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1. EXECUTIVE SUMMARY

The system cycle is too long given the vegetation in the area. Funding the correct cycle is essential to attaining maintenance mode. Ancillary VM systems are suitable and capable. Staffing for VM is capable but is undermanned. Funding needs to be increased for the short term but would carry a substantial ROI in the future.



Maintenance mode:	Not in Maintenance Mode		
Natural cycle	4 Years		
Work Type	Brush: 26% Side Trim: 24% OH: 24%		
	Crown: 6% Removal: 20%		
% Slow, Medium and Fast	35% SLOW 50% MEDIUM 15% FAST		
% P0 Units in Line Now	37.1% or 27,049 trees		
% P1 Units in Line within 1 Year	8.7% or 6,343 units		
Number of units in contact within	72,909 Units		
5 yrs			

2. SYSTEM FINDINGS

2.1. INTRODUCTION

The VEC system has been randomly sampled using the Arborcisiontm stratified random sampling method. In all 10.7% of the system was sampled.

The collection method is to do samples of the line in half mile lengths. In that area we look at any of the workload that will hit the line, given its past growth indicators, within a 5-year period. This information will inform us of the actual costs to either selectively trim or do ground to sky trimming.

These findings are used to assess the system's status:

- The optimum cycle length
- The projected cost to trim the next cycle
- The total number of trees (units) that will touch the line in 5 years
- How those units are distributed
- The risk of cost acceleration through time by circuit
- Specific critical circuits

The VEC system has also been assessed in terms of its capability and capacity to respond to the findings. These assessments are in terms of safety programs, IT systems, communications, manpower, skill sets and exigent environmental aspects. This information and more is on the Arborcisiontm secured web site and in this report. This report summarizes the sites findings and gives management recommendations.

2.2. SYSTEM INDICATORS

2.2.1. WORKLOAD COMPOSITION

The system composition is the proportion of the workload as described by 5 types of trim. Woody vegetation is split into:

1. Brush

a. A single unit is classed as 500 sq. ft ground area. The reason for this is that this area of brush costs approximately the same as a single R1

(4"-8" DBH) removal or a single side trim. Brush is one of the most cost-effective removal types.

2. Side Trim

a. Denotes a tree that is reaching towards the line from the side instead of underneath or above. This is approximately the same price to remove as a unit of brush or an R1 (4"-8" DBH) removal

3. Overhang

a. This is vegetation reaching across the top of the line, above it up to 15ft away vertically, and is classed automatically as 'in contact' with the line because when removing it the job requires the same level of care as if it was in contact with the line. This is often (almost always) the most expensive kind of trim and is often a source of outage when it fails.

4. Crown Reduction

a. This is vegetation directly under the line but is not suitable to remove, or removal permission has been denied. It automatically denotes a tree that is classed as R3 (12"-16" DBH) or above.

5. Tree Removal

a. These are trees that are R1 (4"-8" DBH) or R2 (8"-12" DBH) or above, in ranges of 4" DBH up to 32+" DBH. It is often the case, except in cases of hazard class of tree (due to fail) or extremely poor positioning (when it falls it will break the line) that 'cost effective' removals are R1 and R2.

The total trees encroaching the line within 5 years is 72,909. The Composition of that work by type is as follows.

ТҮРЕ	TREES	PERCENT OF WORK
Brush	19,017	26.1%
Side Trim	17,133	23.5%
Overhang	17,802	24.4%
Crown Reduction	4,468	6.1%
Tree Removal	14,489	<u>19.9%</u>
TOTAL TREES	72,909	100%

COMPOSITION BY WORK TYPE



The Best Practice Standards in comparison to the current composition of VEC is shown below.

Workload Type	Current System	Best Practice	Evaluation
Crown Reduction	6.1%	Less than 7%	Best Practice
Overhang	24.4%	Less than 2%	Critical Area **
Tree Removals	19.9%	Less than 15%	Critical Area**

The workload composition has a very high loading of Overhang (24.4%) and significant loading of tree removal (19.9%). Excessive amounts in both trims tend to occur when the cycle is too long.

Similarly, an overhang was at one time a side trim which was not addressed. The cost of leaving it to become an overhang has more than doubled the cost to address it.

Overhangs are by far the most common form of outage when they fail, so they represent high risk trims in terms of reliability.

2.2.2. GROWTH RATE



Slow Growth: 35%

[Brush 2%, Side Trim 8%, Overhang 12%, Reduction 3%, Removal 10%]

Medium Growth: 50%

[Brush 17%, Side Trim 11%, Overhang 10%, Reduction 3%, Removal 9%]

Fast Growth: 14%

[Brush 7%, Side Trim 4%, Overhang 2%, Removal 2%]

2.2.3 CLASS JUMPING

<u>Class jumping</u> is the growth increase in diameter at breast height, moving a tree from one class to another; such as from brush to R1, R1 to R2, R2 to Crown Removal, etc. There are several ways to suppress the class jumping phenomenon but by far the most effective is to simply fund the correct cycle length. It is critical in any effort to reduce costs and improve reliability and safety that the correct cycle is maintained.

As can be seen, only **15% of the system is fast growth.**

Given that the weather remains as variable as it has been in the next 5 years as it has been in the last 5 years the **Slow growth** will grow back at less than 1ft a year and this is **35% of the system**; **medium growth** will grow back at between 1ft to 2ft a year and this is **50% of the system**.

Given the minimum ROW distances attained at VEC are 30ft (minor exceptions) then neither of these classes can grow back into the line within 4 years, if the clearance of 30ft to 50ft is achieved, it is only the very fastest of the fast growth vegetation that will stand a chance of growing back into the line, or as it is called, being 'in contact'.

Most importantly, the growth that will have been attained will not have class jumped much at all. Almost all the slow growth will be brush or side trim; the lowest cost of trim class. More than 70% of the medium growth will be expected to be in the same classification and this means that around 2/3rd of the system will be in this form as the cycle starts over again.

This is very significant from two points:

- First, the 1/3rd of the system that may have class jumped is still almost all cost-effective trimming, being predominantly R1 removals.
- Second and perhaps most importantly almost none of it has had a chance to reach the wire and come into contact.

Once a unit is in contact with the wire the cost to remove inflates by 23% to 72%, dependent on trim type and level of line involvement. However, line involvement also affects the potential to create an outage.

