs associated with correcting errors, omissions, alternatives, testing, or substitutions shall be borne by contractor.

END OF SECTION

APPENDIX 16

FABRICATION SPECIFICATION

SECTION 05 52 00 – STEEL PENSTOCK FABRICATION

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

A. This specification is for fabrication of the new penstock as shown in the project drawings and indicated in this specification. The penstock shall be provided with the appropriate elbows, transitions, coatings and all other appurtenances as required to complete the job.

1.2 QUALITY ASSURANCE

A. Fabricator Qualifications: The penstock Fabricator must have successful experience in fabrication work of similar or greater complexity with minimum 5 years experience. Provide references upon request.

B. Erector Qualifications: Company specializing in performing the work of this section with minimum 5 years experience.

C. Shop Assembly: Preassemble items in shop to greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation. Owner reserves the right to inspect the fabrication facility at any time during the work. Fabrication Contractor shall coordinate the method of field assembly with the Installation Contractor.

D. Marking: Each Unit shall be marked with unit number, piece designation, upstream end, fabricator, and owner information. Markings shall be stenciled in a manner that is easily visible.

E. Fabricate structural steel members in accordance with CISC Code of Standard Practice (AISC Code of Standard Practice).

F. Perform Work in accordance with CISC Part 7 (AISC Section 10).

G. Maintain one copy of each document on site.

H. Codes and Standards: Comply with the provisions of the latest edition of the following, except as otherwise indicated:

Fabrication	ASME Boiler and PV Code, Section VIII, Div. 1 AWWA C200-12 "Steel Water Pipe 6 In. and Larger"
Shipping	AWWA Manual M11 "Steel Pipe – A guide for Design and Installation"

Welding	CSA W47.1 – Certification of Companies for Fusion Welding of Steel. CSA W59 – Welded Steel Construction. Canadian Institute of Steel Construction (CISC) S16-14 Handbook of Steel Construction latest edition
ASCE 79	ASCE Manuals and Reports on Engineering Practice No. 79 "Steel Penstocks"
AWWA C209	Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipe
AWWA C210	Liquid Epoxy Coatings and Linings for Steel Water Pipe and Fittings
AWWA C222	Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings
CISC S16-14, 6-188	(2014) Welded Joints Standard Symbols
CISC S16-14, 6-183	(2014) Welding Terms and Definitions
CISC G40.20-13	General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel
SSPC:	"Steel Structures Painting Council" – Volume 2
SSPC-SP5:	"White Metal Blast Cleaning"
SSPC-SP6:	"Commercial Blast Cleaning"
SSPC-SP10	"Near-White Metal Blast Cleaning"
SSPC-PA1:	"Shop, Field, and Maintenance Painting"
NACE	"National Association of Corrosion Engineers"
SSPC-PA2	"Measurement of Dry Film Thickness with Magnetic Gages"

1.3 SUBMITTALS

A. Submit all shop and field installation drawings to Owner prior to fabrication or installation. Include complete details and schedules for fabrication and assembly for all steel members including proposed field joint locations. Include details of cuts, connections, holes, and other pertinent data. Indicate welded connections with CSA W59 (AWS A2.4) welding symbols, and show size, length, and type of each shop and field weld.

B. Submit all shop welding procedures to Owner for approval prior to fabrication.

C. Welders Certificates: Certify welders employed on the Work, verifying CSA W47.1 (AWS) qualification within the previous 12 months..

D. The Fabricator shall submit copies of material certification and the welding inspections as required in this specification.

E. Submit a coating inspection report to the Owner for approval prior to shipping.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Shipping and Handling of fabricated sections shall be in accordance with AWWA Manual M11 "Steel Pipe Design and Installation".

B. The Contractor shall obtain all necessary permits and licenses required for shipping of the penstock sections.

C. Deliver materials to site at such intervals to insure uninterrupted progress of work. Contractor shall give Owner at least 24 hours advance notice and receive Owner's permission before delivering material to the site. Deliveries shall be scheduled for between 8 am and 3 pm on non-holiday Mondays through Fridays, unless otherwise agreed to by Owner.

D. Ship materials to permit easy access for inspection and identification before unloading. Before shipping keep steel members off the ground, using pallets, platforms, or other supports. Protect steel members and packaged materials from corrosion and deterioration.

E. Do not store materials on structure in a manner that might cause distortion or damage to members or supporting structures. Repair or replace damaged materials or structures as indicated.

F. Penstock sections shall be delivered with internal bracing/spiders to maintain circularity. These bracings shall be removed only after the penstock section is fully supported, concreted, and welded in its final location. Temporary bracing shall be located so that 9 inches from the ends of penstock sections is clear for field welding and testing.

G. Provide any items which are to be embedded in cast-in-place concrete or masonry, such as anchor bolts and anchorage devices, in ample time so as not to delay that work.

H. Penstock sections shall be provided with temporary lifting lugs. Lugs shall be removed, and welds dressed smooth and flush with the surrounding metal after installation.

PART 2 – PRODUCTS

2.1 MATERIALS

A. Penstock Shell and Joint Plates: ASTM A516 Grade 70 or approved equivalent material with minimum Yield Stress F_y = 260 MPa and Ultimate Tensile Stress, F_u = 480 MPa.

B. Stiffeners and Doublers: ASTM A516 Grade 70 or approved equivalent grade steel.

C. Pipe: ASTM A-53 Grade B

D. Bolts, nuts and washers: ASTM F3125 galvanized.

E. Welding electrodes to comply with asme Section IX or CISC Handbook of Steel Construction.

F. Bars and Strips: M1020.

2.2 COATINGS

A. Interior Lining

1. Surface Preparation: SSPC-SP-10 Blast Near-White (Minimum 2 mil anchor profile)

Self priming for steel; (One coat 20 mils DuraShield 210)

B. Exterior – Exposed and Buried

1. Surface Preparation: SSPC-SP-10 Blast Near-White (Minimum 2 mil anchor profile)

Same as above

C. Alternative coating schedules may be proposed by the Contractor for approval by the Owner. Proposed coatings must provide at least the following baseline specifications:

1. Abrasion Test (ASTM D4060) CS-17 Wheel, 1000 gram 1000 cycles maximum 130 mg loss.

2. Adhesion to Steel (ASTM 4541) 900-1100 psi

3. Salt Fog Resistance (ASTM B117) minimum 2500 hours

4. Interior: Meets NSF /ANSI Std. 60 standards for potable water systems.

PART 3 – EXECUTION

3.1 WELDING

A. Welding shall be performed according to SECTION 40 17 26 – PENSTOCK WELDING.

B. All welding operations including procedures, materials, and repairs are to conform to the ASME Boiler and PV code, Section VIII, Div. 1 or CISC S16-14. All welders and welding operators are to also be certified to Section IX or CWB.

