Performance Management Review and Quantification of Vegetation Management Work, Risks & Resource Requirements

Prepared for

FortisOntario Inc.

Regarding Algoma Power Inc.

By

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Proprietary Notice

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Performance Management Review and Quantification of Vegetation Management Work, Risks & Resource Requirements

1. Executive Summary

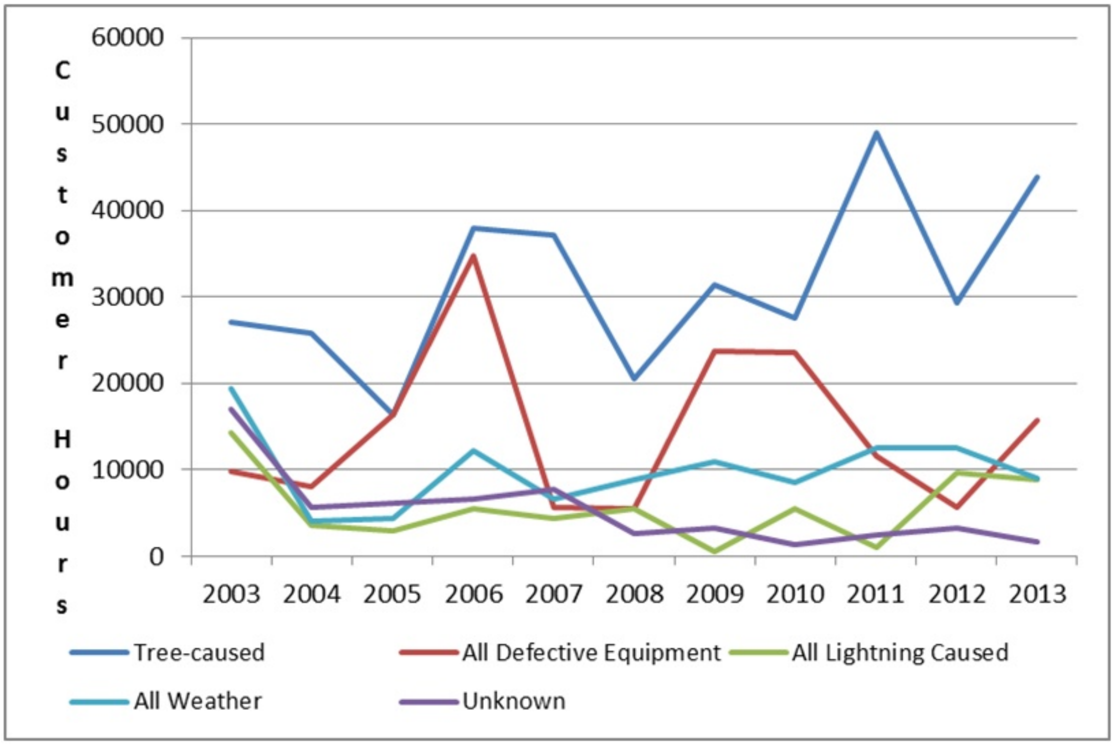
Algoma Power Inc. (API), began a program of widening right of ways in 2002. API has completed the majority of its right of way expansion program and is transitioning to maintenance program. Given this transition, API has undertaken an assessment, through Ecological Solutions Inc. (ESI), to determine the volumes of emerging maintenance work. Maintenance work volumes have been impacted by the capital work and will continue to change as the new edges transition to stable edges. The change in focus from major capital work back to maintenance also provides an opportunity to examine vegetation management (VM) practices to ensure funds are directed to the most efficient and cost effective practices.

This project explores the effectiveness of the API vegetation management (VM) program, identifying shortcomings and opportunities for improvement (Performance Management Review), including variances from standard utility practice, maintenance cycles based on biological fact, quantification of the annual workload volume increment[1], the least cost sustainable VM program, the resources required to achieve it and the term. These outcomes are driven by new, independent data acquired to determine the extent of tree exposure, trees requiring pruning, inventory of trees requiring assessments for hazards, regrowth rates, the area requiring active management broken down into quantity by work types (most cost effective treatment/work practice for conditions).

Trees are the primary cause of unplanned outages for API (*Exhibit 1-1*). This is common for electric distribution services. Indeed, for the majority of North American electric distribution companies tree-caused outages are the leading cause of service interruptions. Consequently, VM, which seeks to limit this cause of interruptions, is the single greatest operating and maintenance expense.

API's VM program falls short of a best in class program. The specifics are provided in 22 detailed findings. The opportunities for improvement are provided in 11 recommendations. In summary the current VM budget is not connected and based on actual field conditions of tree exposure, tree growth and mortality rates. Outage reporting cause codes could be improved to provide more guidance to the VM program and engineering options to improve reliability. A VM reporting system that links with other corporate databases and provides more detail on the work completed and the costs is required. There are operational practices that should be extended or introduced to reduce costs. These include the extension of foliar herbicide use, the introduction of brush mowers and telescoping saws.

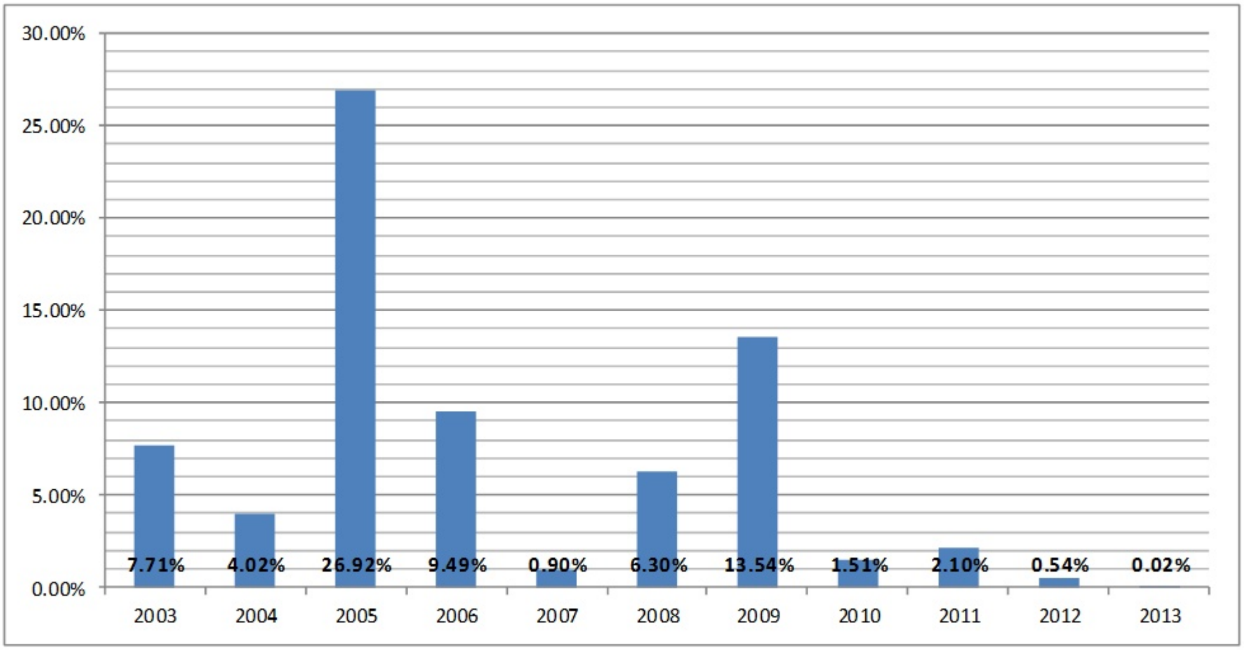
Exhibit 1-1
2003 – 2013 API Outage History By Cause



Trees being the primary cause of service interruptions, it is both necessary and justified that API thoroughly examines its VM program. From the outage statistics we learn that API is definitely moving in the right direction in its VM program as grow-in outages have been minimal since 2010 (*Exhibit 1-2*). From this it can be concluded that while the ratio of tree-related outages remains high, those outages are arising from the failure of trees outside the right of way. It is typical of good VM programs that less than 5% of tree-related outages are due to grow-ins.

The management of trees beyond the right of way is difficult. First, these trees are located off easement, generally, on private property. Secondly, hazard trees (trees that both could contact electric facilities on failure and have a visually assessable fault or indicator of a proclivity for failure) are difficult and costly to identify and remove. Third, it has been shown that the major factor in a utility's tree-related outage experience is the extent of the electric system's tree exposure.[2] [3]

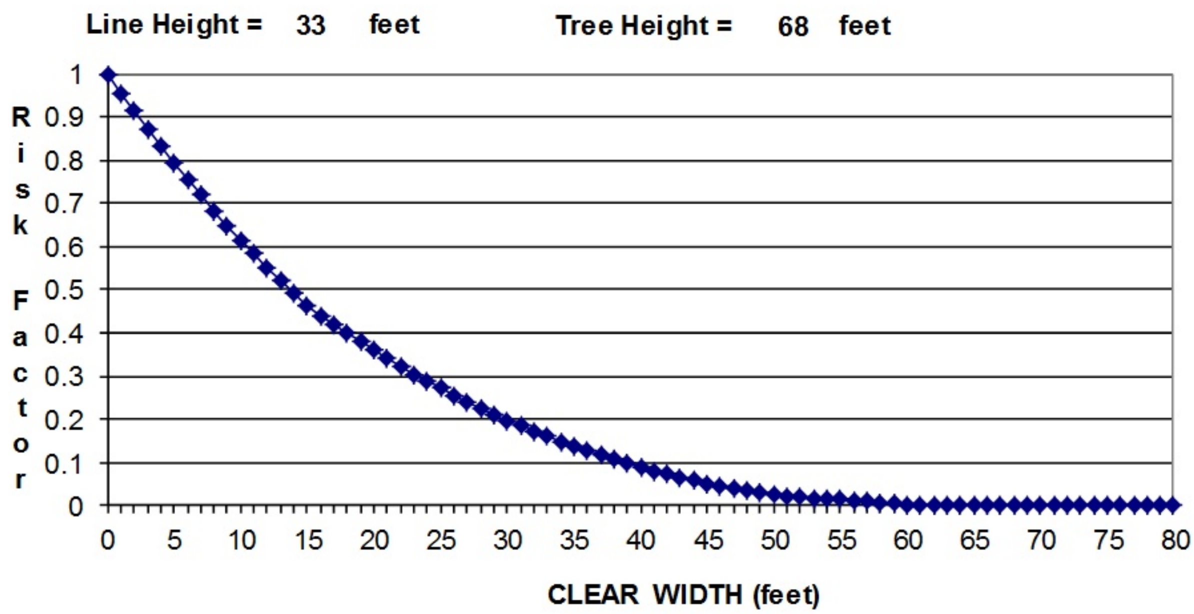
Exhibit 1-2
Ratio of Grow-in Outages to All Tree-caused



This project sought to rigorously quantify API's VM workload and the extent of tree exposure, which it did through data collection at 150 random sample points of 1 km each. It was found that about 85% of API lines have an adjacent treed edge. Forestry timber cruising methodology was applied to derive a measure of tree density outside the right of way. From this it is determined that API has 1032 ± 47 trees per hectare and 825,543 ± 37,705 danger trees (trees which on failure could contact conductors) at the 95% confidence level. Prior to the capital widening which has occurred that figure was considerably higher.

The capital widening was prudent. It decreased the both the number of danger trees (trees that could contact a conductor on failure) and the arc of line exposure for the remaining trees. The benefit in risk reduction is shown in *Exhibit 1-3* by comparing the Risk Factor (RF) at the average 8 feet clear width before widening with the RF at the established 15 feet clear width. The widening will ultimately provide a 32% reduction in tree-caused outages. API has not yet experienced this improvement because widening exposes trees which have grown inside the forest to sudden increases in wind loading, resulting in higher failure rates. Over time the new edges will harden and the reliability gain will be achieved, reflecting the decreased probability of a line contact on failure.

Exhibit 1-3
Line Strike Risk



The forest samples established the percent of decadent trees to be 11.2% of the population. While all of these trees will eventually fail, they may not all become hazard trees. Whether these decadent trees are deemed hazard trees will depend on tree species mode of failure, lean, their position relative to the power line and other trees blocking the fall path to the power line. However, this high percentage is indicative that API's VM is behind on the removal of hazard trees. The work inventory collected from 150 sample sites, which also accumulated hazard tree data, found only 2% hazard trees along the edges. This differential in hazard trees dependent upon distance from the line has two explanations. The capital widening created instability in edge trees. The edge trees that became hazard trees would be apparent if not generally, certainly to any experienced VM and utility passerby who would initiate remedial action. Secondly, both because of budget limitations and the instability created in new treed edges, API has restricted the search for hazard trees to the first metre along the edge. Considering the time since the capital widening was initiated many miles of edge should already have become stable. Yet the system level outage statistics do not show the expected steady reductions in tree-related outages. As API did not indicate that tree-related outages were arising almost exclusively on recently widened line segments, we conclude the expected reduction is not occurring due to an increasing number of hazard trees situated 6 to 15 m from the conductor.

Exhibit 1-4
Tree Species Risk Rating

Species	Records	% of Population	% Decadent	Risk per 1000 trees
Birch, white	679	10.94%	22.24%	24.3352
Fir, balsam	868	13.99%	16.59%	23.2071
Aspen, trembling	625	10.07%	16.32%	16.4384
Maple, sugar	957	15.42%	5.02%	7.7357
Spruce, white	496	7.99%	7.46%	5.9629
Maple, red	634	10.22%	5.68%	5.8018
Birch, yellow	208	3.35%	13.94%	4.6737
Pine, Jack	185	2.98%	14.59%	4.3513
Poplar, balsam	95	1.53%	22.11%	3.3844
Cedar white	306	4.93%	6.86%	3.3844
Pine, white	165	2.66%	12.73%	3.3844
Ash, white	116	1.87%	12.07%	2.2562
Tamarack	39	0.63%	28.21%	1.7728
Aspen, largetooth	48	0.77%	18.75%	1.4504
Spruce, black	237	3.82%	2.53%	0.9670
Oak, red	133	2.14%	3.76%	0.8058
Ash, black	16			
Hemlock, eastern	79	1.27%	3.80%	0.4835
Cherry, pin	14			
Other	2			
Ash, mountain	9			
Elm, American	21			
Pine, red	252	4.06%	0.40%	0.1612
Basswood	2			
Beech, American	1			
Ironwood	18			
Totals	**6205**		**11.20%**	**4.3079**

To improve on reliability API will need to address the backlog of hazard trees and establish a maintenance cycle that prevents the major build up in hazard trees between maintenance events. A 3-year hazard tree cycle is recommended. By weighting species frequency of occurrence with percent decadence provides guidance to the hazard tree program by highlighting which tree species pose the greatest risk to continuity of service (*Exhibit 1-4*).

The Performance Management Review found while API's current VM program has many positive aspects. However, if API is to transition to a sustainable maintenance program, there are some impediments that need to be removed. Doing so will result in improved reliability. There are also some opportunities for improvement and efficiency gains.

Clearance standards are (now) typical of industry standards. The standards are met in the field and good arboricultural practices are applied. Communication between the Forestry group and other API departments is exceptional. The leadership in the Forestry group is knowledgeable and committed to continuous improvement in the VM program.

The major obstacle to achieving a sustainable VM program is that the funding has not been based on an inventory and tree growth and mortality rates that would establish how that inventory changes. Because the VM workload is not static and expands by a logistic function, there is a specific amount of VM (the annual volume increment or AVI) that must be conducted within the year to hold the system in equilibrium. The acceptance of this approach of annually removing the AVI is recommended as it provides simultaneously the least cost program and the lowest incidence of tree-related outages for the established clearance standards and practices. A successful VM program can only be delivered if funding is adequate to remove the AVI. In API's case, there is also a backlog of work in addition to the AVI that needs to be addressed to be able to achieve equilibrium. The backlog occurs in hazard tree removals and pruning work. The pruning backlog will be addressed over the recommended term of the pruning cycle. The backlog of hazard tree work will require additional funding.

API has had recommendations for maintenance cycles in the past but these cycles were never attained. A key distinction in this review is that the various parts of the VM program are assigned separate and distinct maintenance cycles based on growth rates and clearance standards. Maintenance cycles and specific funding requirements will be discussed further.

One of the primary sources of tree-caused outages is the failure of branches overhanging conductors. API has a considerable amount overhangs. This is typical of distribution utilities with adjacent hardwood tree species. Due to the exposure to sugar maples, it is not feasible to remove all overhangs without antipathy from landowners. None the less, adopting a policy of removing overhangs wherever possible would contribute to improving reliability. The greatest effort should be focussed on line segments between the substation and the first protective device: line segments that have the greatest customer impact when lost.

In seeking cost effectiveness it is necessary to consider the maintenance free period provided. With respect to herbicide applications, foliar herbicide applications cost less, are more efficacious and generally provide a greater maintenance free period than stump treating and basal applications. API's foliar herbicide program is currently focussed predominantly on off-road line segments. Expanding foliar applications to all areas of brush regrowth, even while recognizing the constraints of environmental conditions and landowner concerns, offers the potential to substantially reduce the average per hectare cost of brush control.

The introduction of brush mowers, specifically the Hydro Ax, and the telescoping insulated boom saw offer opportunities for cost reductions. Brush mowing is considerably less costly than hand cutting of brush. However, due to much rocky terrain, the area suitable for mowing is restricted. None the less, the cost differential warrants a sound investigation of how much of the right of way can be treated with a mower. The application for the telescoping saw is the removal of overhangs. The telescoping saw is far more productive than pruning from an aerial bucket. However, the greatest cost savings will be found in areas that are not accessible to a bucket truck and would need to be climbed. Use of the telescoping saw will be limited by the need to restrict its use to areas where less than perfect pruning cuts can be tolerated.

To determine the AVI the total amount of work is determined by work category. The maintenance cycles, with the exception of hazard trees, are derived from the growth rates. The right of way area that is subject to invasion by brush because it runs adjacent to natural tree stands is presented in *Exhibit 1-5*.

Exhibit 1-5
Area Requiring VM

Voltage (kV)	Kms	Wire Zone (ft)	Edge type	Mean Clear Width (ft)	ROW Width (ft)	Miles	Acres	% Treed Edge	Potential Treed ROW Acres
44	85.9	7	ROW	54	115	53	744	95.55%	711
25/34.5	174.0	7	ROW	34	75	108	983	89.69%	882
25/34.5		7	Roadside	47		108		89.69%	
7.2/14.4	1425.7	1	ROW	18	37	886	3,973	83.21%	3,306
7.2/14.4		1	Roadside	89		886		83.21%	
Totals	**1686**					**1155**	**5700**	**85.76%**	**4898**

Wire Zone – distance between outer phases
Clear Width – distance between outer conductor and tree boles on edge

The total exposure to outside right of way trees, which have the potential on failure to contact conductors, is presented in *Exhibit 1-6*. Also provided is the annual number of decadent trees, that is, trees that have begun the process of mortality.

The API system is exposed to 825,543 trees that on failure could contact conductors. These trees are called danger trees. Based on a 2% annual mortality rate, 16,511 trees will need to be assessed annually for the risk they pose to power lines. Some portion of these trees will be designated hazard trees. Based on the mean field found tree heights, line heights and tree density we have calculated the arc of line exposure at 8.5 m (28 ft) from the conductor to estimate the probability of a line contact on failure. There are two estimates for the number of hazard trees. The first is based on an annual tree mortality rate of 2% and the second is derived from the percent of decadent trees found in the forest samples, which was 11.2% (*Exhibit 1-7*).

Exhibit 1-6
Tree Exposure

Voltage (kV)	Mean Tree Height (ft)	Mean Line Height (ft)	Trees Per Acre	Ft. To Tree Free @	Danger Trees	Decadent Trees	Mean Danger Tree Depth (ft)
44	63	33	416	54	0	0	0
25/34.5	62	41		47	63,566	1,271	13
25/34.5				47	0	0	0
7.2/14.4	68	33		59	761,977	15,240	41
7.2/14.4				59	0	0	0
Totals					825,543	16,511	

Exhibit 1-7
Hazard Trees

Voltage (kV)	Decadent Trees Calculated From Annual Mortality	Decadent Trees Based on Found Incidence
44	0	0
25/34.5	1,271	7,120
25/34.5	0	0
7.2/14.4	15,240	85,346
7.2/14.4	0	0
Totals	**16,511**	**92,466**
Hazard Trees	**2,683**	**15,026**

Growth rates were obtained by measuring internode lengths for the last five years of growth, measuring at least 30 stems at each of 15 of the 150 sample locations (462 brush samples). Line heights encountered in the sampling were from 7.8 m upwards. Growth beyond the five years sampled was extended by the average and placed in a frequency distribution to determine in what year trees would begin to intrude on conductors. From this it is deduced that brush control requires a 9-year maintenance cycle (*Exhibit 1-8*). Foliar herbicide applications require a 3-year cycle so as to manage the brownout which is generally negatively viewed and raises resistance to herbicide applications.

Pruning regrowth is derived from 307 stems on which the last five internode lengths were recorded. Using a similar process to extend growth over many years based on the 5-year average it is possible to determine when the established clearance is eroded. *Exhibit 1-9* shows the percent of the stems that would intrude on the limit of approach by years. From this the recommended 6-year maintenance cycle for pruning work is derived.

Exhibit 1-8
Brush Growth Based on Observed Growth 2009-2013

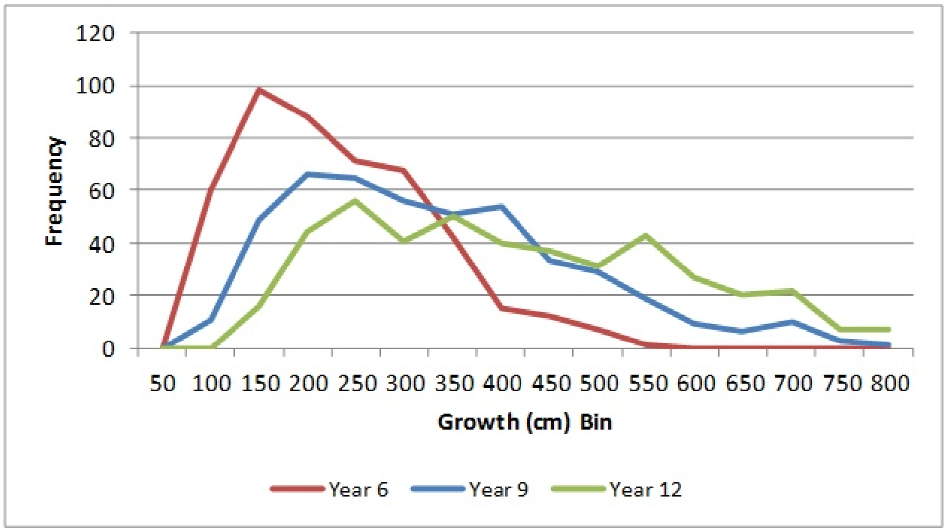
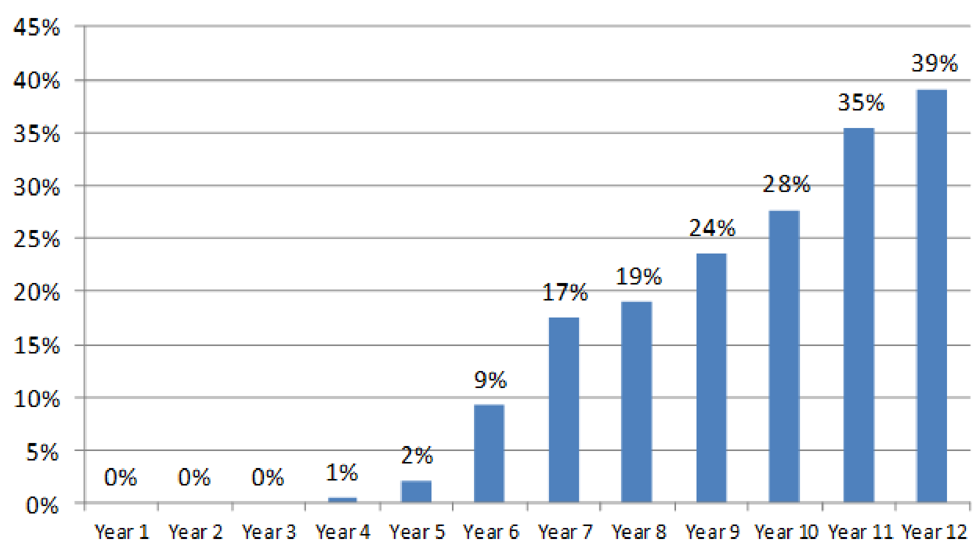


Exhibit 1-9
Pruning Breaching Limit of Approach



Having developed the maintenance cycles for the various work methods, the AVI is developed dividing the total volume for each work type by the maintenance cycle (*Exhibit 1-10*).

