Appendix 5.16: Distribution poles ASP

Regulatory proposal for the ACT electricity distribution network 2019-24
January 2018

Disclaimer: On 1 January 2018, the part of ActewAGL that looks after the electricity network changed its name to Evoenergy. This change has been brought about from a decision by the Australian Energy Regulator. Unless otherwise stated, ActewAGL Distribution branded documents provided with this regulatory proposal are Evoenergy documents.

ASSET SPECIFIC PLAN

Distribution

Poles

Document Number: SM1126

Version Control

Date	Version	Description	Author	Reviewed
20/04/17	1.0	2014-19 regulatory submission		
28/9/17	2.0	New template with options analysis and risk modelling, initial issue for 2019-24 regulatory submission		
31/10/17	3.0	Top down challenge updates		

Approval

Author	**Primary Assets Engineer**	Signature	3/11/17 Date
Endorsed	**Primary Assets Manager**	Signature	3/11/17 Date
Approved	**Branch Manager Asset & Network Performance**	Signature	3/11/17 Date

Reference Documents

Document
National Electricity Rules
National Electricity Law
Utilities Act (ACT)
Electricity Distribution Asset Management Policy v7.0
Asset Management Strategy v2.16
Asset Management Objectives v1.3
Asset Management System Manual
PR5017 Recovery and disposal of reclaimed network assets
SM4606 Environmental PCB Management Plan
Pole Strategy Review 2016

Table of Contents

Glossary

Term	Definition
AAD	ActewAGL Distribution
AEMC	Australia Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ASP	Asset Specific Plan
CAPEX	Capital Expenditure
CB	Circuit Breaker
CT	Current Transformer
FMEA	Failure Mode and Effects Analysis
HV	High Voltage
IED	Intelligent Electronic Device
kV	Kilovolt
LV	Low Voltage
NDT	Non Destructive Testing
MTBF	Mean Time Between Failures
NER	National Electricity Rules
NSP	Network Service Providers
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
OPGW	Optical Ground Wire
PoF	Probability of Failure
PoW	Program of Work
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
STPIS	Service Target Performance Incentive Scheme
VT	Voltage Transformer

NOTE

All analysis has been undertaken using 2017/18 real dollars unless otherwise stated. Budgeted expenditure for CAPEX & OPEX excludes indirect costs.

Document Purpose

This document is an Asset Specific Plan (ASP). This ASP provides the business case for asset management strategy selection and specifies the activities and resources, responsibilities and timescales for implementation for this specific asset class. In conjunction with the other ASPs, it forms ActewAGL's Asset Management Plan, which describes the management of operational assets of the electricity distribution system.

Asset management options are assessed in the context of the asset class' current state, condition, performance, risks, life cycle costs, trends and external environment. A recommended asset strategy is presented with associated capital expenditure and operational expenditure forecasts, including a 10 year budget forecast, for consideration by ActewAGL management.

Detailed in this document are the systematic and coordinated activities and practices whereby ActewAGL manages the asset class in an optimal and sustainable manner for the purpose of achieving the organisational strategic plan.

Audience

This document is intended for internal use by ActewAGL management and staff. As part of legislative, regulatory and statutory compliance requirements, the audience of this document is extended to relevant staff of the ACT Technical Regulator and the Australian Energy Regulator.

Document Hierarchy

ActewAGLs asset management system aligns with ISO 55001. This document complies with ISO 6.2.2 planning to achieve asset management objectives. Figure 1 shows the alignment of ASPs in the asset management system.

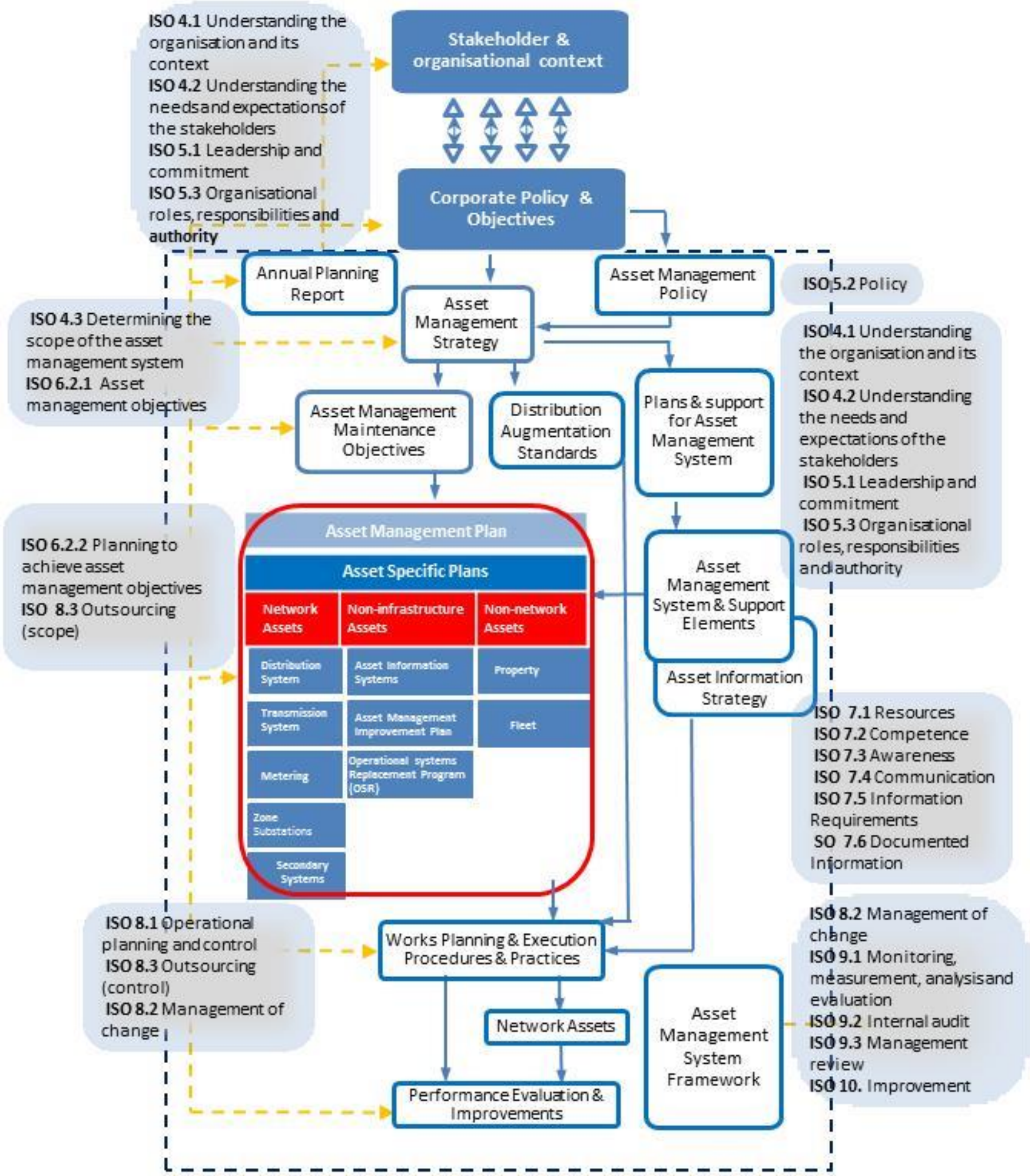

Figure 1: Asset management system structure

1 Executive Summary

The Distribution Poles asset class includes poles that support the overhead network suppling customers. Distribution Poles support 22kV, 11kV and 400V distribution network feeders including components such as conductors, overhead switches and transformers. The distribution network has 49,410 poles of the following material types:

- Timber
- Concrete
- Steel and
- Fibreglass

Distribution poles are critical assets with asset failures presenting significant risk to customers and the community primarily in network reliability and bushfires in high bushfire risk areas. On average, 1,307 customers are affected by an outage from a HV pole failure as well as potential bushfire and safety risk which varies by location. Distribution pole assets have a high cost of failure and should be replaced before complete failure to manage the environmental, safety and network reliability risks.

Since 2011/12, distribution pole performance has been strong and AAD has maintained zero unassisted failures (not caused by storm or 3rd party). Based only on AADs pole population and the industry average for pole failures, AAD could expect 4 failures per year at industry pole failure rates. While the AAD pole strategy may be traditionally been more risk adverse than the industry, AAD intends to have a low rate of in-service pole failures.

The pole strategy was reviewed in 2016 with the objective to seek opportunities to reduce cost while managing risk to an acceptable level. A summary of the options considered are:

- Option - 0: Reactive Strategy – effectively adopt a “run to failure” approach;
- Option - 1: Reduce serviceability criteria and Non-Destructive Testing (NDT) – Proactive condition assessment and replacement, with NDT trial
- Option - 2 Reduce Risk Strategy – Proactive condition assessment and replacement (higher serviceability criteria) with destructive testing

The preferred option from this evaluation is Option 1 – Reduce serviceability criteria and NDT. This strategy includes a Non-Destructive Testing (NDT) trial program for timber poles and reduces the serviceability criteria for pole strength. The NDT trail period is 12 months and finishes in June 2018 where a recommendation will be made to continue with NDT or not. This option lowers the lifecycle cost of timber poles and defers capital investment by enabling poles to remain in service for longer and in poorer condition. Although serviceability criteria is reduced, it is in-line with industry standard and asset performance remains with sufficient structural strength to support the overhead network.

NDT is expected to increase the accuracy of pole strength testing for timber poles while also extending their life. This is supported by inaccuracy in the traditional drilling inspection method that has resulted in poles in good condition to be replaced. NDT does not deteriorate pole condition while drilling inspection methods do deteriorate pole condition.

Key challenge: aging timber pole population – 28,588 poles are timber with an average age of 45 which is also the average design life for timber pole types in AADs network. Modelling results show an uptrend in poles reaching end of life from approximately 2030. This challenge must be managed to have minimal impact on cost for customers and be achievable to deliver. Opportunities to combat this challenge will include maximising the life of existing assets, continual development of asset modelling to predict asset replacement needs, and utilising disruptive network technologies including Remote Area Power Supplies (RAPS) in the future to minimise the need to replace these assets.

The distribution pole asset class has historically had the highest CAPEX budget. With this strategy, the forecast CAPEX expenditure has reduced by 35% in the 2019-24 regulatory period compared to the current 2014-19 period. The reduction is due to the number of poles forecast for replacement and re-enforcement with the new pole strategy. Furthermore the OPEX forecast has reduced by 26% comparing the same periods from NDT.

The estimated 2018-24 budget for CAPEX and OPEX is presented in Table 1.

Total Budget	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
CAPEX	**5,557,800**	**5,227,510**	**4,987,550**	**5,101,600**	**5,227,510**	**5,455,610**
OPEX	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**
Planned Maintenance	22,855	22,855	22,855	22,855	22,855	22,855
Unplanned Maintenance	191,053	191,053	191,053	191,053	191,053	191,053
Condition Monitoring	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000

Table 1: OPEX and CAPEX Optimised Program of Work Budget

This ASP presents a broad-based program of works for this asset class and applies relative considerations of CAPEX, OPEX and risk costs.

2 Asset Class Overview

This section provides an overview of the strategy and objectives specific to the asset class covered by this ASP, provides details of the assets included and their function, and explores the needs and opportunities specific to this asset class.

This ASP covers the Distribution Poles class, which lies within the Primary asset portfolio. The assets within this class are responsible for providing a structure to support medium voltage and low voltage distribution assets. For details of the asset groups contained within the Distribution Pole asset class, refer to section 2.2.

2.1 Asset Class Objectives

The asset class strategy presented in this ASP follows the overall ActewAGL asset management strategy and asset management objectives. The asset class strategy is an integral part of the asset management strategy, with the overall objective to provide safe, reliable and cost effective supply of electricity to customers and compliance with regulatory requirements.

This Distribution Poles ASP has been developed in alignment with the asset management strategy and seeks to meet objectives in the following categories shown in Table 2.