C. The inside surfaces of the welds are to be smooth but do not need to be ground flush. All weld spatter, arc strikes, and other sharp projections that decrease the longevity of the paint system are to be removed. Maximum weld reinforcement profile is to be 1/8 inch.

D. All longitudinal and circumferential shop shell welds shall be shop welded with full penetration double welded butt joints.

E. Stagger the intersection of longitudinal joints at any circumferential seam by a minimum of 1'-0".

3.2 FABRICATION

A. All finished penstock tolerances and general fabrication procedures are to follow the ASME Boiler and P.V. Code Section VIII, Div. 1 and AWWA C200 Section 4.13. The difference between the major and minor outside diameters shall not exceed 1% and the actual outside circumference shall be within 1/4" of the calculated value. Add internal temporary spiders as necessary.

B. The Fabricator shall supply a minimum additional 1'-0" linear feet of penstock for field trimming and final alignment at each end of penstock as shown on project drawings.

C. The Fabricator shall fabricate the pipe to minimize field work. All field joints shall mate between straight cylindrical sections.

D. Each piece shall have external lifting lugs located on the top of the pipe and for straight sections located approximately 6 feet from each end. For eccentric pieces such as elbows the lifting lugs shall be located to facilitate erection, such as having the piece hang true to its final position when lifted.

E. Fabricator shall suppy L4x4x6-inch angles at 10 locations around the circumference of each straight section of pipe to facilitate penstock installation.

F. Fabricator will ensure radious of plate sections are constant to the edges to mitigate peaking at the longitudinal joint.

G. Transission from plate piece to piece along the longitudinal seam will carry a constant radious with no peaks.

3.3 COATINGS

A. See Section 2.2 for surface preparation and coating schedule of the penstock.

B. Do not shop paint within 2 inches of any field weld. Paint shall be free of all runs, drips and holidays.

C. Touch-Up Coating: Clean field welds, bolted connections, and abraded areas of shop applied coating, and provide these areas with the appropriate preceding coating application

D. Penstock Fabricator shall supply touch-up coating for installer's use to repair damaged areas of coatings.

3.4 ADJUST AND CLEAN

A. Shop Pre-fit of Sections: All pieces and joints shall be pre-fit in shop to verify proper fit up.

B. Fabricator shall coordinate and clearly mark mating pieces before shipping.

C. Welds

1. See Section 40 17 26 – Penstock Welding for quality control specifications.

2. Visual: All shop welds shall be visually examined by the Fabricator using an Inspector qualified in accordance with AWS QC1. Owner may visually inspect all welding to ensure conformance to the ASME Code, the AWS code, the approved project welding procedures, and AWWA C206.

3. Owner reserves the right to perform magnetic particle (MT), ultrasonic testing (UT), or radiography testing (RT) of any shop welding.

4. All welds not conforming to any of the above requirements and/or testing shall be repaired and any additional retesting completed at Contractor's or Fabricator's expense.

5. Owner may observe, at their discretion, the work at any stage of fabrication or construction including: (1) welds and welding inspections, (2) surface preparation for coatings, (3) application of pipe coatings, (4) pressure testing activities and (5) shop assembly of fabricated penstock sections prior to shipping. Observations are not to be considered as "stop work" points and Owner may delegate any observation to another party. A one (1) week notice shall be given to Owner before the application of any coatings/painting and for the final scheduled shop assembly and match marking activities.

D. Coatings

1. Material application shall be in strict accordance with the manufacturer's recommendations, the provisions of SSPC-PA1, and the requirements of this specification.

2. Dry film thicknesses shall be measured in accordance with procedures outlined in SSPC-PA2.

E. Fabricator shall shop fit and match mark mating pieces before shipping.

F. Shop Hydrostatic Testing

1. Hydrostatically shop testing penstock sections shall not be required if 100% of all shop welds are RT or UT tested.

2. Hydrostatically shop test penstock sections to a Pressure of 44 psi and conform to the test procedures described in AWWA C200 – Steel Water Pipe – 6in and Larger in Diameter.

3. Complete shop hydrostatic testing before application of linings and coatings.

END OF SECTION

APPENDIX 17

INSTALLATION SPECIFICATION

SECTION 05 52 01 – STEEL PENSTOCK INSTALLATION

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

A. This specification is for installation of the penstock and designated appurtenances that are shown on the Project Plans and indicated in this specification. Penstock shall be installed with the appropriate elbows, transitions, all permanent supports including anchor bolts, and all other appurtenances as required to complete the job.

1.2 QUALITY ASSURANCE

A. Contractor Qualifications: The Installing Contractor must have successful experience in installation of work of similar or greater complexity. Provide references upon request.

B. Codes and Standards: Comply with the provisions of the latest edition of the following, except as otherwise indicated:

ASCE 79	ASCE Manuals and Reports on Engineering Practice No. 79 "Steel Penstocks"
ASME	Boiler and Pressure Vessel Code, Section VIII, Div. 1
AWWA C200	Steel Water Pipe – 6in and Larger
AWWA C206	Field Welding of Steel Water Pipe
AWWA C209	Cold-Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipe
AWWA C210	Liquid Epoxy Coatings and Linings for Steel Water Pipe and Fittings
AWWA C213	Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings
AWWA C214	Tape Coating Systems for the Exterior of Steel Water Pipelines
AWWA C216	Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines
AWWA C222	Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings

AWWA C229	Fusion-Bonded Polyurethane Coatings for Steel Water Pipe and Fittings
AWWA M11	Steel Water Pipe – A Guide for Design and Installation
CISC S16-14, 6-188	(2014) Welded Joints Standard Symbols
CISC S16-14, 6-183	(2014) Welding Terms and Definitions
CISC G40.20-13	General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel
SSPC	"Steel Structures Painting Council"- Volume 2
SSPC-SP5	"White Metal Blast Cleaning"
SSPC-SP6	"Commercial Blast Cleaning"
SSPC-SP10	"Near-White Metal Blast Cleaning"
SSPC-PA1	"Shop, Field, and Maintenance Painting"
NACE	"National Association of Corrosion Engineers"
SSPC-PA2	"Measurement of Dry Film Thickness with Magnetic Gages"
USACE	Corps of Engineers Civil Works Construction Guide CW-09940, "Painting of Hydraulic Structures and Appurtenant Works".
Welding	CSA W47.1 – Certification of Companies for Fusion Welding of Steel. CSA W59 – Welded Steel Construction Canadian Institute of Steel Construction (CISC) S16-14 Handbook of Steel Construction latest edition

1.3 SUBMITTALS

A. Submit all field welding procedures to Owner for approval prior to installation. Provide CWB (Canadian Welding Bureau) certification documentation for all welders and welding operators.

