Q. [Account P05 - Pole Structures - Wood] - Please provide a full description and the date of implementation of each separate type of wood pole inspection program associated with Account P05 - Pole Structures - Wood. Further, identify the number of poles affected by each, by year, during the past 10 years. Finally, identify the impact that each program has on the life expectation of wood poles along with all supporting documentation for each expectation.

A. Please refer to CA-NLH-102, Attachment 1 for a full list of inspections that have been done under the Wood Pole Line Management (WPLM) program since 2005. Prior to 2005, pole structures were inspected by line, with 20% of the structures inspected each year. The number of poles affected each year for the past 10 years is included the response to CA-NLH-102. Please see CA-NLH-187, Attachment 1 for the 2012 WPLM Report as filed as part of Hydro's 2012 Capital Budget Application with the Public Utilities Board for an explanation of the WPLM Program and its impact on the life expectation of wood poles. There is a WPLM Report being prepared for the 2013 Capital Budget, however, it is not yet available.

	Electrical
	Mechanical
	Civil
	Protection & Control
	Transmission & Distribution
	Telecontrol
	System Planning

A REPORT TO
THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES

2012 WOOD POLE LINE MANAGEMENT

July 2011

newfoundland labrador hydro
a nalcor energy company

Table of Contents

1 INTRODUCTION

Newfoundland and Labrador Hydro (Hydro) maintains approximately 2,400 kilometers (kms) of wood pole transmission lines operating at 69, 138 and 230 kV. These lines consist of approximately 26,000 transmission size poles of varying ages, with the maximum age being 45 years. In 2011 over 90 percent of the transmission pole assets are over 20 years old with about 50 percent of these at or over 40 years old. The remaining assets are less than 20 years old.

Prior to 2003, Hydro's pole inspection and maintenance practices followed the traditional utility approach of sounding inspections only. In 1998, Hydro decided to take core samples on selected poles to test for preservative retention levels and pole decay. The results of these tests raised concerns regarding the general preservative retention levels in wood poles. Poles become susceptible to fungi and/or insect attack as the preservative levels deplete. Figure 1 illustrates typical wood pole inspection techniques. Figure 2 shows typical wood pole inspection results.

Figure 1 - WPLM Inspection Techniques

Figure 2 - Typical Wood Pole Inspection Results

Between 1998 and 2003, Hydro undertook additional coring and preservative testing. This testing confirmed that there were a significant number of poles which had a preservative level below that required to maintain the required design criteria. During this period, certain poles were replaced because the preservative level had lowered to the point that decay had advanced and the pole was no longer structurally sound. These inspections and the analysis of the data confirmed that a more rigorous wood pole line management program was required.

Hydro first initiated the Wood Pole Line Management (WPLM) program as a pilot study in 2003. It was 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 and was entitled "Replace Wood Poles – Transmission". The proposal was supported in the application by the

Hydro internal report titled "Wood Pole Line Management Using RCM Principles" by Dr. Asim Haldar, Ph.D, P.Eng.

The Board found that "This approach (by Hydro) is a more strategic method of managing wood poles and conductors and associated equipment and is persuaded that the new WPLM Program, based on Reliability Centered Maintenance (RCM) principles, will lead to an extension of the life of the assets, as well as a more reliable method of determining the residual life of each asset. One of the obvious benefits of RCM will be to defer the replacement of these assets thereby resulting in a direct benefit to the ratepayers".

The Board approved the project submitted in the 2005 Capital Budget in Order No. P.U. 53 (2004). As part of its annual Capital Budget Application process, Hydro committed to provide the Board with an update of the program work that includes both a progress report of the work completed as well as a forecast of the future program objectives. This report would be provided with the annual Capital Budget Application.