Keeping the workload classes 'suppressed' means three benefits come into confluence:

- (i) The costs to trim are all low due to low biomass class
- (ii) Less frequency of trim as much of the work is still classed as brush plus the ingrowth of biomass is still in the early stages of encroachment
- (iii) Very little inflation of costs due to line involvement which in turn means less outages.

A longer cycle is often thought to be generally a good thing because the longer it is between cycles the more the costs can be offset by amortization. This is simply a lack of understanding of how costs are linked to biomass, and how efficiently nature will move into a vacuum of resource to create biomass.

This is the case when the circuit is trimmed, and the area is open to maximum sunlight with no competition for nutrients.

At present, trimming everything in one year, the biomass cost is just a little more than \$20M. Left untouched for 5 years and then trimmed in the 6th year it would rise to cost more than \$76M. This is not MORE work, it is the SAME WORK that has simply gained mass and jumped across class boundaries.

The Arborcision algorithm is designed to minimize that increasing costs by getting the best possible ROI from each dollar spent; even using that method on a 4-year cycle costs will still rise by more than \$6.7M over the 4 years. This is the optimum cycle length in terms of costs in the first cycle.

After the first cycle the same algorithm becomes optimum for reliability due to the strong inverse correlation between costs (which become suppressed) and reliability.



2.2.4 COST FACTORS

Workload Times

The calculation of costs is done as from proprietary data sets in Ai. These data sets show the 'should take times' of each trim type, done in research over several thousand examples of such. The should take times are the distribution of times it should take to do a trim in a particular position or condition. These times are constant through time, even though costs are not. The data shows us how much time it will take to do the work; this is then turned into costs.

Pricing

However, not all costs are equal. Some areas have significantly higher rates (or accept such) than other places, for many reasons. VEC rates of T&M are, in fact, very reasonable, especially given the variety of workload. This cost applied gives us the cost it would take to do the work at the costliest rate, which T&M almost always is, and as such it allows us to create a benchmark to evaluate current methods and their practical application.

Efficiency

The benchmark is applied to the actual costs in recent years. This allows a validation of current method and an idea of the level to which calibration needs to be applied. Once done, the efficiency marker is adjusted to show the costs that the current method needs to apply to completely put the system on a correct cycle. The efficiency calibration is the recognition that a system with so many feedback mechanisms cannot be deconstructed and calculated on a spreadsheet.

Many variables will affect the should take times: unionized workers, workforce experience, the experience of the GF, the location, traffic conditions, weather. There are simply too many to account for localized phenomena, ergo, the efficiency inflation factor does that for us.

By breaking down the calculation into these three critical aspects we can see where costs are being inflated, if that is the case. At VEC this is not the case; costs are in line with expectations.

The conclusion must therefore be that the method of management, although not perfect, is suitable for the current conditions. It should be re-evaluated at the end of the 4 year cycle.

TREES IN CONTACT



There are around 30 trees a mile on average that will touch the line within 5 years

- This means there are an estimated 72,909 trees that will touch the line within 5 years
 - About 37.1% of those (approx. 27,049) are currently touching the line.
 - Another 8.7% (6,343) will touch the line within 1 year
 - This means 45.8% of the system should be in contact within 1 year
 - This is not a good indicator but is due to the excessively long cycle the system is currently on. It should cease to be a problem within one 4-year cycle.

VEC has nearly half of its work (45.8%) units in contact or pending contact with the line within one year. This is the most significant risk to outages, and it should be noted that most of that work is the worst trim to cause an outage, the overhang. This factor will continue to impact the reliability issues for this organization if not addressed.

Again, the shorter the cycle is from its current length to the 4-year optimum the more effectively this problem will be mitigated. Contact with the line also significantly increases costs; but can be mitigated within one cycle.

2.2.5 TREE REMOVAL



The tree removal section of the workload is large relative to normal but that is

because the current cycle length is too long.

Note that the largest proportion of removals is slow growth.

This is literally the wrong way around from what it should naturally be, meaning it is a result of

human intervention.

The reason is how hot-spotting works and what is trying to be achieved when a system is forced to use it.

Each removal class used to be one of many trees in a unit of brush. Each unit that converts is about the same cost as the unit of brush. Allowing slow growth trees to



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grow into removal class units is very inefficient and a clear and indisputable indicator of the system being on an excessively long cycle.

Note also that when we look at the way that regrowth reaches for the line we see a decreasing decay for fast that flattens the effect at 4 years, continually decreasing decay to 5 years for medium and a spiked slow in contact with flat at each year after that. This is the hot-spotting effect in evidence.



The fast graph is the natural system in effect. The medium natural for that growth rate but extended artificially (note the slight rise at year 3). But the extensive share of slow growth in contact is because the slow growth trees rarely get trimmed outside of the natural cycle because most of the time they can wait for the artificial cycle.



This is not bad practice, in fact it is good budget management and necessary because the budget does not cover the system's needs enough, so tough choices must be made.

Given leaving a tree growing into the line less than a foot a year versus perhaps a tree growing at 3 ft a year, when the cycle is scheduled many years into the future, is simply not a hard calculation to make. It is, however, not ideal; that would be to be able to trim both and not need to hot-spot in-between cycles at all within the ROW.

2.3 SYSTEMIC FACTORS

2.3.1 TROUBLE TICKETS

The cost of trouble tickets is a symptom of the system not being in maintenance mode. A large majority of the trouble tickets are simply to trim the trees that are causing concern. These trees are out of cycle making the work is very costly.

Due to the cycle length being so far from its natural optimum the use of trouble tickets, often referred to as hot spotting becomes an increasingly large drain on the budget over time. In many of the most recently trimmed circuits there is evidence of the need over several years to keep intervening on sections of the circuit since the last cycle trim. Effectively, this is at the point where it cannot be truly said, on the larger circuits, that a circuit is trimmed in a single year. In fact, most of those trimmed in 2017 and 2018 show interventions going back several years.

Hot spotting is by far the costliest use of money. In 2017 it was about \$400k of the budget. The frequency of calls to hot-spot, what are termed trouble tickets, is unknown but it is assumed, given the data, that the number is increasing over time.