B. Proposed exterior coating and interior lining schedules and product data for field joints, touch-ups, and lifting lugs.

C. Proposed bracing to be used during shipping to maintain steel shape

1.4 STORAGE AND HANDLING

A. Shipping and Handling of fabricated sections shall be in accordance with AWWA Manual M11 "Steel Pipe Design and Installation".

B. Install any items which are to be embedded in cast-in-place concrete or masonry, such as anchor bolts and anchorage devices, in ample time so as not to delay that work.

C. Protect steel members and packaged materials from corrosion and deterioration.

D. Do not store materials in a manner that might cause distortion or damage to materials, members or supporting structures. Repair or replace damaged materials or structures as indicated.

PART 2 – PRODUCTS

2.1 MATERIALS

A. See Spec Section 05 52 00 for fabrication details of the penstock and any appurtenances.

B. Welding electrodes to comply with ASME Section IX or CISC Handbook of Steel Construction.

2.2 COATINGS

Touch-up and coat uncoated field-welded joints of the installed penstock in the field. Field coatings and linings shall match the coating and lining schedule of the fabricated and supplied penstock. See Section 05 52 00 – Penstock Fabrication for interior and exterior coating specifications.

A. Interior Lining

1. Surface Preparation: SSPC-SP-10 Blast Near-White (Minimum 2 mil anchor profile)

2. Primer Coat: Sherwin Williams Corothane I Galvapav 1K or 2K Zinc Primers @ 3-4 mils dry.

3. Intermediate Coat: Sherwin Williams MacroPoxy 646 PW @ 3-4 mils dry.

4. Stripe Coat: Apply a stripe coat to all weld seams Sherwin Williams MacroPoxy 646 PW @ 3-4 mils dry.

5. Finish Coat: Apply ONE full finish coat of Sherwin Williams MacroPoxy 646 PW, White @ 3-4 mils dry.

B. Exterior – Exposed and Buried

1. Surface Preparation: SSPC-SP-10 Blast Near-White (Minimum 2 mil anchor profile)

2. Primer Coat: Sherwin Williams Corothane I Galvapav 1K or 2K Zinc Primers @ 3-4 mils dry.

3. Finish Coat: Sherwin Williams Dura-Plate 6000 Reinforced Epoxy @ 70-80 mils dry.

2.3 EARTHWORK

See Section 31 00 00 – Earthwork for pipe bedding and pipe backfill material, fill placement and compaction procedures.

PART 3 – EXECUTION

3.1 WELDING

A. Welding shall be performed according to SECTION 40 17 26 – PENSTOCK WELDING.

B. All welding operations including procedures, materials, and repairs are to conform to the ASME Boiler and PV code, Section VIII, Div. 1 or CISC S16-14. All welders and welding operators are to also be certified to Section IX or CWB.

C. The inside surfaces of the welds are to be smooth but do not need to be ground flush. All weld spatter, arc strikes, and other sharp projections that decrease the longevity of the paint system are to be removed. Maximum weld reinforcement profile is to be 1/8 inch.

D. Field joint circumferential welds shall be the full penetration weld, bell and spigot, or banded joint connection as shown on the Drawings. Field shim and fit to meet welding code requirements.

E. Stagger the intersection of longitudinal joints at any circumferential seam by a minimum of 1-0".

F. Welding of the final closure joints shall be done when the temperature of the penstock is under 50° F unless a variation from this condition is approved by the Engineer.

3.2 FIELD COATINGS

A. Install vendor-supplied touch-up coatings to field welded and damaged areas of coatings.

B. Do not shop paint within 2" of any field welds. Paint shall be free of all runs, drips, and holidays.

C. Field Joints:

1. Welded joints shall be smooth, cleaned of mud, oil, grease, and other foreign contaminants. Wire brush clean exposed metal to remove corrosion products.

2. Clean field welds, bolted connections, and abraded areas of shop applied coating, and provide these areas with the appropriate coating schedule.

3. Weld cutback area shall receive a complete coating application. This area shall have SSPC SP-3 "Power Tool Cleaning" after removing welding slag and before applying coating.

D. Touch-Up Coating: Clean field welds, bolted connections, and abraded areas of shop applied coating, and provide these areas with the appropriate preceding coating application.

E. Complete a low voltage wet holiday test in both the field weld area and the penstock shell to determine area requiring new top coat. All locations with indications shall receive a refresher (top) coat.

3.3 INSPECTION

A. WELDS

1. See Section 40 17 26 – Penstock Welding for quality control specifications.

B. COATINGS

1. Material application shall be in strict accordance with the manufacturer's recommendations, the provisions of SSPC-PA1, and the requirements of this specification.

2. Dry film thicknesses shall be measured in accordance with procedures outlined in SSPC-PA2.

C. Operational Testing

1. Prior to operational testing, the penstock will be buried, and soil compacted to final designed conditions and flushed to eliminate any debris that may affect the seals of the turbine. During the operational test, the turbine will be connected to the penstock, and the turbine wicket gates shall be closed using the normal fastest closing rates advisable, but not faster than 5 seconds.

D. Field Leak Check

1. During pipe fill-up, follow the water-up procedures described in Chapter 15 of ASCE No.79.

    a. Conduct a baseline survey of field-final conditions.

    b. The interior of the system shall be inspected in a walk-through by Owner to ensure that construction debris, tools, and personnel have been removed.

    c. Ensure that manholes and valves are closed, and air vents are open.

    d. Contractor shall receive Owner approval (timeline to be determined by Contractor and Owner) to rewater system after items a-c are completed.

    e. Penstock shall be watered at no more than 10 vertical feet per hour. The Owner shall be contacted immediately if any problems arise during the rewatering process.

    f. After rewatering, the bulkheads/stoplogs shall be re-installed and the system to stay statically watered for 24 hours before pressurizing the system beyond normal operating conditions.

2. Owner shall conduct operational testing of penstock preforming unit trips on the penstock.

3. After testing, the penstock shall remain filled with water for at least 12 hours without any leakage. Penstock may operate during this time.