2 PROJECT DESCRIPTION

The WPLM program is a condition-based program, which uses the basic RCM principles and strategies. Under the program, line inspection data in each year is analyzed and appropriate recommendations are made for necessary refurbishment and/or replacement of line components (poles/structures, hardware, conductor, etc.) in the subsequent year. The inspection data and any refurbishment and/or replacement of assets are recorded in a centralized database for easy access and future tracking.

The program is aimed at early detection and treatment of the wood poles before the integrity of the structures is jeopardized. If the deterioration of the structures is not detected early enough, then the reliability of the structures will affect the reliability of the line and the system as a whole. It may also create safety issues and hazards for Hydro personnel and for the general public.

To give the quantitative benefits on the improvement of transmission line reliability, sufficient long term data, derived from two full inspection cycles will be required to provide adequate statistical evidence. In the absence of this long term data, an analysis of recent ice storms, such as in March 2008 and March 2010, can provide a snapshot on how the transmission lines are performing. On March 18-19, 2008 there was a severe ice storm on the Avalon Peninsula. Hydro's test site at Hawke Hill recorded more than 25 mm of radial glaze ice which exceeds the design load of the wood poles on the Avalon Peninsula. There were no reported failures because the poles which were not structurally sound were already replaced during the first WPLM inspection cycle between 2003 and 2007. This was again supported during the ice storm of March 2010, in which there were no failures of Hydro's wood pole assets on the Avalon Peninsula. This supports the need for the proactive condition based management program which Hydro is pursuing.

3 EXISTING SYSTEM

As stated previously, Hydro maintains approximately 2,400 km of wood pole transmission lines operating at 69, 138 and 230 kV. These lines consist of approximately 26,000 transmission size poles of varying ages.

As this is a recurring inspection of transmission lines, there is no relevant data for:

- Maintenance History;
- Outage Statistics;
- Safety Performance;
- Industry Experience;
- Maintenance or Support Arrangements;
- Vendor Recommendations;
- Availability of Replacement Parts;
- Environmental Performance; or
- Operating Regime.

3.1 Age of Equipment or System

The age of each line can be found in Appendix B.

3.2 Major Work or Upgrades

This section is not applicable since the WPLM Program encompasses the annual inspection, treatment and refurbishment of all of Hydro's wood pole transmission lines.

3.3 Anticipated Useful life

The anticipated useful life of a wood pole transmission line is approximately 40 years. Through this maintenance program, Hydro plans to further extend the life of the lines.

4 JUSTIFICATION

A 1998 inspection on the Avalon Peninsula indicated that 48 percent of the poles sampled did not meet the minimum preservative retention level that would protect the pole against rot or insect damage. A similar program in the Central region verified the results obtained from the Avalon Peninsula. At the time, re-treatment of poles on the Avalon Peninsula was not pursued due to budget constraints. Recent failures near the Hardwoods Terminal Station showed further deterioration of these poles. These conditions justify the strong need for a well-managed wood pole inspection and treatment program. Full scale tests of poles at Memorial University since 1999 indicate a 25 percent reduction of average pole strength over a 35-year period. Results of the 2010 testing are discussed later in this Section.

The WPLM program detects "danger poles" 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. Money is saved in the long term by deferring the cost of rebuilding lines and avoiding forced outages.

As this is a recurring inspection of transmission lines, there is no relevant data for the following:

- Net Present Value;
- Levelized Cost of Energy;
- Cost Benefit Analysis;
- Forecast Customer Growth;
- Energy Efficiency Benefits; or
- Losses during Construction.

4.1 Legislative or Regulatory Requirements

There are no legislative or regulatory requirements for the project.

4.2 Historical Information

The historical information for the WPLM program is supplied in Table 1 below. No units or cost per unit is available, since the work is not easily defined into individual units such as a line or structure number. The actual work completed is variable and is dependent on the actual condition of the asset. For example, in most cases the work completed on any one structure is not related to the work on the next structure (i.e. one structure may require a pole replacement and the next structure may need a crossarm or an insulator replacement). The same is true for a breakdown by individual transmission line, where the cost will be affected by the configuration and voltage of the line, its age and geographical location. Table 2 provides the annual statistics for pole replacement and pole component replacement for the five years prior to implementation of the WPLM program and for the years since implementation of the program.