The hot-spot work is made up of hazard trees and secondary line burning or creating an issue of some kind for the membership, which is normal as secondary should not be part of maintenance but normally does not account for more than a small fraction of the work being done. Most of the work is simply to address reliability or safety issues that cannot wait until the next cycle schedule.

The biggest reason for the inefficiency is the travel time to the job. The work is not systematic in nature so has very little benefit by way of repetition and has a large

amount of set up, take down and travel time relative to the number of trees dealt with. If the system was in maintenance mode, then the only trouble tickets should be hazard trees and secondary issues; a small percentage of the current number.

Approximately \$400,000 of the yearly budget goes to this type of work, which is the least efficient work available, is completely ineffective in terms of maintenance and is simply not normal on a system in maintenance.

As the system moves to maintenance mode, these events should drop off significantly because the system has no time to run out of control before the next trim cycle. The savings should be significant. The frequency of outages should drop off at the same time, and the effects of storms have less impact on areas where trimming has occurred. This is normally a measurable difference and quite easy to prove using GLM methods.

2.3.2 SAFETY PROGRAMS

Our experience of the safety policy in action at VEC leads us to conclude it is exceptional and effective. No issues in this regard to report. Very few systems go to such extremes regarding enduring safety of workers on the system.

2.3.3 IT SYSTEMS

IT systems are comprehensive, extensive and up to date. IT staff had no issues in supplying relevant and relative data on request, quickly and efficiently. The only exception to this was the request for the frequency of trouble tickets, but it can be done and apparently will be tracked in future.

The tracking of all work is comprehensive in all other respects. The analysis of effects less so but fit for current purpose; however, it is suggested that ongoing tracking of the effectiveness of the system to improve needs more intelligence, and metrics are suggested later in this document.

2.3.4 COMMUNICATIONS

It is clear to see that whenever tested, communication between departments is effective and immediate when possible. During the interview process it was said that the saying is that VEC is a 'family'. We found this to be a good descriptor.

Pfeffer in his work Seven Factors for a Successful Organization in 1998¹ set out the indicators for a fearful organization. None of those indicators are evident. Staff at VEC are comfortable speaking out and addressing their points of difference in opinion without fear of reprisal or judgement. As such, inter-departmental communications are effective and open as witnessed.

Within the department there are clearly close links to IT, as would be expected, but between Sara and Jeremy it is evident in the organization of work and the way knowledge is referenced between them on given aspects of the system that this is a team working well. Each knows the role of the other; each takes responsibility and is comfortable with learning new information from the other. There is pride in what they do, and the integrity shows in how well they address a quite impossible task under current funding with vigor and hope.

2.3.5 MANPOWER

The VM department is currently undermanned. As an example, we only need to look at auditing as a use of time. It is an essential part of any program. Making sure that VEC got what it paid for is not just simply good practice, it is ethically essential.

To be on the current cycle means covering around 200 miles a year, just as the overhead line of distribution. As this is only one of many tasks; contract negotiation, bid process, trouble ticket process, monitoring line involvement, auditing the trouble ticket work, dealing with membership issues, dealing with internal reporting, the PUC, etc., one can see how much time this can make up.

Walking 200 miles of line a year, checking for clearance, sending crews back to rework and checking for the scaling of the rates as this is done, looking at the quality of trims, clearance gained, negotiating with the membership over permission refusals and all of this is just an overview of a single task from the less than comprehensive list above.

Now it may be that the staff are ok with continuing to hold the system together with goodwill, going above and beyond the job description regularly, as they must do currently, without complaint; but this is not good planning.

¹ Seven Practices of Successful Organizations Pfeffer, Jeffrey 40/2 (Winter 1998): 96-124

How would the staff cope with a 4-year cycle, which is cheaper and more reliable but impossible to achieve on the current manpower. Further, what happens if one of them slips and breaks a thigh? Any serious slip accident, as an example, not infeasible given the terrain they constantly patrol, and we have a situation where one of them is unable to work for a significant period of time. At present Sara and Jeremy are so fully committed they must be regarded as key personnel to each other regarding the execution of the VM program. Neither could achieve the current practice for very long at all without the other in place. This should be considered going forward.

2.3.6 ENVIRONMENTAL SYSTEM FACTORS

The contracting method in play is a combination of price per foot and T&M. There are many methods in effect that have shaped these methods to be quite uniquely suited to the needs of VEC. The two factors that played the biggest part in shaping the method are terrain and socio-economics.

The terrain is as varied as is possible to imagine. It goes from rural farmland to mountainsides and through suburbia. There are many types of tree that grow tall and on slopes, which would threaten the line when they fall. There are roadside properties that need climbing crews because not all the vegetation can be reached even with a bucket. This variation must be taken into consideration, often on the same circuit so the method of process must be adaptable as a result.

The weather has the potential to be extreme as a standard. The method employed must fit so many possible eventualities, many of which threaten fall-in potential given the terrain and indigent vegetation. This problem is exacerbated by the length of time it is trying to be cleared for, and excessively long cycle.

Socio economic factors also play a large part in the shaping of the method. The area has a large variation is wealth and is an area of natural beauty that is dependent on tourism to a significant degree. It is notable that the current percentage of crown reduction work is at best practice levels; this trim been called the ugly-tree trim. It is not conducive to an area of natural beauty and is suppressed well as a result.

2.3.7 CURRENT MANAGEMENT METHOD

These factors help shape the management method in that the method has to be, at a minimum, adaptable and yet effective to manage with little manpower. There is simply not enough manpower to effectively pre-plan the work in any meaningful way, so the system is developed to try to ensure sufficient clearance for as long as possible through wide clearance paths and strictly defined ROW policies that are audited vigorously.

In short terms, the method makes it far easier to evaluate 'success' by the naked eye if one knows how to 'see' what has been done; it mitigates risk over the longest term possible, but unfortunately cannot fully succeed due to the capability of the system to regrow.

It is working well for the manpower at hand and while other methods may be more cost effective in the future, given the achievement of maintenance mode would mean far less dense work to deal with, the current method is as cost effective as can be expected, is in place, is slightly more cost effective as a well-run T&M program and has the benefit of being fully adaptable and scalable going into maintenance mode.

All that said, it is not fully working, as is evident from the composition and percentage of the workload in the line and is probably close to the most efficient it will be under current funding.