4. Contractor's work scope is not considered complete until Owner's operational testing is complete and the penstock had remained operational for a minimum of 12 hours without leakage.

3.4 EARTHWORK QUALITY CONTROL

See Section 31 00 00 – Earthwork for quality control specifications.

END OF SECTION

APPENDIX 18

CHANT REFERENCE PROJECTS

Reference Projects

Chant Projects

PROJECT NAME / LOCATION	ROLE / RESPONSIBILITY
Matabitchuan Penstock Replacement **2.5 MW Francis, 4 Units** OPG – Northeast Ontario Group Haileybury, Ontario 2012 **Project Value: $ 24 million** **Contract Value: $ 400,000** **Contact Information:** Pat Bourgouin (705)-267-7033, ext. 3307 Patrick.bourgouin@opg.com	**CONSTRUCTION MANAGEMENT**  The project was to replace two individual 1.5m diameter penstocks and appurtenances with a partially buried single 2.2m diameter penstock with bifurcations at the top and bottom. Chant scope of work included: • Representing the Owner on site • Provided construction engineering support to owner on design-build project • Responsible for site monitoring, quality, schedule and environmental impact • Detailed productivity and cost tracking/reporting /forecasting, payment certifications • Change management, negotiating with the contractor the eligibility of certain costs as reimbursable • Quality assurance and certain quality control services • Coordination of site activities with other contractors and advising on dispute resolution/solution scenarios

Chant Projects

PROJECT NAME / LOCATION	ROLE / RESPONSIBILITY
Box Canyon Hydroelectric Project Port Mellon, B. C. **Project Total: $ 34million** **Chant Value: $ 2.1million** **Duration:** Jun. 2014 – Dec. 2015 **Owner:** Box Canyon Hydroelectric Corp. (Elemental Energy) **Contact Information:** Ryan Hanson, Owner's Project Manager (604) 695-2916 **Consultant:** Knight Piesold **Contact:** Egbert Scherman (604) 685-0543  	**CONSTRUCTION MANAGEMENT**  A 15 mW run-of-river hydroelectric generating station located near Port Mellon, B.C. The project consists of three high level intake diversions for Box Canyon Creek, Marty Creek, Cascara Creek, a number of small tributaries, a conveyance pipeline, a penstock network and a single unit powerhouse that discharges into McNabb Creek. The scope of work included: • Project and construction management services as well as quality assurance. These services include: - In the early conctractor involvement phase, tailored DBB procurement strategy - Site work performance monitoring, tracking and reporting - Hold and witness point inspections on "delicate" pieces of work Monitoring safety, quality, schedule and environmental impact - Facilitate, through observations and professional experience, the orderly, efficient and effective execution of the work with respect to the design and specifications - Daily/weekly/monthly reportings.

Chant Projects

PROJECT NAME / LOCATION	ROLE / RESPONSIBILITY
Nipissing Generating Station Penstock Replacement Cost Estimate South River, ON **Project Value: $ 8,200,000** **Duration:** Oct. 2012 –Dec. 2013 **Key Personnel:** Damon Liu Ivan Huang **Owner:** Ontario Power Generation Central Operations **Contact Information:** OPG-Central Operations Project Engineer, Dave Bonell dave.bonell@opg.com	Estimating Services  *Nipissing GS Penstock Historical Picture* The Nipissing Generating Station was built in 1909. In 1923, it was upgraded to a total of 2100 kilowatts with two generating units. The original wooden penstock was replaced in 1953with a new one; however, this latest woodstave penstock was demolished in 2010 and the station has not generated power since then. After the Central Operations of OPG examined the economics of bringing the station back online. Chant was assigned the task of evaluating the comparative costs of replacement Fiber Reinforced Polymer (FRP) penstock and steel penstock options. Chant developed an AACE (American Association of Cost Engineers) Class 3 with Chant's stardard contractor style. The work scope was the rehabilitation of the existing intake structure and installation of a new Fibre Reinforced Polymer (FRP) or steel penstock between the intake and the connection with the existing steel penstock portion upstream of the powerhouse and surge tank. A fibre optic communication link is also included between the powerhouse and the spillway with a connection to the intake In 2013, Chant re-evaluate the Project costs based on simply rehalitating the existing intake structure instead of replacement to make the Project more financially feasible.

APPENDIX 19

MATERIAL QUANTITY TAKEOFF

Bay dEspoir - Penstock

Steel Pipe Weight Take Off

A516 GR 70 Carbon Steel

Section		Sta Start	Sta End	Pipe Length	ID	Thickness	OD	Section Area	Density	Total Weight	Total Weight
				m	m	m	m	m2	kg/m3	kg	Tonne
1	1+68 - 1A	168.00	231.68	19.41	5.1820	0.0111	5.2042	0.1813	7,800	27,447.45	27.00
2	1A - 2A	231.68	550.00	97.73	5.1820	0.0111	5.2042	0.1813	7,800	138,202.74	138.00
3	2A - 3A	550.00	800.00	76.20	5.1820	0.0111	5.2042	0.1813	7,800	107,759.69	108.00
4	3A - 4A	800.00	1250.00	137.78	5.1820	0.0111	5.2042	0.1813	7,800	194,843.27	195.00
Total				**331.13**						**468,997**	**468**

Section Length	Section Weight (tonne)
15m	21.00

Chant Limited

Bay D'Espoir

Summary

Penstock 1 Refurbishment					Penstock 1 Replacement
15.25 ft Longitudinally weld weight	15.25 ft Circumferential weld weight	13.5 ft Longitudinally weld weight	13.5 ft Circumferential weld weight	10-5'x1/4P Hatches Weld Weight (5 Hatches)	17' Circumferential weld weight
kg	kg	kg	kg	kg	kg
366	1,391	1,498	3,372	151	419

17' Replacement Penstock 1								Penstock 1 Refurbishment	
SC#1	Coarse Gravel	SC #2	Common Fill	Class A	Excavation			Excavation	BackFill
					Rock	Common Fill	Sand		
tonne	tonne	tonne	tonne	tonne	tonne	tonne	tonne	tonne	tonne
4,860	3,406	7,615	16,009	186	5,354	15,684	8,795	34,761	34,761

Penstock 1 Replacement								Penstock 1 Refurbishment			
SC#1	Coarse Gravel	SC #2	Common Fill	Class A	Excavation			Excavation		Backfill	Interior Coating Surface Area
					Rock	Common Fill	Sand	Excavation by Equipment	Excavation Manually		
m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^2
2,179	1,527	3,415	7,179	83	2,550	7,033	3,944	13,953	1,635	15,588	10,489