Asset Management Objectives	Asset Class Objectives
Responsible	
• Achieve zero deaths or injuries to employees or the public • Maintain a good reputation within the community • Minimise environmental impacts, for example bushfire mitigation • Meet all requirements of regulatory authorities, such as the AER as outlined in the NER, and the ACT Utilities (Technical Regulations) Act 2014.	• No death or injury to employees or the public • Achieve 0 unassisted* pole failures • Deliver bushfire mitigation program • Ensure design and acceptance for new assets complies with standards
Reliable	
• Tailor maintenance and renewal programs for each asset class based on real time modelling of asset health and risk • Meet network SAIDI and SAIFI KPIs • Record failure modes of the most common asset failures in the network	• Complete trial for non-destructive pole testing • Achieve detailed understanding of asset health and incorporation into asset modelling • Measure SAIDI and SAIFI contribution from this asset class • Review ASP at least every 5 years • Record and complete asset failure investigations within 20 business days
Sustainable	
• Enhance asset condition and risk modelling to optimise and implement maintenance and renewal programs tailored to the assets' needs • Make prudent commercial investment decisions to manage assets at the lowest lifecycle cost • Integrate primary assets with protection and automation systems in accordance with current and future best practice industry standards • Deliver the asset class PoW within budget.	• Achieve 90% data completeness for minimum asset data requirements • Make prudent commercial investment decisions for "pole assembly". Consider Poles, OH hardware, OH Switchgear & Automation assets • Deliver PoW outlined in this plan
People	
• Proactively seek continual improvement in asset management capability and competencies of maintenance personnel.	• Implement training needs for non-destructive testing program • Promote continual improvement

Table 2: Asset class objectives

*¶Unassisted means a structural pole failure which is not caused by a weather event or 3rd party incident.

That is, the strategy and ASP must be practical in the sense that it can be implemented, must also be flexible enough to satisfy the future requirements of the ActewAGL network, and must be cost effective and efficient with consideration of both technical and human resources.

2.2 Asset Groups

Distribution Pole assets are classified in terms of the pole material. Table 3 provides the classification of asset groups within the asset class.

Asset Class	Poles
Asset Groups	Concrete Pole Stobie Pole Fibreglass Pole Steel Pole Tanalith Pole Natural Round Timber Pole Creosote Pole

Table 3: Asset Classification – Poles Assets

2.3 Asset Functions

Poles are structures primarily to support AADs overhead distribution network.

Secondary users of these poles include the ACT Government to support some of their streetlight network, Telstra and TransACT to support some of their communications network.

2.3.1 Asset Function Definitions

ActewAGL's distribution pole assets have the same basic function but differ in material/construction type depending on the installation location.

The function of assets in this asset class is described in the following sub-sections.

2.3.1.1 Concrete and Stobie Poles

Concrete poles are the preferred pole type due to their lowest overall lifecycle cost and are installed for all locations where there is crane access.

Stobie poles have not been installed for over 60 years and there is only a small quantity currently in the network.

2.3.1.2 Fibreglass Poles

Fiberglass poles are the preferred pole type for installation in locations with no plant access. Fibreglass is preferred due to its light weight and sectionalised format. Most LV poles in backyards are replaced with fibreglass because the pole can be installed without heavy plant which is practical for pole with limited access in residential backyards.

2.3.1.3 Steel Poles

Steel poles were used in difficult access locations prior to the introduction of fibreglass poles. Similar to fibreglass poles, steel poles were supplied in multiple sections and were lighter weight than concrete poles.

2.3.1.4 Timber Poles (Tanalith, Natural round and Creosote)

Natural round timber poles were the first kind of poles to be installed to support the overhead distribution network. Once timber treatments became available, Creosote poles were used followed by Tanalith poles. Treated timber poles are now only installed in heritage areas as a requirement of the ACT government.

2.4 Needs and Opportunities

Pole needs and opportunities are based on reducing risk and increasing safety. Poles are used to support infrastructure such as overhead bare conductors, switching mechanisms, and transformers. The need is to ensure the pole can perform its function safely, whilst opportunities will include areas of future improvement.

2.4.1 Needs

Asset Replacement

Poles deteriorate over time and have multiple failure modes resulting in the need to be replaced at their end of life. Due to the risks associated with a pole failure (Section 4.3), poles need to be replaced prior to the asset reaching structural failure. Therefore the replacement is to be determined by pole structure condition.

Asset maintenance

There is minimal maintenance opportunities on poles in general and vary slightly between pole material. Steel poles corrode below ground level due to the moisture levels in the soil. To reduce the corrosion, part of the below ground steel pole can be exposed and treated with an anti-corrosion product. Timber poles also usually deteriorate below ground first (rot due to moisture). These timber poles can be reinforced by installing a ridged metal structure, which is fixed to the pole below and above ground level. Since the reinforcement of the timber poles extends the life of the asset, it is considered a capital investment.

Asset Condition monitoring

The replacement of poles is based on condition and needs to occur prior to the asset reaching end of life failure. This results in the need to monitor the pole and forecast pole life based on the measured condition of the pole. Poles condition is calculated using internal and external inspection methods.

2.4.2 Opportunities

Remote Area Power Systems

Remote Area Power Systems (RAPS) is a power supply islanded from the grid which supplies a customer or a small network of customers. These assets are owned and operated by AAD and can consist of wind, solar, batteries and diesel generators for the supply.

Two locations have been identified as suitable sites with potential to remove a total 16km of HV overhead line, and supply the customers with ActewAGL owned and operated RAPS. Sites identified include Gudgenby and Corin. Justification for this change is based on reducing the bushfire risk, and to reduce our OPEX costs to maintain power lines through rugged bushland to supply a few remote customers. The above comment relates to extreme cases of geographical criticality.

Underground Cable Network

An alternative to overhead network is underground network. There have been several studies to determine the cost of undergrounding ActewAGL's existing urban overhead network. The outcome of these studies shows that it is generally not economical.

Undergrounding overhead networks is still considered for specific sections of the network. This can be during asset renewal, reliability issues or bushfire risk. To determine the suitability for undergrounding overhead networks, cost benefit analysis is undertaken for the specific site.

Improved asset condition data

Asset condition data can be improved by improving the testing methods. A new pole testing procedure is being trailed starting from June 2017. With this, it's possible to increase the accuracy of condition data which is a better representation of the pole condition for short term decision making and longer term asset modelling.

AAD is trailing replacing traditional drilling (destructive) inspection techniques for measuring internal rot on a timber pole to non-destructive measuring techniques, such as acoustic, gamma radiation and ultra-sonic waveform analysis. ActewAGL is conducting a trial of non-destructive pole testing during 17/18.

Opportunistic replacement

Opportunistic replacements consider the commercial aspects of asset management and does not rely solely on the condition of poles.

Semi deteriorated poles (poles in fair condition or better) are often replaced due to economic reasons when associated assets have failed or reached end of life. Associated assets include overhead pole hardware such as crossarms, insulators and fixtures. A NPV study is carried out to determine if it is financially efficient to replace the pole at the same time as the associated assets thereby combining work activities, or to replace overhead pole hardware assets and then the pole at end of life which will result in two work activities with multiple crew dispatches.

2.5 Associated Asset Classes

Associated asset classes are as follows:

2.5.1 Functional Relationships

Distribution pole assets have functional relationships with the following asset classes:

- Pole Substations;
- Overhead Lines and Pole Hardware;
- Overhead Switchgear;
- Overhead Services;
- Distribution Earthing;
- Underground Cables;
- Underground Services;
- External party assets such as streetlights and communications assets.
- Vegetation

3 Asset Base

This section provides details of ActewAGL's current asset base for assets that are a part of this asset class, including the current age and condition profiles of the assets and the projected asset count.

3.1 Asset Base Summary

Table 4 gives details of ActewAGL's in-service distribution pole assets as at April 2017.

Asset Type	Quantity	Design Life (yrs)	Average Age (yrs)	Oldest Age (yrs)
Steel Pole	5,904	60	15	30
Tanalith Pole	7,157	50	30	97
Natural Round Timber Pole	15,709	40	52	97
Creosote Pole	5,722	50	43	97
Concrete Pole	11,023	80	18	50
Stobie Pole	359	80	71	75
Fibreglass Pole	3,492	70	4	11
Unknown Pole	44	40	37	89
Grand Total	**49,410**	**56**	**32**	**97**

Table 4: Distribution Pole Assets

3.2 Asset Service Life Expectancy

The design life of the distribution pole assets ranges from 40 to 80 years depending on pole material. This is however affected by a range of aging factors as follows:

- Termites;
- Rot;
- Rust;
- Mechanical Loading;
- Quality of manufacturing;
- Soil type;
- Rainfall.

3.3 Asset Age Profile

Figure 2 shows the age profile of distribution poles.

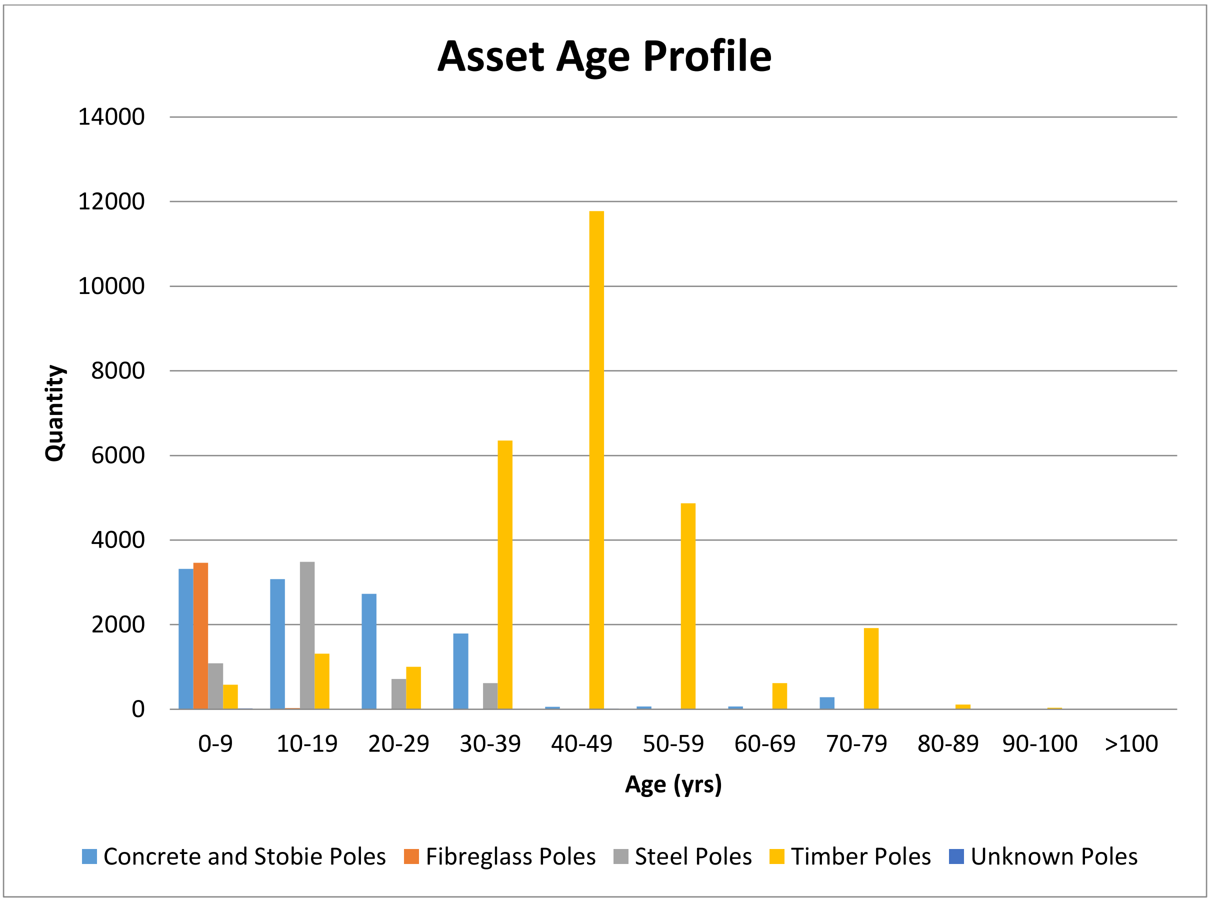

Figure 2: Age Profile of Pole Assets

The asset age profile shows there are a large number of timber poles (Natural Round Timber, Tanalith, Creosote) over 40 years of age, and a small number of assets nearing the top end of the expected life of 80 years. The need for replacement is further demonstrated in the asset condition profile in section 3.4, where asset health is identified as poor for some pole materials.