Table 1: Historical WPLM Program Expenditures

Year	Budget ($000)	Actuals ($000)
2011F	2,019.4	
2010	2,308.2	2,501.2
2009	2,256.2	2,613.3
2008	2,188.3	2,393.2
2007	2,147.8	2,214.1
2006	2,302.6	2,362.5

Table 2: Annual Statistics of Pole and Pole Component Replacement

Year	Poles	Crossarm	Kneebrace	Crossbrace	Comments
2010	60	20	45	58	
2009	72	12	14	25	
2008	93	27	27	25	
2007	97	31	11	19	
2006	144	30	18	21	
2005	99	47	43	58	
2004	54	13	12	22	Start of WPLM
2003	34	29	13	55	
2002	126	53	6	61	
2001	21	16	2	2	
2000	44	30	21	30	
1999	138	7	20	2	
TOTAL	922	295	187	320	

’99 to ‘03	363	135	62	150	5 Years Before WPLM
’04 to ‘10	619	180	170	228	7 Years Since WPLM

4.3 Update of 2010 Work

The first objective of the 2010 program was to inspect, test and treat at least 2,136 poles and associated line components. The inspection schedule is generally built on the strategy of focusing on the older lines first and working towards the newer lines. The exact lines and the number of poles are reviewed on an annual basis and may be modified based on the following criteria:

(1) Age,

(2) Priority (radial or redundant), and

(3) Known problems.

Table 3 summarizes the inspection accomplishments for 2010.

Table 3: 2010 Inspections

Regions	Line Name	Year In Service	Voltage Level	Target Number of Poles to Inspect	Actual Number of Poles to Inspect	Percent Complete
Eastern	TL-219	1990	138kV	350	350	100%
Central	TL-233	1973	230 kV	266	266	100%
	TL-234	1981	230 kV	120	120	100%
	TL-254	1988	69kV	216	218	101%
	TL-260	1990	138 kV	100	112	112%
Western	TL-209	1971	230 kV	92	95	103%
	TL-245	1969	138 kV	68	68	100%
Northern	TL-239	1982	138 kV	100	100	100%
	TL-256	1996	138 kV	224	224	100%
	TL-259	1990	138 kV	200	200	100%
Labrador	TL-240	1976	138 kV	400	1020	255%
Total				2,136	2,773	130%

Overall, the majority of the lines inspected were within one percent of the target value. The only line that showed a large difference in the actual number of poles inspected was TL-240 in Labrador. A large number of poles were inspected on this line because a crew was mobilized from Stephenville. Because of the high costs of mobilizing both the crew and equipment into the region, it was cost effective to keep the crew in the area for an extended period of time and complete the scheduled inspections for both 2010 and 2011. The extra costs were offset by deferring some lower priority work to 2011 and using the 2011 inspection budget for TL-240 to complete this work.

Another objective of the 2010 program was the replacement of defective components identified in the 2009 inspections. A summary of the work completed in 2010 is given in Table 4.

Table 4: Summary of 2010 Refurbishment

Item	TL 209	TL 222	TL 232	TL 234	TL 253	TL 215	TL 227	TL 229	TL 239	TL 226	TL 257	TL 261
Poles	5	9	22	7		11	2	2	2			
Crossarms	8		12		3						1	
Crossbracing	0		46	12								
Kneebraces	20		25									
Insulators	1				2							
Miscellaneous				4				X		X	X	X
Foundations and Anchors				3	2							
Leaning Structures				1								

X – Refers to miscellaneous work completed throughout the line such as installing missing guy guards and safety signage on the structures as required.