The analogy that perhaps best describes the problem is one of 'plate spinning'. A circuit should be cleared in a single year, but often the budget runs out or there simply is not enough because resources are needed elsewhere to stop serious line involvement. This is past work that has grown back, in places, before the end of the current cycle and is now causing problems.

Instead of efficiently using the budget now part of it must be spent, in the costliest way possible, to keep prior trimmed circuits on cycle. This diversion of funds to keep the 'plates spinning', the status quo, creates future problems for the system and of course all parts of the system suffer the same 'cycle busting' issues anyway because the natural cycle is not being addressed. Nature cannot be forced it will always fight back.

The system fighting back is evident in the data. Circuits are trimmed over many years, and long circuits especially have heavy evidence of Trouble-Ticket intervention over many parts of the circuit over time.

2.3.8 PRIOR TRIMMING

In consideration of previous trim quality, 97.6% of the past work was a passing grade, with a fail rate of 2.4%. This is the consideration of trimming practice as it relates to the current work; has past practices promoted current problems.

Anything where the fail rate is below 5% is considered good, therefore the quality of work by the contractors is not a problem.

2.3.9 TRACKING PROGRESS METRICS

There are three very effective methods of determining progress in a system moving from the wrong cycle to the correct cycle over time.

The first and most effective is the **trouble-ticket inter-arrival time**, tracked over time: the Poisson distribution value of inter-arrival time for trouble ticket calls should be tracked over time using the SCP method of monitoring.

There are 7 patterns that show a distinct difference in a process that determines an abnormal event, i.e. not random. As the system improves, signals that denote increases after storms should become less frequent (weather monitored via wind speed, gust speed variance and precipitation) while signals that denote reductions in frequency should become more common until the system settles into a new norm.

SCADA data tracking flow over time should be tracked for periodic (period to be determined from analysis) point analysis via alterations in standard deviation; which should both drop and stabilize after each circuit is trimmed.

Outage frequency (SAIFI) as a moving average (tree related) is a standard tracking device. Efficacy in this regard is heavily influenced by data collection special cause variation, which should be noted via generalized linear modelling methods and incorporation of the data collector as a variable.

2.4 CYCLE LENGTH

The cycle length on the system clearly shows a 3-year cycle, as depicted by the highest bar in the following graph.



However, the primary reason for this peak, which is very close to the 4year peak, is due brush to growing in quickly, as it is mostly medium and fast growth rates, and the residue of overhang (50%

slow growth) which is left over from prior hot spotting work.

If those are taken out then removals, side trim and crown reductions clearly show



an exponentially rising level of increasing costs, a natural rise, to year 5.

This means that the peak at 4 years is the actual natural peak and the 3-year cycle being shown is unnatural and the result of being so far off the natural cycle at present. **The system is therefore recommended to be on a 4-year cycle.**

2.4.1 CYCLE MODEL AND WEATHER

Cycle models address the issue of success, and success can be couched in many terms. In terms of VM we believe it is best to couch success in terms of balance because that is the point when there is the least amount of waste. A system that is constantly being managed, and constantly striving to not be managed as complex adaptive systems² tend to do, will display greater volatility as the system is pushed further from its natural equilibrium.

The greater the level of volatility in a system, the greater the amount of waste; this is the basic principle that governs TQM³ systems and is suitable to apply to UVM



systems.

The current cycle is for 12 years and the objective is to get to an 8-year cycle. It is unlikely to be achievable without further funding. The reason is the capability of the system to take hold at a rapid rate.

Clearing a system, even one that is dominant as slow and medium growth as VEC is, promotes the return of growth as predominantly fast growth. This is a natural expectation; nature rewards the hare more than the tortoise.

Repeatedly clearing an area will naturally promote the

regrowth of fast growth species, as is the case with the brush composition.

 $^{^2}$ A complex adaptive system is described as one with multiple feedback loops to each node within the system. As such, prediction of a particular state at any time is extremely difficult to predict with any degree of accuracy. In such systems, success is therefore best described as a measure of "stability".

³ Total Quality Management, as defined by Deming and adopted by most engineered systems.

Constant regrowth into the system of fast brush, which converts to R1 rapidly, etc., is only stemmed by the regularity of clearance.

The longer the time between the clearance the more susceptible any system is to the vagaries of weather.

In good weather years, the capability for the majority of slow to become medium, the majority of medium to become fast and most of the fast growth to put on a lot more than just 3 feet a year is not only possible but probable.

The weather in the area is extremely varied: it makes sense to plan for the possibility of extreme growth in a cycle of 8 years or longer. In the current system a weather anomaly promoting fast growth rates would simply take the system off budget or impact growth into the system in such a way as to affect negatively the capability to be on schedule for years to come. Shorter cycles have much less susceptibility to weather impacts and recovery is much faster.

The importance of cycle length

It cannot be stressed enough the importance of the correct cycle to a system. If the trees are left to grow too long then the reliability indices drop in an exponential decay; the cost of repair raises hyper-geometrically, power outages become commonplace; the cost of all that class jumping means it's not cost efficient and certainly not good for customer relations, legal risk or outage data.

The balance point is rooted in the probability of interference and the method for determination of the balance point is through the calculation of the Efficiency Savings Dividend (ESD), which is a calculation that accounts for the future cost of class-jumping.

If a tree that can grow into the line is directly under the line it should be removed. It will always be a problem, always be fighting to interfere with the line; it should never be left unless it is already too late to trim it cost effectively.

If it is to the side it can become a side trim, and the further away it gets the more it should become one rather than a removal. Once a tree is removed the space it leaves initially has the potential to be nothing else except Brush. Brush is the most cost-effective form of tree removal there is; easy to do and less chance of an emotional attachment for the land owner. Brush removal also denies the capability of the tree to be anything other than a space for more brush.

So, a crown reduction should have been a tree removal while it was still small, or brush before that, thereby reducing future Crown reductions, and again the 'just clear enough' nature of the current contract to trim is an obvious source of the high proportion of CR on the VEC system.

In high growth years, trees expected to be R1 or maybe R2 by the time it comes around next time are instead too costly to remove and become crown reduction. This is a trait that should be actively planned against as, over time, this proportion will simply continue to expand.

Similarly, as the trees are removed from the side of the lines the proportion of Side Trim relative to total workload increases. Future overhangs are naturally low in occurrence if this approach is maintained.