3.4 Asset Condition Profile

Asset health represents the condition of assets and is an assessment of an asset's capacity to perform its function(s) at the required level of service. Asset condition is calculated using an age-based degradation model and modified by known asset condition, environmental or usage information. Table 5 shows asset health in 2017 and asset forecast to reach critical condition by 2024.

Asset Type	Asset Quantity	Asset Quantity -Critical Health 2018-24	Average Health 2017
Concrete Pole	11,022	1	Excellent
Stobie Pole	359	0	Good
Fibreglass Pole	3,492	0	Excellent
Steel Pole	5,904	0	Excellent
Unknown Pole	44	20	Fair
Natural Round Timber Pole	15,709	5,419	Fair
Creosote Pole	5,722	17	Good
Tanalith Pole	7,157	65	Excellent
Grand Total	**49,409**	**5,522**	**Good**

Table 5: Current Distribution Pole Asset Condition

Natural round timber poles have the largest pole population by pole type deteriorate the fastest and are calculated to be in the worst condition. The majority of pole replacements by 2024 are estimated to replace natural round timber poles.

Assets forecast to reach critical condition are inspected to confirm their condition. Assets assessed as being in "Poor" or "Critical" condition will be subject to further investigation including its overhead hardware to assess options for remedial activities. Remedial action on poles during 2018-24 will include:

- Planned replacement - poles assessed in critical condition
- Opportunity replacement – pole structure in poor condition and overhead hardware assessed in critical condition. These replacements are justified through NPV analysis and are achieve the lowest lifecycle cost of the pole structure assembly.

The asset class health profile in 2017 is summarised in Figure 3.

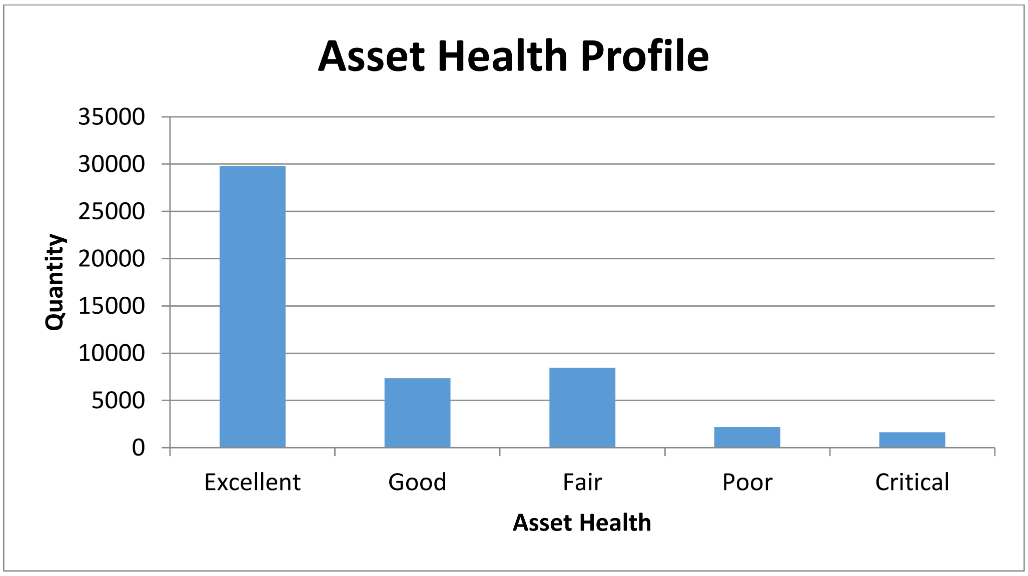

Figure 3: Asset Health profile

3.5 Projected Asset Count

The overhead network is slowly contracting by a rate of about 0.4% per annum based on the reduction of the pole population. The main reason for reduction in pole population is due to new green field sites being underground reticulated and land development occasionally leading to the undergrounding of existing overhead network assets.

Where a pole becomes redundant, it will be physically removed from the ground.

Since the mid 1980's, all new green field sites are underground reticulated. Underground reticulation originally came about in the Australian Capital Territory when developers were willing to pay a higher capital contribution to reticulate with underground network instead of overhead. This reflected the wishes of the block purchasers who were interested to pay more for their block and house so that they would have better amenity through not having overhead power lines. A policy was developed as a result where all new green field sites are underground reticulated. This arrangement suited ACTEA/ ACTEW (predecessors of ActewAGL) as the ongoing maintenance costs are lower, and the reliability is higher.

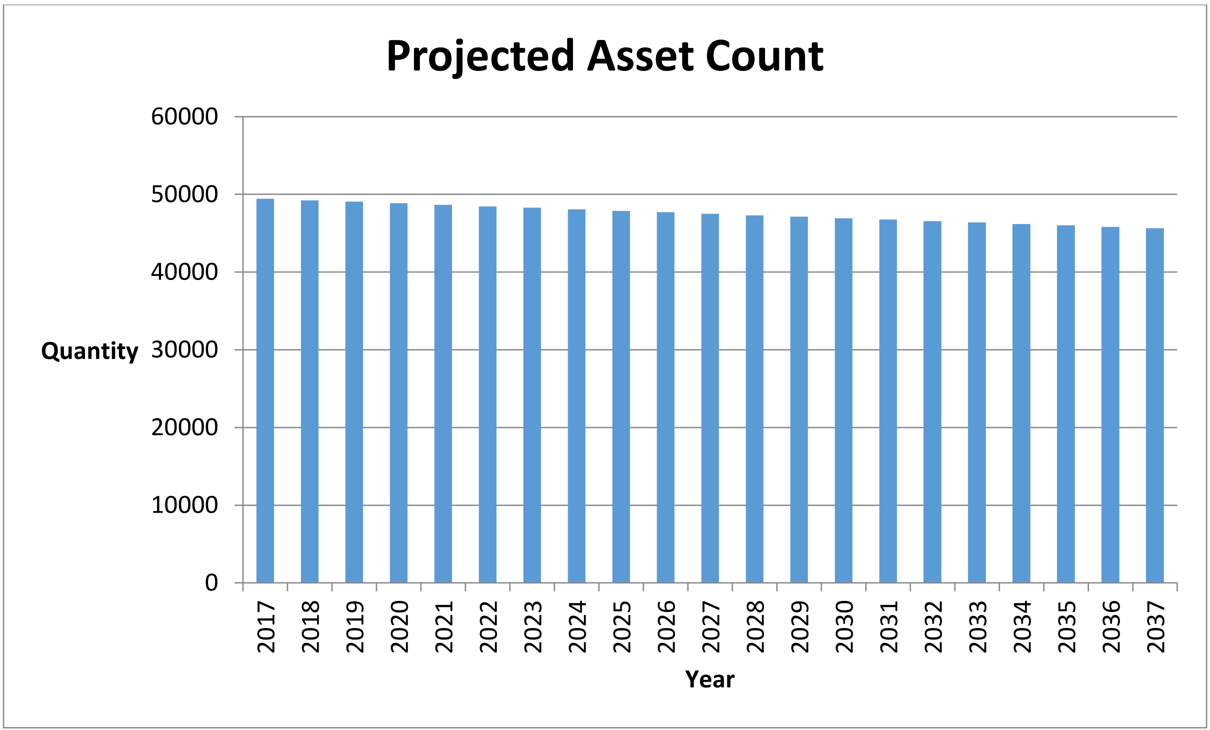

Figure 4: Projected Asset Count

3.5.1 Network Augmentation and Infrastructure Development

The following network augmentation projects affect the asset class population.

- Not applicable for this asset class

3.6 Data Sources

Effective asset management relies on accurate asset information. The Asset Management System uses the following data sources for asset management:

- Geospatial Information System (GIS) Including Asset Inventory – esri GIS
- Works Management System - Cityworks
- Advanced Distribution Management System (ADMS) – Schneider Electric
- Finance Management System - Oracle
- Asset Management & Modelling System - Riva Modelling

3.6.1 Data Quality

3.6.1.1 Data Completeness

- Asset inventory is complete, some quality issues evident
- Condition data - visual, drilling and aerial inspections
- Condition data – NDT instruments (in trail for FY17/18)
- Historic financial history specific to this asset class is available from June 2014 only

3.6.1.2 Data Accuracy

The following outlines data quality issues affecting the quality of this ASP:

- Data errors in pole material type and age

Data Improvements

- Verify pole material type and age
- Improve accuracy of condition assessment testing through NDT
- Enhance asset modelling to include NDT if the NDT trail is successful
- Capture asset fault history and root cause analysis of faults
- Improve process and systems for data capture into asset modelling systems

4 Asset Performance Requirements

This section details the reliability and performance requirements for the respective asset types within this asset class.

4.1 Failure Modes

4.1.1 Failure Mode Effects Analysis (FMEA)

This ASP uses a risk based methodology, based on the ActewAGL Failure Mode and Effects Analysis (FMEA) approach to improving reliability and reducing maintenance costs. A series of factors contributing to probability and consequence of failure for respective asset classes are identified, analysed and rated by a team of cross-functional subject matter experts. These are then utilised as inputs to the overall risk cost calculations.

4.1.2 Deterioration Drivers and Common Modes of Failure

Tables in the following section will for each asset type summarise their common modes of failure. They have been configured to show the assessed effects of each failure mode in terms of severity, occurrence and detection which are the inputs to Riva. Column 6 shows the resultant generated Risk Priority Number (RPN)

The following summarises the deterioration drivers and common failure modes for pole assets by asset type;

4.1.2.1 Timber Poles

Deterioration Drivers

- Moisture levels in soil contributing to below ground rot
- Weather effects of extreme temperatures, sun, wind and rain, which over time deteriorate exposed material.
- Insects such as termites nesting in the pole structure
- Reinforcement fixtures becoming loose due to deterioration

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Structural below ground rot	Pole base sitting in moist soil aver time will introduce below ground rot Effect: Pole weakens at the base resulting in an increased risk of the pole falling over.	10	3	3	90
Structural above ground rot	Pole begins to rot from the inside eating away at the structural integrity of the pole Effect: Weakening of the pole structure resulting in an increased risk of the pole breaking under load	10	2	2	40
Pole top deterioration	Loss of the pole cap results in the pole eroding from the top down due to being exposed to the elements. Effect: loss in structural integrity to support cross arms and other furnishings.	10	2	2	40
Termite attack	Termites nest in the pole feeding of the structure Effect: Weakening of the pole structure resulting in an increased risk of the pole breaking under load	10	6	3	180
Reinforcement Structural Failure	Pole reinforcement becomes loose due to deterioration. Reinforcement material deteriorates due to rust Effect: Reinforcement structure can no longer support pole resulting in pole falling	10	1	2	20
Leaning pole	The base supporting the pole becomes loose over time resulting in the pole to lean Effect: Uneven force on the pole puts strain at the base of the pole results in a broken pole. Strain on the insulators results in broken insulators	10	2	2	40
Third Party Damage	Damage caused by vehicles, animals or people Effect: Any damage which compromises the integrity of the pole structure will require replacement	4	7	8	224

Table 6: Timber Poles Modes of Failure

4.1.2.2 Concrete Poles

Deterioration Drivers

- Moisture levels in soil contributing to below ground deterioration and moisture ingress
- Weather effects of extreme temperatures, sun, wind and rain, which over time deteriorate exposed material.