In addition to the above work completed in 2010, work on two transmission lines inspected in 2009 was deferred until 2011 and 2012 because of outage constraints and increased budget costs. The deferred work on TL-220 and TL-233 comprised components that are generally rated 4. Poles that have a rating of 4 should be replaced within one to three years.

- Work on TL-220 was deferred because of outage restrictions and will be coordinated with scheduled terminal station outages planned for the summer of 2011.
- Work on TL-233 was deferred because a higher number of poles than expected as determined by the IOWA Curve (see Appendix B), with respect to age, have damage caused by ant infestation. For a 37 year old pole, it is expected that approximately 12 percent of the poles should be replaced. TL-233 requires approximately 20 percent pole replacement. Due to budget constraints this work was deferred until 2011 and 2012.

In addition to the inspection and refurbishment work, the following were also completed under the 2010 WPLM Program:

1. A pilot study on the Non-Destructive Evaluation (NDE) of Anchors on the 230kV Wood Pole Lines on the Avalon Peninsula (TL-201, TL-203 and TL-218) was conducted to determine the effectiveness of commercially available NDE techniques. These techniques allow for the inspection of the underground anchors without the need to excavate or destroy the anchor. The study process included a full geotechnical investigation to assess the pertinent soil conditions conducive to corrosion and to develop a site specific "risk index". This was followed by a number of NDE (Non Destructive Evaluation) techniques. To complete the study, a sample of anchor rods were excavated for visual inspections and the validation of the NDE techniques.

   Based on the study it is concluded that the correlation of the NDE techniques with respect to underground corrosion detection was only accurate fifty percent of the time. Further developmental work is needed before these NDE methodologies can be used routinely on a transmission line for underground corrosion assessment. Although it shows that both the soil resistivity measurements and the half-cell measurements did not show a strong correlation with the corrosion measurements, it is recommended that these techniques be pursued further in view of their cost effectiveness and to better understand the results in view of a larger database.

2. As part of the WPLM program, Hydro started testing existing poles removed from the site to understand their behavior and strength degradation so that we can make some decisions for refurbishment or replacement based on a sound analysis of the load and the strength. One of the problems was that only so many poles could be tested as samples (finite numbers) but a general assessment of the large pole numbers at the field that are inspected annually with some non destructive (NDE) evaluation technique is needed. Current equipment used in the inspection does not produce consistent results. One of

the approaches is to use "Modal Hammer" where the pole is hit and the vibration signature is measured, analyzed and later the data is correlated with pole properties such as fiber stress, rotting etc. To further this effort, financial and technical support was provided to the Graduate Student in Engineering program at Memorial University of Newfoundland (MUN) for focus on the research and development of a Non-Destructive Evaluation of wood poles. This included the completion of the full-scale pole testing facility at MUN. In the fall of 2010 the facility was successfully commissioned and eleven poles were tested. The data collected from these old pole tests will be analyzed by a graduate student and this will be part of their investigation and also provide us an understanding of how these poles can be inspected better in the field.

4.4 2011 Work Plans

The proposed inspection and treatment work for 2011 is summarized in Table 5.

Table 5: 2011 Work Plans

Regions	Line Name	Year In Service	Voltage Level	Target Number of Poles to Inspect
Eastern	TL-203	1965	230kV	202
	TL-219	1990	138kV	150
Central	TL-234	1981	230 kV	126
	TL-260	1990	138 kV	331
Western	TL-233	1973	230 kV	155
	TL-243	1978	138 kV	50
	TL-245	1969	138 kV	100
Northern	TL-239	1982	138 kV	100
	TL-259	1990	138 kV	451
Labrador	TL-240	1976	138 kV	0
Total				1,665

As a result of the 2010 inspection program and deferred work from 2009 inspection, a refurbishment program will begin during the spring and summer months of 2011 and continue into the fall. This will include the replacement of approximately 80 poles; 16 cross-arms; 20

cross-braces; and other smaller components. A detailed list of the work to be completed in 2011 is provided in Appendix A.