Exhibit 1-10
Annual Workload Volume Increment

	Brush (m^2)	Herbicide (m^2)	Pruning Top (m^2)	Pruning Side (m^2)	Hazard Trees
	10,206,864	3,048,804	187,354	185,008	3,069[1]
Cycle (years)	9	3	6	6	3
Annually	1,134,096	1,016,268	31,226	30,835	1,023

[1] 386 hazard trees have been added to account for secondary circuit kms

Unit costs are then applied to the work volumes to derive the value of the AVI. This provides the expenditures required to achieve a sustainable VM program (*Exhibit 1-11*). However, any backlog of work must also be addressed (*Exhibit 1-11*) and, therefore, it must be added if the VM is to be returned to a sustainable level.

Exhibit 1-11
Annual Workload Values

	Brush	**Herbicide**	**Pruning Top**	**Pruning Side**	**Hazard Trees**	**AVI**	**HT Backlog**	**Total**
	$22,965,444	$548,785	$515,223	$1,928,242	$507,738		$2,684,764	
Cycle (years)	9	3	6	6	3		3	
Annually	$2,551,716	$182,928	$85,871	$321,374	$169,246	$3,311,134	$680,681	$3,991,816

For a comprehensive accounting of how the backlog of work or cumulative liability is paid off, it is necessary to determine the rate of change of deferred work. This is accomplished by fitting a logistic function to the known data (*Exhibit 1-14*) and then using that function to calculate the effect of funding on the cumulative liability. In this way a schedule of funding, which ultimately brings the cumulative liability to zero was developed. The intent in this funding model (*Exhibit 1-12*) is to arrive at and maintain the cumulative liability as close to zero as possible. It has been assumed in the development of *Exhibit 1-12* that the new funding schedule would not be initiated until 2015. Between capital and maintenance funding for VM in 2014 the value falls over $400,000 short of the AVI. When the backlog is included, the proposed funding will fall over $1 million short.

Exhibit 1-12
Proposed VM Maintenance Budget[1]

	Minimum Required Budget	Proposed Funding	PV of $1	PV of Budget Provided	Unfunded	Liability	Cumulative Liability
Proposed Funding					('000)	('000)	('000)
Start 2014	('000,000)	('000,000)		('000,000)		$680.68	$2,042.04
End 2014	$3.99	$2.88	1.0000	$2.88	$1,109.73	$769.20	$2,811.25
End 2015	$3.99	$4.70	0.9524	$4.48	-$708.18	$0.00	$2,200.89
End 2016	$3.99	$4.70	0.9070	$4.26	-$708.18	$0.00	$1,594.56
End 2017	$3.99	$4.70	0.8638	$4.06	-$708.18	$0.00	$965.98
End 2018	$3.31	$4.30	0.8227	$3.54	-$988.87	$0.00	-$25.68
End 2019	$3.31	$3.31	0.7835	$2.59	$1.13	$1.13	-$24.54
End 2020	$3.31	$3.31	0.7462	$2.47	$1.13	$1.31	-$23.23
End 2021	$3.31	$3.31	0.7107	$2.35	$1.13	$1.51	-$21.72
End 2022	$3.31	$3.31	0.6768	$2.24	$1.13	$1.75	-$19.97
End 2023	$3.31	$3.31	0.6446	$2.13	$1.13	$2.02	-$17.95
Total	$35.83	$37.83		$31.01			-$17.95

[1] In 2013 dollars

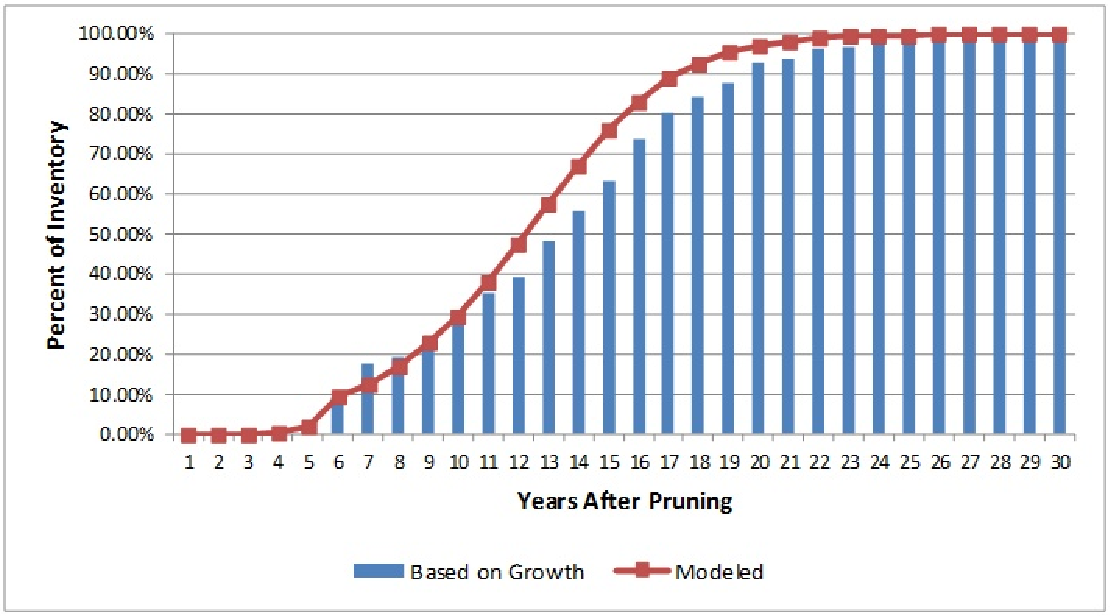
The schedule of VM funding set out in *Exhibit 1-12* should make it apparent that there is only one path to a sustainable VM program. If there is a current cumulative liability then funding must exceed the AVI value to be progressing towards a sustainable program. If there is no current cumulative liability then funding must match the AVI value. The logistic function that fits API's found field conditions informs us that every dollar of work deferred will need to be replaced with $1.155 in the next year. While not correct over the long term, as a logistic function curve has an asymptote, in the short term (i.e. 5 years) deferred work compounds at 15.5% per annum.

Without a commitment to the funding set out in *Exhibit 1-12* there is not much possibility that tree-caused outages will improve in the future. In fact, there are indications that reliability will deteriorate. If the high incidence of decadent trees is not addressed, their ratio of all trees will continue to increase. They will reach a peak over the next 3 to 5 years and it should be expected that tree-related outages will increase 40-60%.

There is a high incidence of hot spots (sites where contact with the conductor will occur within the next year). *Exhibit 1-13* shows the rate of development of hot spots. The field inventory work indicated that 38% of the pruning sites were hot spots. The corresponding number is at year 12 in *Exhibit 1-13*.

ECOSYNC Ecological Solutions Inc.

Exhibit 1-13
Modeling Hot Spot Development

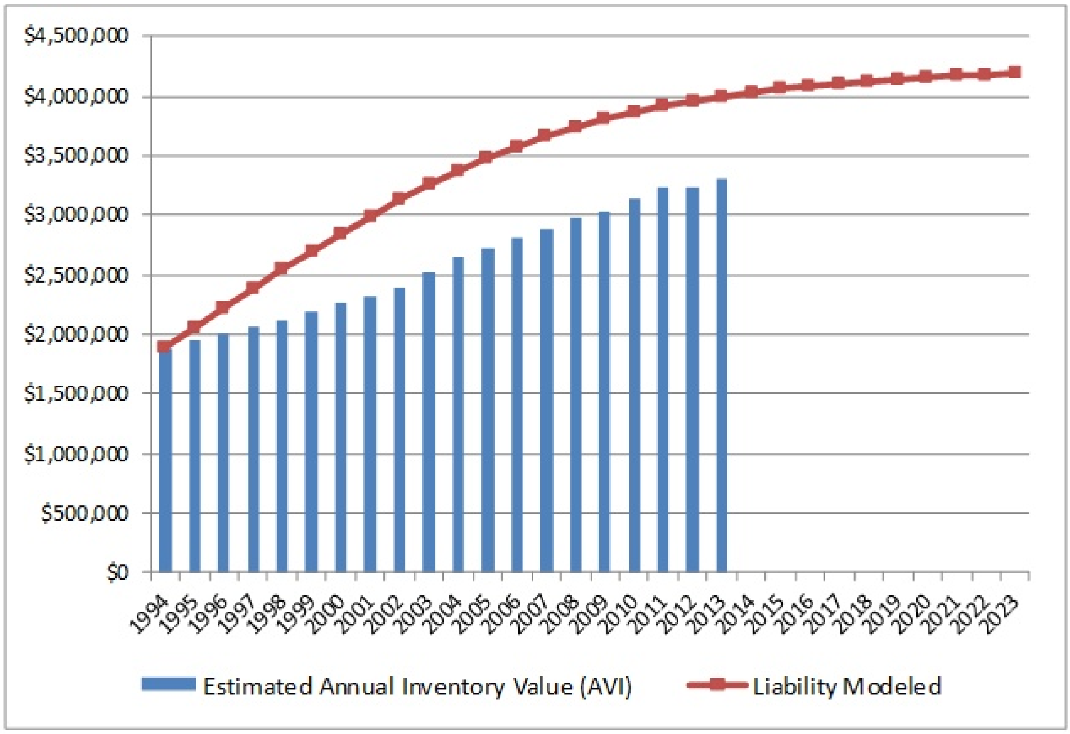


Very few sites were seen where tree-conductor contact was apparent. The fact is corroborated by outage statistics that show virtually no grow-in outages since 2010. This suggests that API has done an excellent job of hot spotting. Hot spotting is, however, inefficient, costing considerably more than routine maintenance work. The implications of not putting the pruning on an appropriate maintenance cycle, such as the recommended 6-year cycle, can clearly be seen in *Exhibit 1-13* looking to the right of year 12, which is the current level. With the number of hot spots expanding rapidly, doubling in fact over the next five years, how realistic is it to think API will be able to continue to avoid grow-in outages?

There is also a financial risk or penalty associated with funding below the AVI value. *Exhibit 1-14* projects forward the current maintenance underfunding which is not far removed from the AVI value but does not address the current backlog or cumulative liability. Deferring work, deferring a commitment to funding that reduces the cumulative liability will incur greater costs when the decision is subsequently made to provide a more reliable service to customers.

After the right of way reclamation work that has occurred, there now exists the possibility that the average cost per hectare for brush, which is the largest cost component, may be substantially reduced through the extension of foliar herbicide use and the introduction of brush mowers. However, reducing the VM funding from the recommended levels on speculation of the area that might be treated with foliar herbicide or mowing need be recognized for the gamble that it is and that the risk side of the equation shows any error that results in deferred work will be compounding at about 15% per annum.

Exhibit 1-14
Modeling the Workload Liability



2013 AVI is derived from field inventory, growth and mortality rates

API's VM program is currently on the cusp. There are many positive aspects. The capital expenditures have served to reduce the current liability. At this point API can move forward to a best in class VM program and a least cost sustainable program. However, the program is not many years removed from a program that is beyond control of deteriorating reliability and increasing public safety and wildfire risk. The positive path forward has been revealed in the recommendations provided.

2. Background

Algoma Power Inc. (API), as an investor owned electric distribution utility, is regulated by the Ontario Energy Board (OEB), to whom it must apply for the rates it can charge its customers.

API has completed the majority of its right of way expansion program and is transitioning to a maintenance program. Given this transition, API has undertaken an assessment to determine the volumes of emerging maintenance work. Future maintenance work volumes have been impacted by the capital work and will continue to change as the new edges transition to stable edges. The change in focus from major capital work back to strictly maintenance also provides an opportunity to examine vegetation management (VM) practices to ensure funds are directed to the most efficient and cost effective practices.

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Trees are the primary cause of unplanned outages for API. This is common for electric distribution services. Indeed, for the majority of North American electric distribution companies tree-caused outages are the leading cause of service interruptions. Consequently, VM, which seeks to limit this cause of interruptions, is the single greatest operating and maintenance expense.

The setting of electricity rates in North America follows a quasi-judicial process. The regulator must provide public notice of a rate application, providing affected parties an opportunity to participate or intervene in the process. The intent of the process is to surface to the regulator all the facts and factors requiring consideration, such that the regulator has before it the best information upon which to base a decision. This report seeks to address that need.

This report describes:

- The investigation process
- Data collection and analysis
- Resulting conclusions, and
- Recommendations

The work is detailed under the following project elements:

- Performance Management Review
- Outage Statistics
- Quantification of the Utility Forest
- Within & Adjacent to ROW
- Outside ROW Tree Exposure
- Tree Growth Study
- Statistical Analysis
- Workload Inventory, Maintenance Cycles & Annual Workload Volume Increment
- Workload Valuation & Funding Requirements
- Risk Indicators & Model Progression
- Recommendations

Background to Utility Vegetation Management

As already stated, on many distribution systems, trees are the primary cause of unplanned service interruptions.[5 6] Even though greater conductor-to-tree clearances are maintained on transmission systems, these systems are not immune to tree-caused outage events. Within less than ten years, there were three major tree-caused cascading-outage events in the U.S. and one in Italy:

- July 2, 1996 on U.S. western grid; 2.2 million customers affected[7]
- August 10, 1996 on U.S. western grid; 7.5 million customers affected[8]
- August 14, 2003 on U.S. northeast grid; 50 million customers affected[9]
- September 28, 2003 intertie-line between Switzerland and Italy; 60 million customers affected[10]

This history suggests that how vegetation management is related to outage events is inadequately understood. A literature review will reveal few articles on establishing a mathematical link between vegetation management expenditures or maintenance cycles with the frequency of tree-caused outage events. Among the scant few that do exist, a number are flawed through the exclusion of critical variables. In the absence of appropriate, statistically derived regression algorithms linking the timing and scope of past maintenance activities with tree-caused outage events, a conceptual approach serves as a starting point and provides guidance.

The following section is included to provide the non-vegetation manager a context for understanding some of the key issues in vegetation management. Vegetation management concepts and principles are presented to make explicit key aspects of the relationship between vegetation management and tree-caused outage events. This information is general to utility vegetation management. None of the data used in the Vegetation Management Concepts and Principles section is derived from API. This introduction seeks to make distinctions between work types, their origins and provide mathematical representations for the change in vegetation management workload over time. More importantly, it should facilitate an understanding that tree-caused outages, while lagging work in the field, are a suitable proxy for assessing the adequacy or effectiveness of a vegetation management program. The vegetation management concepts and principles provide a conceptual template that will subsequently be used to make assessments regarding the adequacy of funding of API's vegetation management program.

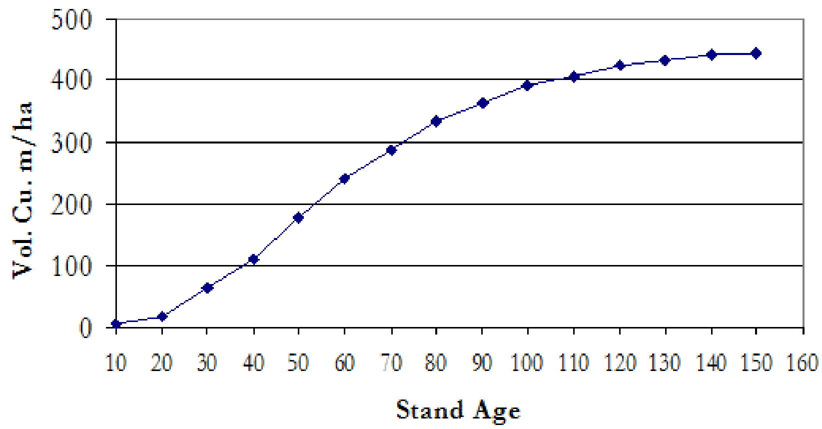
3. Vegetation Management Concepts and Principles

Trees that interrupt electric service can be categorized as in-growth trees and in-fall trees. The inventory of all trees that have the potential to either grow into a power line or, on failure (breakage), fall into and strike a conductor will be referred to as the utility forest. While we commonly think of forests in terms of more or less rectangular blocks, the utility forest amounts to ribbons or transects of the service area. Generally, the centerline of these transects is the power line. The utility forest has the same characteristics as any forest. In most cases the tree species composition is what is native to the area. The same patterns of biomass addition (tree growth) and tree mortality apply. Both of these patterns are significant factors in power line security and both can be mathematically represented by logistic functions, as illustrated in *Exhibit 3-15* and *Exhibit 3-16*. Biomass additions result in trees that encroach on conductors, thereby necessitating tree pruning and either mechanical or chemical (herbicide) brush clearing. Failure to mitigate this encroachment leads to deteriorating safety and reliability. *Exhibit 3-15* shows an asymptotic curve that is typical of biological populations. Tree mortality produces decadent trees that are subject to breakage or tipping over (*Exhibit 3-16*). Tree mortality is not an event that occurs at a specific point in time. Rather, tree mortality occurs over a period of months and years.

Natural tree mortality is a process of losing vigor either due to the stress of competition for light, water and nutrients or an inability to sustain the attained mass. In the early stages of senescence or decline there may be no visible defect. However, as the tree becomes increasingly decadent and subject to failure under increasingly less stress loading, symptoms of the decline become apparent. Such senescent trees must be identified as faulty and prone to failure under weather stress and must be removed prior to the occurrence of stress. *Exhibit 3-16* shows both the forest stand density over time and the population of trees of concern to utility facilities, the Decadent Trees. While the South Carolina forest data (*Exhibit 3-16*) is restricted to sixty-two years, the line for Decadent Trees is seen to be approaching an asymptote. Further, because the capacity of the land-base to produce biomass is limited, the line for the evolution of decadent trees must be asymptotic. The nature of the expansion of the two sources of tree-caused interruptions, biomass addition (in-growth) and tree mortality (in-fall), is additive or constructive. This in conjunction with the process of tree mortality leads to insight into the consequences of failure to manage trees in proximity to power lines.

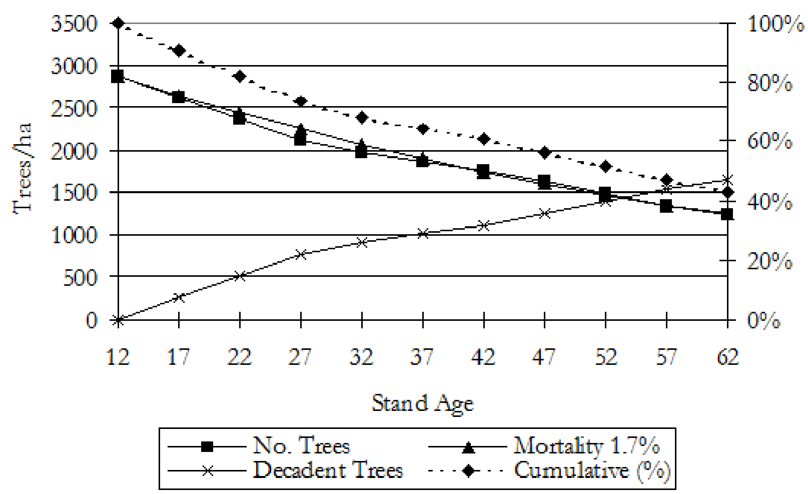
From a utility perspective, trees represent a liability in both the legal and financial sense. The fact that the utility forest changes by a logistic function is significant. It means that the tree liability, if not managed, will grow exponentially.

Exhibit 3-15
Vegetation Management Concepts and Principles
Forest Biomass Addition
Timber Production
Spruce on Good Site



Source: Freedman, Bill and Todd Keith, 1995. Planting Trees for Carbon Credits. Tree Canada Foundation.

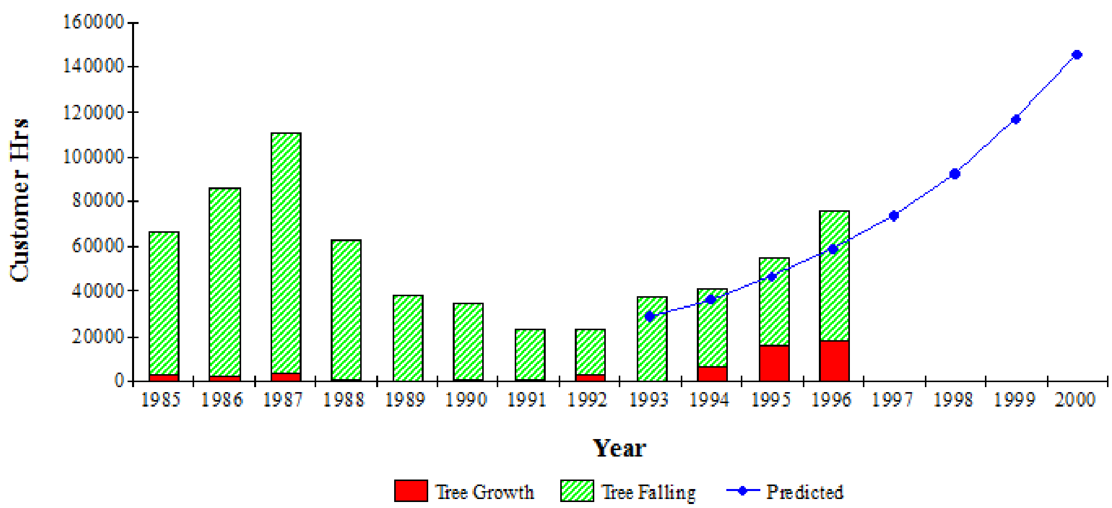
Exhibit 3-16
Vegetation Management Concepts and Principles
Stand Density
South Carolina
State Forest



Source: Crookston, Nicholas L. 1997. Suppose: An Interface to the Forest Vegetation Simulator.
Note: The graph shows the remaining live, viable trees. Of interest to utilities is the 60% of trees in the stand that die over 50 years because they hold the potential to disrupt electrical service.

Trees cause service interruptions by growing into energized conductors and establishing either a phase-to-phase or phase-to-ground fault. Trees also disrupt service when they or their branches fail, striking the line and causing phase-to-phase faults or phase-to-ground faults or breaking the continuity of the circuit. Because the two factors that are responsible for service interruptions, tree growth (biomass addition *Exhibit 3-15*) and tree mortality (*Exhibit 3-16*), change by logistic functions, the progression of tree-related outages is, necessarily, also exponential (*Exhibit 3-17*) up to the approach of the asymptote. Failure to manage the tree liability leads to both exponentially expanding future costs and tree-related outages. Conversely, it is possible to simultaneously minimize vegetation management costs and tree-related outages (*Exhibit 3-18*).

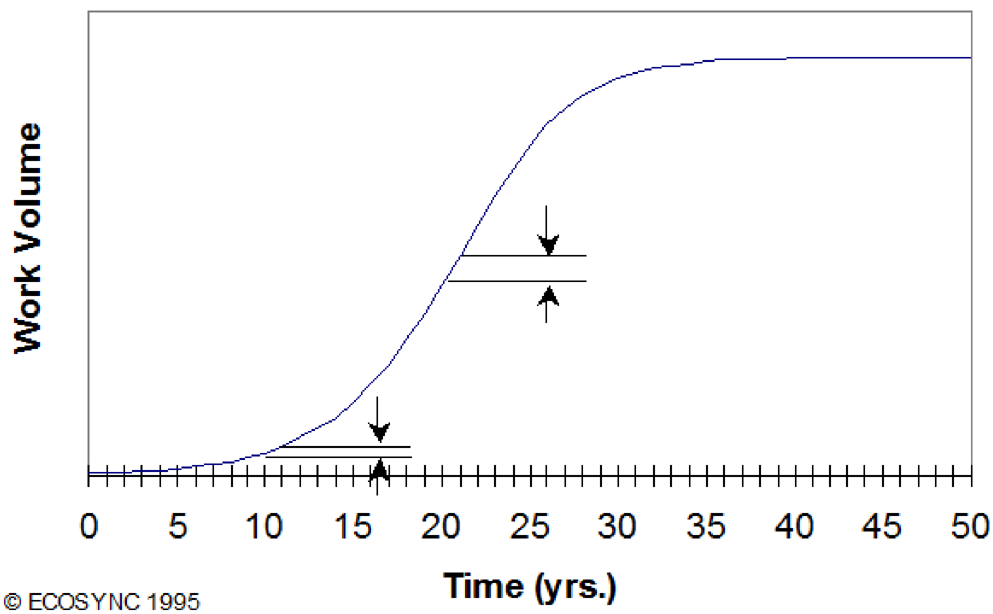
Exhibit 3-17
Vegetation Management Concepts and Principles
Tree-caused Distribution Outage Statistics



Source: Western Canadian utility
Note: This work and prediction for future tree-caused outages was performed in early 1997 to show the expected trend to 2000 based on funding below that required to remove the annual workload volume increment.