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Structural Failure	Chipping and cracking of the protective concrete due to weathering results in moisture ingress and rusting of the internal metal reinforcement Effect: Weakening of the pole structure resulting in an increased risk of the pole breaking under load	10	1	2	20
Leaning pole	The base supporting the pole becomes loose over time resulting in the pole to lean Effect: Uneven force on the pole puts strain at the base of the pole results in a broken pole. Strain on the insulators results in broken insulators	10	2	2	40
Third Party Damage	Damage caused by vehicles, animals or people Effect: Any damage which compromises the integrity of the pole structure will require replacement	4	7	8	224

Table 7: Concrete Poles Modes of Failure

4.1.2.3 Fibreglass Poles

Deterioration Drivers

- Moisture levels in soil contributing to below ground deterioration and moisture ingress
- Weather effects of extreme temperatures, sun, wind and rain, which over time deteriorate exposed material.

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Structural Failure	Protective surface of fibreglass will break down over time as it is exposed to weathering. This results in cracking and chipping of the fibreglass structure Effect: Weakening of the pole structure resulting in an increased risk of the pole breaking under load	10	1	2	20
Leaning pole	The base supporting the pole becomes loose over time resulting in the pole to lean Effect: Uneven force on the pole puts strain at the base of the pole results in a broken pole. Strain on the insulators results in broken insulators	10	2	2	40
Third Party Damage	Damage caused by vehicles, animals or people Effect: Any damage which compromises the integrity of the pole structure will require replacement	4	7	8	224

Table 8: Fibreglass Poles Modes of Failure

4.1.2.4 Steel and Stobie Poles

Deterioration Drivers

- Moisture levels in soil contributing to below ground deterioration and moisture ingress
- Weather effects of extreme temperatures, sun, wind and rain, which over time deteriorate exposed material.
- Fixtures becoming loose due to deterioration

Failure Modes

Failure Mode	Description	Severity	Occurrence	Detection	RPN
Below ground rust of steel pole	Moisture contained in the soil erodes at pole base causing rust Effect: Steel pole bends or breaks under load resulting in a fallen pole	10	1	2	20
Below ground rust of stobie pole	Moisture contained in the soil erodes at pole base causing rust Effect: Steel pole bends or breaks under load resulting in a fallen pole	10	2	2	40
Leaning pole	The base supporting the pole becomes loose over time resulting in the pole to lean Effect: Uneven force on the pole puts strain at the base of the pole results in a broken pole. Strain on the insulators results in broken insulators	10	2	2	40
Third Party Damage	Damage caused by vehicles, animals or people Effect: Any damage which compromises the integrity of the pole structure will require replacement	4	7	8	224

Table 9: Steel and Stobie Poles Modes of Failure

4.2 Asset Utilisation

This section details the utilisation level of the assets. Depending on the asset type, the level of utilisation will have a direct impact on asset condition and performance deterioration rates.

4.2.1 Capacity and Capability

Most distribution poles currently purchased have either a 5kN or an 8kN equivalent tip load capacity. 5kN poles are normally used in inline or service applications. 8kN poles are normally used in termination or angled applications. The ultimate tensile strength of the pole is different for each pole type and is normally displayed on the nameplate.

The standardised height is either a 9.5m or 12.5m pole. 9.5m poles are for low voltage mains and services. 12.5m poles are for high voltage. Other heights are also in use to provide more ground clearance by installing a taller pole, such as 11m, 14m, 15.5m, and 17m poles.

4.2.2 Utilisation

Poles are designed to have 100% utilisation with respect to the asset function to support maximum design load. If a pole has its fixtures and furnishings removed, the pole too will be removed as it will not be serving any purpose.

4.3 Risk and Criticality

This section details the criticality of distribution pole assets and their exposure to risk.

4.3.1 Asset Criticality

A pole has a critical function to maintaining integrity of the overhead network. The pole provides a support structure for overhead conductors, switching devices, transformers and other ancillary devices. The failure of a pole will damage any apparatus on the pole, result in a power outage for customers, and create safety risks and environmental (bushfire) risk.

The criticality of each individual pole will depend on its load, location, and customer type and are used in the risk model. Distribution poles can be supporting conductors carrying loads varying between 5MVA in the HV network, down to the individual customer which could be as low as a few KVA in the LV network.

Pole failure on the HV network will likely cause an outage to the entire HV feeder unless there is an overhead protective device (overhead recloser) installed along the feeder. Poles also support loads with different criticality ranging from residential, industrial and government.

4.3.2 Geographical Criticality

The geographical location for poles varies greatly since they were the primary way of distributing electricity prior to undergrounding of the network. As such poles are installed in rural, bushfire abatement zones and urban sites including LV poles residential backyards. Each location presents unique challenges and risks to the management of poles.

Poles located in BAZ zones have the highest bushfire risk due to the presence of fuel and nearby location to the public and infrastructure. The risk is highest due to the combination of fuel, low time for emergency services to respond to fires before damage to community assets including public health and safety, and close proximity to community assets which could be damaged by fire.

Poles located in a rural environment may have difficult access (behind locked gates, in boggy paddocks or on steep embankments) and have a reduced exposure to third party damage. These poles however have an increased environmental bushfire risk if a failure were to occur. Due to the higher risk consequence of a rural pole failure, it is necessary to monitor the condition of rural poles more frequently than urban poles.

Canberra is unique in that the majority of the low voltage overhead distribution network has been installed in the backyard of residential properties. This installation method was popular (prior to undergrounding of the network) to increase the visual streetscape of residential properties. This has resulted in poles being installed in back yards which is very difficult to access and more difficult to conduct replacements. This results in an increase of cost to maintain urban LV poles located in residential backyards.

There are areas in the ACT where termites are prominent. This has an effect on the likelihood of termite damage to timber poles in the area. Concrete poles are the preferred replacement type which will resolve termite attack over the long term. The short term approach can include treating the timber poles in known areas to defer termite attacks.

Poles located in a roadside in a highly trafficable area are exposed to a greater risk of vehicle impacts and other third party damage. The benefit of a roadside pole is the ease of access for inspection and replacement.

4.3.3 Asset Reliability

Distribution overhead networks are normally the least reliable components for any power utility, and this is no exception for ActewAGL. This level of reliability is largely dictated by the lines being exposed to a wide range of environmental factors. The actual line design is a compromise between cost and aesthetics. It would be possible to build much more robust overhead lines that are less affected by trees, birds, animal, termites, rot, storms, vandalism, etc, at more than 3 times the cost, but it would be a big challenge to make them acceptable to the public.

Pole are designed, maintained and operated to achieve the minimum network distribution reliability requirements.

The last ENA pole failure report (2014/15) showed the industry pole failure rate per 100,000 poles to be 9.5 poles. This has increased from the lowest on record which was 3 failures per 100,000 poles reported in 2010/11. Based only on AADs pole population (~50,000 poles) and the 2014/15 industry average for pole failures, AAD could expect 4 failures per year.

The last unassisted pole failure (not caused by storm or 3rd party) in AADs network was in the 2011/12 financial year. AAD has therefore achieved zero unassisted pole failures in the last 6 years (2017) making AAD poles some of the most reliable in the industry.

With zero recent pole failures, the number of poles identified as “dangerous” (i.e. poles considered to be in very poor condition and at high risk of failure,) can be used as another indicator of pole population health. In the last ten years poor condition pole numbers have reduced by a factor of ten. This suggests that the condition of AADs pole population is good.

Condemnation rates were previously high compared to industry averages, however following a reduction in pole serviceability criteria, current pole condemnation looks to be close to the industry average. With an aging pole population it is expected this rate will increase.

5 Asset Management Strategy Options

This section outlines the options considered for the management of distribution pole assets throughout their lifecycle and their assessed relative merits. It recommends an asset specific strategy that best supports the business asset management policy, strategy and objectives.

5.1 Option Evaluation Methodology

5.1.1.1 Financial Cost/Benefit Assessment

The options are assessed in terms of their resultant OPEX, CAPEX and risk exposure costs. The option specific financial assessments are generated as outputs from the Riva system which are then factored into the options assessment process.

5.1.1.2 Qualitative Risk Assessment

Qualitative assessments of the risks and consequences inherent to each option have been undertaken utilising the standard methodology from the ActewAGL "Energy Networks Risk Assessment Tables".

5.2 Options - Discussion and Evaluations

Options for the asset specific strategies are evaluated against their relative cost, risk, benefits, and consider trade-offs between capital and operational expenditure to deliver the asset management objectives. The options that have been considered are as follows:

- Option 0 – Reactive Strategy;
- Option 1 – Reduce serviceability criteria and NDT Strategy;
- Option 2 – Reduce Risk Strategy

5.2.1 Option 0 – Reactive Strategy

Under this option no controls such as proactive maintenance, condition assessment, planned refurbishment or planned replacement are applied. Any maintenance or asset replacement is purely reactive and is undertaken when the asset is no longer suitable for service which may be due to any of the following reasons:

- Functional failure (structural failure).

Thus this option incorporates:

- Reactive replacement of (failed) assets.

5.2.1.1 Financial Outcomes

The risk of implementing the do nothing strategy is unacceptable due to the safety and bushfire risk presented by pole failures. Additionally this option puts ActewAGL Distribution in breach of asset management policy, strategy and legislative requirements and is contrary to good electricity industry practice. Financial analysis for this option has not been undertaken.

5.2.1.2 Risk Outcomes

The risk outcomes of this option increase over time as the condition of the assets deteriorate through the combined aging effects and thus increasing the probability of failure as assets approach and exceed AAD and industry minimum serviceability criteria to operate without failure.

Functional failure of distribution poles is the failure to structurally support overhead electricity network assets. This failure has a high consequence cost to the environmental, safety and network reliability and therefore if untreated is a high risk.

A qualitative risk assessment of this option highlights the inherent risks (no controls) of this asset class and the risk exposure. This is shown in Table 10.

Likelihood	Inherent Risk – Negligible	Minor	Moderate	Major	Severe
Almost Certain		Medium 1			
Likely		Medium 1	High 1	High 2	
Possible		Medium 7	Medium 6	High 2	
Unlikely		Low 9	Medium 11	Medium 5	
Rare					
	Consequence				

Table 10: Qualitative Risk Assessment – Option 0

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 5.

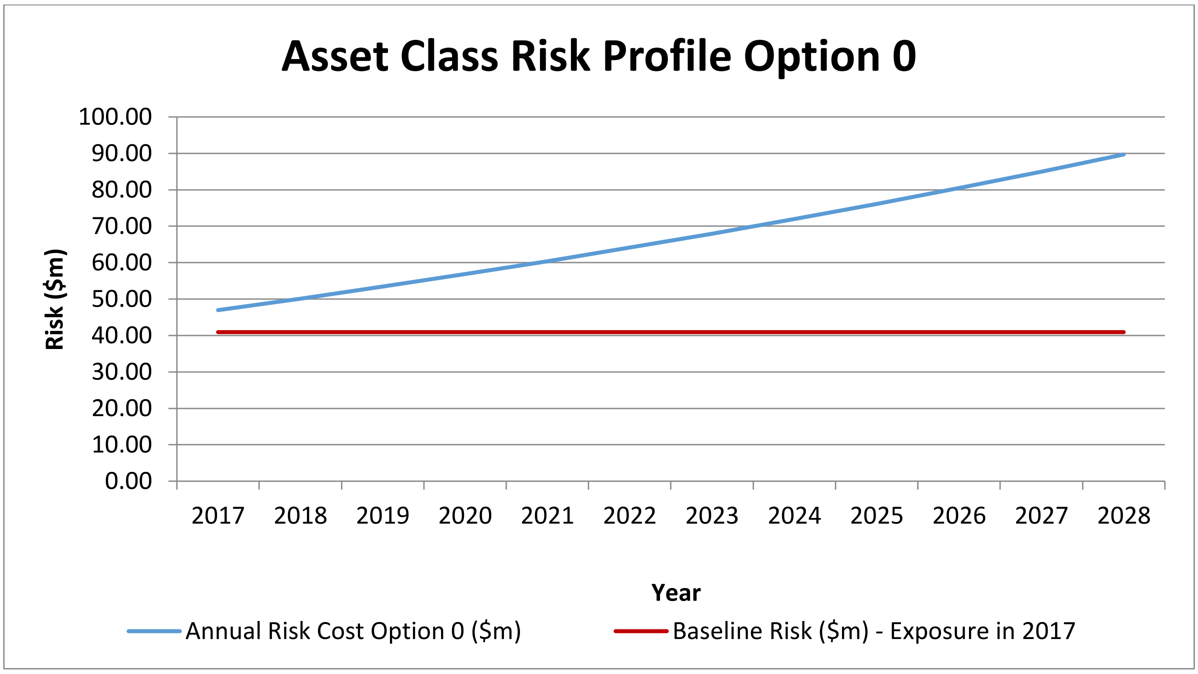

Figure 5: Risk-Cost Analysis – Option 0

5.2.1.3 Summary of Options Benefits

This option delivers the least OPEX and CAPEX at least in the early stages of asset life when the probability of failure is low.