In addition to the work that will be completed in 2011, work on the following lines, will be deferred until 2012 and 2013.

- TL-209 – A portion of work will be deferred until 2012.
- TL-215 – Four poles were rated 4, but were deferred because the poles are in a section of line that is proposed to be re-located in a capital project in 2013.
- TL-233 – The 2011 work will include all work up to Structure #184. The refurbishment work on this line will continue at this structure in 2012.
- TL-240 – Due to costs associated with alternate generation (not included in budget), the work identified will be postponed until 2012 or 2013. This work will also be coordinated with the Lower Churchill Work on TL-240, when it goes ahead. In addition, a general philosophy on maintenance for TL-240 should be developed in light of the overall Lower Churchill Development.

4.5 Alternatives

No alternatives have been explored. In 2005, the Board found that this approach was justified and prudent and approved the expenditures as submitted in the 2005 Capital Budget in Board Order No. P.U. 53 (2004).

This report provides an update of the program work, which includes both a progress report of the work completed as well as a forecast of the future program objectives. This report is provided with the annual Capital Budget Application.

5 CONCLUSION

In conclusion, the major objectives for the 2010 program were achieved. The budget estimate of $2.308 million was exceeded by $.193 million (8.4 percent) for a total expenditure of $2.501 million.

The framework for systematically analyzing a large volume of wood pole transmission line inspection data, developed using the reliability based analysis technique, is still under expansion to include additional components. The method uses a hybrid approach where the uncertainties in load and strength values and the strength deterioration due to aging are taken into account with the condition rating of each pole to develop a condition matrix table.

5.1 Budget Estimate

Table 6 illustrates that the WPLM budget has consistently seen cost overruns in the $200,000 to $300,000 range since 2008, while at the same time some of the refurbishment work has been deferred to maintain control on the budget. Deferred work has and will continue to be scheduled within the reasonable three year period for such inspections.

Table 6: Summary of Budget Overruns in WPLM Expenditures

Year	Budget ($000)	Actuals ($000)	Difference ($000)	Percent Difference
2010	2,308.2	2,501.2	193.0	8.4
2009	2,256.2	2,613.3	357.1	15.8
2008	2,188.3	2,393.2	204.9	9.4
2007	2,147.8	2,214.1	66.3	3.1