It is not possible to totally eliminate the tree liability because the ecological process of succession is a constant force for the re-establishment of trees from whence they were removed. The tree liability then is like a debt that can never be completely repaid. Under such circumstances, the best economy is found in maintaining the debt at the minimum level, thereby minimizing the annual accrued interest. However, irrespective of cost, minimizing the size of the tree liability or utility forest is rarely an option for utilities because there are multiple stakeholders with an interest in the trees. What can be achieved, however, is equilibrium. The tree liability can be held at a constant point by annually addressing the workload increment. To continue the debt analogy, a debt is stabilized when the annual payments equal the interest that accrues throughout the year. The interest equivalent in the utility forest is comprised of annual tree growth and mortality. Actions that parallel the reduction in the debt principal are actions that actually decrease the number of trees in the utility forest. Such actions include removal of trees and brush by cutting or through herbicide use.

Exhibit 3-18
Vegetation Management Concepts and Principles
Stabilizing Tree Workload
(Illustrative Model)



The graph shows the work volume that must be completed in a year to hold tree work inventory, costs and reliability steady. Performing less than the annual workload-volume increment shifts the total tree work inventory to the right, thus necessitating greater annual vegetation management expenditures to arrest the expansion of tree-related service interruptions.

When the pruning cycle removes the annual growth increment and the hazard tree program removes trees as they become decadent (*Exhibit 3-18*), tree-related outages are stabilized. The residual level of tree-related outages reflects the interaction of several characteristics, including the size of the utility forest, chosen maintenance standards (such as clear width), tree-conductor clearance, and tree-species characteristics (such as mode of failure and decay). An expression of a managed tree liability, one in which the annual workload volume increment is removed, is stable tree-related outages. Reducing tree-related outages below an achieved equilibrium necessitates actions that decrease the size of the utility forest. Actions are not limited to vegetation management. For example, increasing conductor height reduces the size of the utility forest as it reduces the number of trees that are capable of striking the line.

Funding

There are three possible outcomes determined by the level of investment made in vegetation management.

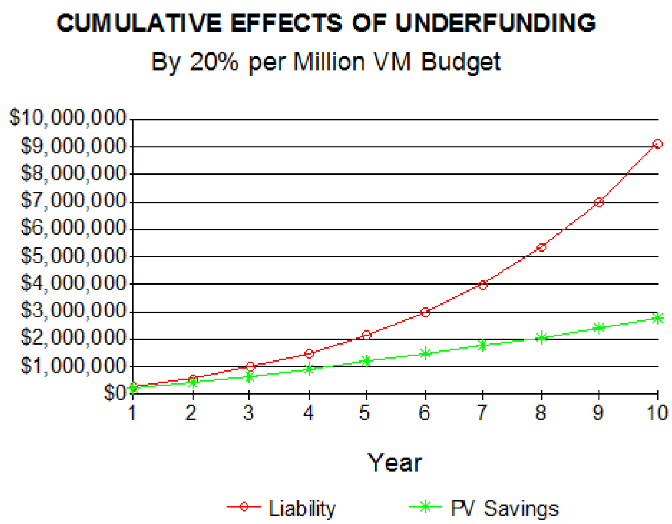
1. The annual workload volume increment is removed, thus keeping the size of the tree liability and next year's workload increment constant.
2. More than the annual workload volume increment is removed, thus decreasing the size of the tree liability and the subsequent year's workload increment.
3. Less than the annual workload volume increment is removed, thus increasing the size of the tree liability. That is because the work not done expands exponentially, thus increasing the workload increment for the following year.

Tree-related outages are an expression of the tree liability. Hence, changes in the tree liability result in proportional changes in tree-related outages (*Exhibit 3-17, Exhibit 3-19*). Actual outage experience may deviate from the trend based on variance from mean weather conditions.

When less than the annual workload volume increment is removed, the fact that tree liability increases by a logistic function has two major implications for future costs and reliability. First, the impact of doing less vegetation management work than the annual workload volume increment, as expressed through tree-related outages, may be relatively imperceptible for a few years. Second, the point at which the impact of under-funding is readily observed in deteriorating reliability is where the effect of annual compounding in the workload, and thereby costs, is large (*Exhibit 3-19*). The lack of a significant negative reliability response to reduced vegetation management investment (see 1992 to 1995 *Exhibit 3-17*) may provoke further funding reductions, thereby exacerbating the size of the future re-investment required to contain tree-related outages.

Recognition that the tree workload expands by a logistic function serves to explain some common utility experience. For many utilities, graphing customer hours lost on tree-caused interruptions over the last ten to twenty years reveals cyclical up and down trends (*Exhibit 3-17*). There are periods when trees are perceived as a problem and funding is increased. Increased funding permits a buying down of the tree liability, reducing tree risks and tree-related outages. Faced with these positive results, spending on vegetation management is reduced. While this tendency is perfectly logical, without the conceptual framework outlined, it is inevitable that funding will be reduced to the point where there is an observable response in tree-related outages. Unfortunately, by the time that tree-related outages are definitively observed to be on an increasing trend, for some years, vegetation management investment has been less than what is required to remove the annual workload volume increment. At this point, the power of compounding is well under way and only a very aggressive increase in funding will arrest the trend. The rate of change in the workload liability in *Exhibit 3-19* is approximately equal to a compounding rate of 27% per year. Warmer and wetter climates with a longer growing season support higher rates of change. In other words, for distribution systems, the rate of change in the tree workload is substantially higher than the discount rate (currently 3-11%) one would conceivably use to derive the present value benefit of deferred maintenance spending. Taking a short-term financial perspective, any deferred or diverted vegetation management funding that inhibits removal of the annual workload volume increment is poorly allocated unless it provides a better rate of return. The example provided in *Exhibit 3-19* shows that returning the work volume and reliability to the original levels after 10 years of under-funding by 20%, increases costs by 80% over maintenance, which annually removes the workload volume increment.

Exhibit 3-19
Vegetation Management Concepts and Principles
Impact of Under-Funding Vegetation Management Revealed Over Time



Notes: Rate of change in liability based on western Canadian utility with a 4-month growing season.
Interest/Discount rate = 6%

It has been shown, through *Exhibit 3-17* and *Exhibit 3-19*, that under-funding VM has a substantial impact on future reliability and costs to return to the level of reliability enjoyed before under-funding. The increase in workload due to deferred maintenance is not linear. Hence, the impacts of a dollar deferred this year cannot be erased with an investment of a dollar next year. Further, this section has provided the conceptual context that utilities have lacked, which lack has allowed the inefficient, repetitive cycles of under-funding followed by reactive catch-up periods.

Exhibit 3-19 illustrates that failing to make the necessary investment in vegetation management will, in most circumstances, prove imprudent. While utilities are expected to justify their intended vegetation management expenditures, regulators play a role in the effectiveness of the program. Failure to understand the nature of vegetation management workload expansion or skepticism that leads to decisions limiting the ability to remove the annual workload volume increment, will impose the inefficiencies illustrated in *Exhibit 3-19*. By focusing on cost containment, the regulatory process risks supporting such inefficiency. Utilities that are pressured to minimize costs must prove the harm that will result as a consequence of failure to fund and perform proposed work. This burden of proof proves very challenging for maintenance work, where it becomes necessary to prove that an event that did not occur would have occurred but for specific actions and expenditures. By insisting on demonstrable harm, the regulatory structure supports a reactive approach to maintenance with the attendant cyclical inefficiencies.

Managing the Tree Liability for Positive Returns

Trees need to be recognized as a liability in a utility context. While this puts utilities in conflict with community perceptions of trees as assets, the conflict does not change the fact that trees hold only the capacity to impair the safe, reliable operation of the electric system, not to augment it in any way. The recognition and quantification of the utility forest as a liability provides a measure of the potential for, or risk of, tree-conductor conflicts. Furthermore, it connects and clarifies the influence of design and operating decisions on maintenance costs and reliability risks.

Managing the tree liability necessitates an understanding of how and where tree risks arise, a quantification of the extent of tree exposure, the rate of change in the tree liability, and a commitment to funding that permits, at a minimum, the removal of the annual workload volume increment.

Appropriate investment in vegetation management is one of the best investments a utility can make. It serves to minimize tree-caused interruptions for the chosen clearance standard, thereby avoiding customer complaints, the need for regulator intervention, and in some cases performance penalties. It avoids the inefficiencies that are inherent in the cycle of allowing trees to become a major problem, getting trees under control by buying down the tree liability, and then losing the investment by failing to contain the tree liability. Investment based on the removal of the annual tree workload increment provides the conceptual approach that is needed to deliver a sustainable, least-cost vegetation management program. Simultaneously, such a program provides the lowest incidence of tree-caused service interruptions (*Exhibit 3-18*) for community-accepted clearance standards, thereby benefiting ratepayers and shareholders alike.

4. Benchmarking

Electric utilities do not operate in markets where they are free to set the price at which they sell their product and service. Co-ops must justify rates to their members. Municipal utilities receive oversight from elected civic officials and investor owned utilities must justify rates through a state or provincial regulatory process.

The commonality between these oversight bodies is that they serve to represent the interest of the ratepayer, to ensure utilities provide a reasonable level of reliability in service at a reasonable price. Determining what constitutes a reasonable service and price is particularly challenging for VM programs.

It is not uncommon for utility regulators to request performance comparisons to other utilities. It is assumed such comparisons will serve to monitor progress in efficiency or provide meaningful information to regulators, ratepayers and shareholders. However, in the field of VM, the information gathered generally fails to illuminate or inform decision-making. All too often the benchmarking studies are designed without any VM expertise. Consequently, such studies do not provide guidance on what the most efficient and effective utilities are doing rather they serve to provide a template to becoming, at best average. Why is that so? Is it possible to compare VM program results between utilities and what would constitute a sound basis for such comparisons?

Answering these questions requires an understanding of what makes up the VM workload; the drivers of this workload; how and what trees cause tree-related outages and under what circumstances. This information is presented in detail in the previous section, Vegetation Management Concepts and Principles and Managing Tree-Caused Electric Service Interruptions[11] and will be used here without further qualification or detailed reiteration.

There are several general practices in utility benchmarking that make the data provided unreliable. Typically, utilities are sent a survey to complete. Completing the survey is a cost to the participating utility. The benefit derived is that the firm undertaking the survey or benchmarking usually commits to providing all the respondents the results and thus the utility will have comparisons to its peers. This process is rife with barriers to obtaining meaningful data, including:

- The level of commitment to providing accurate, detailed data will vary with the utility, the cost of providing the data, etc.
- There is no control on who answers on behalf of the utility. Varying levels of commitment, urgency and competency produce variability in the veracity of the data.
- No audits are performed to verify the data. This allows utilities to state maintenance cycles that are theoretical, an operational fantasy, instead of the operational duration in fact. It also allows for estimates or outright guesses to be supplied. There is no way for the reader of the study to distinguish such a response from an accurate fact-based response.

- In the field of VM there are very few industry defined terms. A key missing is an industry-wide definition for a maintenance cycle. Consequently, two utilities reporting a three-year and a six-year pruning cycle may in fact be doing the same thing – pruning every tree on a circuit every six years and re-doing 35% of them three years later. One utility might call this a 3-year cycle while the other considers it a 6-year cycle with a mid-cycle cycle buster or hot spotting program.
- Questions seeking to establish efficiency or productivity are denominated in dollars, yet there are no questions that serve to make explicit differences in local labour rates.

These general deficiencies in benchmarking VM are adequate reason to reject inter-utility comparisons as a means of improving rate case decision-making. If, however, one wishes to explore whether or not VM benchmarking has any merit whatsoever there is a need to look in more detail, first at what does not work so that that which might, may emerge.

First, let's examine what is generally used for a basis of inter-utility comparisons. In the field of VM the commonly used measures are dollars per mile and dollars per customer. Measures of dollars spent on VM per mile of line or per customer may have meaning within the context of a specific utility over time but are meaningless as a basis of comparison between utilities. It should be obvious that gauging performance or efficiency on dollars per mile results in utilities that grossly under-fund VM emerging as very efficient and thereby, utilities to be emulated. This metric provides no insight to distinguish between efficiency and under-funding. It does not capture the public, nor regulator perception about the adequacy of the level of service provided. That is, there is no connection to the resulting reliability. A top-down driven approach to achieve the lowest dollar per customer or $/mi of line results in a disconnect from the biologically driven need and facts. It leads to under-funding VM, based on a refusal to accept tree growth and mortality rates as independent variables outside the control of the utility. Under-funding VM, as was shown in Vegetation Management Concepts and Principles, is financially imprudent.

The survey may ask whether VM work is contracted out or performed by in-house labour. It may ask whether the utility uses time and materials, cost plus, unit price or lump sum contracts. Generally, there is nothing to help the reader of the benchmarking study determine the merits of these practices beyond their prevalence amongst utilities. There should be no comfort in using the most prevalent practices as that fact alone is no assurance that these practices are the most cost effective or that they provide superior reliability or customer satisfaction.

Benchmarking participants may be asked to provide unit prices. First, without defining the unit there is no assurance that the price is based on a common denominator. Secondly, is it known whether the unit prices are standardized to include all loading such as time for travel, safety tailboards, disposing of wood wastes, etc.? Thirdly, what are the differences in local labour rates between participating utilities and what is their impact on the unit price?

Another common metric upon which utilities are compared is the length of the pruning cycle. Without a common definition of a maintenance cycle such comparisons are meaningless. Further, outside of the utility arborist profession, there is a commonly held belief that shorter maintenance cycles will have a substantial effect on the extent of major storm damage. Managing Tree-Caused Electric Service Interruptions[12] presents the facts to dispel this erroneous belief.

For the purpose of comparisons, utilities need to be matched on customer density per mile of line and in examining VM, on tree density or trees per mile of line. This includes both trees within the right of way and trees outside the right of way that are capable of interfering with electrical service on failure (danger trees or in the new ANSI terminology, risk trees). As trees outside the right of way account for 85% or more of tree-related outages, clearly this measure of exposure is required. Yet, at this writing very few utilities have quantified this exposure.

It is inappropriate to compare a utility with 12,000 miles of line and 20 million customers to a utility with 50,000 miles of line and 5 million customers. It should be a foregone conclusion that the second utility, if in similar environmental conditions, will spend far more maintenance dollars per customer. Nor is it appropriate to compare a utility averaging 1600 trees per mile with one that averages 800. While not inconceivable it is, however, unlikely that one could compare the efficiency of the VM programs. It might be assumed that the first utility having twice the tree exposure will have twice the VM program costs and twice the number of tree-related interruptions. This assumption would, however, be wrong. The relationship between tree exposure and outage incidents is a logistic function. It is not linear[13] [14] [15]. As detailed in section Vegetation Management Concepts and Principles, VM workload can also be described by a logistic function or curve. Given this, it would require advanced statistical analysis to make the two utilities comparable.

Reliability is measured in outage incidents, outage duration and customers affected. These records plotted by year provide an excellent relative measure of the success of the VM program. Historically, this data did not represent a sound foundation for comparing the effectiveness relative to outside VM programs. The variability in outage reporting had always been a concern even within a utility. Hence, these measures could be used on a relative or historical basis providing there was no reason to think that outage reporting had changed for better or worse. Technological advancements have provided systems that automate the capture of outage data. While these systems have made outage data far more accurate and reliable, they do not facilitate inter-utility comparisons because the statistics in themselves do not provide the context. Utilities that have higher tree exposure (trees/mile) will have both a higher absolute number of outages and a higher ratio of tree-caused outages relative to all unplanned outages. Can you determine whether a New England utility where tree-related outages are 26% of all unplanned outages has a less effective VM program than an Arizona utility with 8% tree-related outages? For the basis of comparison it is necessary to have an inventory of trees capable of growing into or falling onto the lines. Comparing utilities on the number of tree incidents per 1000 trees of exposure would constitute a rational, meaningful approach. However, even this metric would need to be carefully weighed to reflect differences in tree species, environmental conditions experienced and the occurrence of pest infestations.

While some variables or means for making comparisons between utility VM programs have been provided they are more data intensive and require a higher level of statistical analysis. The criticisms of VM benchmarking cannot be easily overcome. If utility VM programs are to be compared the following factors are required or must be accounted for.

- Very similar tree exposure
- Similar clearance standards
- Similar urban-rural mix
- Similar customer density
- Known and similar growth rates
- Similar geographic area and environmental conditions
- Defined and thereby, standardized and comparable terms i.e. hazard tree, danger tree, risk tree, maintenance cycle
- Uniform measures of productivity i.e. man-hours per unit, which removes the influence of labour rates
- Similar units of measure for VM practices i.e. acre, hectare, m^2, tree pruned, tree removals by similar size categories
- Similar political and regulatory environment i.e. no rules eliminating or severely limiting any integrated VM practice such as herbicide applications

Benchmarking that does not address these considerations cannot inform the decision-making process, regarding the appropriate size, scale and cost of a VM program. While making use of such benchmarking data, in the absence of anything else, may have enormous appeal to regulators as an avenue of demonstrating due diligence, its worth must be recognized.

When the nature of the source and expansion in the vegetation management workload is understood, then a new approach for ensuring the effective use of ratepayer dollars appears for the regulator. There is a specific amount of VM work that needs to be completed every year to achieve a least cost sustainable VM program. Failure to remove the annual workload volume increment results in exponentially expanding costs. The questions of relevance to both utility management and the regulator become:

- How do we determine if the current utility VM program is a sustainable program?
- How do we determine if the current utility VM program is the least-cost sustainable program?
- How does one determine the annual workload volume increment?
- How does one assess utility VM productivity?
- What are unit costs?
- Are there historical tracking metrics that will ensure the least-cost sustainable program and provide a snapshot of program status?

Contrary to inter-utility benchmarking, answering these questions will simultaneously provide a clear path to both an effective VM program and effective regulatory oversight of the utility VM program.

While this section has focussed on discouraging the use of benchmarking to inform regulatory decision making that is not to say that benchmarking has no merit whatsoever. The use of benchmarking by utilities to identify industry trends, practices and common or emerging issues for the purposes of continuous improvement is a valid application. When the benchmarking study has been designed by UVM professionals and the results are evaluated in the context of the potential pitfalls that have been outlined, it provides utility management carefully considered guidance for VM program improvement.

5. Performance Management Review

This section addresses API's vegetation management organization, processes and outcomes. Information on API's vegetation management program was garnered through data requests, interviews, and field tours.

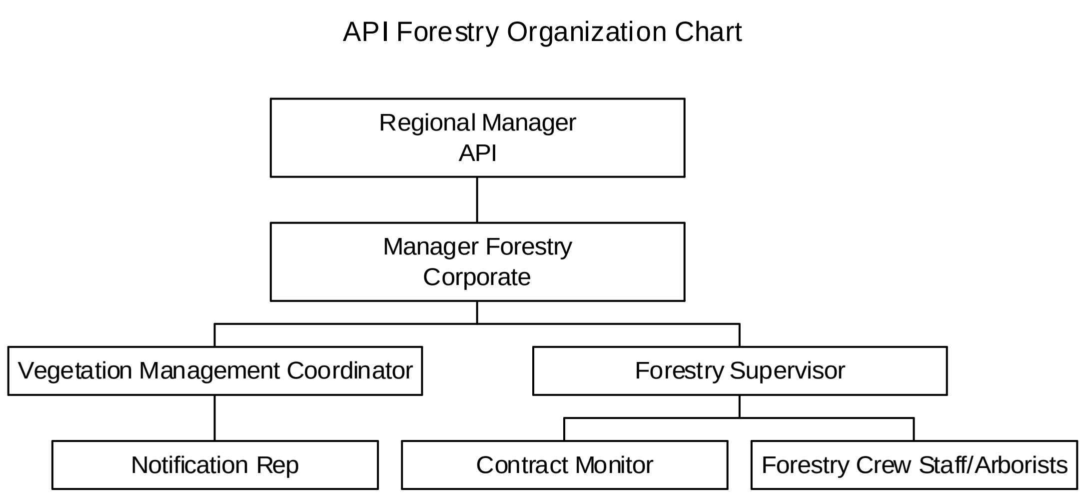
Vegetation management is critical in providing reliable service to the customer. Tree-conductor contacts are the single largest cause of unplanned service interruptions on the API system. Based on a visual qualitative assessment, API's exposure to trees is very high. (Quantitative assessments of tree exposure will be subsequently presented) It is only in the most developed urban areas that tree exposure is low and typical of conditions found at other utilities.

Organization [16]

The Manager Forestry Corporate holds the responsibility for API's vegetation management program and reports to the CEO of FortisOntario. Working under the direction of the Manager Forestry are the Vegetation Management Coordinator and the Forestry Supervisor. The Vegetation Management Coordinator holds the responsibility for planning, work and budget tracking and administration of the VM program. The Forestry Supervisor holds more of the field responsibility overseeing API's in-house VM crews and the Contract Monitors.

The organization chart [17] is presented in *Exhibit 5-20*.

Exhibit 5-20
API Forestry Organization Chart



Staffing [18]

API's staffing is as follows:

- Manager Forestry
- VM Coordinator
- Forestry Supervisor
- Contract Monitors – 3
- Notification Representative – 1 contracted position
- API Forestry Crew – 7

Facilities [19]

Vegetation management is performed on:

- 209 km sub-transmission – 44 kV, 34.5 kV
- 1556 km distribution – 2.4 kV, 4.6 kV, 7.2 kV, 12.5 kV, 25 kV
- 171 km secondaries
- substations

Easements & Rights [20]

All the sub-transmission lines have easements. Not all distribution lines have easements, though for any new lines an easement of 6 m (20 feet) each side of centre is obtained. Old easements are variable ranging from 30 feet to 100 feet. Registered easements have clear rights and those rights are exercised.

Where there are no easements API uses the authority of the Electricity Act.

Besides easements there are other types of negotiated rights. Along highways there are encroachment rights. There are permits with First Nations communities and agreements with the Ministry of Natural Resources and some forest management companies.

Clearance Standards & Pruning Maintenance Cycles

Work on First Nations lands is done on a 5-year cycle. There is no clear maintenance cycle for other work. API has been trying to achieve a 6 to 8-year maintenance cycle but funding limitations make it uncertain that this objective can be achieved. In the past maintenance cycles have extended to over 10 years.

The current distribution standard is to clear to 4.5 m each side of the lines. The target for pruning is also 4.5 m. For high priority secondaries API applies a 1.5 m ground to sky clearance. For lower priority secondaries API clears 1 m around the line.

Where sub-transmission is located alongside a roadway the clear width sought is 4.5 m. However, much of the sub-transmission is off-road. The off-road rights of way are variable in clear widths maintained ranging from 10 to 17 m from the line.

Tree Workload & Budgeting [21]

API does not currently have a tree workload inventory. Nor does API have growth and tree mortality studies to be able to forecast workload and resource requirements.

API indicated an effort was made in 2009 to determine an annual budget based on maintenance cycles. It was estimated at $3.2 million.

In 2010 set the annual budget at $2.7 million and there it has remained through 2013.

Work Planning [22]

Work planning is conceptually organized into cycle work, off-cycle work and demand work. Cycle work is broken down into approximately 50 km blocks. Off-cycle work looks at line segments while demand work is for an individual property.

In creating the work plan the first point of reference is past work. Cycle work planned and scheduled may be modified and re-prioritized based on field observations including patrols, the number of requests received from the public and interruption data. Once the program plan is assembled the landowner notification process begins. The main notification process is a mail-out.[23] With notifications complete, a work package [24] is issued. The Contract Monitor monitors the progress of the work. When the work is completed the work package is returned by the Forestry Supervisor and the VM Coordinator and Notification Representative update the records.

Modifications to the work plan are rare and when they do occur are usually budget driven. The monthly meetings may lead to a re-prioritization but that would really just shuffle components within the annual plan. If there is emergent work it is typically entered into the following year's plan.

Storm work does not affect the work plan. It is not charged to the preventative budget. There have not been issues with being unable to catch up on planned maintenance work after crews being diverted to storm work.

The VM Coordinator attends weekly engineering meetings. There is a formal process for planning capital projects which tracks who has responsibility, accountability and who needs to be consulted and or who needs to be informed.[25] Through these measures Forestry is both apprised of all capital projects and provides input to clearance standards, line location discussions and site preparation costs.

Maintenance Cycles [26]

For right of way brush control on First Nation lands API has been using a 5-year cycle.

API currently is targeting a 6 to 8-year maintenance cycle for brush control but is uncertain whether that is achievable due to budget limitations and whether that is the optimal maintenance cycle.

Pruning work is also thought to require a 6 to 8-year maintenance cycle but API indicated that there are areas that have not been re-pruned for over 10 years.