Consider the effect on the system over time of removing trees based on their capability to interfere with the line, regardless of volatile growth considerations. The system naturally has low incidence of overhang and crown reduction.

Tree removals eventually drop to natural proportions caused by weather incidents, accidental damage, disease and large and unstable growth in from the sides.

Eventually the predominant growth is growth coming in from the side and brush under the line, which becomes proportionally high, and then in order of decreasing frequency we then have brush, tree removals, crown reductions and finally overhangs. At this point the system is now described as being in maintenance mode. This status is what we term as a system in balance.

The root of the historical difficulties of a system lies in the evidence left behind; the patterns within the data in conjunction with information from those that work within the system show the capability of the system to improve. The whole point of doing the cycle models is to lay a path to the achievement of the transformation of a system out of balance into one that is in balance; a path to the maintenance

mode. The recognition of that point is the measure of one proportion of work type to the other.⁴

Recommended Trim for eac	h Circuit Group			
Circuit Group Q	Optimal Trim	Price	Price Per Mile	Location
otals	-	\$896,125.00		
-4	Year 2	\$275,537.71	\$8,759.35	YES
-1	Year 2	\$493,208.75	\$6,628.95	YES
-3	Year 2	\$119,831.83	\$2,431.82	YES
-3	Year 1	\$7,546.71	\$6,337.40	YES

2.4.2 EMPIRICAL EVIDENCE IN THE DATA

If we look at some of the most recently trimmed circuits, we can see the following:

We can see that the cost per mile is coming back at about \$5,600 BUT the cycle schedule it is asking for is to do them either this year or next year. While it is true that these circuits were completed in this year or in 2017, so should not be ready to trim until 2029, there is already a need to trim them.

It is not poor trimming; the fact is that whilst completed in 2017 or 2018 these circuits have been trimmed and have all had trouble ticket work done on them for several years into the past.

The current management method works, but the current funding does not as it does not address the need to cycle more often.

Note the composition of the workload in these four circuits: the cost of overhang alone, a systemic result of the long cycle and under-funding, is 25% of the current costs. This trim type would almost disappear in a single cycle, the effect of this

⁴ This is a proprietary method and as such this information is confidential and covered by our copyright with all rights reserved.

alone would drop the per-mile cost to \$4,200; this is on a par with current costs, but the system is far more reliable and far less susceptible to storm damage

However, the costs on display are still carrying the effects of the long cycle sporadic instances of regrowth, in other words they contain growth over several years, some of it longer than 4 years. As such the regrowth in future cycles would be significantly less and carry far less class jumping costs, hence less frequent removal classes and no line involvement, which even on these circuits is still at 37% (most of which is the overhang class) but is at least a further 23% of 13% of the selected circuits PLUS less vegetation and the vegetation there is very cost effective to remove. This perfectly describes a system in maintenance mode, and the cost of this is now significantly cheaper than the current 12-year cycle.

So, to summarize, a shorter cycle is measurably cheaper than the longer circuit because it mitigates cost inflation factors. The side-bar benefits are more reliability and improved storm resistance.

2.5 CRITICAL CIRCUITS

When considering the cycle for VEC it should be understood, from the outset, that



there are critical circuits due to the imbalance of potential for costs to inflate over time on each circuit.

These can be shown on this graphic, where the larger the circle the larger the potential for price increases over time.

Q	Optimal Trim	Price	Price Per Mile
	-	\$5,975,146.30	-
	Year 1	\$819,985.27	\$19,364.39
	Year 1	\$763,791.56	\$8,691.18
	Year 1	\$508,579.18	\$11,307.98
	Year 1	\$431,621.67	\$13,433.79
	Year 1	\$369,245.77	\$7,461.92
	Year 1	\$328,067.89	\$3,727.35
	Year 1	\$304,350.40	\$7,819.45
	Year 1	\$291,421.36	\$7,536.18
	Year 1	\$266,154.88	\$13,230.54
	Year 1	\$242,301.70	\$3,898.70
	Year 1	\$237,723.91	\$6,222.69
	Year 1	\$188,138.10	\$9,928.06
	Year 1	\$178,431.99	\$6,827.75
	Year 1	\$171,319.37	\$8,440.92
	Year 1	\$164,902.07	\$13,558.90
	Year 1	\$159,034.88	\$4,490.65
	Year 1	\$156,559.25	\$9,964.08
	Year 1	\$103,549.00	\$5,540.18
	Year 1	\$81,545.84	\$5,546.38
	Year 1	\$66,461.20	\$15,176.84
	Year 1	\$45,712.85	\$3,303.75
	Year 1	\$41,707.79	\$6,640.12

As such, even though the group for year 1 is 31 circuits, 6 of those circuits (20%) carry approximately 50% of the savings for that year.

These are clearly critical circuits and should not be done in any other year if possible.

3 FINANCIAL

3.1 BUDGET

The system should be put on a 4-year cycle. The cost of maintenance for this would be \$26.7M over the 4-year period, or \$6.6M per annum.

In the first cycle it should be expected that the legacy of the previous growth will continue to generate T&M costs, albeit on a decreasing basis.

It is highly recommended that the process of permissioning, auditing and potential manifest creation for some contract methods be outsourced. The language of the contracts also needs expert help, as does the updating of the ROW policy where necessary.

It is critical that the question of bid pricing, permission to address overhang and crown reductions, as well as distance of trim from the line be addressed as it is the source of a great deal of the current legacy issues.

The budget should therefore be:

Description of Budget Costs	
Estimated Cost to Trim including Class Jumping	\$26.7M
Estimated Cost to Trim Per Budget Year	\$6M
Breakdown of costs	
Cost of Trimming for workload alone in	\$20.7M
the next 3 years	
Cost of class jumping	\$6M
Full ESD potential (included already)	\$11.85M

3.2 OTHER COSTS

The maintenance costs do not include:

- Herbicide program costs
- Trouble Ticket costs
- Additional Manpower Needs

3.3 ESD – COST SAVINGS

The Estimated Savings Dividend (ESD) is calculated on the impact of the trim cycle on potential growth – class jumping and regrowth behaviors. The ESD for VEC is an estimated \$11.85 MILLION.