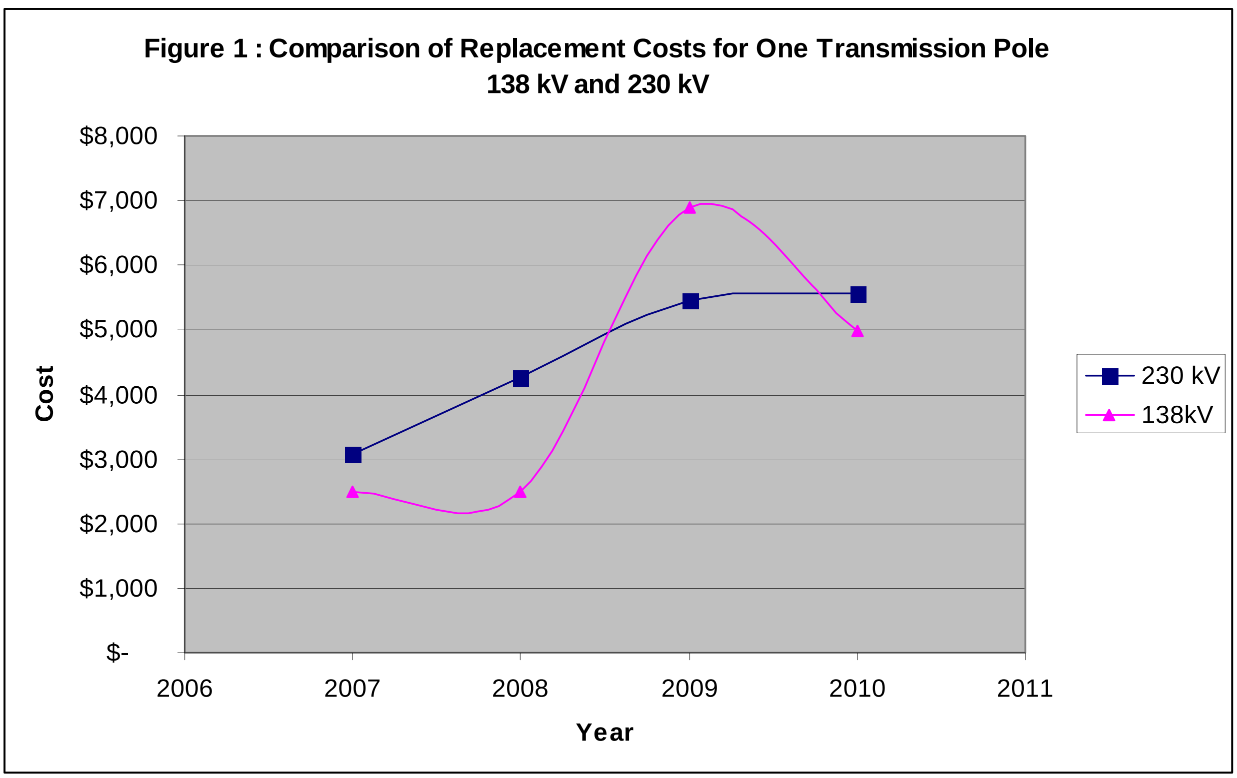
The main reason for the annual budget shortfall has been the increasing costs for component refurbishment since 2007. Table 7 shows the annual contract price of replacing a single pole on a typical two pole structure that Hydro utilizes for both 138kV and 230kV. The price represents an average annual cost for projects that have been tendered under the Public Tendering Act. The table illustrates that the average cost for this piece of work has increased by more than 75 percent between 2007 and 2010.

Table 7: Replacement Costs for One Transmission Pole

Year	230 kV	138kV
2010	$5,575	$4,988
2009	$5,457	$6,900 **
2008	$4,250	$2,500
2007	$3,083	$2,500

** The high cost for a 138kV pole in 2009 is due to the majority of the work being completed in Labrador, where costs are generally higher than prices on the Island.

Figure 1 provides a graphical representation of Table 7.



Although the process of deferring non-critical work to future years has worked thus far, the amount of work has slowly been increasing and at some point will not be manageable. To date, there has been no overall increase to the long term WPLM budget to account for this large increase in contract costs. Without a cost adjustment, the amount of work being deferred will continue to increase on an annual basis. The new five year budget attempts to re-forecast the budget to account for these increased costs.

The WPLM budget shown in Table 8 includes the complete inspection of the stated lines, including the visual inspection supported by field testing each pole using non-destructive testing, and limited full-scale testing to establish correlation full treatment of the pole (internal and external) as required. In addition, the budget for 2012 has been increased to account for the backlog of work that has accumulated over the last two to three years.

It is assumed that a percentage of those poles inspected will also be rejected according to the IOWA curve (shown in Appendix B) depending on their age and group. Poles rejected in the field will be analyzed with respect to reliability issues, and if rejected after structural analysis, a recommendation to refurbish and/or replace will be made.

Using the average age of the poles being inspected along with the IOWA curve, the anticipated pole replacement rate is calculated and this is used to develop the future refurbishment program. A schedule of the pole inspections from 2011 to 2016 is provided in Appendix B. The table also provides the average age and pole rejection rate for each year.