API expenditures have been $2.7 million annually since 2010. API believes there is a backlog of work.

API is looking for guidance on maintenance cycles and that is one of the reasons for undertaking this project.

Hot Spotting [27]

API estimates 5% of the VM budget is spent on hot spotting.

API is cognizant of areas with "cycle busters" and these are put into the plan under off-cycle work. Demand requests are prioritized and put into the program accordingly.

API has sought to limit demand work, off-cycle and hazard tree work as hot spotting being more expensive puts a further strain on an already limiting budget.

Tree Removals [28]

API is transitioning from a capital widening program to maintenance. The only tree removals sought from outside the right of way are for trees that have been designated hazard trees. As the general standard is to remove all tall growing brush from within the right of way, the only trees that exist on the right of way are ornamental or landscape trees which the landowner wishes to retain.

Hazard tree identification is a joint responsibility between the contractor and the Contract Monitor. However, due to budget constraints API has had to limit hazard tree identification and removal work. Consequently, operationally it is the Contract Monitors who identify hazard trees for removal. To work within the constrained budget API has been trying a new approach, limiting the search for hazard trees to the first metre beyond the right of way edge excepting trees from further back that constitute a clear, imminent threat.

For distribution lines there are no hazard tree specific patrols. The only vegetation patrols conducted are condition patrols which are used for work prioritization and planning. Line patrols are required every six years and these may serve to identify imminent tree threats.

On sub-transmission API did undertake a hazard tree project that went full depth in an effort to gain a clearer understanding of the extent of the work involved. API had not yet tabulated results. On sub-transmission a VM working patrol is conducted every three years. These patrols are supplemented by annual line patrols which may pick up imminent tree threats.

A request for the number of trees removed annually over the last five years could not be fulfilled.

Herbicides [29]

API is using herbicides where possible. For distribution lines because the right of way has been heavily populated by tall brush necessitating clearing, herbicide use has been restricted to stump treatments. Thought is now being given to maintaining the cleared areas with foliar and basal herbicide applications.

API has conducted foliar herbicide applications on sub-transmission lines and a little on distribution lines.

Forestry plans and conducts the substation weed control program but this work falls under the station budget.

Alternatives to Pruning [30]

API uses a whole range of alternatives to repetitive pruning. From a construction perspective API has used undergrounding, line moves, tree framing and line height increases. These are done on an individual business case basis.

The forestry group has used some tree height agreements, which they consider of questionable effectiveness. They do have a formal tree replacement process but have not actively pursued tree replacements as with a severely limiting budget it is believed that expenditures on other actions will provide a greater customer service, reliability and financial return.

Reliability [31]

API reported that there have been inconsistencies in data capture and reporting of outages. In general, API is working at educating staff regarding reporting and this effort will intensify as there are changes planned for cause codes and the reporting forms.

Regarding tree-related outages API reported that they were 28-33% of all unplanned outages. Tree-related outages are captured under inadequate clearance or falling trees. The location of the offending tree is not captured. There are a number of weather codes, such as winds greater than 80 km/hr, snow, icing, that may be obfuscating tree-related outages as it is not clear whether tree-related outages occurring as a consequence of one of these weather conditions would be recorded under the weather condition code or the falling trees code. While recognizing these limitations to optimal utility, the available data is used to prioritize the work and interruption reports are regularly circulated within API groups including Forestry.

API believes the capital right of way widening program has served to increase tree-related outages.

Reliability data from 2003 through Oct 15, 2013 was examined. [32] The data shows trees are the primary cause of unplanned interruptions on the API system (*Exhibit 5-21*). Equipment failure emerges as the second most important cause. It will be noticed that we have chosen to compare cause codes on the basis of customer hours interrupted. We prefer this approach as it provides the complete picture, subsequently using System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) to gain a better understanding of the status of the VM program.

It is typical that when right of way widening has occurred that there follows a period of increased tree-related SAIFI. Decreasing tree-related SAIFI and increasing SAIDI values is actually an indicator of a VM program that is not only headed in the right direction but is starting to show the results. Excellent VM programs have a very low percentage of grow-in outages. Further, while they have good hazard tree identification and removal programs, because no hazard tree program can be 100% successful and the fact that healthy, structurally sound trees fail provided enough stress loading, the majority of tree-related outages arise from tree failures that break electric system hardware driving up restoration times or SAIDI.

When we use customer hours interrupted tree-related outages appear to be even a bigger factor than what was stated by API staff (*Exhibit 5-22*). Over the period of 2003 to 2013, tree-related outages have accounted for 33% to 59% of all unplanned customer interruption hours. However, the influence of trees and the VM program on reliability may be even greater. There are a number of weather related causes such as snow, icing and winds exceeding 80 km/hr, which may be capturing tree-related outages, thereby obfuscating the role of the VM in system reliability.

Exhibit 5-21
2003 – 2013 API Outage History By Cause

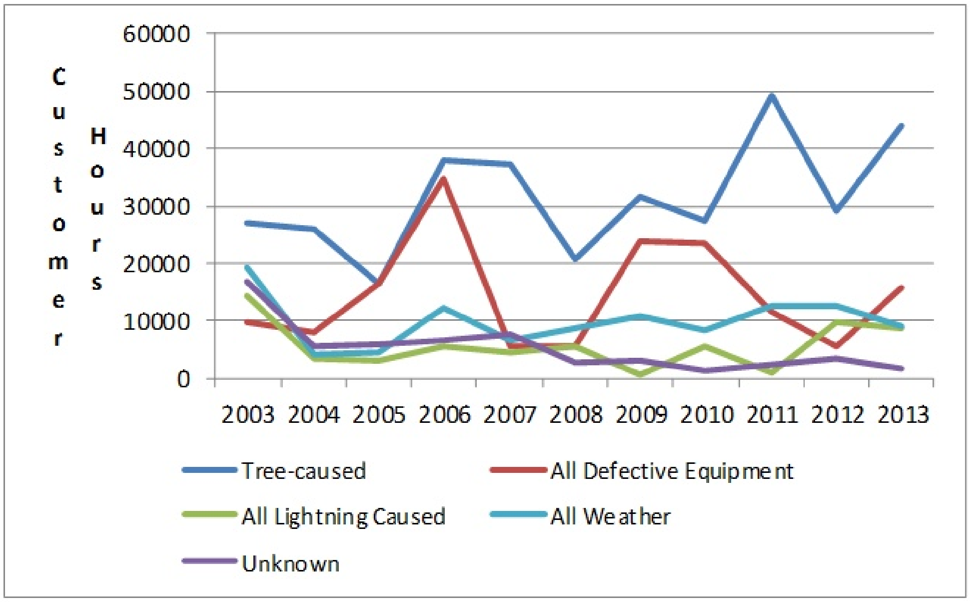
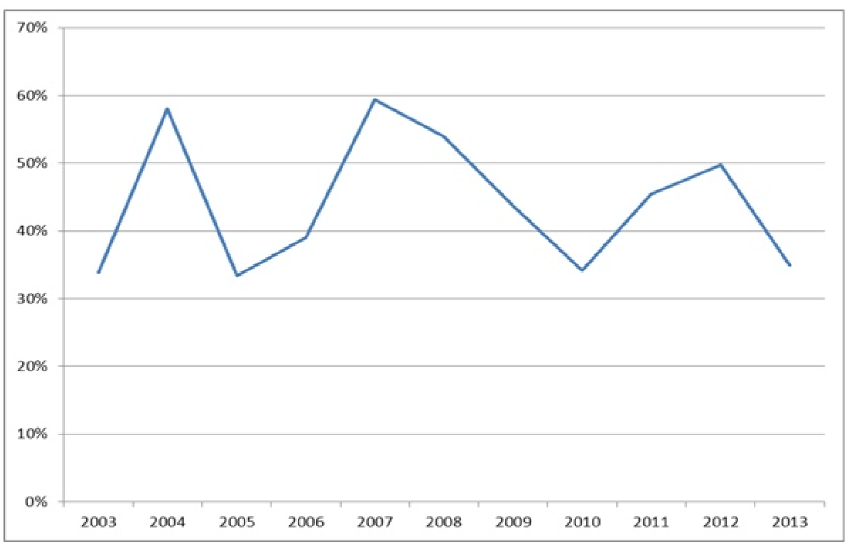


Exhibit 5-22
Percent Tree-related Outages



Both SAIFI (*Exhibit 5-23*) and SAIDI (*Exhibit 5-24*) show a slightly increasing trend.

Exhibit 5-23
API SAIFI 2003 - 2013

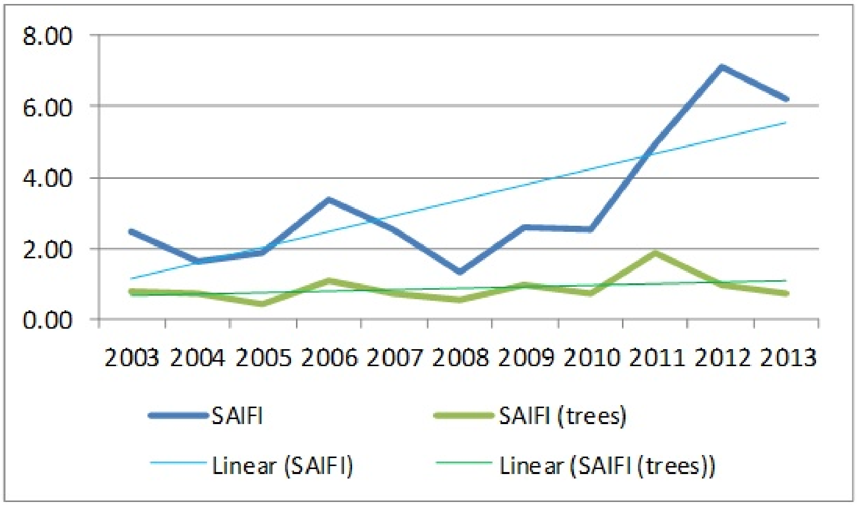
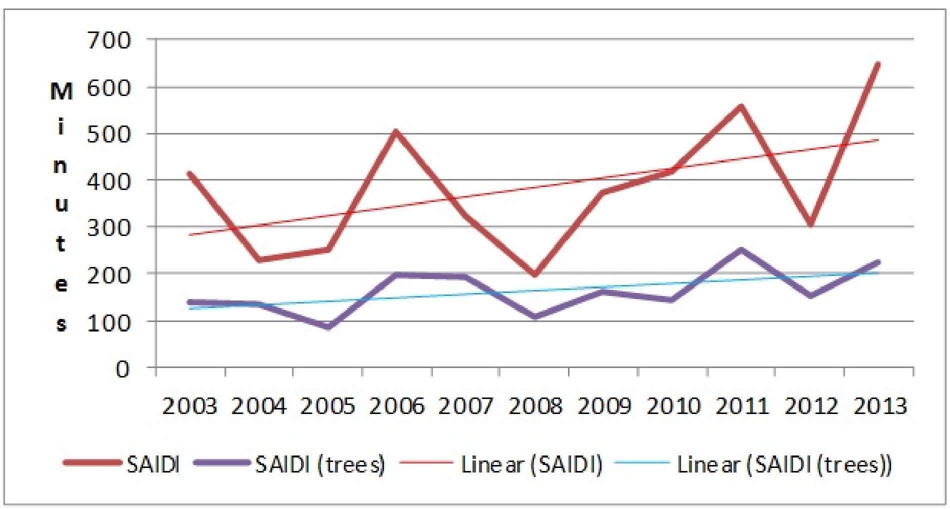
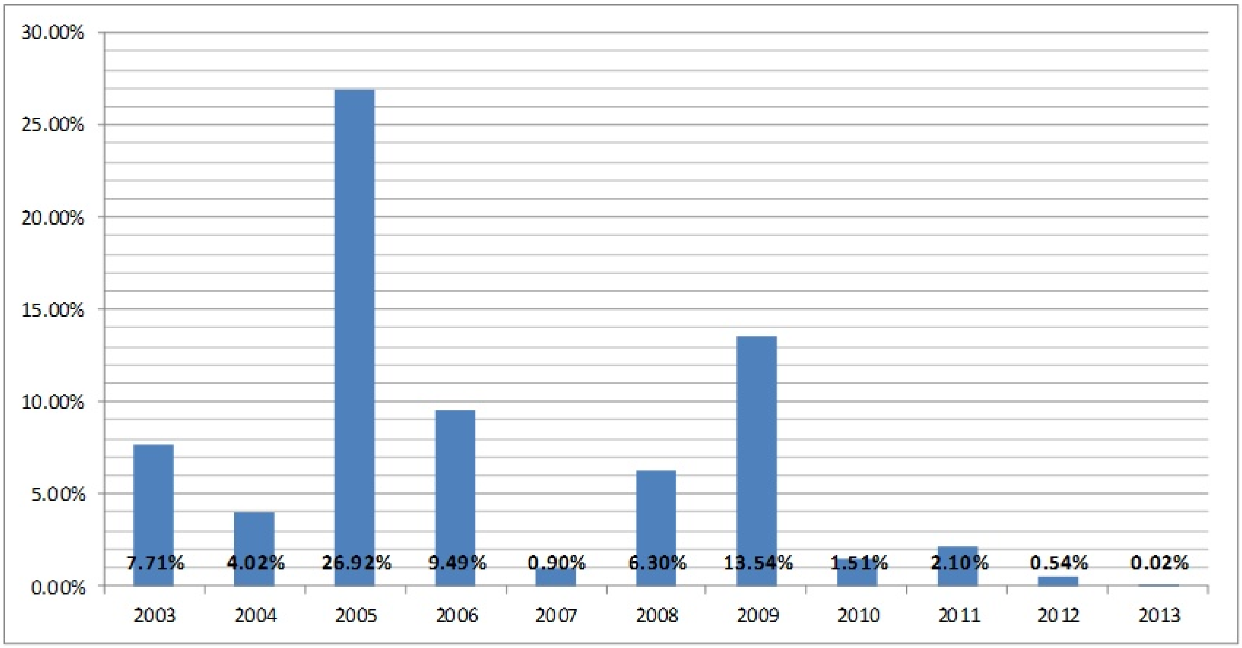


Exhibit 5-24
API SAIDI 2003 - 2013



Tree fault causes are divided into poor clearance and falling trees. We reclassify these causes into Grow-in and Fall-in outages. *Exhibit 5-25* shows the ratio of grow-in outages relative to all tree-caused outages. From 2010 through present the ratio of grow-in outages has been only a few percent of all tree-caused outages.

Exhibit 5-25
Ratio of Grow-in Outages to All Tree-caused



Field Work/Contracting [33]

API performs its VM field work through a mix of contract and in-house crews. There is one in-house crew. It is used in the performance of special jobs, demand work and projects such as the recent hazard tree work.

Contract crews are supplied through two contracting firms.

Work is generally contracted on the basis of $/km with a $/tree size category for the removal of hazard trees. While the work is not actually bid, API does request quotes for some work each year to maintain competition between contractors.

Productivity [34]

Work progress is tracked on spreadsheets. API monitors work completion on a timely basis but does not measure crew productivity. Incentive contracts have not been used.

Quality Assurance [35]

The Contract Monitors are in the field with the crews and consequently audits are performed as the work progresses. The Contract Monitors verify the right of way width, conductor clearances, the right of way floor, stump heights, stumps treated and dispersal of wood chips. The audit results are reported on the ROW Commissioning Report form.[36] The Forestry Supervisor performs this function for the in-house crew. On small projects a full audit is undertaken while large projects are spot checked.

Information & Data Systems [37]

API has a variety of systems for housing records. For the most part these systems are not integrated, that is they do not communicate with each other. There is an Access database for customer information that is used for customer notification purposes. Work tracking or progress is maintained by entries to Excel spreadsheets.[38] VM patrol data is submitted via paper forms.[39] Interruption reports from the field are filed on paper forms.[40] Accounting is housed in a SAPI database.[41]

Decision Support [42]

While no specific process was reported to be in place for the evaluation of alternatives, API did indicate that undergrounding of line segments, line moves, etc. are done following the preparation of a business case.

Field Conditions and Observations

1. **Lakeshore Drive C3K3420C [43] Desbarats Part 2**
    - ROW 15 ft. each side of centre established in 2010 during line upgrade
    - 75 spans
    - L/C & B/C 2008
    - 3 hazard trees
    - 2 white pine overhangs
    - Most brush regrowth about 2 m in height
    - Some spans with 3-4 m aspen regrowth
    - Along houses ROW floor clear; trim clearance 4-8 ft.
2. **McClennan Rd D4M3510D8 [44] Desbarats Part 1**
    - 18 spans
    - 15 ft. ROW each side established 2010 during line upgrade

- Cut and treat B/C & L/C 2008
- Brush regrowth 3 m
- 2 overhangs
- Some trim clearances 1.5 m

3. Hardwood – Old Port Rd. C4K3430C [45] Desbarats Part 2

- 5 spans
- B/C & L/C 2009
- 1 overhang
- Brush regrowth 3 m

4. 10th Side Rd B2L3610D [46] Part 2

- 73 spans
- Various portions:
    - Maintenance 2004, L/C, B/C, 2006 B/C
    - Line Upgrade 2011 L/C
- Pruning clearance 1.5-3 m
- Brush regrowth 2-3 m
- 1 hazard tree

5. 10th Side Rd B2L3610C [47] St. Joes Part 1

- 82 spans
- Trimmed 2001-2002
- Trim clearance 0.3 m
- Brush cut & treat (B/C) 2006
- ROW 4- 15 ft. with most ~ 8 ft.
- A lot of trimming required where ROW clearance is 10 ft. or less
- 15 hot spots
- 8 spans with overhanging maple
- Most of the overhead clearance > 10 ft.

6. P-Line B1M3611C [48] St. Joes Part 1

- 63 spans
- Reclaimed/expansion 2002-2003

- B/C 2006
- 5 hot spots
- ROW brush regrowth variable 1-4.5 m with most ~ 1.3 m

7. **Hwy 548 A2M3612C [49] St. Joe's Part 1**
   - 21 spans
   - Reclaimed/expansion 2003-2004
   - Last cleared 2006 B/C
   - ROW clearance 6-10 ft.
   - Brush regrowth 4-6 m
   - 4 hot spots
   - 8 spans of overhangs
8. **Hwy 548 \U-Line A1M3613C7 [50] St. Joes Part 1**
   - 49 spans
   - Reclaimed/expansion 2003-2004
   - B/C 2006
   - ROW Clear width 4-10 ft. with most at 8 ft.
   - Brush regrowth 1-3 m
   - 3 hot spots
   - 9 spans of overhang
9. **Hwy 548 \ U-Line A2N3634 [51] St. Joes Part 4**
   - 78 spans
   - New construction on primary 2007
   - 10 spans with a 22 ft. clear width
   - Remainder of ROW with 8 ft. clear width
   - Reclaimed/expansion 2000-2003
   - B/C 2006
   - Brush regrowth 2-4 m
   - This line scheduled for maintenance this year
   - 18 hot spots
   - 14 spans of overhang

- 3 hazard trees

10. Hwy 548 B1N3633 [52] St. Joes Part 4

- 58 spans
- Reclaimed/expansion 2002-2003
- B/C 2006
- ROW Clear width 3-8 ft.
- Brush 1-3 m
- 8 hot spots
- 3 spans overhang

11. Hwy 548 B3M3622 [53] St. Joe's Part 4

- 62 spans
- Reclaimed/expansion 2002-2003
- B/C 2006
- B/C & L/C 2013
- 1 overhang
- No brush
- ROW clear width 15-20 ft.

12. Trap Rock – Caribou Rd [54]

- 34.5 kV
- Used mulching and followed up with foliar herbicide
- ROW clear width > 20 ft.
- ROW currently populated with compatible species

13. Centreline Rd C1N3831 [55] Bruce Mines Part 2

- New line section 2013
- 195 spans
- B/C 2011
- ROW clear width 4-10 ft.
- Very little brush; mostly compatible
- 7 spans overhang
- 15 hot spots to prune

14. Hwy 101 [56]

- 296 spans
- Done with mulcher 2013
- Only brush is in stream buffers and steep slopes

15. **Jack Pine Tower Rd. LSU419710B1 HWY 101 Part 1**

- Narrow with spindly tree boles on edge
- L/C 2013
- Brush 1-3 m
- 1 hazard tree

16. Costello's Line .95 km T2G9710 [57] **HWY 101 Part 1**

- ROW clear width 18 ft.
- Mulched 2013

17. Whitefish Lake Rd U1G9711D [58] **HWY 101 Part 1**

- Cleared in 2012 L/C & B/C
- Brush regrowth 1-1.5 m but very little

18. Wawa 1 & 2 [59]

- Done in 2007 and 2012
- No brush
- Clear width 32.5 ft.; 35 from centre
- 1 hot spot

19. Wawa 3-phase Steep Hill Line [60]

- Cleared in 2008
- Clear width 10-20 ft.
- Brush 1-3 m
- Switches to underbuilt and back

6. Audit Findings & Conclusions

Finding 6-1 The API organization supports a responsive VM program.

To an extent API benefits from the small size of the organization. All in the Forestry department are very well informed on all aspects of the VM program. There is an evident commitment to continuous improvement and an enthusiastic openness to ideas, methods, technology, etc. that will facilitate improving service.

In large utilities there is often a disconnect between various departments that results in situations where departments in accruing benefits and efficiencies to their own group unwittingly create liabilities for other groups and the company as a whole. It is all too common that capital projects create future maintenance liabilities. This does not occur at API. There is excellent communication between various groups and processes have been put in place to ensure sustaining such communication.

Finding 6-2 The annual VM budget has not been based on biological fact.

Past studies have indicated that the API distribution VM program needed considerable work to improve service reliability.[61] While appropriate maintenance cycles were recommended, these recommendations appeared to be based on researcher experience, without the support of actual growth studies. To date API has not succeeded in establishing those maintenance cycles or cycles based on the biological facts of tree growth and mortality rates. While the current right of way conditions reveal considerable progress towards a sustainable program has been made, it cannot be fully realized unless funding is founded on the current inventory of work, tree growth and mortality rates.

While not impossible it is implausible that a problem that has not or cannot be measured will be successfully managed. In our over 35 years in the utility VM business we know of no utility that is successfully managing its vegetation that has not quantified the workload. There are various means of quantifying VM workload but the quickest is to establish an inventory of work supplemented by tree growth and mortality rates. As illustrated in section 3, Vegetation Management Concepts and Principles, there is a specific amount of annual funding required to achieve a sustainable VM program.

Finding 6-3 API does not have established maintenance cycles.

API is seeking to establish a 6 to 8 year cycle. Yet areas were seen that had not been maintenance pruned in over 10 years. It's not known if the targeted cycle, which represents a slippage from past recommendations is due to a lack of confidence in the recommendation or a concession to the fact that an 8 year cycle may be the very best or most optimistic cycle that's possible under the current funding allocation.

Finding 6-4 Branches overhanging distribution conductors are common.

Branches overhanging conductors have a large impact on reliability. Some of the overhangs are sugar maples that have commercial value and consequently, landowners will naturally seek to limit the amount of pruning. Some of the overhangs are from specimen trees such as white pines in landscaped settings. However, the majority of overhangs are from volunteer native, natural tree stands of little commercial value. Given restricted funding, addressing these overhangs may have been viewed as a lower priority than other work and unaffordable.

API does not have an outage code specific to branch failures. As a consequence, the impact on customer service of allowing the overhangs to exist is not known.

Finding 6-5 The VM work delivered in the field is consistent with the expressed standards and specifications.

The field tour revealed that current work is meeting the clearance standards and specifications. While sections of right of way were seen that do not have the desired 4.5 m clear width from centre-line, the edges were well established. Such sites either were not targeted in the capital widening or perhaps there were landowner objections that were not overcome.

In most cases where brush has been removed, cut stumps have been treated with herbicide. This was evident from the sporadic occurrence of spans with brush regrowth of substantially greater stem densities and height than the norm for the line section. Such areas being sporadic and limited suggest a landowner refusal to herbicide application.

Pruning work is consistent with good arboricultural practice. Such practice serves both to maintain the health of the trees and also to maximize the length of the maintenance cycle.

Finding 6-6 API VM program is well organized but the potential for greater cost effectiveness exists.

The work being done is consistent with industry best practices. However, the use of herbicides has been largely restricted to stump treatments as the right of ways required reclamation or clearing. Foliar herbicide applications have been restricted predominantly to sub-transmission lines. Foliar herbicide applications are not only more effective then stump treatments but also are less costly.

Most of the brush is hand cut. While the frequent occurrence of rock outcroppings limits areas that could be mowed by Hydro Ax, there are many kilometres, particularly south of the Montreal River, that are suitable.

On the areas re-growing after reclamation API has introduced some of the more cost effective practices such as foliar herbicide applications and mowing/mulching but the opportunity exists for a wide scale adoption of these practices.