3.4 BID PRICING

The Arborcision algorithm generates a specific order of trim to save money from the potential of the system to increase in cost over time.

In this way, the order of trim makes a big difference due to class jumping and growth into the line.

Following the 4-year suggested plan the order of trim saves increasing costs of:

- First Year ROI from trimming is \$3.8M
- Second Year ROI is \$4.2M
- Third Year ROI is \$2.5M
- Fourth year ROI is \$1.35M

It should be clearly noted that any alteration to the order of trim incurs extra costs and by default decreases the savings.

4 RECOMMENDATIONS

4.1 METRICS AND TRACKING

The following metrics should be created and tracked over time to measure improved (provable statistically) success in the program.

- Trouble ticket inter arrival time, tracked over time
- SCADA data variance over time
- Outage frequency (SAIFI) as a moving average

4.2 Suggested Plan

- Full funding is advised high initial costs but lower prices later reaps benefits in fiscal, legal risk, storm strengthening and reliability terms.
- Suggested 4 year cycle in line with natural growth rates
- Alternative options are:
 - a. Multi-cycle approach, leveraging benbefits from the first partial covberage of the system onto other parts of the system.
 - Assessing the 'worst' parts of the system, in either growth rate terms (fastest) or in reliability terms and put those on shorter cycle
 - c. Assess portions of the system that will require a lot of hotspotting and put partial parts of the circuit onto shorter cycles
 - Alter the ROW policy specs to try to create conditions for a longer cycle by aggressively addressing the fast growth trees (15% of the system)

5 Appendix A: Validation of Findings

Below is a histogram of the workload with a Normal distribution fitted; note the data is skewed to the right and seems to fit a Weibull distribution.



Below is a table of statistical moments

The UNIVARIATE Procedure							
Variable: logTC							
	Moments						
N	3442	Sum Weights	3442				
Mean	1262.54422	Sum Observations	4345677.21				
Std Deviation	887.077682	Variance	786906.814				
Skewness	0.57811347	Kurtosis	-1.0413335				
Uncorrected SS	2707746346						
Coeff Variation	70.2611178	Std Error Mean	15.1201542				

All the above statistics are within normal bounds except the Kurtosis, which is very slightly higher than ideal. This means that in some parts of the data the system is sporadic in its workload definition, but in terms of accuracy it is not a problem. The result of the large kurtosis is a distribution with a high peak and 'fat' tails, which

means in the extreme edge of the distribution the propensity for extreme values is possible on some of the circuits; as the system settles into the new composition (after the first cycle) these issues should dissipate. The reason for the slightly high kurtosis is the way the circuits are done pieces and parts at a time, so is expected in the data.

The standard tests to establish suitability for inference have been done on the data. Autocorrelation is not an issue in the data, as determined by the Durbin-Watson test. All of this means that the data is suitable for inference using parametric testing, and that the data is a cohesive representation of the VEC system.

6 Appendix B: Sampling Methodology

Any sampling method should seek to remove bias at every opportunity, because the point of sampling a system is to arrive at an unbiased representative sub set of the whole system so that extrapolation and inferences can be made.

All UVM systems are broken into "management centers", and they form a natural set of clusters to build a hierarchy onto. It is sensible to do this, not simply for reason of reporting, but also because the system may have bias inserted in some form by these man-made boundaries, and it makes sense to recognize this from the outset. Within these management clusters, but seen from a holistic perspective, the system has other natural clusters, both man-made and natural; Ai has researched the nature of these relationships and uses them to build "layered" representations (strata) of a system, thereby accounting for human, natural and management legacy sources of bias in the selection criteria. These strata are the essence of bias in any UVM system and must be accounted for to remove specific and special variance sources.

A form of cluster analysis is done to create weighted stratified sub-systems and we apply those weightings to each of the management centers to create sample ratios of weighted strata for each. The next step involves separating each of the circuits in the system into their respective strata and ordering them by label hierarchy. The reason for this is to create a natural rank order that may contain the temporal bias of when each was created: bias such as design imperatives, size, shape, collective environmental constraints, etc. It may also serve to incorporate any systematic bias imposed by management directives at the UVM organizational level, should any of these exist. Again, we seek to remove even the possibility of bias in the selection techniques used.

When ordered in this way, with weightings and strata in place, a random sample within strata is obtained in proportion to the weight of each stratum; these form the list of circuits to be sampled. In this way no part of the system is given a predetermined bias by the sampler, regardless of system design or geographic anomalies.

Once a sample is obtained, the data regarding process of collection and the selection data itself is analyzed to ensure that the collection method is uniform and that the data itself is homogenous. In other words, we remove any possible bias inserted by the people collecting the data. We used our ready team to collect the data; a selection of people with specific skills that minimize the chance of bias at the root cause of subjectivity in decision making.

To summarize, this is a method of collecting random samples, systematically selected from weighted sub-strata that covers the UVM system comprehensively, using geographic, demographic and managerial criteria, so that the samples selected remove bias in four layers of complexity: utilizing four types of random selection methods nested together using our unique and empirically tested method. They are dispersed across all managerial sections (geographically) and clustered to match population dispersion.

Only when the nature of the system demands it as necessary are the samples adjacent to each other. The collection processes are then analyzed to ensure that application of method is statistically uniform; and that content has no outliers to a 95% tolerance limit. The sampling method, in Ai's opinion, covers all possible sources of bias. The result is a valid view of the system that can then be analyzed to answer the client's questions.

Sampling Process

Once the samples were set the crew were designated a login to use on specific software designed by Ai to capture the data needed. The data was analyzed as it is downloaded (daily) and tested for conformity between collectors and for internal auditing of staff.

At the end of each day the data collected was downloaded to a central secured server and several quality checks were done: location of sample to data entry point; time of sample; proportion of composition elements (side trim, removals, etc.); travel time; density of workload; location. Because each circuit is shared the data can be assessed for potential error. Also, because each key stroke on the tablet is stored and time stamped the process of each collector can be assessed in terms of having trouble with classification of the work, or being unfamiliar with the software, or finding the samples, as well as seven other internal quality checks in terms of data and process.

Any crew member that had shown a statistically valid variation in process is followed by a senior staff member to ensure he/she was adequately trained. All data was randomly selected for audit by senior staff. All outliers were routinely checked.