Penstock 1 Replacement			
Penstock Length	Geotextile Fabric	6" Perforated PVC	203mm Drain Pipe
m	m^2	m	m
331	5,235	331	19

Chant Limited

Bay D'Espoir

Weld Weight Calculation

Assume: circumferential excavation length is 5' per each

50% of welds need to be refurbished, 70% of welds require full depth refurbishment, 30% require shallow depth refurbishent

Shallow weld were assumed to have a depth equal to half the can thickness and do not require excavation for two-sided access

Full depth welds were assumed to have a depth equal to the full can thickness and require excavation for two-sided access

New Penstock 17" Circumferential Welding							
Number	Weld Length	Thickness	D	A part	B part	C part	Weld Weight
EA	ft	in	in	lbs/ft	lbs/ft	lbs/ft	lbs
30	1602	7/16	7/16	0.279	0.174	0.124	**924**

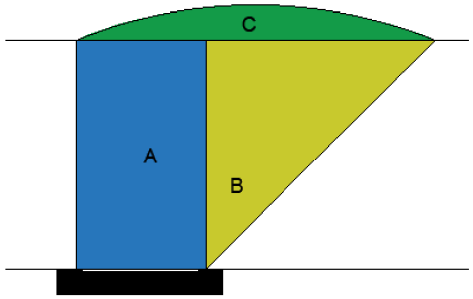
Haching/Doors Welding Weight										
Thickness	A Part	B Part	C Length	C Part	Vertical Weld	A Part	B Part	C Length	C Part	Horizontal Weld
in	lbs/ft	lbs/ft	in	lbs/ft	lbs	lbs/ft	lbs/ft	in	lbs/ft	lbs
7/16	0.372	0.174	7/16	0.124	16	0.279	0.325	5/8	0.177	7.81
9/16	0.478	0.288	1/2	0.142	22	0.359	0.538	3/4	0.213	11.1
11/16	0.584	0.431	9/16	0.159	28	0.438	0.804	7/8	0.248	14.9
3/4	0.638	0.512	5/8	0.177	32	0.478	0.956	15/16	0.266	17
3/4	0.638	0.512	5/8	0.177	28	0.478	0.956	15/16	0.266	17
13/16	0.691	0.601	5/8	0.177	31	0.518	1.12	1	0.283	19.21
1 1/16	0.903	1.03	3/4	0.213	46	0.677	1.92	1 1/4	0.354	29.51
1 1/4	1.06	1.42	7/8	0.248	58	0.797	2.66	1 7/16	0.407	38.64
1 3/8	1.17	1.72	15/16	0.266	67	0.877	3.21	1 9/16	0.443	45.3
1 9/16	1.33	2.22	1 1/16	0.301	82	0.996	4.15	1 3/4	0.496	56.42
Total					**409**					**257**

General Information							Circuferential Shallow Weld Refurbished								
Station	Thickness	length	No.	Slope	Longitudinal Total Refurbished Weld Length	Circumferential Total Refurbished Weld length	Half Thickness	1.5 Thickness	A Part	B Part	B&C part Depth	C Part	D Part Depth	D Part	Circumferential Shallow Weld Weight
	in	ft	EA		ft	ft	in	in	lbs/ft	lbs/ft	in	lbs/ft		lbs/ft	lb
4A	**9/16**		4			95.82	1/4	13/16	0.188	0.568	7/16	0.115	9/16	0.159	29.61
	7/16	160.04	18	14.5	160.04	431.18	3/16	5/8	0.188	0.398	5/16	0.059	1/2	0.142	101.8
	1/2	126.57	15		126.57	359.32	1/4	3/4	0.188	0.478	3/8	0.084	9/16	0.159	97.99
	9/16	74.78	9		74.78	215.59	1/4	13/16	0.188	0.568	7/16	0.115	9/16	0.159	66.62
5A	3/4		4			95.82	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	16.44
	9/16	127.71	15	5	127.71	359.32	1/4	13/16	0.188	0.568	7/16	0.115	9/16	0.159	111.03
	5/8	223.57	25		223.57	598.87	5/16	7/8	0.188	0.159	1/8	0.0094	7/16	0.124	86.31
6A	13/16		4			95.82	3/8	1 3/16	0.188	0.239	3/16	0.021	7/16	0.124	16.44
	5/8	49.04	6	10	49.04	143.73	5/16	7/8	0.188	0.159	1/8	0.0094	7/16	0.124	20.71
	11/16	94.24	11		94.24	263.50	5/16	1	0.188	0.159	1/8	0.0094	7/16	0.124	37.98
	3/4	145.44	17		145.44	407.23	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	69.88
	3/4	4	1		4	23.95	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	4.11
	3/4	12	1		12	23.95	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	4.11
7A	3/4		4			95.82	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	16.44
															679.47
	3/4	12	1	10	12	21.21	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	3.64
	3/4	4	1		4	21.21	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	3.64
	3/4	4	1		4	21.21	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	3.64
	3/4	4	1		4	21.21	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	3.64
	3/4	8	1		8	21.21	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	3.64
	3/4	8	1		8	21.21	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	3.64
	3/4	108.92	13		108.92	275.67	3/8	1 1/8	0.188	0.239	3/16	0.021	7/16	0.124	47.31
	13/16	116.27	13		116.27	275.67	3/8	1 3/16	0.188	0.239	3/16	0.021	7/16	0.124	47.31
	7/8	114.56	13		114.56	275.67	7/16	1 5/16	0.188	0.319	1/4	0.037	1/2	0.142	56.73
8A	1 1/8		4			84.82	9/16	1 11/16	0.188	0.478	3/8	0.084	9/16	0.159	23.13
	15/16	144.17	17	6.5	144.17	360.50	7/16	1 3/8	0.188	0.319	1/4	0.037	1/2	0.142	74.19
	1	142.09	16		142.09	339.29	1/2	1 1/2	0.188	0.398	5/16	0.059	1/2	0.142	80.11
	1 1/16	33.91	4		33.91	84.82	1/2	1 9/16	0.188	0.398	5/16	0.059	1/2	0.142	20.03
	1 1/8	135.33	16		135.33	339.29	9/16	1 11/16	0.188	0.478	3/8	0.084	9/16	0.159	92.52
	1 3/16	20.91	2		20.91	42.41	9/16	1 3/4	0.188	0.478	3/8	0.084	9/16	0.159	11.57
9A	1 3/8		4			84.82	11/16	2 1/8	0.188	0.638	1/2	0.15	9/16	0.159	28.88
	1 3/16	87.47	10	11.5	87.47	212.06	9/16	1 3/4	0.188	0.478	3/8	0.084	9/16	0.159	57.83
	1 1/4	103.42	12		103.42	254.47	5/8	1 7/8	0.188	0.568	7/16	0.115	9/16	0.159	78.63
	1 5/16	103.42	12		103.42	254.47	5/8	2	0.188	0.568	7/16	0.115	9/16	0.159	78.63
	1 3/8	103.42	12		103.42	254.47	11/16	2 1/8	0.188	0.638	1/2	0.15	9/16	0.159	86.65
	1 7/16	103.42	12		103.42	254.47	11/16	2 1/8	0.188	0.638	1/2	0.15	9/16	0.159	86.65
	1 1/2	22.36	2		22.36	42.41	3/4	2 1/4	0.188	0.717	9/16	0.19	5/8	0.177	16.18
10A	1 3/4		4			84.82	7/8	2 5/8	0.188	0.877	11/16	0.283	5/8	0.177	38.81
	1 1/2	58.49	7	20	58.49	148.44	3/4	2 1/4	0.188	0.717	9/16	0.19	5/8	0.177	56.64
	1 9/16	64.34	8		64.34	169.65	3/4	2 3/8	0.188	0.717	9/16	0.19	5/8	0.177	64.74
11A	1 7/8		4			84.82	15/16	2 3/4	0.188	0.956	3/4	0.337	11/16	0.195	42.65
	1 9/16	10.26	1	20	10.26	21.21	3/4	2 3/8	0.188	0.717	9/16	0.19	5/8	0.177	8.09
Total															**1119**