Finding 6-7 API has been doing a good job of managing hot spots.

The field tour sought to obtain an understanding of right of way conditions where work had been recently completed, in areas that had not had work done for a number of years and may be considered mid-cycle, areas that were currently being worked and areas that were scheduled for work next year.

First, API's conceptual organization of the work into on-cycle, off-cycle and demand work is a useful construct. It forces recognition of what is being managed, what is behind and where there are "cycle busters" that warrant consideration for other approaches.

While the field tour revealed a considerable number of hot spots (locations where trees can be expected to make contact with conductors during the next growing season), they were predominantly in areas scheduled for work either currently or within the next year. Such a finding is expected and is indicative of effective management as in concentrating the work to scheduled areas the cost inefficiencies associated with hot spotting can be avoided.[62]

Finding 6-8 VM work on secondaries has added to the funding needs.

As reliability issues have emerged on secondaries, API has changed their standards to include work on secondaries as a part of routine maintenance. Due to a fixed budget funding this work requires sacrificing or delaying work on primary circuits.

Finding 6-9 API's approach to contracting VM work is judicious.

Given the scale of API's VM program the approach to contracting is good. Formal bidding of work would add administrative costs for little or no benefit. The time that would be spent in preparing and evaluating bids is better spent in communicating needs to the two contractors and maintaining the good working relationship.

In asking for quotes for a number of projects each year API is adequately reminding the contractors that it is a competitive environment while at the same time affording themselves the opportunity to compare current costs to historical costs.

Finding 6-10 Information and data systems require improvement.

API requires a data system designed around VM processes capable of linking with and communicating with other company databases. Providing data in response to the information requests was at times laborious. In one case the data could not be provided. This has implications for internal processes as questions may not be considered or answered due either to inability to provide meaningful data or due to the time and expense involved in obtaining data.

Further, were the field information collected more detailed it would provide insights useful in forecasting workload and costs.

7. Review of Outage Data

Finding 7-11 Tree-related outages are the primary cause of customer interruptions.

Trees are the number one cause of unplanned service interruptions followed by equipment failures (*Exhibit 5-21*). This is actually typical of distribution systems in general.

While it would be expected that unplanned outages as a whole are correlated to tree-related outages, in API's case the Pearson Product Moment Correlation Coefficient (r) is 0.69 with the probability of error 0.0031, a highly significant result. The high r-value highlights the fact that trees are the primary driver of the outage statistics.

Finding 7-12 API's tree-related outage experience is higher than industry norms.

Over the period of 2003 to 2013, tree-related outages have accounted for 33% to 59% of all unplanned customer interruption hours. The average is over 40% whereas industry averages are in the 20-25% range measured in customer outage hours.[63] [64] Due to location and the resultant amount of tree exposure of API's electric system, reliability statistics will always likely be on the higher end of industry norms. As tree exposure has been shown to be not only the primary driver in tree-caused outage incidents[65] [66] but also perhaps the only statistically significant indicator, there is limit to the amount of reliability improvement possible.

Finding 7-13 API's capital widening of distribution right of way has not yet improved reliability.

The outage data shows the impact of trees on reliability (*Exhibit 5-21*) and consequently, the importance of the VM program. That SAIFI and SAIDI show a slightly increasing trend (*Exhibit 5-23*, *Exhibit 5-24*) should not be a surprise following the recent capital widening of rights of way which has occurred. This widening served to expose trees which had grown inside tree stands to greater wind loading. Such trees have not deposited the tension and compression wood that results from frequent load exposure. Over the first few years of increased wind loading a considerable number of these trees fail. However, after three years the ratio of failures begins to decrease. While we have no quantitative study to reference showing when the newly established edge becomes as firm as the former edge, previous experience suggests this will occur five to eight years after widening.

Ultimately, the benefit of the capital widening will become apparent. It decreased the both the number of danger trees and the arc of line exposure for the remaining trees. Consequently, the capital widening was prudent.

It should be noted that the reliability data contains the effects of major storms. Major storms can obfuscate what changes are occurring in reliability during normal operating conditions. Additionally, we examined outage data for the system as a whole. As such, any demonstrable reliability improvement for specific capital widened line segments will not have been noted.

In examining the field conditions it was found that clear widths of line segments that have not undergone capital widening were generally 8 feet from centre line. Applying the average variables found for line height, tree height and tree density to the proprietary Optimal Clear Width Calculator (OCWC), it can be demonstrated that the widening that has occurred will ultimately pay reliability dividends. The Line Strike Risk chart (*Exhibit 7-26*) shows a substantial reduction in risk between an 8 foot clear width and a 15 foot clear width. That change in tree risk is further clarified in *Exhibit 7-27,* which shows an expected reduction in tree-caused interruption of 32%. It is also clear from the Line Strike Risk chart, *Exhibit 7-26*, that there is a diminishing return in line security with increasing clear width and that a clear width of 15 feet (4.5 m) is the starting point of that diminishing return.

Exhibit 7-26
Line Strike Risk

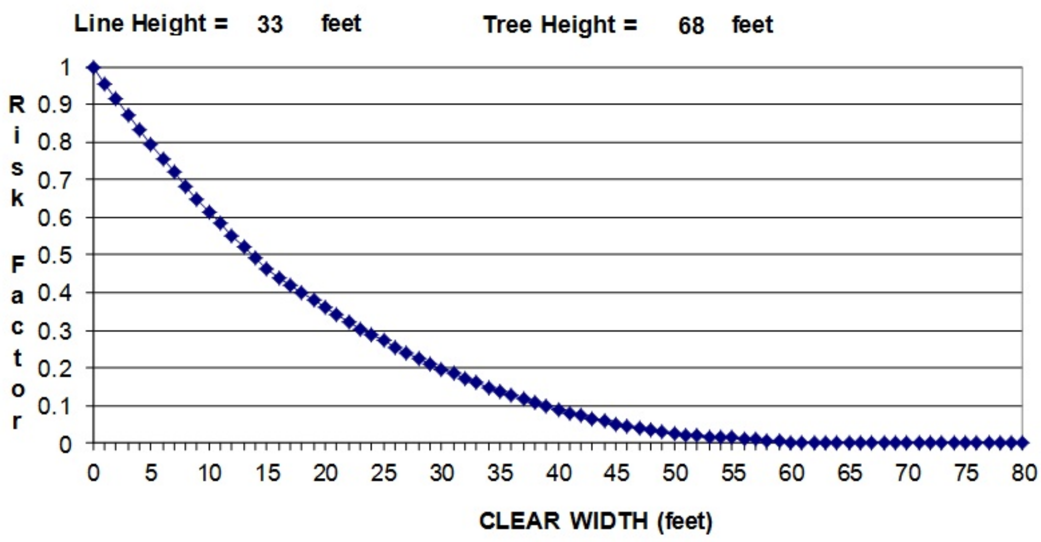


Exhibit 7-27
Expected Reliability Benefit of Widening

Cost: Benefit Analysis

Line Segment Specific:		Ac/mi	Trees/mi	Cost/mi	Line Security Improvement
Line Height	33				
Tree Height	68				
Trees/Ac	416				
Current Clear Width	8.00				
Current Risk Factor	0.683				
Increase Width	7	0.85	353		
New Risk Factor	0.465				32%

Finding 7-14 API's current outage cause codes fail to deliver insight into what VM actions will deliver significant reliability improvements.

API currently has two tree cause codes and they could be said to capture grow-in outages and fall-in outages. There is no distinction being made regarding the type of tree failure, nor is there detail on the location of the offending tree.

Finding 7-15 The level of tree grow-in outages is indicative of a well-managed VM program.

For reasons of reliability and public safety, electric utilities have a clear responsibility to maintain a separation between trees and energized conductors. Because of this responsibility and the attendant liability, the primary focus of VM programs is on work within the right of way. All well managed VM programs have a very low incidence of grow-in outages. VM programs with grow-in outages comprising less than 2% of tree-related outages are common for properly funded and well guided VM programs.[67] [68] [69]

Based on our observations and experience, we consider programs where grow-in outages represent 5-15% of all tree-related outages as falling off best in class and completely lost and in need of very substantial remedial re-investment when grow-in outages exceed 15%.

Thus, the history of grow-in outages, *Exhibit 5-25,* informs us that API's VM program has been shifted from one in serious trouble to one that is currently on the cusp of either becoming a best in class program or reverting to being very far behind. Since 2010, grow-in outages have been below 2%, which is consistent with best in class programs. No doubt a considerable amount of this grow-in outage experience reduction is attributable to the reclamation work which has eliminated the risk of vertical grow-ins from within the right of way in all but landscaped settings. The question for the future is whether the investment in reclamation will be protected or lost.

Finding 7-16 API's tree-related outages are due to the failure of trees from outside the right of way.

As API's standard is to clear all trees, except specimen or landscape trees, out to the right of way edge the possibility of tree from inside the maintained right of way failing and causing an interruption is extremely limited. That suggests that since 2010 over 98% of tree-related outages are due to the failure of trees located beyond the maintained right of way (*Exhibit 5-25*).

8. The Utility Forest

Work was undertaken to quantify the utility forest. The utility forest is comprised of all trees that could now or in the future interfere with the reliable delivery of electricity. The utility forest is not static but tends to increase over time as trees adjacent to power lines continue to increase in height thereby adding to the number of trees capable of interfering with electric service. As such, the utility forest comprises both trees and brush within the right of way and trees outside the right of way capable of contacting power lines on failure.

Utility VM is focussed first and foremost on the right of way. However, it is well established that for most utility VM programs the majority of tree-related outages arise from outside the right of way.[70] [71] Typically, tree failures from outside the right of way account for 85-98% of tree-related outages. Consequently, failing to include the utility forest outside the right of way in determining the VM workload would constitute a major oversight.

Finding 8-17 About 85% of API power lines have a treed edge.

The approach to quantifying the utility forest was a combination of digital and field data collection. API provided an overlay of their lines on Google Earth. A random sample of 150 points were marked in Google Earth and GPS coordinates were documented (*Exhibit 8-28*, *Exhibit 8-29*). Each of these 150 points was assessed for the amount of treed on both sides of the right of way. The amount of treed edge is 84.72% ± 2.74% (95% confidence level). The voltage class was determined for every sample point. The data in Google Earth is both somewhat aged and the time the data was collected can be variable. To determine if current conditions varied significantly from those in Google Earth a subset consisting of 36 of sample points was field verified for treed edge. A Student T test pairing the digital assessments derived from Google Earth with the field assessments found no significant difference between the two.

For each of the 150 random sample points a field inspection determined the quantity of work categorized as brush, crown prune, lateral prune, hazard trees and the spans having branch overhangs. At 10% of these sample points growth data was collected providing 461 brush growth records and 307 pruning regrowth records. At 73 of the sample locations data was collected from the adjacent forest to determine tree species, tree height and tree density. This resulted in 6,205 tree records. These records provide a clear picture of the species composition of the utility forest and the health of the outside right of way forest. Based on the sampling, 23% of API VM work is off-road or cross-country.

Exhibit 8-28
North Sample Points

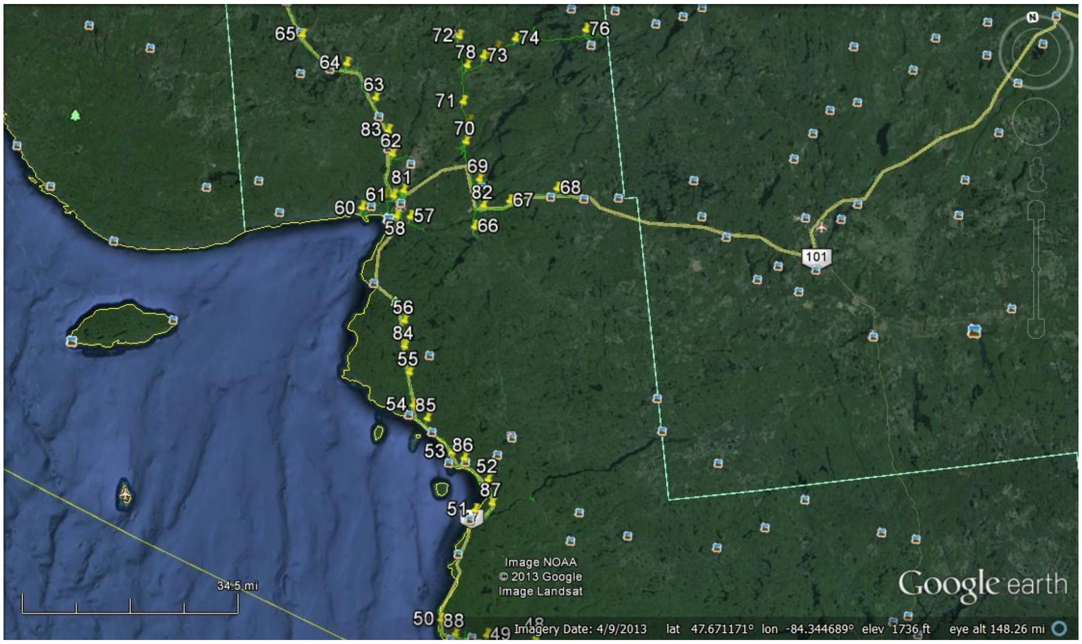
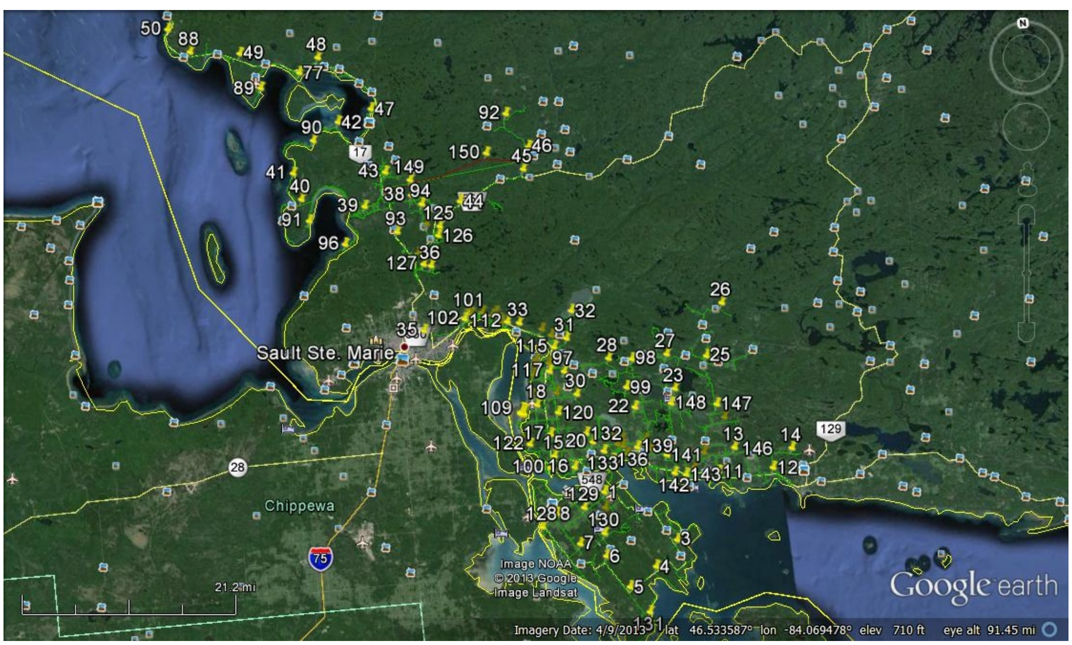


Exhibit 8-29
South Sample Points



ECOSYNC Ecological Solutions Inc.

Within Right of Way

It can be expected that brush will develop where there are adjacent trees supplying seed or through vegetative reproduction (root suckers). This will provide an upper limit to the brush work of 2031 ha or 5037 acres (*Exhibit 8-30*).

Exhibit 8-30
Maximum Area For Brush Control

Voltage (kV)	Kms	Actual edges sampled	Wire Zone (ft)	Edge type	Mean Clear Width (ft)	ROW Width (ft)	Miles	Acres	% Treed Edge	Potential Treed ROW Acres
44	85.9	10	7	ROW	54	115	53	744	95.55%	711
25/34.5	174.0	20	7	ROW	34	75	108	983	89.69%	882
25/34.5			7	Roadside	47		108		89.69%	
7.2/14.4	1425.7	116	1	ROW	18	37	886	3,973	83.21%	3,306
7.2/14.4			1	Roadside	89		886		83.21%	
Total	**1686**	**146**					**1155**	**5700**	**85.76%**	**4898**

[1] Weighted average
Wire Zone – the distance between the outside conductors

Generally, utilities strive to convert right of way plant species to power line compatible species that will resist the establishment of incompatible species. This process is greatly aided by the use of herbicides. Without herbicides seeding of compatible species can be used, however, the duration of the compatible species is limited as nature strives to re-establish species endemic to the area. The extent of brush control necessary will vary from the upper limit based on the extent and success of herbicide programs or the length of time since seeding. Based on the field inventory conducted rather than 85.76% (*Exhibit 8-30*) of the right of way area containing brush, we estimated 65% of the area currently requires active management.

Finding 8-18 65% of API's right of way currently requires active VM.

Sampling of 1 km sections at the 150 random sites found the inventory of work set out in *Exhibit 8-31*. While the amount of treed edge indicated 85% of the right of way is subject to being populated by incompatible species the field sampling reveals a lesser amount of 65% of the right of way currently requires active ongoing management. The difference is likely due to the benefits of herbicide applications which by eliminating incompatible species allow compatible species to flourish. This vegetative cover then resists, to some degree, the invasion of incompatibles. It is not say that the condition is permanent. At some point this 20% of the right of way area will require mediation. If it can be done with herbicides minimal inputs will sustain the early succession meadow community. However, if it is necessary to use cutting methods, these will rather than eliminating the incompatible species, expand their composition of the plant community. It need be recognized that there exists a risk of adding back the 20% of the brush workload either through choosing cutting methods or excessively long maintenance cycles that preclude the use of herbicides and therefore, limit the choice solely to cutting methods.

As we will be discussing work volumes in another section, we wish, at this point only, to highlight certain generalities that come to light in this inventory. First, the number of hot spots averages 4 per kilometre. This is a very high ratio. While ESI's own brief field tour revealed that hot spots tended to be concentrated in areas scheduled for work, the high average frequency suggests a program while well managed, is also close to the breaking point. Secondly, the data collected on overhangs suggest about 14% of the system has overhangs. The hazard trees noted in *Exhibit 8-31* capture only trees that are apparent from within the right of way or more commonly from the adjacent roadway. These hazard trees comprise 2% of the tree exposure along the edge (first 2.5 m).

Exhibit 8-31
Inventory Based on Sampling

Voltage (kV)	ROW Width (m)	Brush (m^2)	Brush Height (m)	Crown Trim (m^2)	Lateral Trim (m^2)	Hot Spots	Spans Overhang	Hazard Trees
44	29.5	209,008	1.18	14	0	1	0	17
25/34.5	21.94	187,324	1.57	457	456	5	2	37
7.2/14.4	11.52	724,504	1.65	14,042	13,872	594	226	644
Summary	**13.83**	**1,120,836**	**1.61**	**14,513**	**14,328**	**600**	**228**	**698**

Finding 8-19 Over 14% of API spans have branch overhangs.

The spans of overhang were documented during the inventory data collection. It was found that 14.3% of the spans have branch overhangs.

Outside Right of Way

To determine the outside right of way tree exposure data was collected at 73 of the 150 sample points. At each of these sites the following data was recorded:

- Line height

- Clear width on each side (distance from adjacent tree boles to nearest conductor)
- Wire zone
- Tree height on each side for the dominant (emergent) and co-dominant canopy
- 3 replicates each side of Basal Area Factor 10 samples recording tree circumference at breast height, tree species and decadence

Based on this data of over 6200 tree records, it was determined that API's tree density is 416 ± 19 trees per acre (1032 ± 47 trees/ha) at the 95% confidence level. Using tree height, line height and clear width and applying the Pythagorean Theorem the depth of the utility forest beyond the right of way edge was calculated. With the area determined and having calculated the mean tree density, the extent of the outside right of way tree exposure can be computed (*Exhibit 8-32*).

Exhibit 8-32
Tree Exposure

Voltage (kV)	Kms	Wire Zone (ft)	Mean Clear Width (ft)	Miles	% Treed Edge	Mean Tree Height (ft)	Mean Line Height (ft)	Trees Per Acre	To Tree Free @ (ft)	Danger Trees
44	85.9	7	54	53	95.55%	63	33	416	54	0
25/34.5	174.0	7	34	108	89.69%	62	41		47	63,566
25/34.5		7	47[1]	108	89.69%				47	0
7.2/14.4	1425.7	1	18	886	83.21%	68	33		59	761,977
7.2/14.4		1	89[1]	886	83.21%				59	0
Total	**1686**			**1155**	**85.76%**					**825,543**

[1] Roadside – distance from line, across road, to trees on edge

Finding 8-20 API's system is exposed to 825,543 trees which could interrupt service.

Danger trees are trees which on failure could contact conductors. The relevance of the number of danger trees is two-fold. First, it has been shown that tree exposure is very strongly correlated to tree-related outages.[72] [73] This is of utmost importance during storms that place stress loading on trees. Secondly, due to natural tree mortality, a certain percentage of the tree exposure will suffer decadence and ultimately death. There are two annual mortality rates applicable for API's service territory. For the boreal forest the rate is 3% per annum and for the Great Lakes St. Lawrence ecozone the rate is approximately 1%. We have used an average of 2% annual mortality. On that basis, it should be expected that each year 16,511 trees will become decadent and require evaluation for their potential to interfere with lines should they fail. Factors such as the arc of line exposed, the likelihood of a failed tree being blocked by other trees, whether the decadent tree is emergent to the co-dominant canopy, typical mode of failure, lean, etc. will serve in making a determination whether a tree is a hazard tree requiring mitigation or not.

While much of API's system has a forested edge, the actual exposure to danger trees of 490 trees per km is not a high ratio for a distribution system.[74] As even healthy trees fail and cause interruptions provided the stress loading from wind, ice or snow, this has a positive implication for reliability. The number of tree-caused outages arising from healthy, structurally sound trees has been shown to fall in the 45 to 70% range.[75] These are trees that are not targeted by the VM program. Consequently, the lower the system's exposure to trees, the better the reliability prospects.[76]

From the forest samples the composition of the utility forest is derived (*Exhibit 8-33*). One of the variables captured in assessing the forest plots was whether the tree was healthy or decadent. The average level of decadence inside the forest stand is 11.2% (*Exhibit 8-35*). Further species details are provided in *Exhibit 8-34*.

Finding 8-21 API's system is threatened by a high ratio of hazard trees.

The fact that the ratio of hazard trees is 2% along the edge but over 11% inside the forest edge shows API has been doing a good job of identifying and removing hazard trees from the forest edge. However, trees more than 2.5 m from the edge have not received adequate attention. While it is possible to accept a larger percentage of decadent trees inside the forest because of the reduced arc of line exposure and the consequent probability that a failure will not result in a line contact the found ratio of over 11% is about two times greater than the upper limit of expectations. Typical maintenance cycles would see the percentage of decadent trees top out at 5-6% just before retreatment. The observed level of decadent trees are sure to be contributing substantially to API's outage experience.

Working with the species composition and the found incidence of decadence it is possible to determine which tree species represent the highest levels of risk to the system. The data is presented in *Exhibit 8-35*. White birch is known to have a process of degeneration through branch failures. Both balsam fir and trembling aspen are susceptible to trunk failures. The top three at risk species are prevalent in the boreal ecozone.