5.2.1.4 Summary of Options Dis-benefits

This option delivers the following dis-benefits (negative outcomes):

- Non-compliance with regulatory obligations;
- Non-compliance with Asset Management policy, strategy and objectives
- Inconsistent with contemporary industry practice and prudent asset management;
- Unacceptable risk exposure

5.2.2 Option 1 – Reduce Serviceability Criteria and NDT Strategy

Option 1 covers the existing strategy as applied to the management of the distribution pole assets. This strategy includes condition monitoring and condition based refurbishment and replacement to manage assets at the lowest lifecycle cost. This strategy looks to optimise CAPEX and OPEX costs and manage the risk presented through considered CAPEX and OPEX trade-offs which incorporate:

- Condition monitoring - includes non-destructive, destructive testing and visual inspection;
- Planned refurbishment on the basis of condition;
- Planned replacement on the basis of condition.

This strategy was adopted by AAD in July 2017 optimising the strategy to lower the total cost of ownership with minimal impact on risk.

Condition monitoring

Condition monitoring of poles is fundamental to manage the risk of distribution poles in a manner that considers trade-offs between risk and cost. The majority of AADs pole population are timber poles which experience different rates of deterioration due to their inherent naturally occurring material and the environmental conditions they are subjected to. Differing condition deterioration within the asset population along with a high failure consequence, means that it is essential to monitor asset condition so that assets with rapid condition deterioration are replaced before functional failure and assets which deteriorate slowly remain in service while they meet performance criteria.

This strategy aspires to exclusive use non-destructive testing of pole strength which does not deteriorate pole condition from testing and test methods are not subjective (compared to traditional drilling methods) thereby increasing inspection accuracy and reducing the number of poles incorrectly condemned. Currently both traditional (drilling) and non-destructive testing is used until the completion of the non-destructive testing trail program and a recommendation is made for the preferred testing techniques.

Planned refurbishment

Planned refurbishment is a cost effective treatment to extend the service life of poles while managing the risk. Pole refurbishment is 'nailing' or 'staking' of timber poles increasing the strength of the weakest part of the pole, extending the service life by an average of 8 years. Poles are refurbished when the minimum criteria for below ground wall thickness is reached and while the serviceability criteria is met for wall thickness at above ground.

Planned replacement

Planned replacement is required when poles fail to meet minimum service criteria to reduce the risk of functional failure. There are 3 categories for pole replacement:

Non-refurbished – fails serviceability criteria for below ground wall thickness and serviceability criteria for above ground.

Refurbished – is refurbished and fails serviceability criteria for above ground.

Economic – pole top components in poor condition and its more economic to bring forward the pole replacement to combine pole top works in one activity.

Serviceability criteria for this strategy is:

Pole Strength Category	Activity	Below Ground Wall Thickness	Above Ground Wall Thickness
5kN	Refurbish	< 30mm (front or back) < 50mm (average front and back)	> 60mm (front or back) > 60mm (average front and back)
	Replace	< 30mm (front or back) < 50mm (average front and back)	< 50mm (front or back) < 50mm (average front and back)
8kN	Refurbish	< 50mm (front or back) < 50mm (average front and back)	> 60mm (front or back) > 60mm (average front and back)
	Replace	< 50mm (front or back) < 70mm (average front and back)	< 50mm (front or back) < 50mm (average front and back)

5.2.2.1 Risk Outcomes

This option enables the risks presented by deterioration and inherent design faults to be mitigated through the combination of:

- Condition monitoring
- Planned replacement of assets in poor condition with high risk exposure

The exposed asset class risk ratings for this option are shown in Table 11.

Likelihood	Option 1 Risk: Negligible	Minor	Moderate	Major	Severe
Almost Certain					
Likely		Medium 1			
Possible					
Unlikely		Low 9	Medium 5	Medium 3	
Rare		Low 11	Low 11	Medium 5	
	Consequence				

Table 11: Qualitative Risk Assessment – Option 1

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 6.

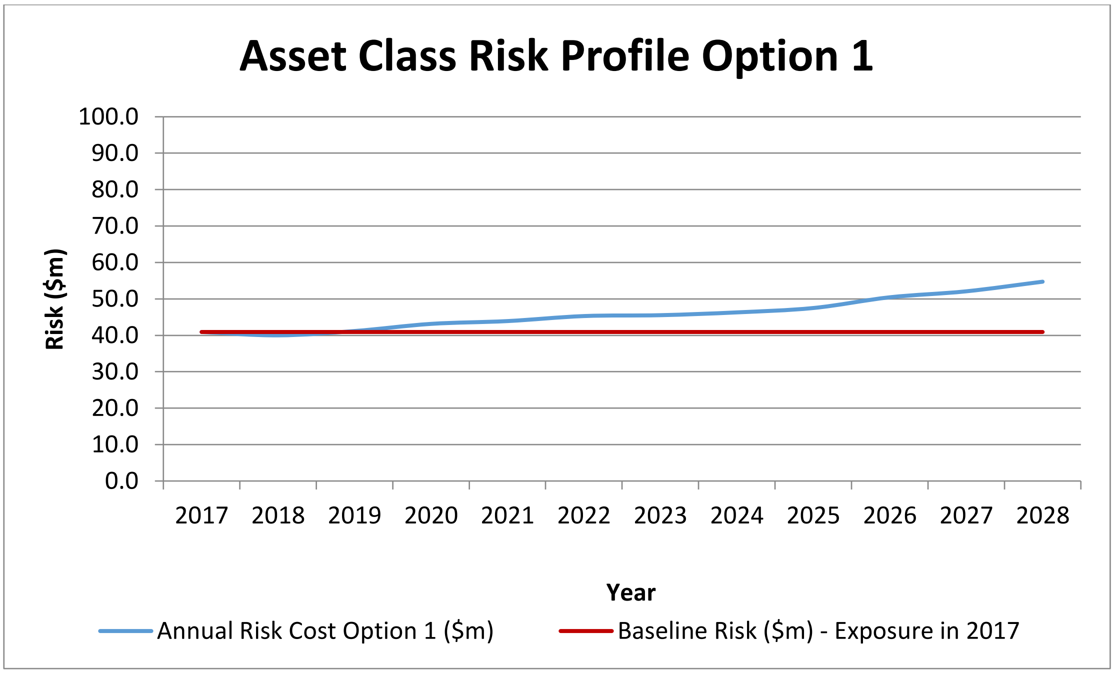

Figure 6: Risk-Cost Analysis – Option 1

Summary of Options Benefits

This option delivers the following benefits:

- Non-destructive testing reduces condition deterioration rates thereby deferring capital expenditure;
- Non-destructive testing increases the accuracy of inspection – poles are not incorrectly condemned;
- Reducing serviceability criteria lowers the lifecycle cost and defers capital investment.

5.2.2.2 Summary of Options Dis-benefits

Inherent to this option is the ongoing operational costs associated with condition monitoring. If the inspection interval is too low then the condition monitoring expenditure will be unnecessary and premature. If this interval is too high then undetected incipient failure may occur resulting in a functional failure of the pole.

This option has a marginal risk increase compared to Option 2 – Reduce Risk (Strategy used prior to June 2017)

5.2.3 Option 2 – Reduce Risk

This option considers a scenario to reduce the risk exposure of distribution pole assets. This strategy was the strategy implemented prior to July 2017. This option utilises condition monitoring and condition based refurbishment and replacement with the following changes compared to the current strategy (option 1).

- Destructive testing includes drilling to determine the remaining good wood wall thickness to calculate pole strength
- Minimum serviceability criteria – wall thickness 50mm for 5kN and 70mm for 8kN poles

Up to Jul 2017, this strategy was in place at AAD and achieved the lowest pole failure rates in the industry with zero pole failures since 2011. This serviceability criteria is considered conservative when compared against other DNSPs and recent functional failure rates and results in a lower risk exposure.

5.2.3.1 Risk Outcomes

This option reduces the risk by:

- Replacement of poles in better condition (poor opposed to critical) when the probability of failure is lower, thus lowering the risk

The exposed asset class risk ratings for this option are shown in Table 12.

		Option 2 Risk				
Likelihood	Almost Certain					
	Likely					
	Possible					
	Unlikely		Low 6	Medium 3		
	Rare		Low 12	Low 15	Medium 9	
		Negligible	Minor	Moderate	Major	Severe
		Consequence				

Table 12: Qualitative Risk Assessment – Option 2

A quantitative risk assessment for this option has been modelled to estimate the risk exposure and is shown in Figure 7.

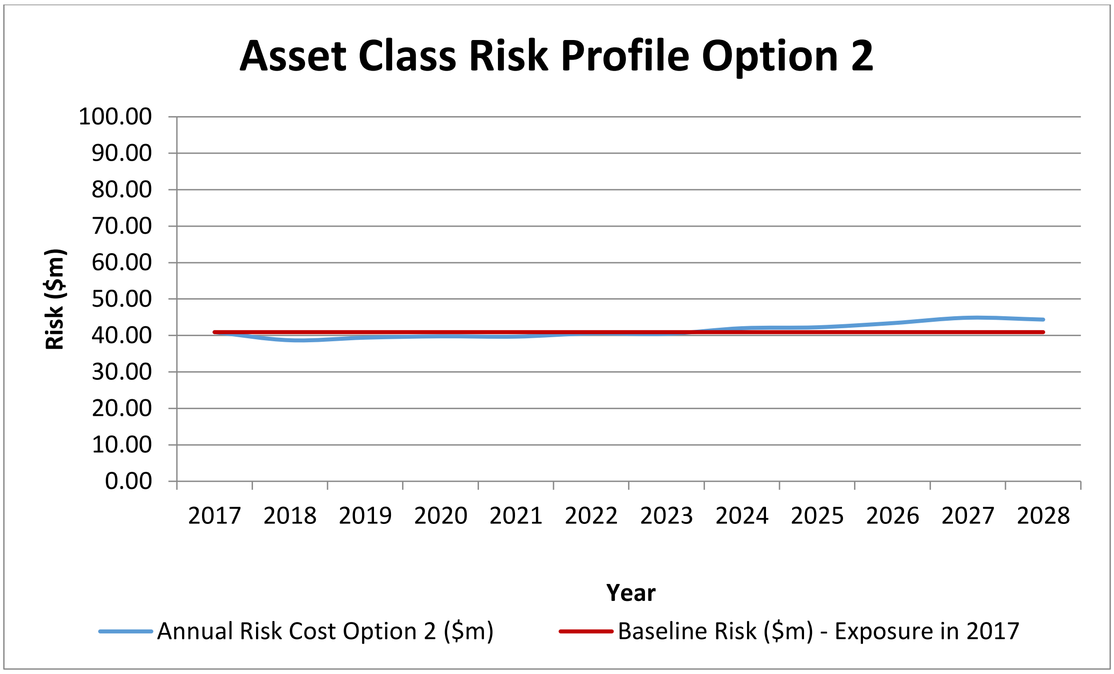

Figure 7: Risk-Cost Analysis – Option 2

5.2.3.2 Summary of Options Benefits

This option delivers the following benefits:

- Lowest risk exposure

5.2.3.3 Summary of Options Dis-benefits

This option results in the following dis-benefits (negative outcomes):

- Highest capital expenditure
- Destructive testing techniques increasing the rate of asset deterioration and reduces the service life;

5.3 Option Evaluation

This section provides a summary comparison of the evaluations of the options.