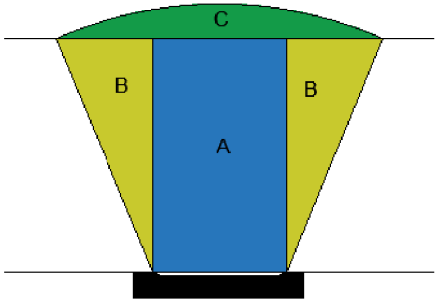
General Information							Longitudinal Shallow Weld Refurbished		
Station	Thickness	length	No.	Slope	Longitudinal Total Refurbished Weld Length	Circumferential Total Refurbished Weld length	A part	B Part	Longitudinal Shallow Weld Weight
	in	ft	EA		ft	ft	lbs/ft	lbs/ft	lb
4A	**9/16**		4			95.82	0.106	0.035	0
	7/16	160.04	18		160.04	431.18	0.06	0.027	4.18
	1/2	126.57	15	14.5	126.57	359.32	0.106	0.035	5.35
	9/16	74.78	9		74.78	215.59	0.106	0.035	3.16
5A	3/4		4			95.82	0.239	0.106	0
	9/16	127.71	15	5	127.71	359.32	0.106	0.035	5.4
	5/8	223.57	25		223.57	598.87	0.166	0.044	14.08
6A	13/16		4			95.82	0.239	0.106	0
	5/8	49.04	6		49.04	143.73	0.166	0.044	3.09
	11/16	94.24	11		94.24	263.50	0.166	0.044	5.94
	3/4	145.44	17	10	145.44	407.23	0.239	0.106	15.05
	3/4	4	1		4	23.95	0.239	0.106	0.41
	3/4	12	1		12	23.95	0.239	0.106	1.24
7A	3/4		4			95.82	0.239	0.106	0
									58
	3/4	12	1		12	21.21	0.239	0.106	1.24
	3/4	4	1		4	21.21	0.239	0.106	0.41
	3/4	4	1		4	21.21	0.239	0.106	0.41
	3/4	4	1		4	21.21	0.239	0.106	0.41
	3/4	8	1	10	8	21.21	0.239	0.106	0.83
	3/4	8	1		8	21.21	0.239	0.106	0.83
	3/4	108.92	13		108.92	275.67	0.239	0.106	11.27
	13/16	116.27	13		116.27	275.67	0.239	0.106	12.03
	7/8	114.56	13		114.56	275.67	0.325	0.124	15.43
8A	1 1/8		4			84.82	0.538	0.159	0
	15/16	144.17	17		144.17	360.50	0.325	0.124	19.42
	1	142.09	16		142.09	339.29	0.425	0.142	24.17
	1 1/16	33.91	4	6.5	33.91	84.82	0.425	0.142	5.77
	1 1/8	135.33	16		135.33	339.29	0.538	0.159	28.3
	1 3/16	20.91	2		20.91	42.41	0.538	0.159	4.37
9A	1 3/8		4			84.82	0.804	0.195	0
	1 3/16	87.47	10		87.47	212.06	0.538	0.159	18.29
	1 1/4	103.42	12		103.42	254.47	0.664	0.177	26.09
	1 5/16	103.42	12	11.5	103.42	254.47	0.664	0.177	26.09
	1 3/8	103.42	12		103.42	254.47	0.804	0.195	30.99
	1 7/16	103.42	12		103.42	254.47	0.804	0.195	30.99
	1 1/2	22.36	2		22.36	42.41	0.956	0.213	7.84
10A	1 3/4		4			84.82	1.3	0.248	0
	1 1/2	58.49	7	20	58.49	148.44	0.956	0.213	20.51
	1 9/16	64.34	8		64.34	169.65	0.956	0.213	22.56
11A	1 7/8		4			84.82	1.49	0.266	0
	1 9/16	10.26	1	20	10.26	21.21	0.956	0.213	3.6
Total									312