Note that there will always be outliers, there has to be in the initial stages anyway because the data is not yet representative, so this does not designate erroneous data, but rather it is simply a 'belt and braces' approach to ensure as far as possible the efficacy of data collected and the systematic removal of error from the process. Once the initial data round is collected the data is checked and staff are sent out again to 'trim up' the data so that it is at the end a representative sample of the original data.

Representative Sample

The data runs through several checks to ensure it is a normally distributed sample. These are the Kolmogorov-Smirnoff, Cramer-Von Mises and the Anderson Darling tests. It is then tested for robustness of Scale using the Trimmed Means Method. Finally, it is tested for location (does the data come from a Normal distribution) using the Student's t, Sign and Signed Rank Tests.

Once the findings confirm that the data is good, the data is tested for conformance to a 5% error variance. This is done by 'slicing' the dataset into subsections from 1% to 99%. These slices can be tested for the efficacy of their proportion by creating a symmetrical confidence limit from the rankings and testing the cumulative binomial distribution of the data conforming to that slice; this probability is denoted as the 'Coverage'.

To be a representative sample, each 'slice' must be less than 5% in error from the rest of the body. In other words, capturing more data would not improve the dataset significantly because each slice is a part of the whole; a cohesive set.

It follows that if we collect enough data to satisfy the coverage criterion at the 95% limit to the 95th percentile it is, representative dataset because it is stabilized between categories and is a coherent set across all category definitions.

Whatever that dataset then denotes, is what is in the field to within 5% variation. Tests are done on the data as it is collected to assure that bias in the collection of data in not inserted as part of the process.

As the dataset builds, further testing on the ability of the data to state that it is all from a cohesive and single set (that it represents the system) creates a second round of samples to "true-up" the data; this entails testing the quantile of the probability density function (PDF) that the data describes for proportionality to each other.

Testing Quantiles of the Probability Density Function (PDF)

This test is shown in the table below:

Quantiles (Definition 5)									
Level	Quantile						Order Statistics		
		95% Cor	nfidence	95% Confidence		LCL	UCL	Coverage	
		Lin	nits	Limits		Rank	Rank		
		Assu	ming	Distribut	ion Free				
		Norn	nality						
100%	3012.03601								
Max									
99%	3012.03601	3270.312	3384.476	3012.0360	3012.036	3397	3420	95.10	
95%	2830.04243	2677.040	2768.000	2830.0424	2830.042	3245	3296	95.40	
90%	2615.11625	2360.050	2440.074	2615.1163	2830.042	3064	3133	95.01	
75% Q3	2129.87426	1828.393	1894.085	1962.8094	2129.874	2532	2632	95.10	
50%	946.70517	1232.899	1292.190	931.9994	946.809	1664	1779	95.00	
Median									
25% Q1	527.35254	631.003	696.696	510.2667	540.684	811	911	95.10	
10%	295.80907	85.014	165.038	289.8346	313.816	310	379	95.01	
5%	216.67307	-242.912	-151.952	169.5166	218.993	147	198	95.40	
1%	62.41742	-859.388	-745.223	41.0661	67.590	23	46	95.10	
0% Min	7.46624								

The right-hand column shows the coverage. This is the cumulative binomial probability that this data set, at each quantile slice, is proportionally cohesive to the rest: that the slice is what one would expect it to be given the variance displayed within it and in relevance to the variation in the whole set. To satisfy the 5% error variance criteria, we must have more than a 95% coverage value to at least the 95th percentile, and it does in fact show that we do.

This also shows that the estimated (from the data) average of each quantile is within the 95% confidence bounds empirically. In simple terms, this test shows that each data sample 'belongs' to a cohesive whole: each data point is in fact part of the same group, and therefore we can be sure that adding more data does not significantly improve the findings.

7 Appendix C: Distribution and Normality

The test for Normality in a data set is done to establish the validity of parametric hypothesis testing and inference. In most cases we are looking for validation of expectation in the data, so data that shows the number of people in a queue would be a Poisson distribution, and the times between an incidence an exponential distribution, etc.

While collecting the number of trees within a fixed radius from random points within a natural forest would show a Normal distribution, as all-natural systems display, the evidence of a Weibull distribution actually depicts a pattern left in the system: that pattern is primarily human in origin, as the Weibull distribution denotes human processes are evident; that the pattern is human in origin, and hence unnatural in the pure sense.

The Weibull distribution is unique in one respect, which is that it can mimic other distributions as its shape changes. So as its mean approaches 0 it mimics the exponential distribution, and at 1 it mimics the Poisson distribution, and when it reaches around 3.17 it mimics the Normal distribution. In many engineering



settings it mimics the hyper-geometric mean as its mean value rises even higher. The reason for this is that human processes can be described using all distributions; it just depends on the process being measured. The graph below clearly shows an adherence of the data to a Weibull distribution.

Of course, the Central Limit Theorem states that all distributions, if sampled above 30 times, will give a Normal distribution, the most common of all distributions and one naturally occurring ubiquitously throughout nature. In this way it is only imperative in testing for 'Normality' that we find a distribution with sufficient capability to sample, and our sampling method ensures that this is the case. The importance of the determination of the Weibull distribution is that it shows evidence of a consistency from human intervention.

8 Appendix E: Predictive Modeling

Tests that determine categorical significance are called Canonical or Generalized Linear Modeling techniques. In recent times they are often referred to as Predictive Modeling. They are useful for finding the correlated or root causes of variation in the system in respect of categories.

As an example of this, let us assume that we have two simple category of tree type: hardwood and conifer; and within these categories we have Diameter at Breast Height (DBH) categories. We also assume we have associated costs for the removal of failed trees from a storm. If we were to run a GLM procedure on the costs to remove relative to DBH and Tree Type; and associate those costs and those relationships with tree contractors doing the work, we could determine by what percentage of probability where the dominant cause of cost increase lies: contractor, tree type, DBH or any combination of all three. Understanding this allows for targeted planning and the ability to calculate the potential ROI for the execution of the plan. It also allows good auditing to occur, because we have a method of benchmarking expectations. Conversely, if no model exists we can say with some degree of certainty that none of these attributes are drivers of cost after a storm, and that auditing does not need to account for these variables in evaluating results.

