Q. **Reference: Volume II, Wood Pole Line Management Program - Various, Tab 11, page 1, lines 4 to 8**

> The WPLM Program is an annual program that detects deteriorated poles and other line components early to avoid safety hazards and to identify poles that are at early stages of decay to ensure that corrective measures can be taken to extend the average life of these poles. This is a least-cost strategy in the long-term through the deferring of rebuilding lines and avoiding forced outages.

Provide the analysis substantiating WPLM as a *least-cost strategy*.

A. Please refer to Attachment 1 to Newfoundland and Labrador Hydro's response to NP-NLH-039 for a report entitled "Progress Report #2 (2012-2017) Review of the Current Wood Pole Line Management (WPLM) Program."[1] The analysis discussed in the report substantiates the Wood Pole Line Management Program as a least-cost strategy.

[1] "2019 Capital Budget Application," Newfoundland and Labrador Hydro, October 9, 2018 (rev. 1), originally filed July 31, 2018, "2019 Capital Plan," app. C.

Progress Report #2 (2012-2017)

Review of the Current Wood Pole Line Management (WPLM) Program

July 2018

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1 Introduction

Newfoundland and Labrador Hydro (Hydro) maintains approximately 2,500 km of wood pole transmission lines operating at 69, 138 and 230 kV voltage levels. The pole plant asset includes approximately 26,000 transmission size poles. Figure 1 presents the overall Island Interconnected System transmission line network.

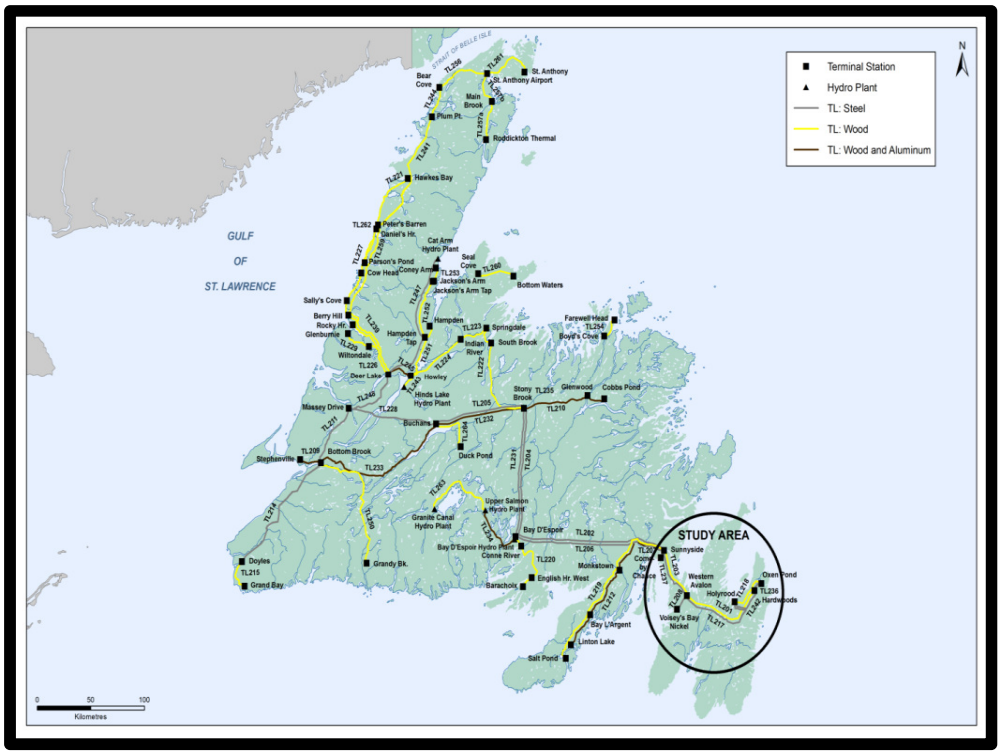

Figure 1: Island Map showing all High Voltage Transmission Lines and Study Area

Hydro first initiated the Wood Pole Line Management (WPLM) Program as a pilot study in 2003. Under this pilot study, Hydro completed the inspection of poles on the Avalon Peninsula. After the pilot study, Hydro determined that the program should continue as a long term asset management and life extension program. The program was presented to the Board of Commissioners of Public Utilities (the Board) in October 2004 as part of Hydro's 2005 Capital Budget Application. The proposal was supported in the application by the Hydro Internal Report

titled *"Wood Pole Line Management Using RCM principles".* The program was approved by Board Order P.U. 53(2004). The emphasis was to support a planned shift from a time based to a condition-based maintenance program. Based on data collected to date, the WPLM Program has improved the reliability, extended the life of the pole plant asset and reduced the total cost of ownership over the complete life of the poles. It should be noted that the results reported in this study consider only the pole inspection data since 1998, and excludes data such as line failure under extreme wind and ice conditions, or any other poles replaced previous to the initiation of the WPLM program.