Exhibit 8-33
Utility Forest Species Composition Trees Species (%)

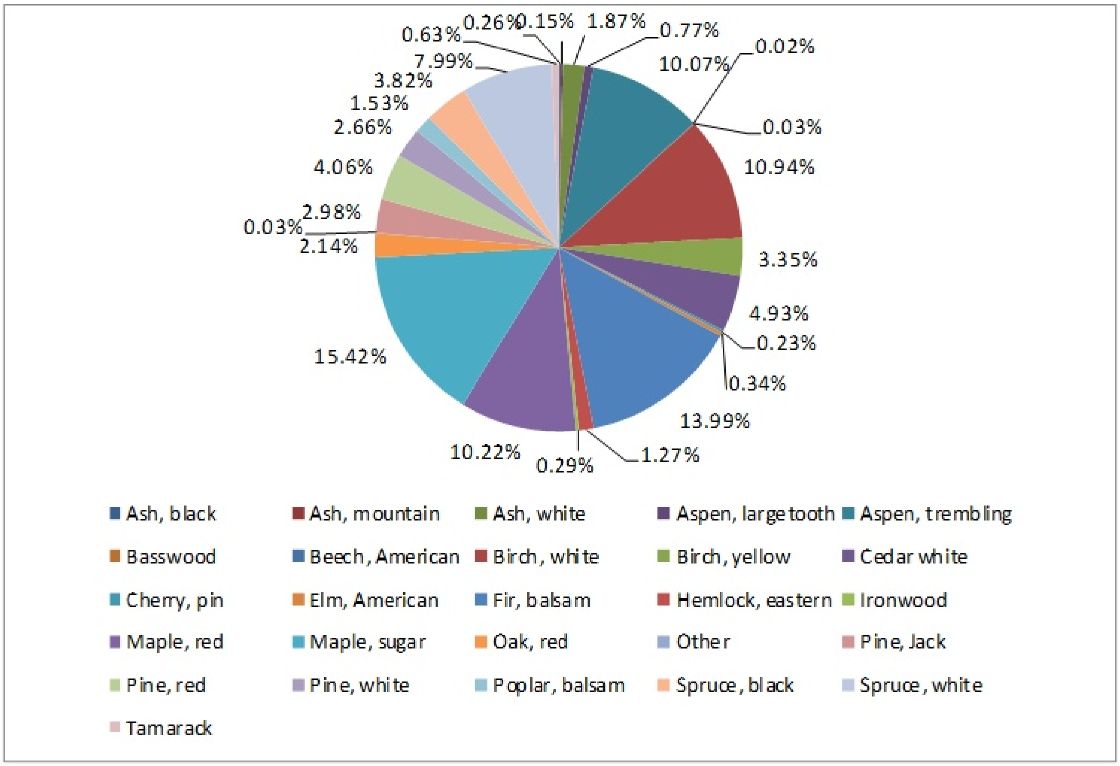


Exhibit 8-34
Utility Forest Health

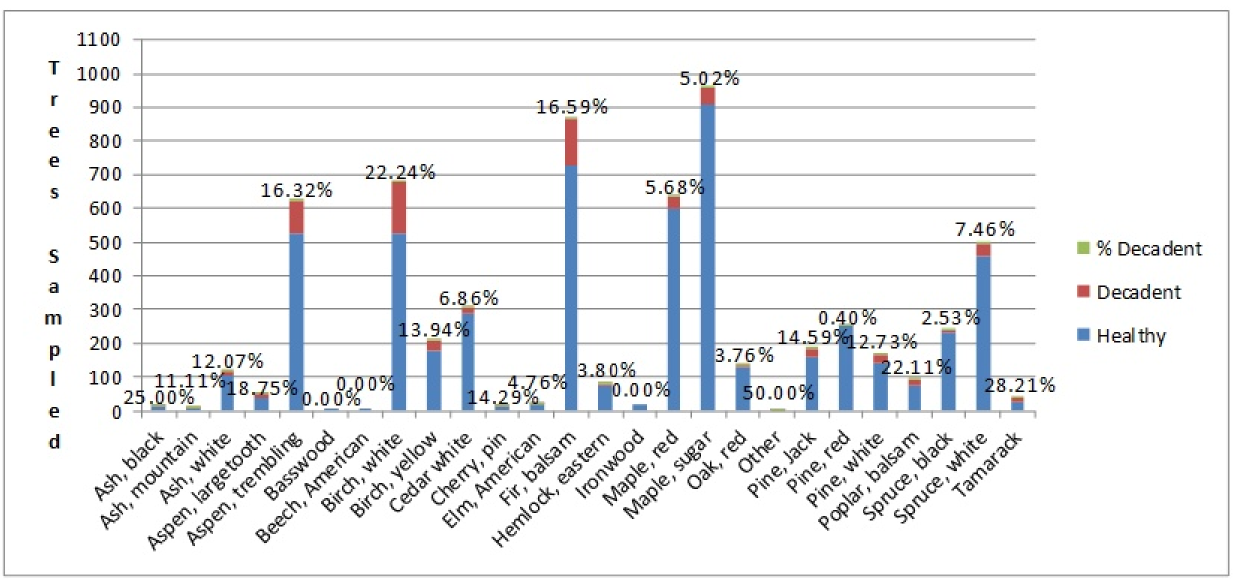


Exhibit 8-35
Tree Species Risk Rating

Species	Records	% of Population	% Decadent	Risk per 1000 trees
Birch, white	679	10.94%	22.24%	24.3352
Fir, balsam	868	13.99%	16.59%	23.2071
Aspen, trembling	625	10.07%	16.32%	16.4384
Maple, sugar	957	15.42%	5.02%	7.7357
Spruce, white	496	7.99%	7.46%	5.9629
Maple, red	634	10.22%	5.68%	5.8018
Birch, yellow	208	3.35%	13.94%	4.6737
Pine, Jack	185	2.98%	14.59%	4.3513
Poplar, balsam	95	1.53%	22.11%	3.3844
Cedar white	306	4.93%	6.86%	3.3844
Pine, white	165	2.66%	12.73%	3.3844
Ash, white	116	1.87%	12.07%	2.2562
Tamarack	39	0.63%	28.21%	1.7728
Aspen, largetooth	48	0.77%	18.75%	1.4504
Spruce, black	237	3.82%	2.53%	0.9670
Oak, red	133	2.14%	3.76%	0.8058
Ash, black	16			
Hemlock, eastern	79	1.27%	3.80%	0.4835
Cherry, pin	14			
Other	2			
Ash, mountain	9			
Elm, American	21			
Pine, red	252	4.06%	0.40%	0.1612
Basswood	2			
Beech, American	1			
Ironwood	18			
Totals	**6205**		**11.20%**	**4.3079**

Growth Rates and Maintenance Cycles

Growth rates were determined by measuring internode lengths of the five most recent years of growth. Growth rates were determined for brush regrowth for deciduous and conifer species and for pruning work divided into deciduous, conifer, crown growth and lateral growth. The growth rates are used to guide the selection of the maintenance cycle. Doing so, however, is a complex issue. If average growth rates are used, then by definition one half of the locations would have trees already exceeding the limit of approach. On the other hand if the highest found growth rate is used then much of the work would be performed before it is necessary.

Exhibit 8-36
Average Annual Brush Regrowth Rates

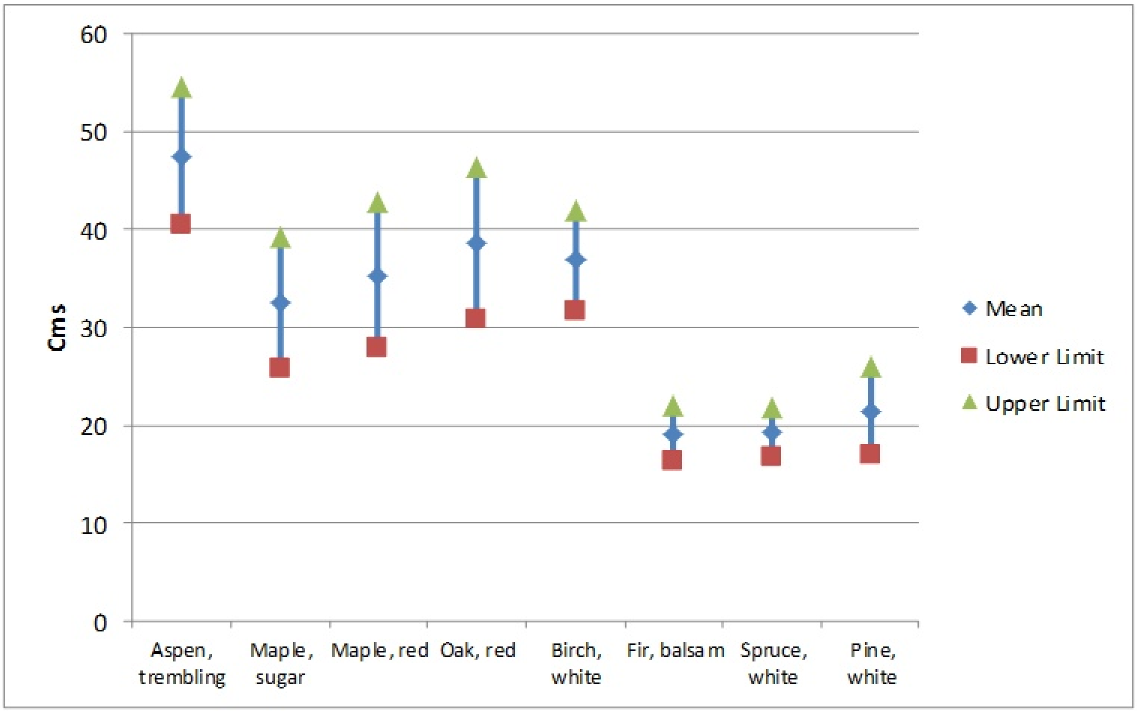


Exhibit 8-36 shows the regrowth rates for the major tree species along with the confidence interval at the 95% level.

Exhibit 8-37 provides the average brush growth rates across all species encountered. *Exhibit 8-38* shows the maximum brush growth rates on a cumulative basis. If the maximum growth rates are sustained over 6 years some of the brush will exceed the minimum encountered line height of 7.8 m. As the tree species exhibiting the higher growth rates are also the same species that are most prevalent, white birch, trembling aspen, sugar maple and red maple, a maintenance cycle that is skewed towards the maximum growth rate is necessary to avoid direct contact between trees and conductors. The field data collected does not support the assumption that maximum growth rates will be sustained over multiple years.

Exhibit 8-37
Average Brush Regrowth Rates

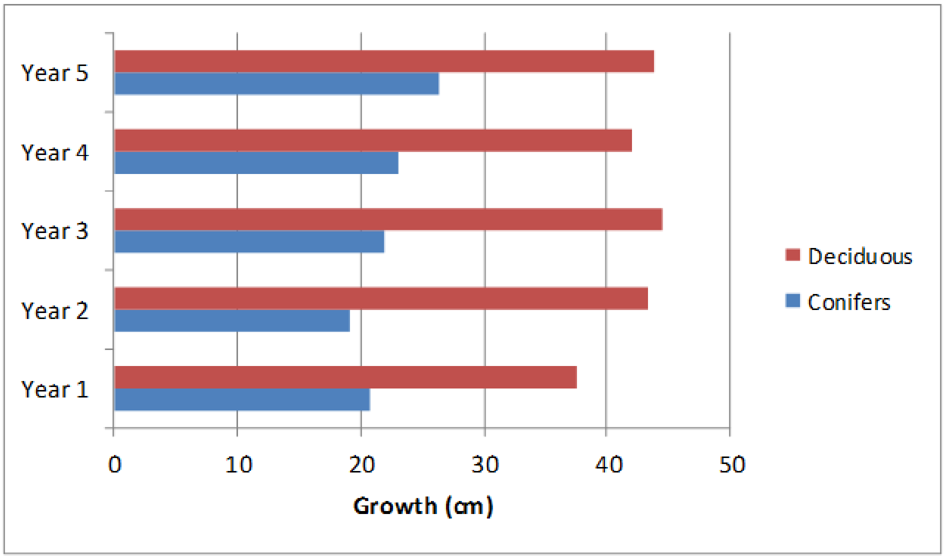
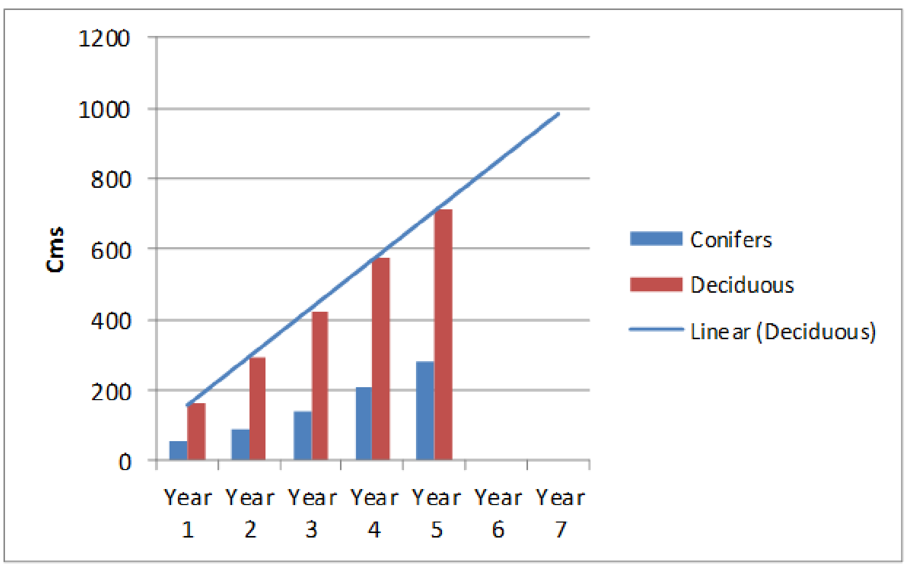


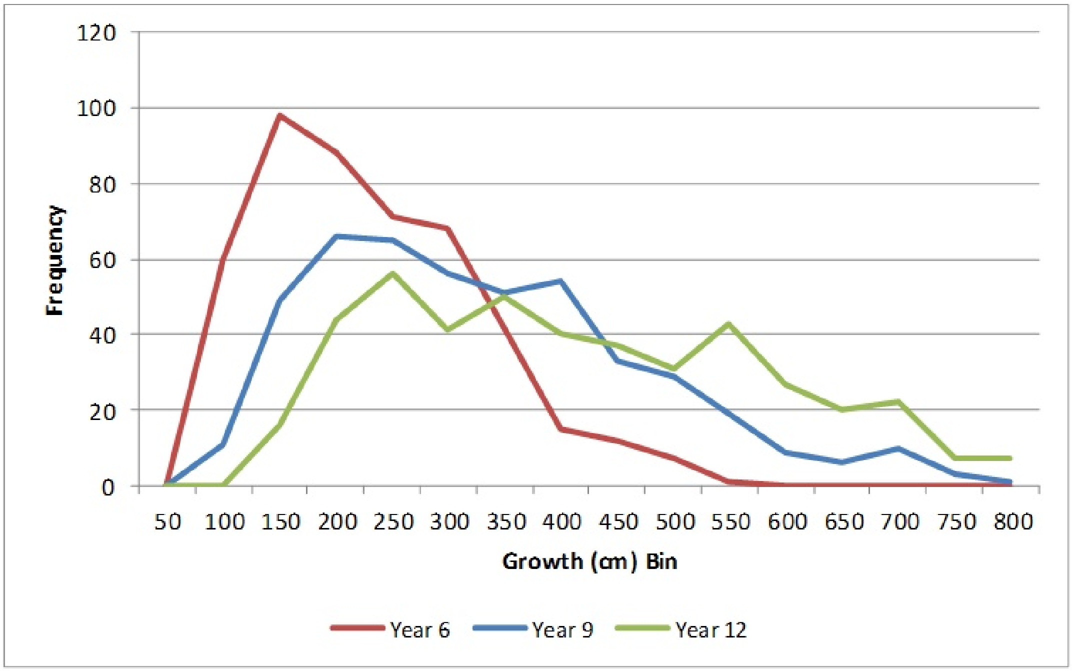
Exhibit 8-38
Maximum Cumulative Brush Growth



By dividing observed growth rates into 50 cm bins a frequency distribution can be developed (*Exhibit 8-39*). The average growth over the first 5 years was used to estimate growth beyond 5 years.

Examining *Exhibit 8-39* it is found that at 9 years there are a small number of trees intruding upon conductors, whereas a 12 year cycle does not meet public safety and reliability objectives. A 9-year maintenance cycle for brush may be considered a just in time cycle.

Exhibit 8-39
Brush Growth Based on Observed Growth 2009-2013



Accordingly, a 9-year maintenance cycle is recommended for right of way brush cutting. The appropriateness of this cycle cannot be confirmed or denied without funding support for a 9-year cycle.

The observed growth being applied to determine the maintenance cycle assumes that the growth observed for 2009-2013 is typical. If it is found that on a 9-year cycle too much of the brush is encroaching on primary conductors, from a public safety and fire prevention perspective this maintenance cycle would then need to be rejected and shortened.

Pruning regrowth is examined similarly. *Exhibit 8-40* shows the average regrowth for trees requiring pruning. *Exhibit 8-41* provides the maximum cumulative pruning regrowth over the last five years. Once again the most prevalent species appear heavily in the list though a number of conifer species are included as well as minor species such as pin cherry, ironwood and willows.

Exhibit 8-40
Average Pruning Regrowth Rates

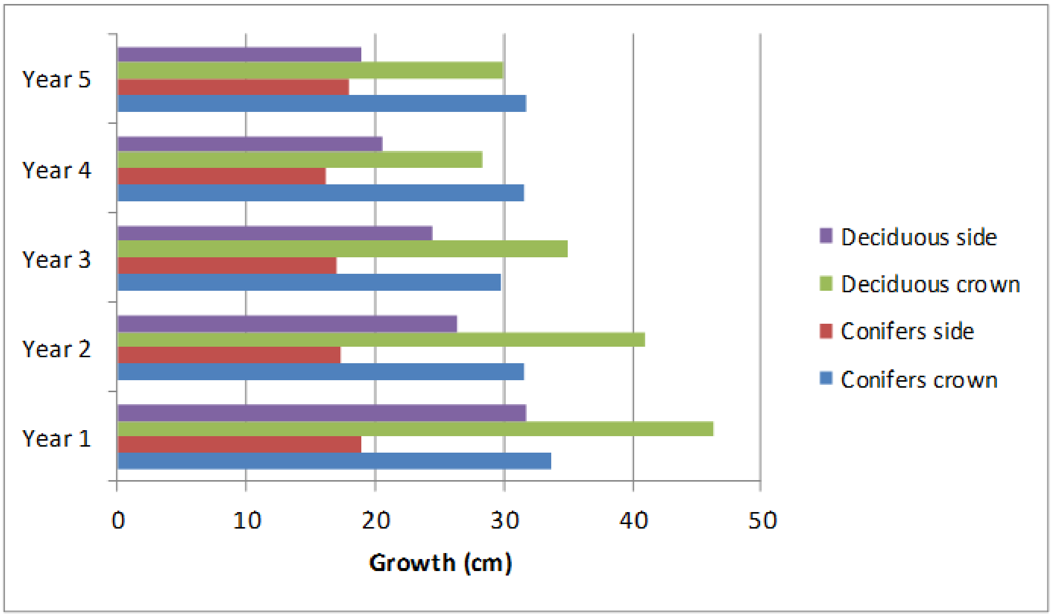
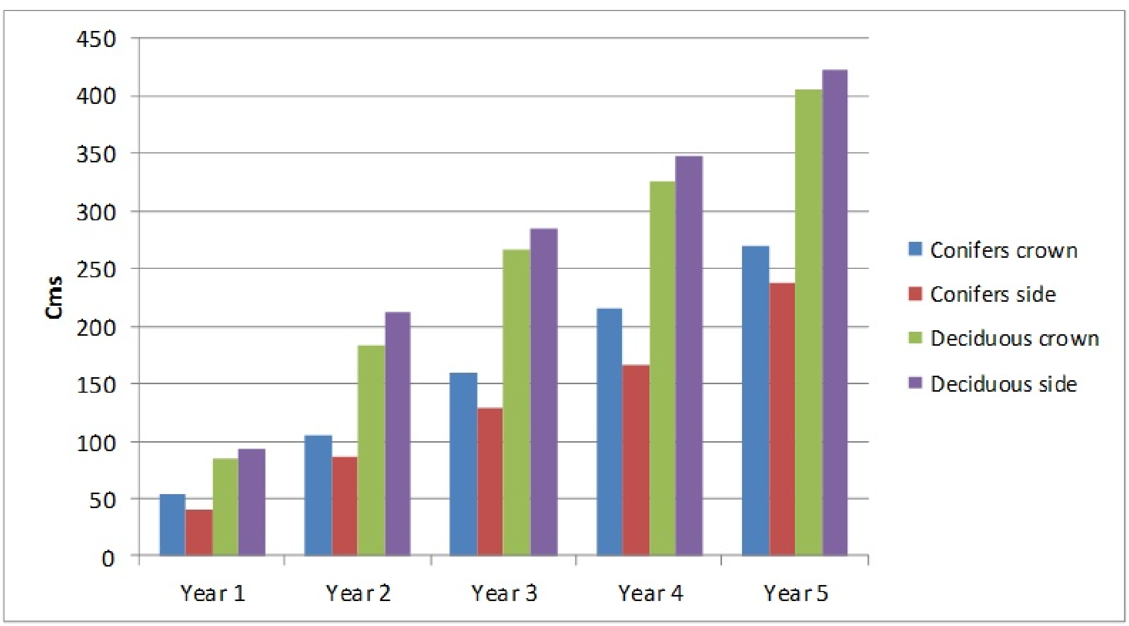


Exhibit 8-41
Maximum Cumulative Pruning Regrowth

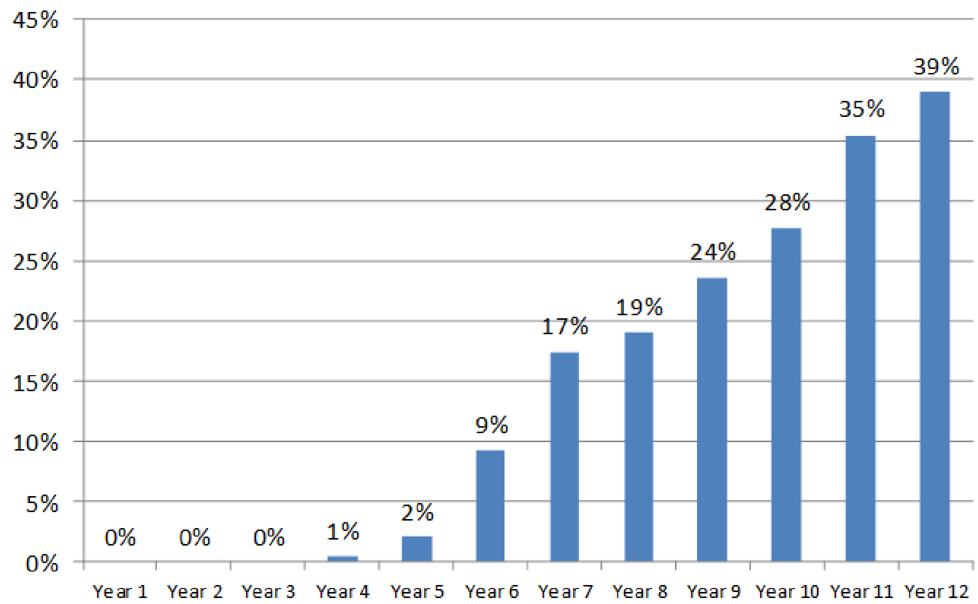


On collecting the data for areas requiring pruning, the data was segregated based on whether regrowth would be crown growth or lateral growth. It is seen in *Exhibit 8-40* and *Exhibit 8-41* that there is a difference between crown and lateral regrowth. A Paired Student T test was applied and for both coniferous and deciduous species to the first two years of regrowth. The results indicated a significant difference in growth rates.

Clearance sought on pruning is 4.5 m. However, customers can influence the clearance obtained and from what was observed in the field, API, similar to many other utilities, achieves an average clearance that would be closer to 3 m.[77] From *Exhibit 8-41* and *Exhibit 8-42* it can be seen that if the last five growing season have been representative then a 3-year pruning cycle would avoid all encroachment. However, at the current time there are areas that have not been pruned in 10 years. To go to a 3-year cycle represents a substantial increase in costs. For the near term a 6-year pruning cycle is recommended. During that 6-year period all trees should be pruned to 4.5 m or the maximum allowed by the landowner.

After the initial 6 years switching to a 4-year cycle may be preferable. With funding in place to achieve a specific cycle, only trees that would impinge on the primary conductor prior to the arrival of the next maintenance event should be pruned. From *Exhibit 8-42* it can be deduced that at 4 years only about 20% (Year 7) of the trees will require pruning. On a 4-year cycle some percentage of the trees will only require pruning of lateral growth every 4th or 5th cycle (*Exhibit 8-40, Exhibit 8-42* and *Exhibit 11-54*). As only 1% of the trees would breach the limit of approach grow-in outages would be essentially zero. Using this selective approach to pruning much less woody material is removed per pruning event reducing site cleanup and wood chip disposal time.

Exhibit 8-42
Pruning Breaching Limit of Approach



9. Quantification of Work Volume

In Vegetation Management Concept and Principles, borrowing from forestry terms, the concept of an annual workload volume increment was introduced. It is comprised of biomass additions and tree mortality. If the annual workload volume increment or AVI is removed, the system remains in equilibrium. It is the path to a sustainable VM program. We need, therefore, to quantify the AVI.