Table 8: Budget Estimate

Project Cost ($x 1,000):	2012	2013	2014	2015	2016	TOTAL
Material Supply	539.7	897.0	1000.0	1000.0	1000.0	4,436.7
Labour	804.5	1191.8	1,261.0	1,147.0	1,011.0	5,415.3
Consultant	226.0	130.0	130.0	130.0	130.0	746.0
Contract Work	500.0	750.0	1,000.0	1,000.0	950.0	4,200.0
Other Direct Costs	80.3	80.4	93.3	88.9	81.3	424.2
Interest and escalation	158.9	335.1	519.6	621.9	636.5	2,272.0
Contingency	209.9	297.5	340.0	328.4	309.8	1,485.3
TOTAL	**2,519.3**	**3,681.8**	**4,343.9**	**4,316.3**	**4,118.3**	**18,979.6**

As stated above, the new five year budget has been re-forecasted to account for the increased costs of construction.

5.2 Project Schedule

The annual project schedule is highly dependent on the annual work load and availability of outages and is therefore determined during the spring of each year.

APPENDIX A

2011 Inspections and Refurbishment Work

Inspections and Refurbishment Work to be completed in 2011

Region	Central	Eastern	Western	Northern	Labrador	Total
Proposed Inspections	**477**	**352**	**305**	**551**	**0**	**1685**
Refurbishments:						
Number of Poles	**69**		**8**	**1**		**78**
Number of Crossarms	**7**		**9**			**16**
Number of Crossbracing	**17**					**17**
Number of Kneebraces	**36**		**4**			**40**
Number of Conductor Repairs	**4**		**3**			**7**
Number of Foundations	**1**	**4**		**1**		**6**
Number of Clamps	**4**	**2**				**6**
Number of Dampers	**1**	**1**		**1**		**3**
Number of Insulators	**8**	**1**	**3**	**2**		**14**
Number of Insulator Plumbness						**0**
Number of Structure Plumbness				**2**		**2**
TOTAL NUMBER OF ITEMS	**147**	**8**	**27**	**7**		**189**