1.1 Basic Facts of the WPLM Program

- Identification of "danger poles (non climbable)" that require immediate replacement to avoid safety hazards.
- Inspections conducted to identify poles that need to be replaced to maintain structureal integrity and reliability.
- Long-term maintenance of accurate pole plant asset data.
- Streamlining of capital budgeting process based on condition data.
- Treatment of poles to protect against decay and ant attacks thus extending the life of the asset.
- Extension of asset life.
- Life extension also provides an opportunity to reduce environmental footprint because Hydro replaces less poles.
- Reduction of total ownership costs.

2 Scope of WPLM Program

The objectives of the WPLM Program were to address four specific items as follows:

1. inspect poles and associated line components such as conductor, hardware and insulators;
2. treat all poles;

3. develop and implement an electronic data collection system to facilitate field data collection and subsequent data analysis; and
4. make data based, optimized decisions to rehabilitate, or replace poles and associated hardware.

The aim of the program is to ensure that deteriorated poles are identified and retreated for life extension, and identify in a timely manner poles requiring replacement before in-service failures occur, thereby avoiding more expensive repairs, service outages and danger to line workers.

3 Report Scope

As stated in Board Order P.U. 2(2012) *"This report should provide evidence of, for example, results of non-destructive testing, undertaken to date, whether the program has met the stated objectives of deferring replacement of assets, if the program has resulted in improved reliability of the system, and what the current best practice is in other jurisdictions with respect to wood pole asset management."*

In order to provide evidence with specific examples to show what Hydro has accomplished so far with the WPLM program, the following areas are presented in this progress report to show the validity and the justification of continuing such a program in the future.

- improved reliability of the system
- current industry's best practice in other jurisdictions
- demonstrated evidence of the actual and expected long term benefits

The analysis presented in this report primarily considers the data for two of the lines in the Avalon Peninsula transmission line system. These lines were chosen because they are exposed to the most severe environmental conditions representing the worst case scenario, and it has

data available for multiple inspection years. The first comprehensive Progress Report (Interim Report) was submitted to the Board in the 2013 Capital Budget Application in 2012.[1]

4 Improved System Reliability

Figure 2 illustrates the transmission reliability improvement of the Island Interconnected System. It shows the total forced outage hours due to structural failures on wooden transmission lines before and after implementation of the WPLM program. The pilot project on WPLM started in 2003 with a two year duration. The full program was launched in 2005.

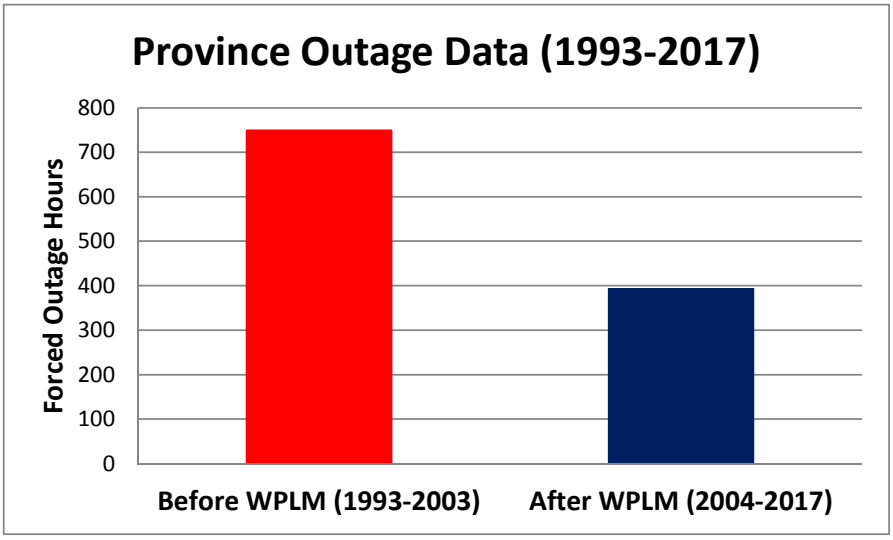

Figure 2: Outage Data for the Province

[1] Please refer to http://www.pub.nf.ca/applications/nlh2013capital/files/application/NLH2013Application-WoodPoolLineMgt.pdf.