Work volume is derived from a combination of aerial photography and actual field measurements. Some of the field measurements are used in a conceptual approach and this can then be compared to the actual field inventory garnered. It's already been stated that aerial images were obtained using Google Earth. For each of the 150 images a 1 km section was evaluated for the amount of treed edge on each side. The incompatible species invasion pressure is on right of ways with adjacent tree stands. Assuming the establishment of incompatible species is significant only in right of way with adjacent trees then we can apply the percent of treed edge to the total system length to determine the linear length of right of way that will require management. Right of way widths were obtained in the field sampling. These widths will permit an area calculation of what may be said to be the maximum area requiring management (*Exhibit 9-43*).

The biggest risk to the transmission of electricity arises from trees located outside the right of way. The length of exposure was already determined in *Exhibit 9-43*. As part of the field data collection process the height of the conductor and the height of the trees was obtained. Timber cruising techniques were used to determine the number of trees per acre. Consequently, the mean total tree exposure (danger trees) can be calculated.

API's primary system is exposed to 825,543 ± 37,705 trees which on failure could interrupt service (*Exhibit 9-44*). Decadent tree development has been calculated using a 2% annual mortality. This is the number of trees becoming decadent annually and is used as the base when calculating the AVI. However, there are further considerations. First, the forest data indicated that 11.2% of trees were decadent, indicating API has a backlog of hazard trees. The second point applies to both the AVI trees and the backlog: not all the decadent trees will be considered a hazard to service. Some of the trees will be blocked from striking the line on failure by other trees. Some trees decay by shedding branches and trunk sections (i.e. white birch) and without a whole trunk failure would not intercept a conductor. Some trees will develop a lean that makes line contact on failure highly unlikely. Based on the average line height and tree height, the risk factor (RF) at a clear width of 28 feet from the nearest conductor was calculated using the OCWC. It is a RF of 0.225. Because judgements regarding whether a tree will contact the line on failure need to be made we have added 0.1 to the RF to provide a margin of safety. As a clear width of 0 provides a RF of 1, RF/2 provides a reasonable measure of the probability of interruption. Thus applying a factor of 0.1625 to the decadent trees, an estimate of hazard trees is derived (*Exhibit 9-45*).

Exhibit 9-43
Area Requiring VM

Voltage (kV)	Kms	Wire Zone (ft)	Edge type	Mean Clear Width (ft)	ROW Width (ft)	Miles	Acres	% Treed Edge	Potential Treed ROW Acres
44	85.9	7	ROW	54	115	53	744	95.55%	711
25/34.5	174.0	7	ROW	34	75	108	983	89.69%	882
25/34.5		7	Roadside	47		108		89.69%	
7.2/14.4	1425.7	1	ROW	18	37	886	3,973	83.21%	3,306
7.2/14.4		1	Roadside	89		886		83.21%	
Totals	**1686**					**1155**	**5700**	**85.76%**	**4898**

Exhibit 9-44
Tree Exposure

Voltage (kV)	Mean Tree Height (ft)	Mean Line Height (ft)	Trees Per Acre	Ft. To Tree Free @	Danger Trees	Decadent Trees	Mean Danger Tree Depth (ft)
44	63	33	416	54	0	0	0
25/34.5	62	41		47	63,566	1,271	13
25/34.5				47	0	0	0
7.2/14.4	68	33		59	761,977	15,240	41
7.2/14.4				59	0	0	0
Totals					**825,543**	**16,511**	

Exhibit 9-45
Hazard Trees

Voltage (kV)	Decadent Trees Calculated From Annual Mortality	Decadent Trees Based on Found Incidence
44	0	0
25/34.5	1,271	7,120
25/34.5	0	0
7.2/14.4	15,240	85,346
7.2/14.4	0	0
Totals	**16,511**	**92,466**
Hazard Trees	**2,683**	**15,026**

An inventory of workload was also derived from the sampling of 1 km section at 150 sites. *Exhibit 9-46* shows the work found within the 150 samples. The variability in workload from one kilometre to the next can be high. This creates challenges for a system as small as API's. Even having sampled every 12th km, the confidence level needed to be adjusted to ± 10% at the 90% confidence level. The data in *Exhibit 9-46* was used to calculate per kilometre workload and then this was extended by the system kilometres as shown in *Exhibit 9-47*.

Exhibit 9-46
Found Inventory of Work

Voltage (kV)	Length (m)	ROW Width (m)	Brush Length (m)	Brush (m^2)	Crown Trim (m^2)	Lateral Trim (m^2)	Hot Spots	Spans Overhang	Hazard Trees
44	10000	29.5	7085	209,008	14	0	1	0	17
25/34.5	16000	21.94	8538	187,324	457	456	5	2	37
7.2/14.4	124000	11.52	62891	724,504	14042	13872	594	226	644
All	**150000**	**13.83**	**78514**	**1,120,836**[1]	**14,513**	**14,328**	**600**	**228**	**698**

[1] ± 10% at 90% confidence level

Exhibit 9-47
Extension of Work to System

Voltage (kV)	Brush (m^2)	Crown Trim (m^2)	Lateral Trim (m^2)	Hot Spots	Spans Overhang	Hazard Trees
44	1,794,329	135	0	9	0	146
25/34.5	2,037,140	5,591	5,579	54	22	402
7.2/14.4	8,329,930	181,628	179,429	6,829	2,598	7,404
Secondaries	434,151					386
Totals	**12,595,550**	**187,354**	**185,008**	**6,892**	**2,620**	**8,339**

While the workload data in *Exhibit 9-47* is close, it is not the full picture as future work arising in areas recently completed and meeting the clearance requirements have not been captured.

Establishing Annual Workload (Volume Increment)

To capture the full extent of the work, some further adjustments are necessary as the inventory would not capture work that is not needed or apparent at this time. This would include areas that were pruned this year and consequently meet the clearance standard. The crown and lateral trimming quantities as well as brush will be affected. As API's most optimistic estimate is that it may be on an 8-year pruning cycle under the current funding, the trim area will be multiplied by 1.125 to account for areas that were pruned in the last year.

Brush workload is similarly affected as areas recently cleared would not show regrowth, neither would areas cleared in the last year which were stump treated with herbicide. The total potential area for brush control was previously determined to be 4898 acres (*Exhibit 9-43*) which is 19,750,000 m^2. However, API has used some herbicides and one of the intents of this is to shift the right of way to a power line compatible species composition resistant to invasion by incompatible species. It is consequently, necessary to determine to what extent the right of way has been converted to this condition and what portion of the right of way requires ongoing active management. Based on the inventory adjusted for areas recently done or that were cleared in the last year and stump treated we estimate the area requiring active brush management to be 65%.

Finding 9-22 23% of API's ROW kilometres have no adjacent roadway.

API is currently using foliar herbicides on off-road sub-transmission. We have assumed that all off-road brush areas could be treated with foliar herbicides. API's off-road area is 23% of the total kilometres.

Making these adjustments provides the total workload less any backlog. Dividing these totals by the maintenance cycle yields the annual workload volume increment (AVI). The AVI (*Exhibit 9-48*) is the work that must be done every year. Any work deferred expands according to a logistic function (see curve *Exhibit 3-18*).

Exhibit 9-48
Annual Workload Volume Increment

	Brush (m^2)	Herbicide (m^2)	Pruning Top (m^2)	Pruning Side (m^2)	Hazard Trees
	10,206,864	3,048,804	187,354	185,008	3,069[1]
Cycle (years)	9	3	6	6	3
Annually	1,134,096	1,016,268	31,226	30,835	1,023

[1] 386 hazard trees have been added to account for secondary circuit kms

Backlog of Work (Cumulative Liability)

It has been shown that there are two approaches to arriving at the area containing brush. We have a conceptual approach using the extent of tree exposure that was digitally derived. The second approach was the direct approach, collecting data on brush found in the field. The field data was then used to refine the conceptual approach as there is no way to determine from available photography the extent of the right of way conversion to compatible species. Applying the length of tree exposure and the field determined mean tree height, line height and tree density the total tree exposure was calculated. The inventory of decadent trees found in the field informs us both that using average tree mortality rates will lead to under-estimating the number of hazard trees and that there is a backlog of hazard trees requiring attention. There is a difference of over 75,000 decadent trees between field observed numbers and what would be expected based on average mortality. It amounts to a backlog of just over 12,000 hazard trees (*Exhibit 9-45*).

The amount of pruning required can only be derived from a field inventory. The field derived amount is what is used in arriving at the AVI. If there is a backlog in pruning work it is captured somewhat in the area which stems from a measure of length times depth. The rather high incidence of hot spots averaging 4 per km indicates the pruning is behind. However, the number of locations with evidence of trees already contacting conductors was small. Essentially, we have taken a measure of the area subject to grow in and needing pruning at some point. The length of pruning exposure is relatively static. The main variable is the depth or rate at which the clearance zone is penetrated and occupied. This rate has been addressed through the growth studies.

10. Workload Inventory Valuation

It is necessary to place a value on both the AVI and any backlog of work (Cumulative Liability). The unit costs used are found in *Exhibit 10-49*.

Exhibit 10-49
Unit Costs

Operation	Cost
Brush Removal	$2.25/m²
Crown Trim	$2.75/m²
Lateral Trim	$10.42/m²
Tree Removal	165.44/tree
Mowing	$0.60/m²
Foliar Herbicide	$0.18/m²

Tree removal was broken into three dbh size categories: 4-12 in; 12-24 in; > 24 in. The unit cost is the weighted average based on the size distribution found in the forest sampling. The distribution by size category is 71%; 28% and 1%, respectively. A cost has been shown for mowing though no area has been ascribed. While this cost has been entered to encourage thinking of the possible economy of using this practice, one must be cautious about varying cycle lengths between methods. This can be addressed by calculating and comparing long term maintenance costs on a present value basis (see *Exhibit 12-57*).

Exhibit 10-50
Annual Workload Values

	Brush	Herbicide	Pruning Top	Pruning Side	Hazard Trees	AVI	HT Backlog	Total
	$22,965,444	$548,785	$515,223	$1,928,242	$507,738		$2,684,764	
Cycle (years)	9	3	6	6	3		3	
Annually	$2,551,716	$182,928	$85,871	$321,374	$169,246	$3,311,134	$680,681	$3,991,816

Exhibit 10-50 shows the AVI to be $3,311,134. This is the amount that needs to be spent annually, based on current methods, if a sustainable program is to be delivered. The AVI can change for a number of reasons. If more widening occurs, reducing the system's tree exposure, then the number of hazard trees that will develop annually is also reduced. If mowing were introduced and it were found that 25% of the brush currently hand cut could be mowed then that too would change the AVI. A guiding principle for a

sustainable program is that the AVI must not be changed for reasons other than escalation unless the change is both quantified and is itself sustainable.

Exhibit 10-50 also shows that over the first three years of this program, the backlog of hazard trees is to be removed and this will require total annual VM funding of $3,991,816. As it is unlikely that the VM program will be funded at this level in 2014, projections will need to be made for 2015 forward. This being the case, the backlog or VM liability will expand necessitating a greater investment in the future.

Confidence in the Workload, AVI and its Valuation

While some of data collected is so extensive as to permit statements of a mean ± 5% at a 95% confidence level, some is not that rigorous. The area of brush falls easily within ± 10% at a 90% confidence level. The brush being the largest component of the AVI and the lowest confidence level, then this is what we must ascribe to the overall AVI. It need be interpreted as the mean amounts and value, ± 10% at a 90% confidence level.

The pruning area, the number of hazard trees/km and the spans of overhang/km do not meet ± 10% at a 90% confidence level standard. The hazard trees/km and the spans of overhang/km were only used to gain insight to the program and to provide direction to possible means of improving reliability. The actual data used for hazard trees is derived from the forest data of over 6000 records and it meets the highest or 95% confidence level.

The annual value of the pruning is only about 12% of the total AVI and thereby, we can state that the failure to achieve a narrow confidence interval does not substantially affect the overall AVI value or confidence in it.

As previously stated we have used two approaches to arriving at the AVI with points of intersection between the two. Not detailed here is the application of unit prices to the field inventory collected over the 150 km segments. Comparing the value thus derived to the calculated AVI the result is 101.9% This high level of agreement corroborates both the validity of the approach and the AVI value. The difference stems from the AVI being adjusted to include work done in the last year which would not appear in the field inventory.

Funding Required

There is a specific amount of work that needs to be done annually (AVI). This amount has been determined to cost $3,311,134 employing the current practices. There is also a backlog of hazard tree work, which if not addressed will continue to very adversely affect reliability. When this backlog is included the funding required is $3,991,816 for the first three years. That is, the total current Cumulative

Liability must be addressed. Having removed the backlog, the funding requirement will then drop back to AVI value of $3,311,134 (in 2013 dollars).

The AVI includes funding for some hazard tree work. However, it is only for what would be newly emergent hazard trees. If the backlog of hazard tree work is not funded, resources will inevitably be drawn away from other work considered necessary in the AVI simply because it will not be possible and would be irresponsible to walk by obvious hazard trees that are imminent threats to safety and reliability. Consequently, funding intended to remove the AVI will be diverted making it impossible to achive the objective of removing the AVI.

It is recommended in this report that VM be put on a rational basis. This cannot be accomplished without addressing both the AVI and the current backlog of work (Cumulative Liability). Further, as current funding is inadequate to meet the requirements of the AVI and the backlog, all deferred work will be compounding at over 15% (*Exhibit 11-55*). The same applies to currently outstanding work that is scheduled for future years. The only way to avoid this compounding is to complete the entire backlog in the current year. That is not feasible as a sudden large increase in work would necessitate hiring more contract crews and staff to administer and monitor the work, thereby introducing inefficiencies that quite possibly exceed the rate of workload expansion.[78] The proposed funding buys down the workload liability over a period of years.

Exhibit 10-51
Proposed VM Maintenance Budget[1]

	Minimum Required Budget	Proposed Funding	PV of $1	PV of Budget Provided	Unfunded	Liability	Cumulative Liability
		Proposed Funding				('000)	('000)
Start 2014	('000,000)	('000,000)		('000,000)		$680.68	$2,042.04
End 2014	$3.99	$2.88	1.0000	$2.88	$1,109.73	$769.20	$2,811.25
End 2015	$3.99	$4.70	0.9524	$4.48	-$708.18	$0.00	$2,200.89
End 2016	$3.99	$4.70	0.9070	$4.26	-$708.18	$0.00	$1,594.56
End 2017	$3.99	$4.70	0.8638	$4.06	-$708.18	$0.00	$965.98
End 2018	$3.31	$4.30	0.8227	$3.54	-$988.87	$0.00	-$25.68
End 2019	$3.31	$3.31	0.7835	$2.59	$1.13	$1.13	-$24.54
End 2020	$3.31	$3.31	0.7462	$2.47	$1.13	$1.31	-$23.23
End 2021	$3.31	$3.31	0.7107	$2.35	$1.13	$1.51	-$21.72
End 2022	$3.31	$3.31	0.6768	$2.24	$1.13	$1.75	-$19.97
End 2023	$3.31	$3.31	0.6446	$2.13	$1.13	$2.02	-$17.95
Total	$35.83	$37.83		$31.01			-$17.95

[1] In 2013 dollars

Exhibit 10-51 lays out a schedule for VM funding (Provided Budget column) stated in 2013 dollars. It addresses the required funding (AVI), expands all unfunded work by the found rate of workload change, determines the present value of the total VM liability assuming a 5% interest rate and sets out the VM investment schedule which eliminates the VM liability. In doing so, it has been assumed that funding for 2014 will be as currently planned and that the new funding level will begin in 2015.

11. Risk

To electric utilities trees are a liability. They have no capacity to improve electric service. Trees in proximity to power lines present a public safety hazard and thereby, constitute a legal liability. However, the major impact of trees is seen in reliability. Consequently, trees are a liability in terms of quality customer service. As was shown in Vegetation Management Concepts and Principles, VM as a whole represents a financial liability. All of these risks need to mitigated and managed.

As vegetation is not static, neither are the risks associated with trees in proximity to power lines. A number of areas of risk are examined.

Reliability

In some cases it is possible to show a direct link between funding and the deterioration of reliability or conversely, the improvement in reliability in response to an increased spend. This is somewhat obfuscated in API's case due to widening which increased the instability of edge trees. None the less, it is seen in *Exhibit 11-52* that every substantial increase in VM spending drove tree-related outages down. It should be anticipated, however, that at some point the susceptibility to increased failure along the new edge would become evident. It need be noted that the data does not separate out the influence of major storms. Thus, some of the peaks may be skewing the data as one or two major storms can easily increase annual outage statistics by 20-30%.

When tree-related outages as a percent of total unplanned outages are charted with the annual VM spend (*Exhibit 11-53*), the benefit of increased VM is evident in decreasing customer interruptions. As the major capital widening was completed in 2011, a trend of a decreasing percentage of tree-caused outages is expected to emerge through 2018 as the edges become more stable. However, if the annual spend does not equal or exceed the AVI value the gain may be offset by an increase in outages from other sources, such as hazard trees beyond the edge. We estimate that if the current hazard tree program persists, the percent of decadent trees will continue to increase to an asymptote where additions are balanced by annual failures, and as a consequence, that tree-caused outages will increase by 40-60% over the next five years.

Exhibit 11-52
VM Spend vs Tree-related Outages

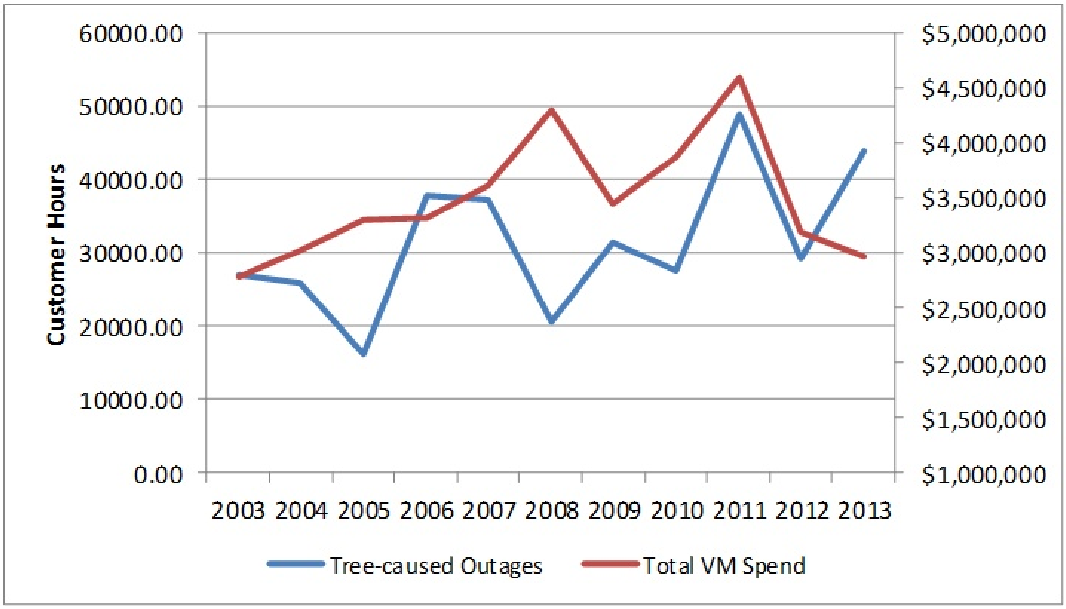
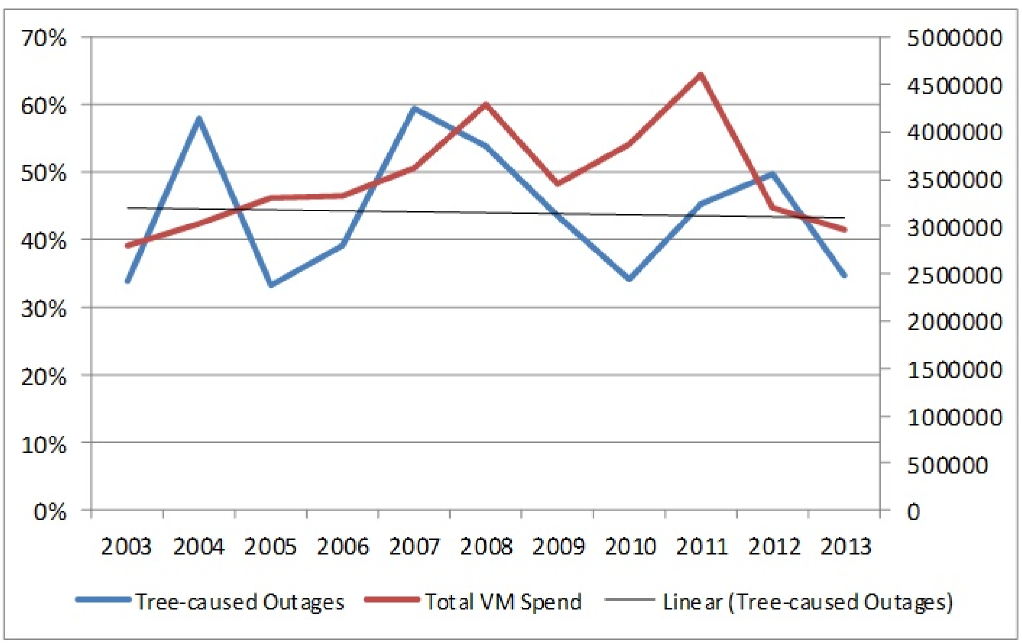


Exhibit 11-53
VM Spend vs % Tree-related Outages



Hot Spots

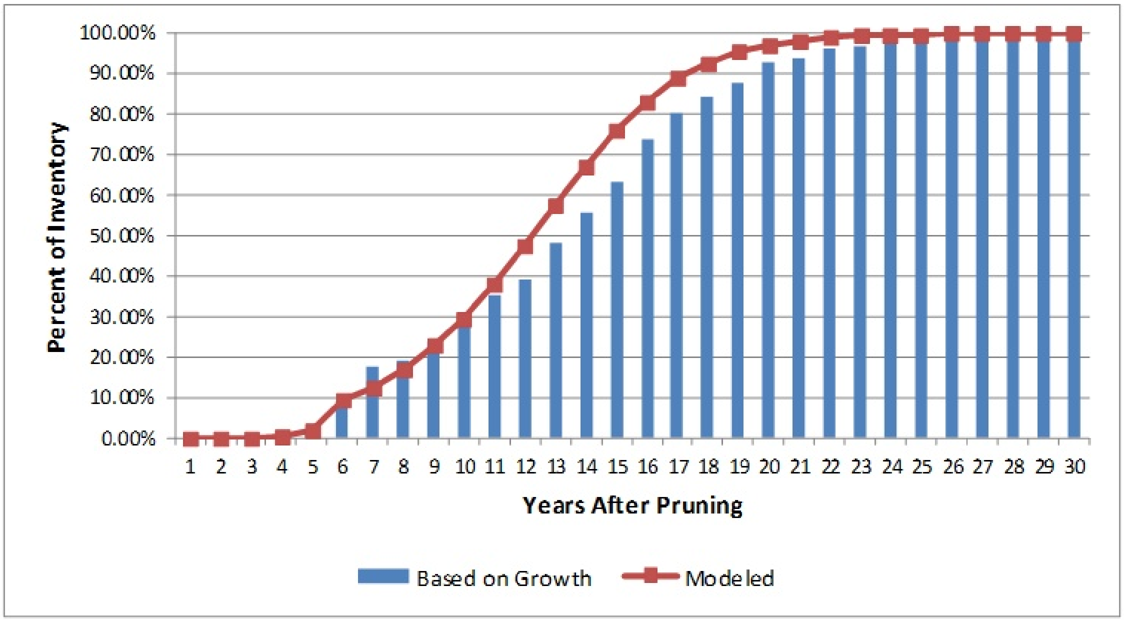
The incidence of hot spots was high, at about 4 per kilometre. Virtually none of the hot spots seen were actually in the conductor. While the incidence of hot spots is greatest in areas that have not received attention for quite some time, the inventory showed the incidence to be widespread. Hot spots within areas scheduled for work will be resolved, however hot spots occurring in areas not scheduled need to be managed on a demand basis. One study showed the management of hot spots to cost 30% more than maintenance pruning.[79] Hot spots jeopardize reliability and public safety and increase maintenance costs. Consequently, hot spot work needs to be minimized and carefully managed.

Chasing hot spots can sink a VM program to a state of total ineffectiveness. Not only does the windshield time involved erode cost effectiveness but also, there comes a breaking point where the hot spots are emerging faster than the capacity to address them. At that stage grow-in outages increase. An increasing rate of grow-in outages should be seen as an alarm for public safety. Grow-in outages do not occur at distribution voltages until branches are bridging phases. Such overgrown conditions create the potential for children to come into contact with conductors when climbing trees. For these reasons it would be useful to further examine the status of hot spots.