5.3.1 Engineering & Risk Evaluation

Option 0 – Reactive strategy has no planned asset replacement before failure and as such does not meet the asset class objectives to achieve zero unassisted pole failures. The asset class risk for this strategy also increases to an unacceptable level.

Option 1 and 2 are proactive strategies replacing assets before failure and include planned maintenance condition monitoring to manage risk. These strategies satisfy the asset class objectives, control risk to an acceptable level and are technically feasible.

Option 1

Option 1 - Reduce serviceability criteria and NDT and has the lowest serviceability criteria of the options considered maximising the in-service life for poles. Although this option has lower serviceability criteria, it is in-line with industry standard and asset performance remains with sufficient structural strength to support the overhead network.

Option 1 also includes innovative testing methods including NDT which is estimated to increase the accuracy of pole strength testing for timber poles while also extending their in-service life.

This is supported by an investigation into pole testing in 2017 found inaccuracy in the traditional drilling inspection method that has resulted in poles in good condition to be replaced. The NDT found these poles to be in serviceable condition and could have remained in-service. In-service life is extended since NDT does not deteriorate pole condition while drilling inspection methods do deteriorate pole condition.

This option manages the risk to an acceptable level and has a marginal risk increase compared to option 2.

Option 2

Option 2 – Reduce risk, has higher serviceability criteria and pole inspections using traditional drilling methods. This option was adopted by AAD prior to July 2017 and has achieved zero pole failures since 2011/12 which is the lowest pole failure rate for Australian DNSPs. With zero failures, this strategy could be considered conservative leading to replacement of poles before end of life.

As stated above, traditional drilling inspection methods have been proven inaccurate resulting in poles in good condition being replaced and accelerated condition deterioration through drilling. With new innovate NDT testing methods available today, inspection by drilling is not a prudent inspection method.

This option manages the risk to an acceptable level and is has the lowest risk.

5.3.2 Financial Evaluation

Financial comparison of technically feasible and acceptable risk options are summarised in Table 13. This summary includes forecast budget CAPEX and OPEX for the period 2018-24 and for comparison the 10 year and 30 year NPC of TOTEX and risk exposure.

Option	Budget ($m) 2018-24			NPC ($m) 10 yrs			NPC ($m) 30 yrs			Average Annual Risk 30 years ($m)	Rank
	TOTEX	CAPEX	OPEX	TOTEX	Risk	TOTEX + Risk	TOTEX	Risk	TOTEX + Risk		
Option 0	-	-	-	-	358.62	-	-	1,262.68	-	114.50	-
Option 1	45.18	31.56	13.62	48.89	256.30	305.19	128.81	667.85	796.66	55.86	1
Option 2	62.96	43.98	18.98	70.86	234.69	305.56	165.18	557.83	723.01	45.78	2

Table 13: Cost and Risk Strategy Options Summary

The graph in Figure 8 provides an overview of risk exposure

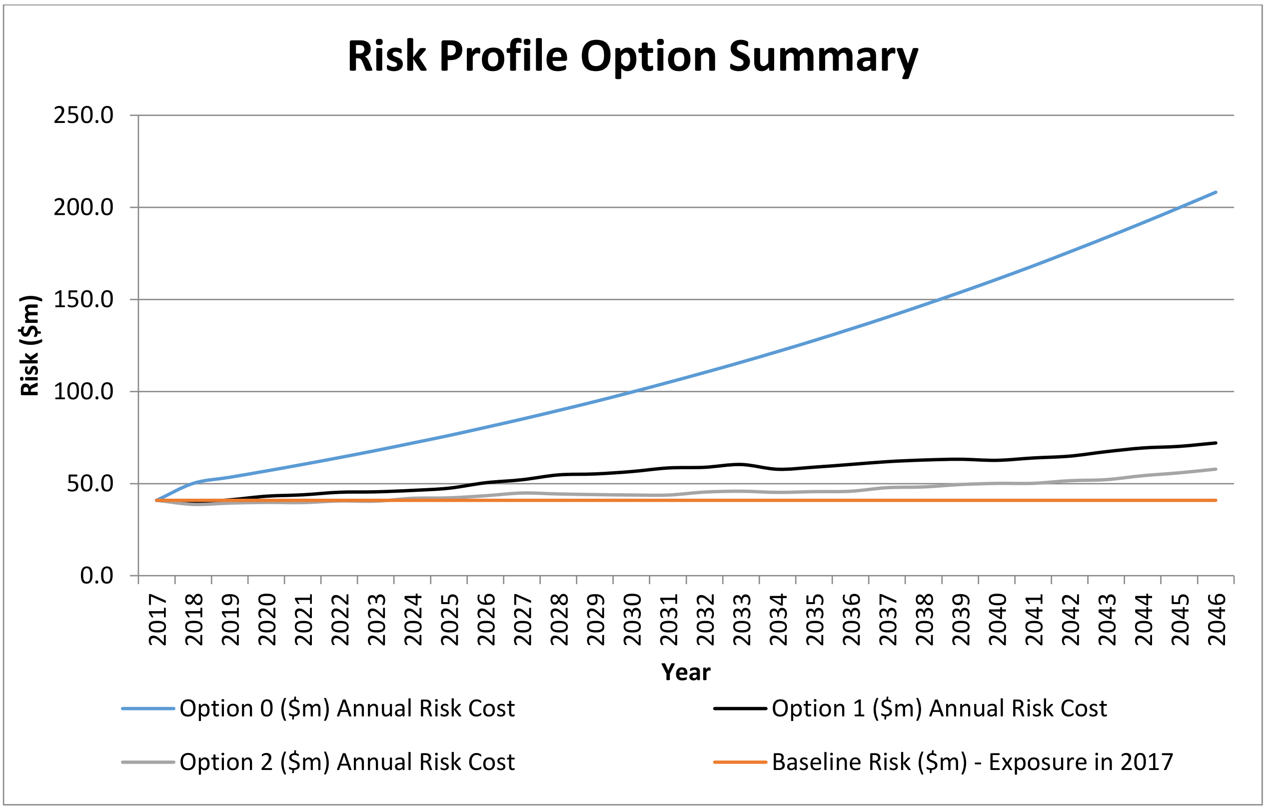

Figure 8: Risk Profile Comparison – Distribution Pole Assets

5.3.3 Corporate Criteria Satisfaction Comparison

The evaluated options are also compared utilising the ActewAGL corporate methodology in which qualitative assessment is made of the extent to which each option satisfies the specified criteria as shown in Table 14.

Criteria	Description and Weighting
Cost	This ranks the relative CAPEX and OPEX costs associated with the options. The weighting reflects the relative importance of this criterion.
Risk – Safety, Environmental, Reliability, Other	The extent to which the option provides mitigation/controls to risks identified. The weighting reflects the relative importance of this criterion.
Strategic Objectives	The extent to which the option meets the requirements of the asset management strategic objectives. The weighting reflects the relative importance of this criterion.
Innovation/Benefits	The extent to which the option provides business benefits including but not limited to information or intelligence to support innovative asset management and network operation. The weighting reflects the relative importance of this criterion.

Table 14: Option Evaluation Scoring Criteria

	Criteria				Option Score
	Cost	Risk	Strategic Objectives	Innovation/ Benefits	
Criteria Weighting	30%	30%	30%	10%	100%
Option 0	Not considered - rating not provided				
Option-1	*3*	*2*	*3*	*3*	*90%*
Option 2	*2*	*3*	*2*	*1*	*73%*

Scoring Key			
0	Fatal flaw	1	Unattractive
2	Acceptable	3	Attractive

Table 15: Scoring Matrix

5.4 Recommended Option

This section provides and overview of the recommended option and its outcomes.

5.4.1 Recommendation

The recommended option is Option 1 – Reduce serviceability criteria and NDT. This option satisfies the asset class objectives, manages risk to an acceptable level and delivers the outcomes which most completely satisfy the Corporate Criteria.

Options 1 and 2 analysed in the financial comparison manage risk to an acceptable level for both short and long term forecasts. Emphasis is given to the lowest cost option for the shorter term (10 year NPC) as it defers replacement lowering the likelihood of investment in assets which may become stranded in the future.

The lowest TOTEX cost option is also preferred for the same reason such that preference is given to lower cost options until the long term requirement for assets becomes clearer.

Option 1 has the lowest 10 year NPC and lowest TOTEX in all financial scenarios.

This option provides the means for the assets' reliable service life to be maximised while minimising asset total lifecycle cost through prudent condition monitoring using NDT and serviceability criteria developed to enable maximum in-service life to be achieved while retaining asset performance to support the overhead network. In doing so, this strategy allows the exposure to business, environmental, safety and reliability risks to be managed to within acceptable levels and is the least TOTEX option.

5.4.2 Forecast Asset Condition

Health profile is determined by asset condition and performance history. Condition is determined by the asset's capacity to meet requirements, asset reliability and its level of obsolescence. Obsolescence will be determined by maintenance requirements and availability of support from manufacturers.

The future health profile is the asset health profile at the end of the Regulatory Period, year 2024, under the recommended option to maintain risk exposure. This forecast is based on:

- Initial health profile
- Deterioration due to aging
- Deterioration where condition monitoring identifies specific risks for certain models of equipment
- Allowance made for replacement and refurbishments.

Figure 9 represents the projected future health profile of the asset base with the implementation of the recommended option.

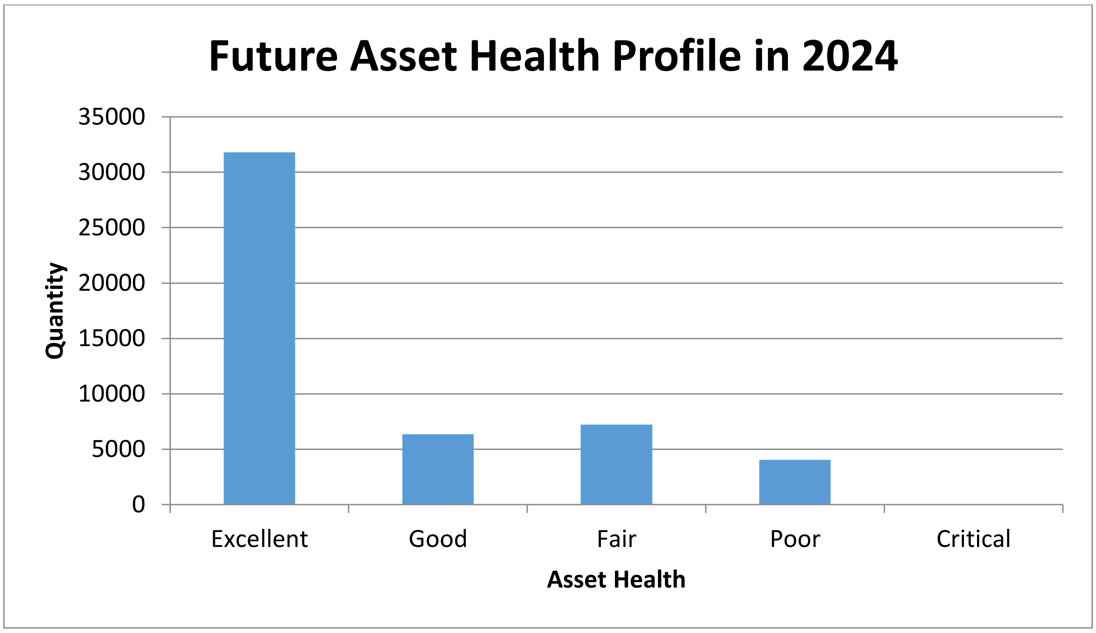

Figure 9: Asset Future Health Profile – Poles Assets

6 Implementation

This section provides implementation details for the recommended asset management strategy option.

6.1 Asset Creation Plan

6.1.1 Network Augmentation Requirements

The ActewAGL network includes approximately 49,000 poles, the majority of which are wooden and subject to gradual rotting and subsequent loss of strength. As wooden poles deteriorate they require strengthening works such as nailing or attaching steel armour guards and are therefore no longer used for augmentation projects.