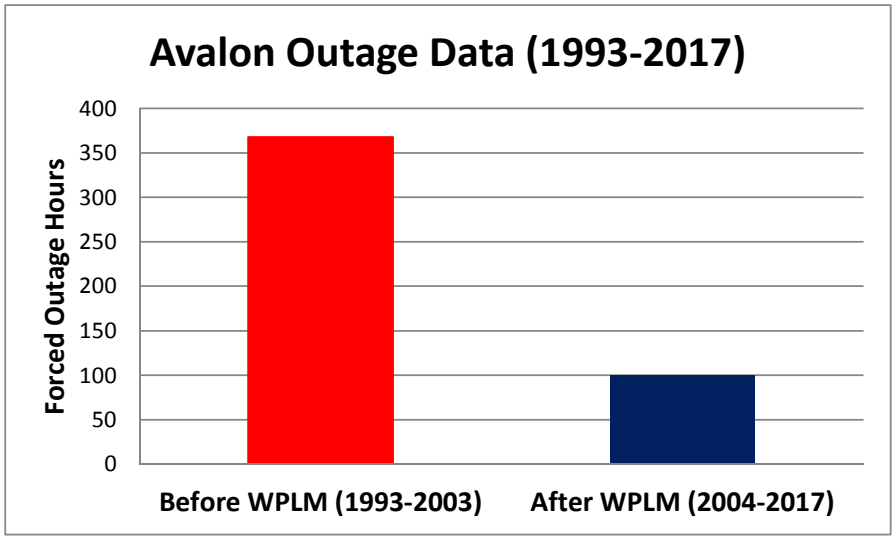

Figure 3: Outage Data for Avalon Peninsula

As shown in Figure 2 and Figure 3, the outage data demonstrates that there has been a material improvement on the Avalon Peninsula since the WPLM Program was launched in 2003. During this same period, the Avalon has experienced severe wind and ice storm events. The improvement on the Avalon Peninsula is over 70 percent, and the province-wide improvement is close to 50 percent.

5 Industry Best Practice

Two benchmarking criteria were used to compare Hydro's WPLM Program data with industry best practice. The first considers the annual cost of maintenance with respect to the replacement asset value (RAV). Based on Avalon Peninsula pole plant asset data, the ratio of average annual maintenance cost over RAV is 0.10%, well below the generally accepted industry best practice of one to four percent.

The second criterion uses other utilities' replacement rate data obtained from various sources. Hydro's current WPLM program is in line with many utilities' best practices within North

America. A CEATI survey conducted in 2012[2] by the Wind and Ice Storm Mitigation Interest Group indicated that most utilities have:

- regular inspection program;
- preventive treatment program; and
- realized life extension.

The comparison of Hydro's replacement rate and the expected mean life is also in line with other utility data when one considers the variability in climatic conditions. Hydro's comprehensive inspection and maintenance program enables measurement and comparison on an ongoing basis to ensure the program continues to deliver against stated objectives.