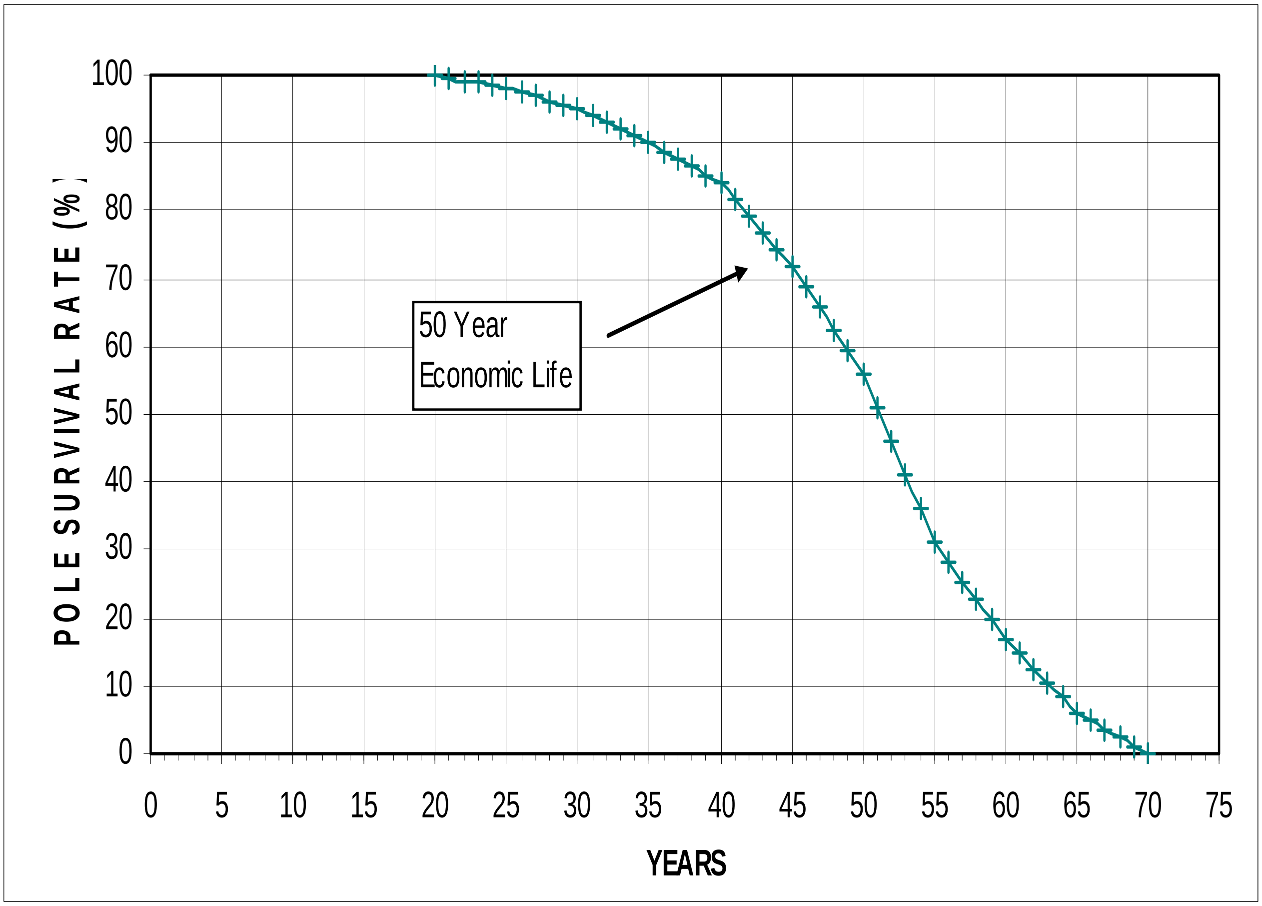
APPENDIX B

WPLM Inspection Schedule 2011-2016
(With Average Age of Transmission Lines and Estimated Pole Rejection Rates)

WPLM Inspection Schedule 2011 to 2016

Line	# poles	Year	2011	2012	2013	2014	2015	2016
No. of Poles Inspected			1595	2477	2593	2727	2773	2706
Weighted Average Age			1983	1974	1971	1972	1977	1982
Age at Inspection			28.31	38.42	41.31	42.33	38.40	33.78
Rejection Factor			2.6%	11.2%	11.6%	12.5%	7.7%	3.5%
Central								
TL 220	766	1970		273				
TL 234	489	1981	126					
TL 246	274	1981		274				
TL 251	579	1981						250
TL 252	652	1981						
TL 260	463	1990	361					
TL 210	606	1969					435	225
TL 233	640	1973						
TL 222	914	1987		150	500	421		
TL 254	218	1988						
TL 223	351	1988				250	75	
TL 224	626	1969		150	350	151		
TL 253	188	1992						
TL 232	755	1981					350	350
TL 263	730	2002						
Eastern								
TL 201	781	1966			300	300	214	
TL 203	417	1966	202	245				
TL 218	446	1983				150	250	46
TL 212	312	1969						236
TL 219	1750	1990	150	200	113			150
Western								
TL 215	437	1969						
TL 209	186	1971						
TL 243	159	1978	50		171			
TL 225	49	1970						
TL 233	640	1973	155		150	320	173	
TL 250	1269	1987					150	320
TL 245	266	1969	100	262				
Labrador								
TL 240	2640	1978		329	350	350	350	375
Northern								
TL 221	594	1970		271	221			
TL 229	306	1978						
TL 241 (C)	552	1983						200
TL 241 (N)	530	1983				250	280	
TL 244	274	1983					265	
TL 239	674	1982	100					
TL 226	693	1970		163	250	250		
TL 227	972	1970			250	225	150	
TL 257	691	1988		119				
TL 256	524	1988						274
TL 259	663	1990	461					
TL 261	511	1996						250
TL 262	25	2002						

IOWA CURVE (Used to Determine Pole Replacement Rates)



The pole rejection rate is one minus the Pole Survival Rate.