We have extended the 5 years of growth data collected out to 30 years. The data records were then put into a frequency distribution, the bins consisting of 50 cm increments. *Exhibit 11-54* shows the percent of trees that will breach the limit of approach within the year. The limit of approach was taken as 3 m. While one could argue this limit of approach given API targets a 4.5 m clearance, what cannot be argued is the pattern of hot spot development. In other words, the pattern seen in *Exhibit 11-54* remains the same regardless of the limit of approach chosen. Changing the limit of approach serves only to move the curve left or right by a few years.

The current level of hot spots is 38%. The closest match in *Exhibit 11-54* is year 12. This provides insight into the current status of the VM and also into what might be expected in the future if the pruning program is not put on maintenance cycle based on growth rates. The number of hot spots is in an exponential expansion phase. The future will prove very challenging as the number of hot spots doubles in the next five years. Grow-in outages will likely make a strong reappearance and the efforts to avoid them, by increasing hot spotting activities, will increase inefficiency and increasingly draw resources away from other also essential VM activities, such as hazard tree removals and maintenance pruning.

Exhibit 11-54
Modeling Hot Spot Development



Hazard Trees

There is a current backlog of hazard tree work valued at $2,042,044. It is recommended that this backlog be addressed over the first 3 years of the new program.

Failing to do so will increase tree-related outages. However, considering that at present 11.2% of the danger trees beyond the edge are decadent API is not far from the limit of maximum hazard tree-caused outages. BC Hydro found that mountain pine beetle invested trees all failed within 8 years. Applying the same assumption to API's service territory, the highest level of decadent trees is 16% of the danger tree population. However, hardwoods such as maples and oaks may take longer to fail. We have assumed 18% standing decadent trees to be the upper limit. Such an increase in standing decadent trees would result in a proportionate increase in tree-related outages of 40-60%.

If the AVI funding is provided but there is a failure to fund the removal of the backlog of hazard trees reliability will deteriorate for two reasons. Assuming one could remove only the hazard trees which have developed over the last three years, the then residual and current backlog would become increasingly decadent to the ultimate point of failure. This may be expected to occur over the next 5 to 6 years. However, a failure to fund the removal of the backlog has even more serious implications. It would necessitate a prioritization where only about one of every five hazard trees are removed. That raises a legal risk. Practically, however, it would likely be decided, the risk being recognized, that more than 20%

of the hazard trees will be removed. Such action and expenditure would preclude attaining the 3-year cycle for hazard trees and as the effects of this decision become apparent in the areas not yet done, invite the transfer of funds from other program aspects precluding their attainment of the maintenance cycle and lead to a reactive program.

Funding

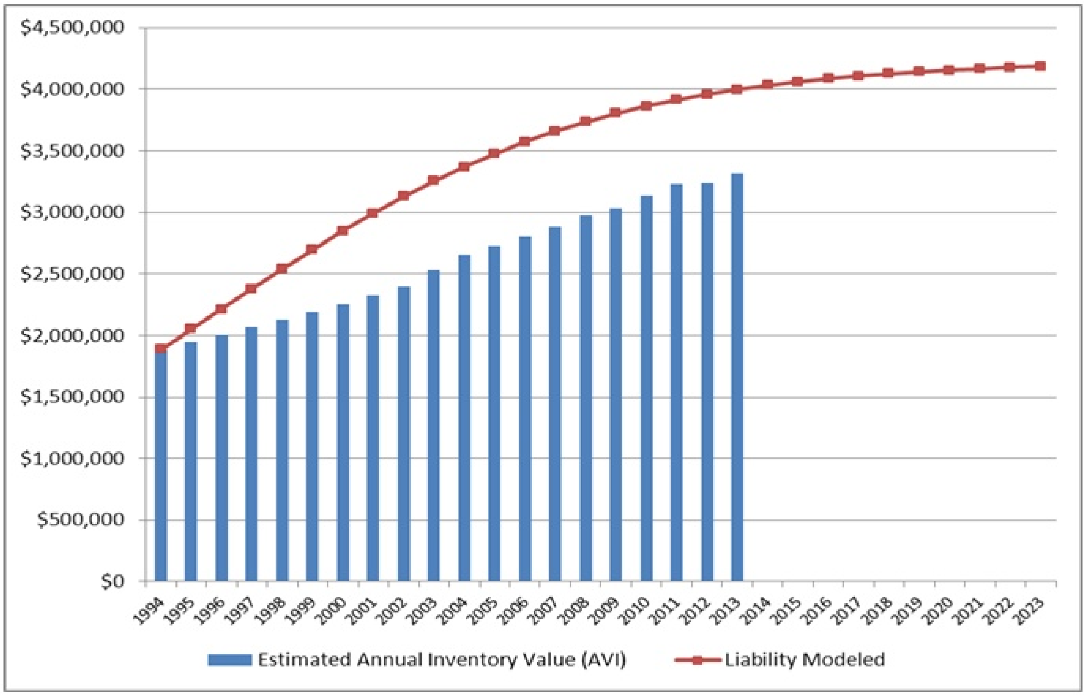
The AVI is valued at $3,311,134. While we have indicated that the funding requirement is higher than the AVI for the first 3 years of the proposed VM budget and program to address the backlog of hazard trees the critical value is the AVI. If funding does not meet or exceed the AVI value, the work not done does not remain static but expands according to a logistic function.

Knowing the current AVI value, the AVI was backward calculated to 1994, discounting by a 3% per annum cost of living increase and adjusting for the effects of the capital widening program on increasing brush area and decreasing total tree exposure and consequently hazard tree needs. A 30 year logistic model was then created so that it closely relates to the estimated starting point in 1994 and the total 2013 workload liability value. In fitting this model, the rate of expansion of API's VM work was determined (*Exhibit 11-55*). It is a factor of 1.155. For the sake of simplicity, it could be stated that $1 of deferred work this year will cost $1.155 next year.

Having determined the rate of change in the workload it is possible to quantify the net effects of underfunding, that is funding below the AVI value. To illustrate it has been assumed that the VM budget going forward will be $2,700,000. That leaves a shortfall of $629,048 from the AVI value. *Exhibit 11-56* shows the impact of 10 years of underfunding. The liability line shows what it would cost to get the program back to the least cost sustainable level. It should be noted that *Exhibit 11-56* is illustrative and does not include the value of the current backlog of work of $2,042,044. Rather, the data it presents assumes a program that has been fully funded in the past and becoming underfunded going forward.

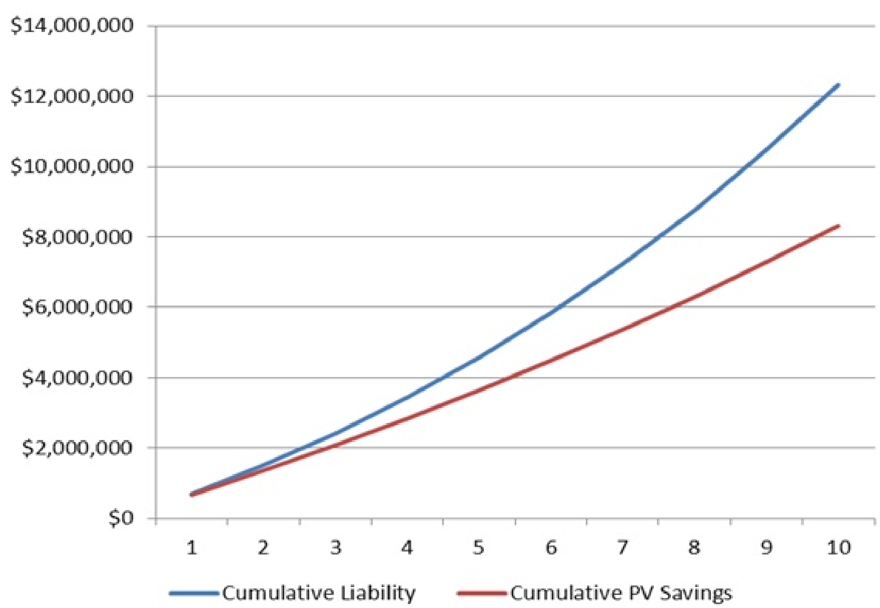
Exhibit 11-56 shows underfunding or deferring VM work is financially imprudent. This will inevitably be case as long as the rate of change in the workload substantially exceeds the discount rate used in determining the present value. In this illustration the workload rate of change is 15.5% versus a discount rate of 5%.

Exhibit 11-55
Modeling the Workload Liability



2013 AVI is derived from field inventory, growth and mortality rates

Exhibit 11-56
Present Value Impact of Current VM Underfunding



However, the failure to fund VM as set out in Exhibit 10-51 will have greater cost implications for the future. First, the potential gains in cost effectiveness through the recommended practices would be precluded. The window for treating brush with herbicides is limited. Brush suitable for herbicide applications represents the lowest level of public and reliability risk for a utility. Consequently, it is the first work deferred under constrained funding. Deferred work becomes brush that needs to be cut by mowing or hand cutting, escalating costs by as much as 20 times (Exhibit 12-57). Secondly, the recommended cycles are to prevent trees breaching the limits of approach. Without the funding necessary to attain these maintenance cycles trees will increasingly breach the limits of approach, necessitating a greater skill set, more expensive practices and workers to complete the work.

12. Conclusions and Recommendations

Recommendation 12-1 Fund the VM program based on the inventory and tree growth and mortality (Refer to *Finding 6-2, Finding 6-1, Finding 8-17, Finding 8-18*).

It is completely unreasonable to expect a VM program that is not funded on the biological facts of an inventory, tree exposure and tree growth and mortality to deliver a least cost sustainable program. To do otherwise is as imprudent as basing decisions on the assumption of winning the lottery, which while not impossible is highly improbable.

Vegetation Management Concepts and Principles provides how and why only an approach that annually addresses the annual workload volume increment will provide a least cost sustainable program while simultaneously minimizing tree-related service interruptions.

With the recently completed work performed to quantify API's work inventory, tree exposure and tree growth and mortality rates, the foundation for a least cost sustainable VM has been provided. While this new data provides direction on potential cost savings it also shows that there is a risk of the workload expanding from 65% of the right of way area to 85% of it if funding is inadequate to establish the recommended maintenance cycles. As areas treated with herbicide are not affecting reliability, worker and public safety, when funding is inadequate this is the work that is deferred. Once this deferred area is over-height for herbicide applications it is necessary to apply cutting methods which are not only more expensive but also tend to increase the stem density of incompatible species. The relative stability of the early succession plant population is disrupted and the area then requires regular maintenance (based on the recommended cycles).

The funding requirements to address the current Cumulative Liability have been provided in Exhibit 10-51.

Recommendation 12-2 Establish the maintenance cycles required to deliver a sustainable, least cost VM program (Refer to *Finding 6-3*, *Finding 6-2, Finding 6-5, Finding 6-7*).

The recently completed field work also provides data for the derivation of maintenance cycles. It need be noted there is not one maintenance cycle but several depending on the treatment to be applied.

Brush that is to be cut, whether by hand or machine, has a maintenance cycle of 9 years.

Brush that will be treated with foliar herbicide has a maintenance cycle of 3 years. Due to the short duration, annual variability in growth rates can have a substantial impact. Consequently, while funding should be based on the assumption of a 3-year cycle, field conditions must be checked to determine whether the treatment needs to be moved forward in time or delayed. This will necessitate either patrols of the all the areas for which herbicide applications are planned within the next two years or a considerable familiarity with the actual field conditions. In this way line segments may be moved forward into the current schedule or deferred to the following year.

Pruning work has a 6-year maintenance cycle. This will serve to both reduce the number of hot spots and to geographically concentrate the hot spots, which serves to reduce the extent of the cost inefficiencies inherent to handling hot spots. To further improve on reliability it is recommended after the first six year cycle is complete, to shift to a selective 4-year pruning cycle. In this case, each tree needs to be assessed and pruned only if it would intrude into conductors before the next pruning event four years hence.

Hazard trees are to be maintained on a 3-year cycle. The rate of hazard tree development is such that if hazard trees were only addressed on the 9-year brush maintenance cycle, the currently high level of decadent trees would be a constant condition with negative implications for service reliability. A 3-year maintenance cycle for hazard trees is expected to reduce the amount of decadent trees to about half the current level in areas just before retreatment. That is the worst case is the $1/3^{rd}$ of the service territory due for work would have about ½ of the current level of decadent trees while the other $2/3^{rds}$ of the service territory will have 0-4% decadent trees.

This hazard tree maintenance cycle along with the gradual firming of edges is expected to substantially decrease tree-related outages. Until such time as the edges are firm, there should be an annual hazard tree patrol for edges beginning with the most recently widened areas. Once stability of the edge is established the area can be rolled into the general hazard tree program.

It will be beneficial to monitor outages in the boreal forest ecozone versus the Great Lakes St. Lawrence ecozone. It is in the boreal forest ecozone where the tree species with the highest mortality rate and risk of failure occur. It may be found that the area warrants a more aggressive hazard tree program. Conversely, it may be found that in the Great Lakes St. Lawrence ecozone a longer cycle can tolerated.

Recommendation 12-3 Seek to eliminate branch overhangs (Refer to *Finding 6-4, Finding 8-19*).

It is recommended that API eliminate branch overhangs wherever possible. There may be substantial landowner resistance to removing overhangs on sugar maples as doing so may impact syrup production. However, this condition is restricted to the southern part of the service territory and predominantly St. Joseph Island. It was also noted that occasionally landscape white pines with substantial branch overhangs are encountered. As conifers tend to shed older branches, the risk of branch failure on such pines can be minimized by monitoring the lower branches for health and vitality, removing any decadent branches back to tree trunk.

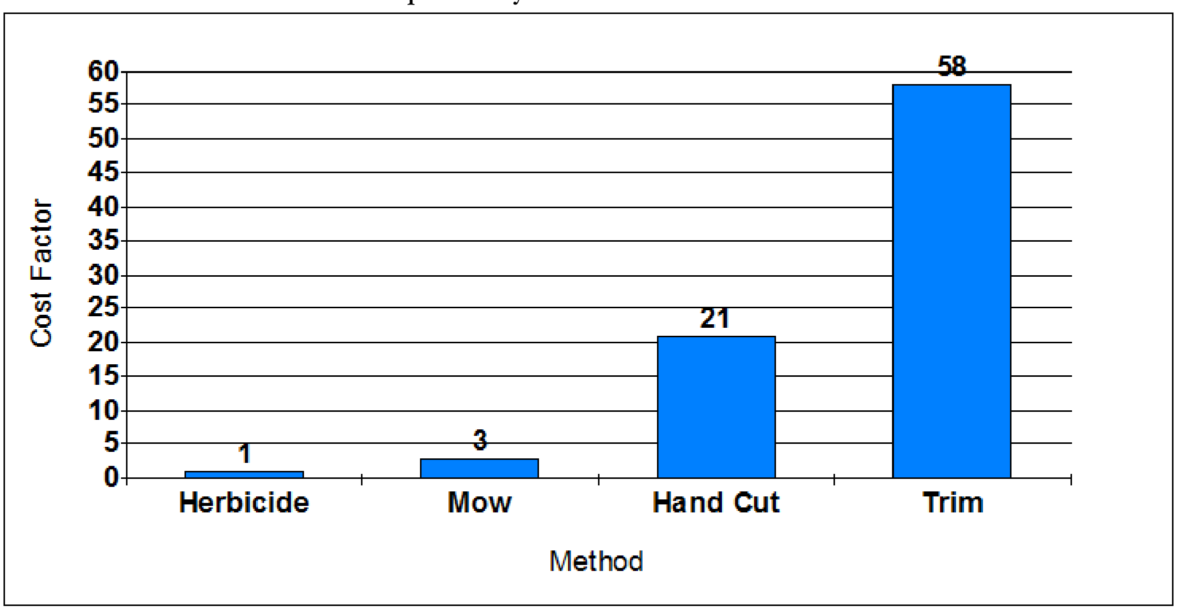
For trees that are not in landscaped settings and do not have commercial value beyond the wood itself, a ground to sky clear width of 4.5 m is recommended. As outage data does not detail outages arising from tree branch failures it is not possible to predict the reliability gain available.

Recommendation 12-4 Extend the use of herbicides and the introduction of alternative cutting equipment and procedures (Refer to *Finding 6-6*).

It is recommended that API extend its foliar herbicide program to include areas that are along roadways. Foliar herbicide results are superior to other methods (stump treating, basal) because the plants are intact, growing actively and thereby capable of translocating herbicide to the roots. Herbicide use being controversial with the public it is important that API continue its landowner permission based approach and also use rigorous brush height restrictions so as to manage the visual impact based on public traffic along and visibility of the site.

At this time only areas recently cleared could be considered for foliar herbicide applications. The plan going forward, however, would include the intention to follow up with herbicides 1 to 3 years after areas have been cleared. It's not known how much of the area housing brush could gain public acceptance for foliar herbicide application. Consequently, while a measure of the cost savings possible is presented in *Exhibit 12-57*, the AVI must not be adjusted to reflect these savings until such time as brush area to be transferred is known.

Exhibit 12-57
PV Cost Comparison by Method Over 20 Yrs. Maintenance



Source: TransAlta Utilities 1993.

Exhibit 12-57 also highlights another recommended practice which is brush mowing. The cost factor comparison to hand cutting provides a compelling reason to introduce the practice. It would be applied where brush exceeds the height limitations for herbicide applications and on an ongoing basis, in areas that cannot be treated with herbicides. Due to rocky terrain the area suitable for mowing is restricted. None the less, the potential savings warrants a determination of the area that could be mowed. API has used mulchers that have same restrictions in needing to avoid rocks. Mulchers have a higher unit cost than mowers but they do lead to a longer maintenance free period. Once again, the AVI value must not be adjusted until such time as there is an actual measure of the area that can be mowed.

The right of way reclamation work that has been done provides the opportunity to employ earlier intervention and less costly methods. API's current average per hectare cost for brush control, which reflects the reclamation, is $12,717. This is, relative to the industry high. Extending the use of foliar herbicide to as much as possible of the recently cleared area and introducing mowing hold the potential to substantially lower the average $/ha. If we assume 30% of the brush currently hand cut could be mowed the average $/ha would fall to $10,331. If foliar herbicides could be used to maintain 50% of the area supporting brush the average price per hectare would become $6,975. Were it possible to meet both the mowing and foliar herbicide hypotheticals the costs would drop to $5,731/ha. Clearly these practices hold the potential for significant savings in maintenance costs. The adoption of this recommendation will impact the AVI in two ways. First, once the area that can be transferred from hand cutting brush to foliar herbicide and mowing treatments is firm and known, a new lower AVI value can be calculated. However, as there are brush size limits for these operations, any deferred work may become unsuitable for the method and therefore will need to completed in the future through a more expensive method. Accounting for this escalation in costs requires a higher rate of change for any deferred work.

It has been recommended that overhangs be removed where possible. There are numerous kilometres of overhang that are not sugar maples but comprised of species that tend to shed branches. Typically, the extent of the overhang is not large. For that reason we recommend the use of a telescoping saw trimmer such as the Jarraff. This equipment does not provide fine pruning but a skilled operator can reduce stubs to 5-10 cm. Such equipment provides an economical means of attaining a ground to sky clearance.

Recommendation 12-5 **Work on secondaries requires separate funding so that this work does not occur at the expense of work on primary lines (Refer to *Finding 6-8*).**

API has been experiencing tree-related outages on secondaries. In response, API has begun clearing secondaries. At the present time, however, funds expended on clearing secondaries decreases the funding available for the maintenance of primary lines.

The workload, funding and AVI presented here have been adjusted to reflect this initiative.

Recommendation 12-6 **For capital projects a clear width of 6 m is recommended. (Refer to *Finding 7-13*, *Finding 7-12*, *Finding 7-11*).**

API's relatively low exposure to trees provides some guidance to tree-related outage mitigation. The risk of an interruption on tree failure is high where the right of way has not been widened, such that clear widths are only 8 feet (*Exhibit 7-26*). Much of this issue has already been addressed but there remain areas where widening would be beneficial.

Clear width is the distance from the outside conductor to the tree line or tree boles. It is shown in *Exhibit 7-27* that increasing the clear width to 4.5 m (15 feet) is expected to reduce tree-related outages 32%. However, a clear width of 6 m (20 feet) will result in a 48% reduction. API is currently establishing a right of way of 6 m each side of centreline. This recommendation slightly extends this practice to ensure a 6 m clearance between the conductor and tree boles should the line be on horizontal cross-arms.

Recommendation 12-7 **Place particular focus on line segments between the substation and the first protective device. (Refer to *Finding 7-11, Finding 8-19*, *Finding 8-21*).**

The greatest reliability improvement will be attained if the most rigorous standards are applied to the portion of line between the substation and the first protective device. For these line segments overhangs should not be tolerated. They should receive the greatest attention in patrolling for hazard trees. It is also on these line segments where a greater clear width would provide the greatest overall reliability improvement.

Recommendation 12-8 **Obtain a VM reporting system that links to other company databases (Refer to *Finding 6-10*).**

Part of the audit process involved the request for information. Some of the requested data was not easily attained.

For most distribution utilities VM is if not the primary, certainly one of top three O & M expenses. As such it warrants support through the provision of IT, accounting and other financial management services. Given VM's role in O & M expenses and reliability there is need for a good information management system. This system should collect data on VM work done, costing for the same and to be able to forecast future needs. Further, the system should link with customer, accounting and mapping databases.

Recommendation 12-9 Collect field data in more detail (Refer to *Finding 6-10*).

API currently tracks cost per kilometre. This is inadequate,[80] particularly, in light of the recommendations made which have established the need for various maintenance cycles based on the treatment. It is recommended that API track work performed as follows:

- Brush (<4 in dbh) removal – m^2
- Herbicide - m^2
- Pruning – m^2 or trees (>4 in dbh) and trim brush (<4 in dbh) in m^2
- Tree removals – trees by size category
  - 4-12 in dbh
  - 13-24 in dbh
  - > 24 in dbh
- Clearance on work completion for pruning and clear width for brush

API's VM program has been in a state of flux. Should the recommendations regarding different treatment methods, maintenance cycles and the funding to support them be accepted, then there will be a transition period for which there is no precedence at API and consequently, the currently known costs per kilometre will not apply and serve.

The greater detail provided by following this recommendation will provide greater insight into the VM program in general and provide a basis for comparing different methods. The data presented in *Exhibit 12-57* is a good example of the type of insight afforded by the more detailed VM reporting recommended and it need be recognized that this insight is not at all available if costs are tracked by kilometre.

Recommendation 12-10 Create more detailed tree outage cause codes (Refer to *Finding 7-14*).

It is recommended that cause codes make distinction between grow-in outages and fall-in outages and whether the offending tree is within or outside the maintained right of way. Fall-in outages should be further detailed as uprooted, trunk failure or branch failure. These distinctions will provide direction to the VM program but may also suggest engineering options to address tree-caused outages.[81] [82]

It is suggested that an arborist follow up on some portion of tree-caused outages to establish the tree species and the distance of the tree from the nearest conductor. This information will provide guidance on species vulnerabilities and how they might be addressed. The distance factor will provide guidance for the hazard tree program. As the availability of human resources may prevent inspection on each tree-caused outage a prioritization such as inspecting tree-caused outages on sub-transmission and/or all whole circuit outages may provide a reasonable starting point.

Recommendation 12-11 Substantially increase the intensity of the hazard tree program (Refer to *Finding 7-16, Finding 7-15, Finding 8-20, Finding 8-21*).

API's relatively low incidence of interruptions arising from tree in-growth indicates that API's tree-related outages are arising from hazard trees and overhangs. There are several aspects that need to be separated for API to successfully manage hazard trees.

The ratio of decadent trees more than 2 m beyond the forest edge is very high and this condition is likely contributing substantially to the outage experience. It is recommended that hazard trees beyond the edge (first 2 m) be treated on a 3-year cycle. While growth rates indicate a 9-year maintenance cycle will be adequate for the right of way, a tree mortality rate averaging 2% suggests hazard trees will continue to be a problem if this maintenance cycle is applied outside the right of way.

In the context of the capital widening which has occurred, the instability created by this action needs to be addressed. It is recommended that API patrol for edge hazard trees on an annual basis all areas that were widened. As the edge will become firm over time the patrols should be prioritized based on the most recently newly established edges. If good records are kept on the number of hazard trees identified and removed, the time it takes to establish a firm edge will be revealed. With this data it will be possible to determine whether ongoing annual hazard tree patrols are warranted and where the inspection cycle can be extended.

Once the newly established edges are firm, it is suggested API use the generally recommended 3-year hazard tree inspection cycle and removal cycle.

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