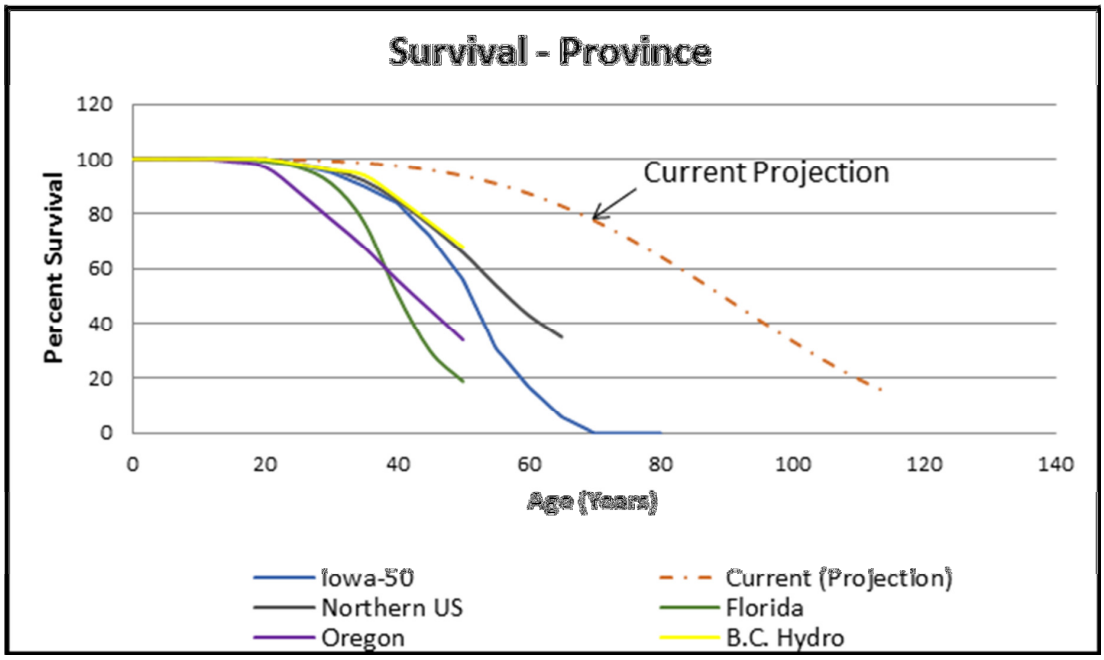

Figure 4: Comparison with Other Utilities

Figure 4 compares typical wood pole plant survival rates and indicates demonstrable value from the WPLM Program as compared to other North American utilities.

[2] Goel, 2012.

The comprehensive inspection and maintenance program of the WPLM Program provides the basis to ensure investment on the appropriate assets in a timely manner. Hydro's pole replacement rate is 0.36% per year for the Avalon and 0.10% per year for the province compared to the published data of 0.5 percent to 0.7 percent per year for the west coast of North America. The continued collection and analysis of field data through the WPLM Program is critical to extracting this demonstrated value.

6 Program Benefits

6.1 Reliability Improvements

The outage data shows that there has been an Island wide step change reduction in failures since the WPLM Program was launched despite the line system experiencing severe ice storm events in 2008 and 2010 and a number of wind storms including Hurricane Igor in 2010 and the wind storm of March 2017. This improved performance is attributable to the on-going inspection and preventive treatment program that Hydro has carried out since 2005.

6.2 Asset Life Extension

A standard 50-year IOWA curve was used for this study as a reference base case. The 50-year curve shown in Figure 5 indicates that 50 percent of pole plant asset is typically replaced by the time the asset age has reached 50 years. Figure 5 also illustrates the survival curve for the pole plant asset for the Island Interconnected System.

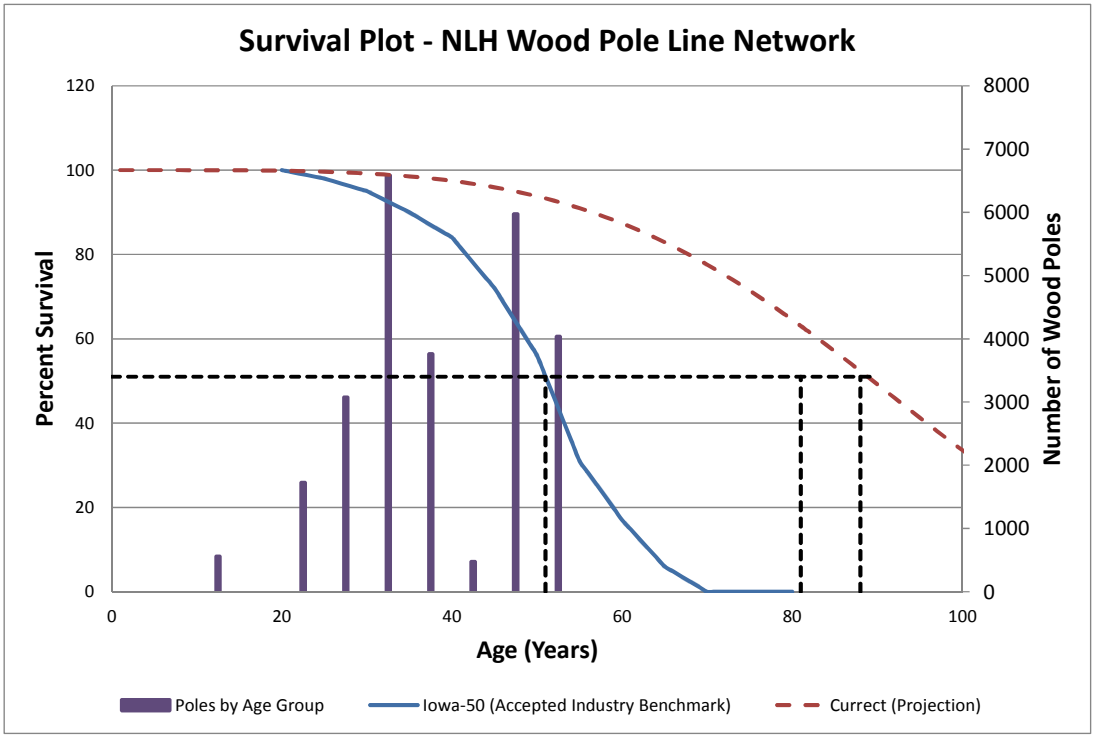

Figure 5: Survival Curves for the Pole Plant Asset (Island Interconnected System) and the Asset Age Distribution