Pre-stressed spun concrete poles are the preferred type for overhead distribution augmentation projects, and for the past 5 years, an average of 271 new concrete poles have been installed on our distribution network. Two-part fibreglass poles are used in locations that are difficult to access (typically for low voltage applications in urban residential property back yards).

Underground infrastructure is preferred for augmentation of the distribution network in urban areas due to the reliability it provides. New overhead installations may be considered in rural areas where it is not economical to invest in underground assets.

6.2 Asset Maintenance Plan

The objective of this maintenance plan is to economically achieve the longest possible reliable working life of assets. This is done through condition monitoring and has been adapted to ActewAGL's assets, operating environment and conditions.

6.2.1 Development

The maintenance plan is designed to achieve the objectives of the asset specific strategy. The following engineering techniques were used to develop the maintenance plan:

- Failure Mode and Effects Analysis (FMEA)
- Condition monitoring
- Historic performance
- Industry working groups
- Continuous review of asset performance and fine-tuning of maintenance triggers.

The maintenance plan is summarised in Table 16.

Asset Type	Maintenance Task	Maintenance Trigger
Timber Pole	Aerial Photography	Rural - 2 yearly
		Urban - 3 yearly
	Visual Inspection	Rural - 2 yearly
	Ground Inspection	Rural - 4 yearly
		Urban - 5 yearly
Concrete Pole	Aerial Photography	Rural - 2 yearly
		Urban - 3 yearly
	Visual Inspection	Rural - 2 yearly
Steel Pole	Aerial Photography	Rural - 2 yearly
		Urban - 3 yearly
	Visual Inspection	Rural - 2 yearly
Fibreglass Pole	Aerial Photography	Rural - 2 yearly
		Urban - 3 yearly
	Visual Inspection	Rural - 2 yearly

Table 16: Distribution Pole Maintenance Interval Summary

6.2.2 Condition Monitoring

6.2.2.1 Testing

Timber poles are tested using a drilling technique. A small hole is drilled into the pole which allows the inspector to measure the approximate size of any internal rot within the pole. A thin ruler can be placed inside the drill hold and used to measure the good wood thickness of the pole. The location of the drill will depend if the pole has been reinforced.

Non reinforced poles will be tested at the base of the pole below ground level. The drilling is conducted at an angle to the pole to minimise the soil disturbance at the base of the pole. On each pole, one drill is conducted on two axis to determine the remaining good wood.

On reinforced poles, the drilling takes place approximately 1 metre above ground level. Since the pole has already deteriorated blow ground which required reinforcement, the testing location is moved up the pole to a location close to where the reinforcement is secured to the pole. A similar methodology to below ground testing is used to determine the size of defect and the remaining good wood.

All drill holes are filled with a resin once the testing is complete to reduce the damage on the pole. If the holes are not filled in upon completion, it provides an additional pathway for moisture ingress and reduces the physical integrity of the pole.

There is currently a trial being carried out to investigate the possible use of non-destructive testing of the poles. The trial uses equipment to strike near the base of the pole and provides the inspector with an indication of deterioration. Base on this information, the inspector can choose to carry out the drilling test described above, or can move on to the next pole. This non-destructive test eliminates the need to drill poles which have no internal rot.

6.2.2.2 Visual

Visual inspections on poles are carried out to identify defects on the pole top, pole furnishings (such as cross arms and insulators) or pole top equipment (such as air break switches). The visual inspection program is broken up into ground based and aerial.

Ground based inspections are carried out by personnel to identify defects on the pole, furnishings and equipment. An online form is completed on the spot and submitted to the words management program on completion of the form. If a priority one defect is found, the inspector can immediately arrange to have a reactive crew attend site and repair the defect.

Aerial inspections are currently being carried out by a contractor through the use of aircrafts (helicopters in the past). The aircraft is able to move quickly through the air and capture high resolution images of pole tops. The images are then assessed and used to identify defects on the pole, furnishings or equipment. All of the captured images are stored in AAD’s works management program Cityworks.

6.2.3 Maintenance Strategy

Although there are many defects which are identified and repaired on a pole structure, there are very few maintenance items which directly relate to the pole. There is no ongoing pole maintenance program, as all the rectification works are defect driven. Pole maintenance activities may include straighten leaning pole, treating termites, replacing pole caps and removal of redundant poles.

Over time, steel poles tend to rust below ground due to the constant moisture in the soil. The underground rusting can be reduced by reapplying a galvanised surface on the pole. This will reduce the rate of decay and increase the potential life of the pole.

6.3 Asset Renewal Plan

Poles tend to be replaced one by one as the reach their individual end of life. Due to the different rate of deterioration between poles, it is very rare that it is found to be economical to replace a large number of poles along a single line. There are occasions where there may be a few (2-3) poles that are located on the same line next to each other and have reached end of life at the same and can be economically replaced as one packaged works.

6.3.1.1 Refurbishment

Timber poles are the only type of poles which are currently being refurbished. Timber poles tend to rot at the base due to the constant moisture present in the soil. This weakens the pole at the base and increases the likelihood of failure. The testing methodologies mentioned in the previous section are used to identify failing poles. Given that the rotting has only occurred at the base, it is possible to apply a support structure (usually made of metal) fixed to the pole which runs both above and below ground. This added support structure commonly known as a 'nail', reinforces the pole at is existing weak spot. The installation of a nail is low cost and can typically extend the life of the pole between 10 and 15 years.

6.3.1.2 Replacement

Timber and steel poles are very rarely used as replacements as industry have moved towards concrete and fibreglass. Concrete poles are preferred due to their durability, and fibreglass poles are preferred due to their light weight. Timber poles are replaced with concrete poles in most cased where crane access is available.

The AAD network has poles which were installed in residential backyards. This presents many asset management difficulties including replacement. The original pole material type installed in backyards was timber, and then steel. Fibreglass poles are now used to replace poles in backyards due to their lightweight modular design. This reduces the size of the plant required and allows for the installation within small areas.

6.4 Asset Disposal Plan

Timber poles are cut up using a chainsaw usually on site for the ease of transportation, and disposed. Treated timber poles are disposed as a whole unit and is not cut up due hazards associated with the treatment in the pole.

Steel poles are either recycled at a recycling centre if they are no longer able to be re-used, or are placed back into stores if it is estimated to have sufficient life left.

Concrete and fibreglass poles are generally re-used as the AAD population has not reached end of life. For the few which have been removed due to defects, they are disposed at a waste management centre.

6.5 Associated Asset Management Plans

Distribution pole assets have related functions to the following asset classes:

- Overhead lines and pole hardware;
- Overhead switchgear and automation;
- Pole substations

6.6 Asset Strategy Optimisation Plan

The aim of the asset optimisation plan is to provide:

- Completion of the non-destructive inspection program trail and integration into asset modelling systems.
- Review steel pole refurbishment strategies

7 Program of Work

This section provides the Program of Work and the resulting operational and capital expenditure forecasts.

7.1 Maintenance Program

This section outlines the operational expenditure for preventative maintenance, corrective maintenance and condition monitoring and is shown in Figure 10.

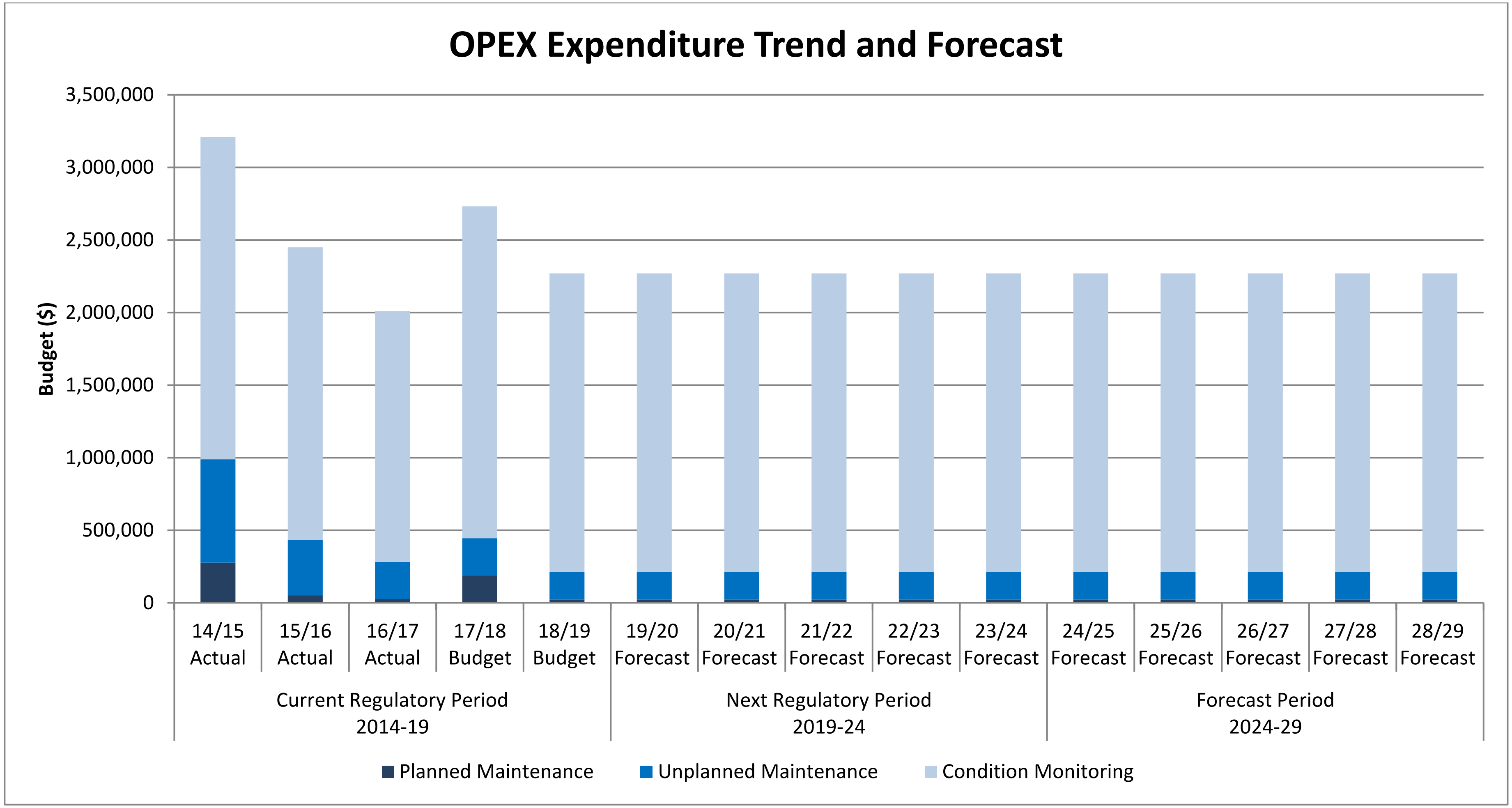

Figure 10: OPEX for Maintenance Program of Distribution Poles

7.2 Capital Program

This section outlines the capital expenditure for asset replacement and refurbishment and is shown in Figure 11.