General Information							Circuferential Full Depth Weld Refurbished								
Station	Thickness	length	No.	Slope	Longitudinal Total Refurbished Weld Length	Circumferential Total Refurbished Weld length	A part	B part	B&C part Depth	C Part	D part Depth	D Part	E Part	F Part	Circumferential Full Penetration Weld Weight
	in	ft	EA		ft	ft	lbs/ft	lbs/ft	in	lbs/ft	in	lbs/ft	lbs/ft	lbs/ft	lb
4A	**9/16**		4			95.82	0.188	0.319	1/4	0.037	1/2	0.142	0.188	0.106	65.73
	7/16	160.04	18		160.04	431.18	0.188	0.159	1/8	0.0094	7/16	0.124	0.188	0.106	233.74
	1/2	126.57	15	14.5	126.57	359.32	0.188	0.239	3/16	0.021	7/16	0.124	0.188	0.106	217.82
	9/16	74.78	9		74.78	215.59	0.188	0.319	1/4	0.037	1/2	0.142	0.188	0.106	147.9
5A	3/4		4			95.82	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	88.8
	9/16	127.71	15	5	127.71	359.32	0.188	0.319	1/4	0.037	1/2	0.142	0.188	0.106	246.49
	5/8	223.57	25		223.57	598.87	0.188	0.398	5/16	0.059	1/2	0.142	0.188	0.106	453.16
6A	13/16		4			95.82	0.188	0.638	1/2	0.15	9/16	0.159	0.188	0.106	95.85
	5/8	49.04	6		49.04	143.73	0.188	0.398	5/16	0.059	1/2	0.142	0.188	0.106	108.76
	11/16	94.24	11		94.24	263.50	0.188	0.478	3/8	0.084	1/2	0.142	0.188	0.106	218.76
	3/4	145.44	17	10	145.44	407.23	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	377.42
	3/4	4	1		4	23.95	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	22.2
	3/4	12	1		12	23.95	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	22.2
7A	3/4		4			95.82	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	88.8
															2388
	3/4	12	1		12	21.21	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	19.65
	3/4	4	1		4	21.21	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	19.65
	3/4	4	1		4	21.21	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	19.65
	3/4	4	1		4	21.21	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	19.65
	3/4	8	1	10	8	21.21	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	19.65
	3/4	8	1		8	21.21	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	19.65
	3/4	108.92	13		108.92	275.67	0.188	0.568	7/16	0.115	9/16	0.159	0.188	0.106	255.5
	13/16	116.27	13		116.27	275.67	0.188	0.638	1/2	0.15	9/16	0.159	0.188	0.106	275.76
	7/8	114.56	13		114.56	275.67	0.188	0.717	9/16	0.19	9/16	0.159	0.188	0.106	298.72
8A	1 1/8		4			84.82	0.188	1.04	13/16	0.396	11/16	0.195	0.188	0.106	125.46
	15/16	144.17	17		144.17	360.50	0.188	0.797	5/8	0.234	9/16	0.159	0.188	0.106	421.93
	1	142.09	16		142.09	339.29	0.188	0.877	11/16	0.283	5/8	0.177	0.188	0.106	432.02
	1 1/16	33.91	4	6.5	33.91	84.82	0.188	0.956	3/4	0.337	5/8	0.177	0.188	0.106	115.9
	1 1/8	135.33	16		135.33	339.29	0.188	1.04	13/16	0.396	11/16	0.195	0.188	0.106	501.85
	1 3/16	20.91	2		20.91	42.41	0.188	1.12	7/8	0.459	11/16	0.195	0.188	0.106	66.98
9A	1 3/8		4			84.82	0.188	1.35	1 1/16	0.677	3/4	0.213	0.188	0.106	161.62
	1 3/16	87.47	10		87.47	212.06	0.188	1.12	7/8	0.459	11/16	0.195	0.188	0.106	334.88
	1 1/4	103.42	12		103.42	254.47	0.188	1.2	15/16	0.527	11/16	0.195	0.188	0.106	428.22
	1 5/16	103.42	12		103.42	254.47	0.188	1.28	1	0.6	3/4	0.213	0.188	0.106	458.68
	1 3/8	103.42	12	11.5	103.42	254.47	0.188	1.35	1 1/16	0.677	3/4	0.213	0.188	0.106	484.87
	1 7/16	103.42	12		103.42	254.47	0.188	1.43	1 1/8	0.759	13/16	0.23	0.188	0.106	516.75
	1 1/2	22.36	2		22.36	42.41	0.188	1.51	1 3/16	0.845	13/16	0.23	0.188	0.106	91.05
10A	1 3/4		4			84.82	0.188	1.83	1 7/16	1.24	7/8	0.248	0.188	0.106	225.63
	1 1/2	58.49	7	20	58.49	148.44	0.188	1.51	1 3/16	0.845	13/16	0.23	0.188	0.106	318.69
	1 9/16	64.34	8		64.34	169.65	0.188	1.59	1 1/4	0.937	13/16	0.23	0.188	0.106	384.64
11A	1 7/8		4			84.82	0.188	1.99	1 9/16	1.46	15/16	0.266	0.188	0.106	249.26
	1 9/16	10.26	1	20	10.26	21.21	0.188	1.59	1 1/4	0.937	13/16	0.23	0.188	0.106	48.08
Total															**6314**