Data analysis from the first fourteen years of the WPLM Program is aligned with an incremental increase in effective average pole life. This gain in the expected asset life of the entire pole plant asset can be achieved through the successful continuation of the WPLM Program.

Figure 6 utilizes the data from four inspection cycles (1985, 1998, 2005, 2015-2017) for the Avalon Peninsula pole system. Hydro's original data closely follows the IOWA curve. Furthermore, it is expected that the pole treatment program will extend the life of the pole plant asset. This is shown by the solid blue curve. Based on the current projection (solid red curve), the expected mean life is approximately 80 years[3], which is significantly higher than the

[3] The 80 year projected life determined in this study is greater than the approximately 60 year estimated useful life derived in the 2015 depreciation study. The difference is primarily because this study considers only the pole

conventional economic life of 40 years historically used in the industry.[4] This projection will be further refined as more data is collected, but it can be seen that life extension is being recognized through execution of this project. The typical IOWA curve assumes an expected asset life of 50 years. Analysis of data shown in this report indicates that the asset life of the pole plant asset on the Avalon Peninsula is 30 years longer than the benchmark IOWA.[3] Hydro has revised its asset depreciation of pole life from an estimated useful life of 53 years to an average life of approximately 60 years,[3] which is reflective of the life extension now being realized.

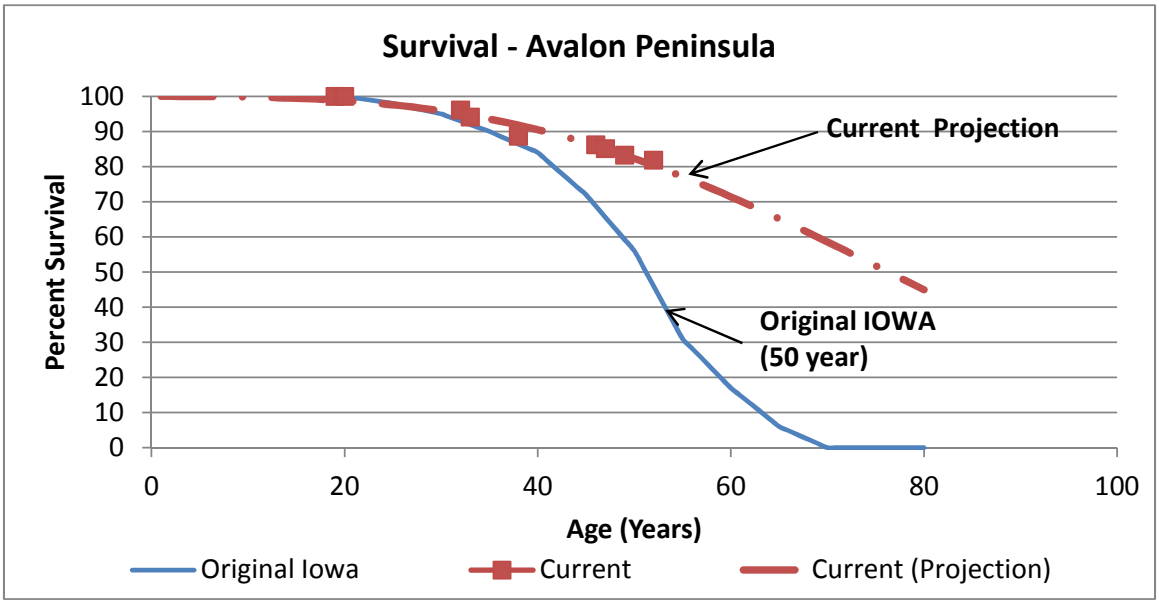

Figure 6: Survival Curves for Avalon Pole Plant Asset

6.3 Reduced Total Cost of Ownership (Net Present Value Analysis and Results)

Based on Hydro's cost data, Figure 7 compares the unplanned replacement cost versus planned replacement cost of a pole.

inspection data since 1998, and excludes data such as line failure under extreme wind and ice conditions, or any other poles replaced previous to the initiation of the WPLM program.