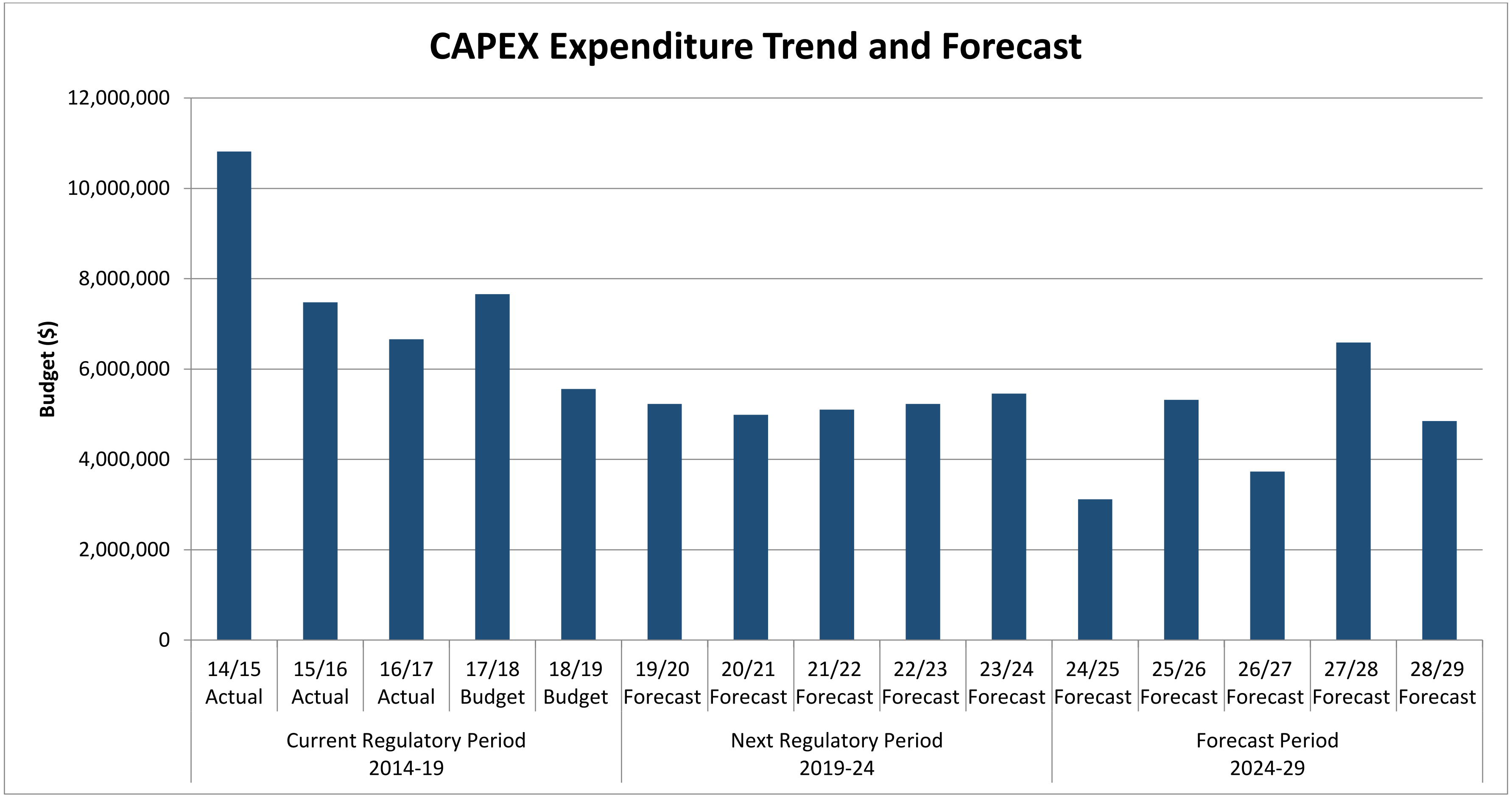

Figure 11: CAPEX Program for Distribution Poles

7.3 Budget Forecast

This section provides a 10 year forecast for the CAPEX & OPEX budgets and is shown in Table 17.

Total Budget	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29
CAPEX	**5,557,800**	**5,227,510**	**4,987,550**	**5,101,600**	**5,227,510**	**5,455,610**	**3,115,377**	**5,315,371**	**3,729,330**	**6,584,556**	**4,851,436**
OPEX	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**	**2,269,908**
Planned Maintenance	22,855	22,855	22,855	22,855	22,855	22,855	22,855	22,855	22,855	22,855	22,855
Unplanned Maintenance	191,053	191,053	191,053	191,053	191,053	191,053	191,053	191,053	191,053	191,053	191,053
Condition Monitoring	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000	2,056,000

Table 17: CAPEX & OPEX 10 Year Budget Forecast

7.4 Program of Work Summary

The program of work for summary for 2018-24 is shown in Table 18.

Year	2018/19		2019/20		2020/21		2021/22		2022/23		2023/24	
Tasks	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)	Units	Budget ($)
CAPEX	**887**	**5,557,800**	**837**	**5,227,510**	**787**	**4,987,550**	**807**	**5,101,600**	**837**	**5,227,510**	**877**	**5,455,610**
Replacement	**492**	**5,089,330**	**462**	**4,782,760**	**442**	**4,578,380**	**452**	**4,680,570**	**462**	**4,782,760**	**482**	**4,987,140**
Replace Pole with Difficult Access	2	82,020	2	82,020	2	82,020	2	82,020	2	82,020	2	82,020
Replace Pole	490	5,007,310	460	4,700,740	440	4,496,360	450	4,598,550	460	4,700,740	480	4,905,120
Refurbishment	**395**	**468,470**	**375**	**444,750**	**345**	**409,170**	**355**	**421,030**	**375**	**444,750**	**395**	**468,470**
Nail Pole	395	468,470	375	444,750	345	409,170	355	421,030	375	444,750	395	468,470
OPEX	**10,623**	**2,269,908**	**10,623**	**2,269,908**	**10,623**	**2,269,908**	**10,623**	**2,269,908**	**10,623**	**2,269,908**	**10,623**	**2,269,908**
Planned Maintenance	**5**	**22,855**	**5**	**22,855**	**5**	**22,855**	**5**	**22,855**	**5**	**22,855**	**5**	**22,855**
Remove Redundant Overhead Network	5	22,855	5	22,855	5	22,855	5	22,855	5	22,855	5	22,855
Unplanned Maintenance	**68**	**191,053**	**68**	**191,053**	**68**	**191,053**	**68**	**191,053**	**68**	**191,053**	**68**	**191,053**
Maintain or Replace Rural private pole	1	10,635	1	10,635	1	10,635	1	10,635	1	10,635	1	10,635
Maintain Pole - High Priority Repair	55	121,165	55	121,165	55	121,165	55	121,165	55	121,165	55	121,165
Straighten Leaning Pole	3	26,538	3	26,538	3	26,538	3	26,538	3	26,538	3	26,538
Investigate concrete pole spiral cracking	5	16,715	5	16,715	5	16,715	5	16,715	5	16,715	5	16,715
Repair fibreglass pole installation	4	16,000	4	16,000	4	16,000	4	16,000	4	16,000	4	16,000
Condition Monitoring	**10,550**	**2,056,000**	**10,550**	**2,056,000**	**10,550**	**2,056,000**	**10,550**	**2,056,000**	**10,550**	**2,056,000**	**10,550**	**2,056,000**
Aerial Photographic Inspection	Included in vegetation management budget											
Test Soil Compaction	50	10,900	50	10,900	50	10,900	50	10,900	50	10,900	50	10,900
Ground Inspection	10,500	2,045,100	10,500	2,045,100	10,500	2,045,100	10,500	2,045,100	10,500	2,045,100	10,500	2,045,100
Grand Total	**11,510**	**7,827,708**	**11,460**	**7,497,418**	**11,410**	**7,257,458**	**11,430**	**7,371,508**	**11,460**	**7,497,418**	**11,500**	**7,725,518**

Table 18: PoW Summary

Appendix A Maintenance Plan Details

Appendix A provides additional details of the data used in evaluation of the asset management strategy options, including the costing and budget forecasting.

A.1 Maintenance Task Costing

Unit costs for this asset class have been estimated and are summarised below.

A.1.1 Planned Maintenance Tasks

Asset Type	Task	Unit Cost ($)
All Pole Types	Remove Redundant Overhead Network	4,571

Table 19: Planned Maintenance Task Unit Costs

A.1.2 Unplanned Maintenance Tasks

Asset Type	Task	Unit Cost ($)
All Pole Types	Maintain or Replace Rural private pole	10,635
	Maintain Pole - High Priority Repair	2,203
	Straighten Leaning Pole	8,846
Concrete Pole	Investigate concrete pole spiral cracking	3,343
Stobie Pole	Investigate concrete pole spiral cracking	3,343
Fibreglass Pole	Repair fibreglass pole due to incorrect installation	4,000

Table 20: Unplanned Maintenance Task Unit Costs

A.1.3 Condition Monitoring Tasks

Asset Type	Task	Unit Cost ($)
Timber Pole	Inspection Level 1	54
	Inspection Level 3	144
	Inspection Level 4	322
	Inspection Level 5	144
	Inspection Level 6	322
	Inspection Level 7	54
Concrete Pole	Inspection Level 1	54
	Inspection Level 7	54
Fibreglass Pole	Inspection Level 1	54
	Inspection Level 7	54
Steel Pole	Inspection Level 1	54
	Inspection Level 2	144
	Inspection Level 7	54
Stobie Pole	Inspection Level 1	54
	Inspection Level 2	144
	Inspection Level 7	54
All Pole Types	Ariel Inspection	25

Table 21: Condition Monitoring Task Unit Costs

A.1.4 Replacement and Refurbishment Tasks

Asset Type	Task	Unit Cost ($)
Timber Pole	Replace Pole	10,219
	Refurbish Pole (nail)	1,186
Concrete Pole	Replace Pole	10,219
Fibreglass Pole	Replace Pole	10,219
Stobie Pole	Replace Pole	10,219
Steel Pole	Replace Pole	10,219

Table 22: Replacement and Refurbishment Task Unit Costs

Appendix B Risk Definitions

Appendix B provides reference information detailing how the severity of an effect, the probability of failure and the likelihood of detection are defined and ranked for the analysis of risk.

B.1 Severity

Effect	SEVERITY of Effect	Ranking
Catastrophic	Hazardous-without warning. Very high severity ranking, potential failure mode affects safety, noncompliance with policy and without warning.	10
Extreme	Hazardous-with warning. Very high severity ranking, potential failure mode affects safety, noncompliance with policy with warning.	9
Very High	Item inoperable, with loss of primary function	8
High	Item operable, but primary function at reduced level of performance	7
Moderate	Equipment operable, but with some functions inhibited	6
Low	Operable at reduced level of performance	5
Very Low	Does not conform. Defect obvious.	4
Minor	Defect noticed by routine inspection	3
Very Minor	Defect noticed by close inspection	2
None	No effect	1

B.2 Occurrence

PROBABILITY of Failure	Failure Probability	Failure rate Lamda "λ"	Ranking
Very High: Failure is almost inevitable	Very High: Failure is almost inevitable. Possible Failure Rate >= 1 every week.	0.1429	10
	Very High: Failure is almost inevitable. Possible Failure Rate >= 1 every month.	0.0333	9
High: Repeated failures	High: Repeated failures. Possible Failure Rate >= 1 every 3 months.	0.0111	8
	High: Repeated failures. Possible Failure Rate >= 1 every 6 months.	0.0056	7
Moderate: Occasional failures	Moderate: Occasional failures. Possible Failure Rate >= 1 every year.	0.0027	6
	Moderate: Occasional failures. Possible Failure Rate >= 1 every 3 years.	0.0009	5
	Moderate: Occasional failures. Possible Failure Rate >= 1 every 5 years.	0.0005	4
Low: Relatively few failures	Low: Relatively few failures. Possible Failure Rate >= 1 every 8 years.	0.0003	3
	Low: Relatively few failures. Possible Failure Rate >= 1 every 15 years.	0.0002	2
Remote: Failure is unlikely	Remote: Failure is unlikely. Possible Failure Rate >= 1 every 20 years.	0.0001	1

B.3 Detection

Detection	Likelihood of DETECTION	Ranking
Absolute Uncertainty	Control cannot prevent / detect potential cause/mechanism and subsequent failure mode	10
Very Remote	Very remote chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	9
Remote	Remote chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	8
Very Low	Very low chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	7
Low	Low chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	6
Moderate	Moderate chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	5
Moderately High	Moderately High chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	4
High	High chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	3
Very High	Very high chance the control will prevent / detect potential cause/mechanism and subsequent failure mode	2
Almost Certain	Control will prevent / detect potential cause/mechanism and subsequent failure mode	1