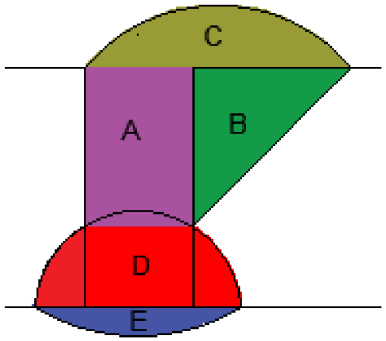
General Information							Longitudinal Full depth Weld Refurbished						
Station	Thickness	length	No.	Slope	Longitudinal Total Refurbished Weld Length	Circumferential Total Refurbished Weld length	A Part	A&B part Depth	B Part	C Part	D Part	E Part	Longitudinal Full Penetration Weld Weight
	in	ft	EA		ft	ft	lbs/ft	in	lbs/ft	lbs/ft	lbs/ft	lbs/ft	lb
4A	**9/16**		4			95.82	0.186	7/16	0.325	0.159	0.188	0.106	0
	7/16	160.04	18		160.04	431.18	0.133	5/16	0.166	0.124	0.188	0.106	80.32
	1/2	126.57	15	14.5	126.57	359.32	0.159	3/8	0.239	0.142	0.188	0.106	73.89
	9/16	74.78	9		74.78	215.59	0.186	7/16	0.325	0.159	0.188	0.106	50.46
5A	3/4		4			95.82	0.266	5/8	0.664	0.213	0.188	0.106	0
	9/16	127.71	15	5	127.71	359.32	0.186	7/16	0.325	0.159	0.188	0.106	86.18
	5/8	223.57	25		223.57	598.87	0.213	1/2	0.425	0.177	0.188	0.106	173.56
6A	13/16		4			95.82	0.292	11/16	0.804	0.23	0.188	0.106	0
	5/8	49.04	6		49.04	143.73	0.213	1/2	0.425	0.177	0.188	0.106	38.07
	11/16	94.24	11		94.24	263.50	0.239	9/16	0.538	0.195	0.188	0.106	83.52
	3/4	145.44	17	10	145.44	407.23	0.266	5/8	0.664	0.213	0.188	0.106	146.3
	3/4	4	1		4	23.95	0.266	5/8	0.664	0.213	0.188	0.106	4.02
	3/4	12	1		12	23.95	0.266	5/8	0.664	0.213	0.188	0.106	12.07
7A	3/4		4			95.82	0.266	5/8	0.664	0.213	0.188	0.106	0
													748
	3/4	12	1		12	21.21	0.266	5/8	0.664	0.213	0.188	0.106	12.07
	3/4	4	1		4	21.21	0.266	5/8	0.664	0.213	0.188	0.106	4.02
	3/4	4	1		4	21.21	0.266	5/8	0.664	0.213	0.188	0.106	4.02
	3/4	4	1		4	21.21	0.266	5/8	0.664	0.213	0.188	0.106	4.02
	3/4	8	1	10	8	21.21	0.266	5/8	0.664	0.213	0.188	0.106	8.05
	3/4	8	1		8	21.21	0.266	5/8	0.664	0.213	0.188	0.106	8.05
	3/4	108.92	13		108.92	275.67	0.266	5/8	0.664	0.213	0.188	0.106	109.56
	13/16	116.27	13		116.27	275.67	0.292	11/16	0.804	0.23	0.188	0.106	131.85
	7/8	114.56	13		114.56	275.67	0.319	3/4	0.956	0.248	0.188	0.106	145.71
8A	1 1/8		4			84.82	0.425	1	1.7	0.319	0.188	0.106	0
	15/16	144.17	17		144.17	360.50	0.345	13/16	1.12	0.266	0.188	0.106	204.36
	1	142.09	16		142.09	339.29	0.372	7/8	1.3	0.283	0.188	0.106	223.69
	1 1/16	33.91	4	6.5	33.91	84.82	0.398	15/16	1.49	0.301	0.188	0.106	58.94
	1 1/8	135.33	16		135.33	339.29	0.425	1	1.7	0.319	0.188	0.106	259.37
	1 3/16	20.91	2		20.91	42.41	0.452	1 1/16	1.92	0.336	0.188	0.106	43.94
9A	1 3/8		4			84.82	0.531	1 1/4	2.66	0.39	0.188	0.106	0
	1 3/16	87.47	10		87.47	212.06	0.452	1 1/16	1.92	0.336	0.188	0.106	183.81
	1 1/4	103.42	12		103.42	254.47	0.478	1 1/8	2.15	0.354	0.188	0.106	237.16
	1 5/16	103.42	12	11.5	103.42	254.47	0.505	1 3/16	2.4	0.372	0.188	0.106	258.52
	1 3/8	103.42	12		103.42	254.47	0.531	1 1/4	2.66	0.39	0.188	0.106	280.53
	1 7/16	103.42	12		103.42	254.47	0.558	1 5/16	2.933	0.407	0.188	0.106	303.48
	1 1/2	22.36	2		22.36	42.41	0.584	1 3/8	3.21	0.425	0.188	0.106	70.64
10A	1 3/4		4			84.82	0.691	1 5/8	4.49	0.496	0.188	0.106	0
	1 1/2	58.49	7	20	58.49	148.44	0.584	1 3/8	3.21	0.425	0.188	0.106	184.78
	1 9/16	64.34	8		64.34	169.65	0.611	1 7/16	3.51	0.443	0.188	0.106	218.79
11A	1 7/8		4			84.82	0.744	1 3/4	5.21	0.531	0.188	0.106	0
	1 9/16	10.26	1	20	10.26	21.21	0.611	1 7/16	3.51	0.443	0.188	0.106	34.89
Total													**2990**



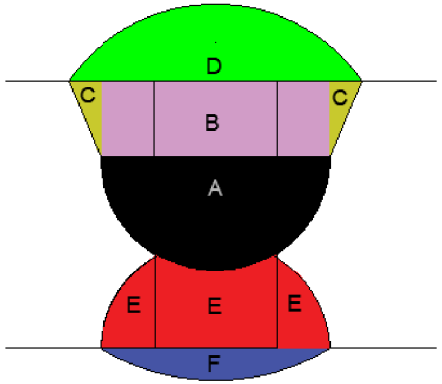
Hatches Horizontal Welding



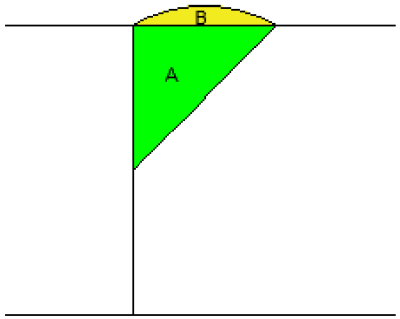
New Penstock Circumferential Welding
and Hatches Vertical Welding



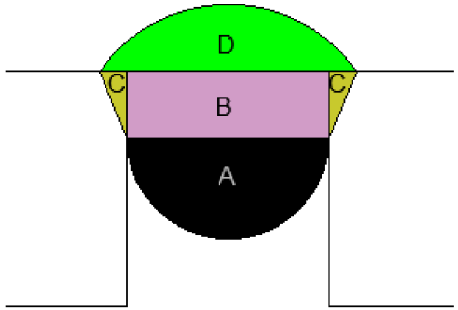
Refurbished Penstock Full Depth Longitudinal Welding



Refurbished Penstock Full Depth Circumferential Welding



Refurbished Penstock Shallow Longitudinal Welding



Refurbished Penstock Shallow Circumferential Welding

Affidavit





IN THE MATTER OF the *Electrical Power Control Act, 1994,* SNL 1994, Chapter E-5.1 ("*EPCA*") and the *Public Utilities Act*, RSNL 1990, Chapter P-47 ("*Act*"), and regulations thereunder; and

IN THE MATTER OF an application by Newfoundland and Labrador Hydro ("Hydro") for approval of capital expenditures for section replacement and weld refurbishment of Penstock 3 at the Bay d'Espoir Hydroelectric Generating Facility, pursuant to Subsection 41(3) of the *Act.*

AFFIDAVIT

I, Gail Randell, of St. John's in the province of Newfoundland and Labrador, make oath and say as follows:

1) I am Vice President, Major Projects for Newfoundland and Labrador Hydro, the applicant named in the attached application.
2) I have read and understand the foregoing application.
3) To the best of my knowledge, information, and belief, all of the matters, facts, and things set out in this application are true.

SWORN at St. John's in the province of Newfoundland and Labrador, this 12th day of March 2026, before me:

Commissioner for Oaths, Newfoundland and Labrador

Gail Randell

SAMANTHA KEATS
A Commissioner for Oaths in and for
the Province of Newfoundland and Labrador.
My commission expires on December 31, 2027