[4] Mankowski, Hansen and Morrell, 2002.

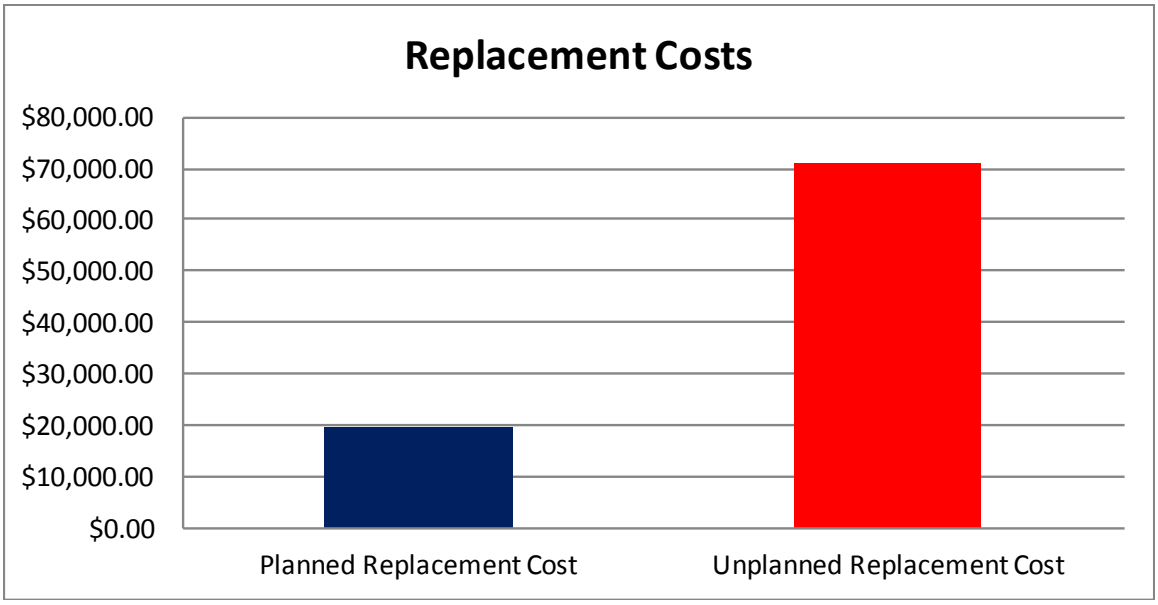

Figure 7: Comparison of Costs – Planned versus Unplanned

6.3.1 Optimum Inspection/Maintenance Interval –Justification (Haldar,2018)

A Weibull probability distribution model was developed and the analysis of a line on the Avalon system provides an optimum maintenance (inspection) interval where the cost of maintenance (inspection) is balanced against the future replacement (failure) cost. Based on Hydro's cost data, results show that the model predicted inspection interval (Figure 8) is in line with several utilities' best practices.[5] Freeman and Ragon (2010) also reported a typical inspection cycle as 8 -12 years for wood pole lines. Their study was based on the following inspection techniques: visual, sound and bore, full excavation and treatment for achieving 99% efficiency.