In this output in the VEC data, what we are asking of the data is whether categories such as age, location, region, customer interaction, DBH, density of workload, etc. are drivers of cost to the system or not. The tests also show us how these variables may react in combination with each other.

ECHO

Generalized Linear Modlling (GLM) is a method of determining whether groups within, or aspects of variables within a distribution are similar enough to be called indistinguishable, or statistically significantly different. There are many such tests that have different weightings relative to the nature of the data at hand.

In the case of the VEC data we needed to know why the patterns in the ESD showed such a short cycle relative to the actual cycle they are on, which is 12 years.

In order to determine what the data says, in other words how long the effects of trimming go back into the data through time, we used the "clearance" variable against costs.

This means that for all trees classed as PO (in the line) there is a distribution of costs, and for all trees P1 year away from the line (clearance =1) there is another distribution of costs, and so on.

The hypothesis is that the system should display a large propensity to be indistinguishable across most of a 12 year spectrum, in order for the 12 year cycle to be the correct one. Therefore the question being asked is: at what point does the clearance data show a difference in price; at what point does the effect of trimming wear off? In short, how long does VEC effectively get for its money?

The tests used were Waller, students-t, Duncan and Students Neuman Keul (SNK). The effects are shown below. Each of them shows the same finding: the echo back through time wears out at 3, years, so the 4 year cycle is appropriate.

The GLM Procedure Waller-Duncan K-ratio t Test for logTQ

Note: This test minimizes the Bayes risk under additive loss and certain other assumptions.

Means with the same letter are not significantly different.							
Waller Grouping		Mean	N	Clearance			
	А	371.75	357	1			
	A						
	А	368.95	328	2			
	А						
В	А	358.46	717	0			
В							
В		341.54	363	3			
	С	315.91	360	4			
	С						
	С	314.35	334	5			
	D	257.46	308	9			

The GLM Procedure Duncan's Multiple Range Test for logTQ

Note: This test controls the Type I comparison-wise error rate, not the experiment-wise error rate.

Means with the same letter are not significantly different.							
Duncan	Grouping	Mean	N	Clearance			
	A	371.75	357	1			
	A						
	A	368.95	328	2			
	A						
В	A	358.46	717	0			
В							
В		341.54	363	3			

Means with the same letter are not significantly different.								
Duncan	Grouping	Mean	N	Clearance				
	С	315.91	360	4				
	С							
	С	314.35	334	5				
	D	257.46	308	9				

The GLM Procedure Student-Newman-Keuls Test for logTQ						
a	Means with the same letter are not significantly different.					
SNK C	SNK Grouping		Ν	Clearance		
	A	371.75	357	1		
	А					
	А	368.95	328	2		
	А					
В	А	358.46	717	0		
В						
В		341.54	363	3		
	С	315.91	360	4		
	С					
	С	314.35	334	5		
	D	257.46	308	9		

WEALTH

The information below is from a categorical analysis of the data, with the dependent variables being cost of the workload (logTC). This type of analysis is often called canonical analysis and is a form of regression. The objective is to find categorical aspects (can be non-numerical) of the system that contribute either to

disproportionately increasing costs or to disproportionately increasing workload quantity.

Localized Increased Costs

We have almost always found that customer intervention in trimming practice results in making it more expensive. This is not so unusual as it may at first seem. The contractors are not paid to liaise with the customer base, but rather to trim the trees. The more invested a customer is with their landscape the more involved they are with the process, and as a result we often find less clearance, selectively 'skipping' trims that are historically difficult to get and especially the case of less work being done if it is not roadside.

The first box shows us the result of an ANOVA (Analysis of Variance) test for a model based on the analysis of variance by cost. The Pr>F test being 0.0001 (less than 0.05) in table 7 shows a clear model is generated. This denotes that the choice of variables in the model significantly explains the variation within the model.

However, while a clear model for explaining the variation is found the following table 8 shows it is possible to predict using that model as the R-Sq value is above 0.20; the minimum required for a model to be a valid predictor; with a value of 0.650509 this is regarded as a strong model.

It must be concluded therefore that there is influence of the contractor's behavior that results in a cost increase relative to customer involvement.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	124	106003868.8	854869.9	39.66	<.0001
Error	2642	56951414.0	21556.2		
Corrected Total	2766	162955282.7			

R-Square	Coeff Var	Root MSE	logTQ Mean
0.650509	43.55430	146.8202	337.0969

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AverageHouseValue	62	101821054.9	1642275.1	76.19	<.0001
WorkType	1	244370.0	244370.0	11.34	0.0008
Clearance	6	655041.7	109173.6	5.06	<.0001
AverageHous*WorkType	55	3283402.2	59698.2	2.77	<.0001

The model shows, in the table above (Type 1 SS) that the value of a home, onroad/off-road (worktype) and the proximity to the line (Clearance) are all positive factors to price. The strength of the relationship can be gauged by the F-value. This table shows how each subsequent variable may affect the other, and as can be seen the value of the home and the factor of being on-road or off-road are drivers of cost in conjunction with each other..

In the lower table (Type 3 SS) the strength of the relationship is measured as independent variables. Notice that worktype alone is not a significant driver; it is only a drivber of cost when in a wealthy area. Note also that the effect of the wealthy are is diminished when considering it as a driver without worktype joined, although it is still strongly significant. Note also that clearance is a factor for cost in both.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AverageHouseValue	62	91213003.62	1471177.48	68.25	<.0001
WorkType	1	17.42	17.42	0.00	0.9773
Clearance	6	648811.88	108135.31	5.02	<.0001
AverageHous*WorkType	55	3283402.20	59698.22	2.77	<.0001

The conclusion must therefore be that wealthy areas are more expensive to trim, mostly because clearance is affected, and that this is more so the case when work is offroad as opposed to onroad. This is evidence that the contracting execution is being affected by the membership is wealthy areas.

Given that the current contracting method leaves the connection to the client primarily with the contractor, through necessity from manpower resource shortfall and by dint of the fact that the contracts are written that way, very little can be done to address this fact other than to stress in the ROW specs that full clearance must be gained or VEC staff must be called in to negotiate. This would be a significant increase in time spent by VEC in contact with the client to an already stretched resource.

It would help in the next cycle to be cognizant of it and try to address it when possible, but for the next cycle it is far more important to simply get onto the correct cycle length. It can then be reassessed.