[5] Murkowski, Hansen and Morrell, 2002

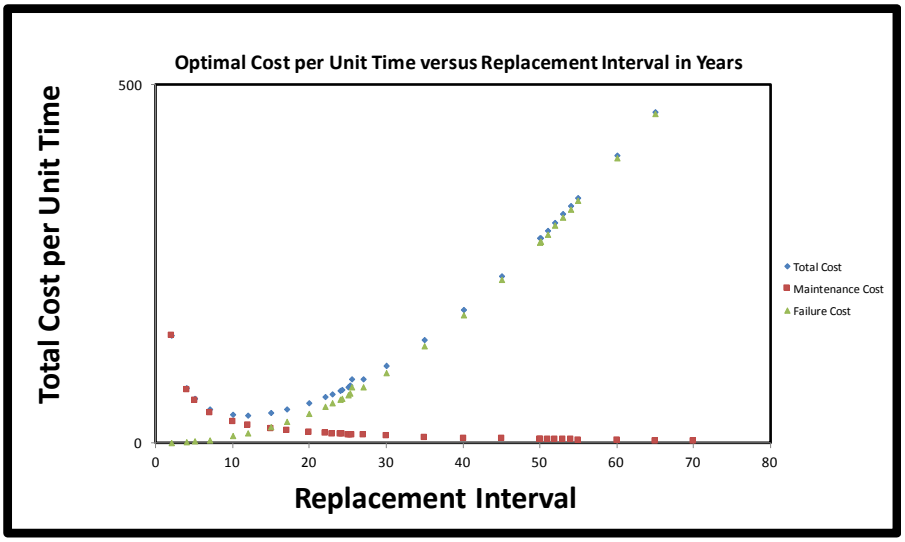

Figure 8: Optimum Inspection/Maintenance Interval

6.3.2 NPV Analysis of Cost Deferral – Maintenance of Existing Line Asset versus Building New Line Asset

By maintaining the asset health in good condition, Hydro will be able to defer the cost of replacing the pole plant asset (i.e. building new lines). Figure 9 shows the net present value of the asset replacement cost for a service life of 50 years calculated for the 10-year period of 2018-2027. This cost is compared with the maintenance cost under the WPLM program during the same period. The customer will benefit from cost avoidance by not replacing the Avalon Peninsula pole line system in 2018 because the lines can be maintained for an incremental 10-year period until 2027 and potentially beyond 2027 depending on what Hydro finds during the next five-year inspection cycle.

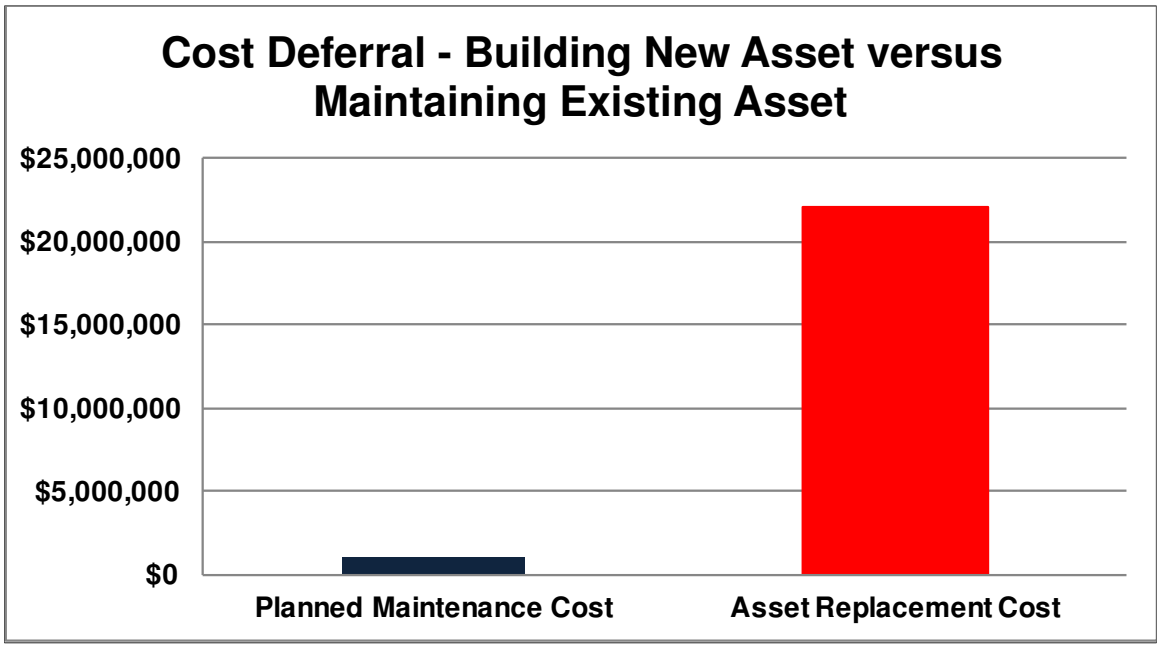

Figure 9: Benefit of WPLM Program – Cost Deferral for New Asset

7 Non-destructive Tests

Hydro's WPLM program is a comprehensive pole inspection, test and treatment program. It consists of two 10-year cycles initiated in 2005. Under this program poles are inspected by sounding, boring and visual means. Poles are then internally treated with preservative where appropriate, and identified for scheduled repair, or replacement if deemed necessary. A limited number of full scale tests are also done periodically to validate the field data. Figure 10 presents the summary of defects found during the inspection of Island Interconnected System.

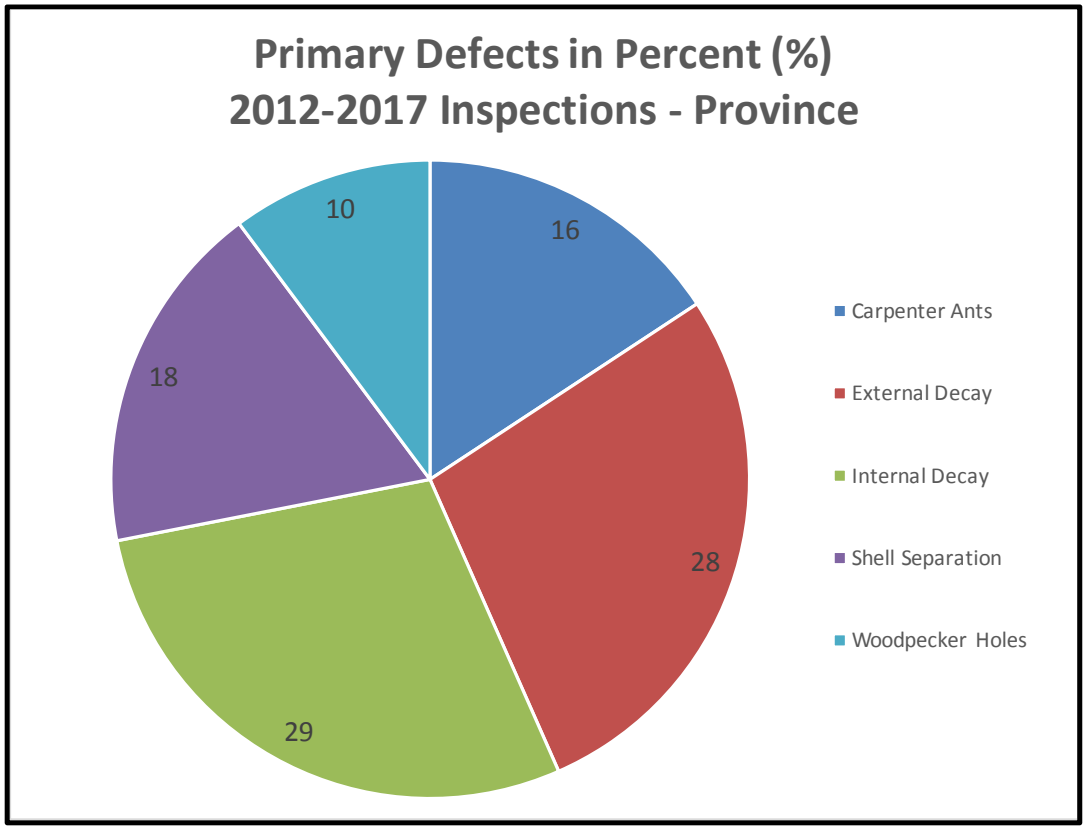

Figure 10: Primary Defects found during the Inspection of Avalon Pole System (2012-2017)

Major findings from the field tests are:

- pole strength and capacity declines with age; and
- danger poles (not climbable) or the poles that do not meet the design strength must be replaced to maintain safety and avoid forced outages.

8 Summary

In summary, Hydro's WPLM program is achieving the goals of increasing reliability, extending asset life, and reducing total cost of ownership. This WPLM Program is well aligned with best practices used in the industry.

The assessment demonstrates that the cost of the WPLM Program and the inspection interval of 10 years is well justified by cost avoidance savings through reduced in-service failures and reduced unplanned repair costs, as well as life extension of existing pole plant assets by between 10 to 20 years. The overall pole replacement rate per year is well below the published industry data. The development of a rigorous methodology to assess and analyze the pole inspection data allows Hydro to continue to proactively identify the right level of expenditure on the right poles at the right time.

9 References

Goel, Anand 2012 End of Life of Wood Structures (confidential report prepared for the WISMIG participants, CEATI Report No. T103700-3372, -http://www.ceati.com/)

Freeman, Mike and Ragon, Kevin 2010 A Review of wood Pole Testing Equipment Compared to Visual and Excavation Techniques used in Test and Treat Programs, Proc. Southeastern Utility Conference, Technical Forum, pp178-188

Haldar, Asim 2018 Condition Based Asset Management of Overhead Lines – a Probabilistic Framework, CEATI Report No. T073700 – 3263, Montreal, TODEM Interest Group

Mankowski, M, Hansen, E and Morrell, J 2002 Wood Pole Purchasing, Inspection and Maintenance: A survey of Utility Practices, Forest Product Journal, Vol. 52, No. 11/12