Poles

AMS - Electricity Distribution Network

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1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' electricity distribution network. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of galvanised steel, steel reinforced concrete and wood poles in AusNet Services' Victorian electricity distribution network.

Australian hardwood poles form approximately 47% of the entire pole population. Steel reinforced concrete poles were introduced in the early 1970s and make up 31% of the population. The remaining 22% are the galvanised steel lighting poles. Pole staking was introduced in the late 1980s to manage the rising of the wood poles' replacement rate. AusNet Services currently has a fleet of approximately 23,000 staked poles. In order to economically extend the service life of a greater range of deteriorated poles, AusNet Services is continuously exploring alternative pole staking and rebutting techniques. This include new wood preservatives and new pole reinforcement techniques.

The distribution pole inspection program is undertaken through a combination of ground (test and inspected) and aerial based inspection activities as approved by Energy Safe Victoria, as satisfying the requirement for inspections and intervals contained in the Electricity Safety (Bushfire Mitigation) Regulations. These rules have been developed using a risk-based approach to reduce the risk of a pole failure "as far as practicable" as required by the Electricity Safety Act.

Proactive management of pole application, inspection, maintenance, refurbishment and replacement practice is required to ensure that stakeholder expectations of cost, safety, reliability and environmental performance are met.

1.1 Asset Strategies

1.1.1 New Assets

- Monitor the availability, procurement costs, transport costs and supply of wood poles.
- Monitor the availability, procurement costs, transport costs and supply of concrete poles.
- Establish new public lighting installations on galvanised steel poles.
- Establish new service poles using CCA treated wood poles
- Establish new LV only circuits on CCA treated wood poles.
- Establish new simple MV structures on CCA treated wood poles.
- Establish new complex MV structures on concrete poles.
- Establish new sub-transmission structures on concrete poles.
- Effectively earth all conductive poles in accordance with published standards.
- Customer requests pole materials will be considered.

1.1.2 Inspection

- All poles shall be subject to a cyclic inspection involving a condition assessment and any other visual inspections as per the criteria established in the Asset Inspection Manual 30-4111.
- Stay wires and rods shall be inspected at the same time as the pole.

1.1.3 Refurbishment

- Reinforce wood poles on condition.
- Reinforce galvanised steel poles on condition
- Where technically feasible all wood poles shall be reinforced to extend expected remaining life for a minimum of two years.
- Where technically feasible, reinforce Underground Residential Distribution (URD) steel poles in place of replacement.

1.1.4 Replacement

- Replace galvanised steel, concrete and wood poles on unserviceable condition.
- Replace deteriorated wood poles, which have previously been treated for termite infestation with other pole types as per the Standard Maintenance Guidelines SOP 70-03.
- The selection of replacement poles shall follow the same guidelines as for New Assets.
- Replace stay wire and rod and as required, replace bed log when replacing deteriorated poles.

1.1.5 Research and Development

- Monitor trial and implement more economic materials and technologies for poles, staking and preservative treatments.
- Investigate alternative inspection techniques to monitor wood decay.
- Collect more accurate measurement of poles by using non-destructive technologies such as “Wood Scan”, to monitor pole deterioration rates.
- Investigate, trial and implement the use of non-destructive testing for steel poles
- Develop stay solutions for concrete poles.
- Establish guidelines for the economic extension of wood pole life using staking, rebutting and refurbishment of pole tops.
- Establish guidelines for economic replacement of poles when other assets are being replaced.
- Investigate safety issues of poles in relation to proximity of the carriageway, e.g. monitor effectiveness of the raptor trial, and solutions to streetlight poles on dangerous corners.
- Investigate, develop and implement new wood rot prevention techniques to protect staked wood poles and control decay at reinforcement attachment points.
- Investigate, develop and implement economic new wood pole life extension techniques including alternative staking, rebutting techniques and introducing longer stakes for wood poles.

2 Introduction

2.1 Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of galvanised steel, steel reinforced concrete and wood poles in AusNet Services' Victorian electricity distribution network. This document is intended to be used to inform asset management decisions and communicate the basis for activities.

In addition, this document forms part of our Asset Management System for compliance with relevant standards and regulatory requirements. This document demonstrates responsible asset management practices by outlining economically justified outcomes.

2.2 Scope

This Asset Management Strategy applies to all poles associated with the distribution and sub-transmission electricity networks.

Assets relating to pole top infrastructure are described in:

- AMS 20-52 Conductor
- AMS 20-57 Cross-arms
- AMS 20-66 Insulators – High and Medium Voltage

2.3 Asset Management Objectives

As stated in *AMS 01-01 Asset Management System Overview*, the high-level asset management objectives are:

- Comply with legal and contractual obligations;
- Maintain safety;
- Be future ready;
- Maintain network performance at the lowest sustainable cost; and
- Meet customer needs.

As stated in *AMS 20-01 Electricity Distribution Network Asset Management Strategy*, the electricity distribution network objectives are:

- Improve efficiency of network investments;
- Maintain long-term network reliability;
- Implement REFCL's within prescribed timeframes;
- Reduce risks in highest bushfire risk areas;
- Achieve top quartile operational efficiency; and
- Prepare for changing network usage.

3 Asset Description

3.1 Asset Function

Poles provide load bearing structural support for overhead conductors and equipment in the electricity distribution network. The purpose of poles is to establish safe electrical and physical clearances between electrical conductors and the ground, and other structures. Moreover, sufficient strength is required to withstand forces.

3.2 Asset Population

AusNet Services' electricity distribution network has approximately 399,000 concrete, wood and galvanised steel poles supporting 2,600km of sub-transmission lines, 29,000km of MV feeders, 6,600km of LV circuits and 151,000 public lighting lanterns in the eastern part of Victoria[1][2].

Wood (Australian hardwood) poles form 47% of the pole population as shown in Table 1. Steel reinforced concrete poles were introduced in the early 1970s and make up 31% of the population. The remaining 22% are the galvanised steel public lighting poles. In addition, there are a few Fibreglass (glass reinforced plastic) poles installed in the network as a long term trial, the performance and reliability for the Fibreglass poles are yet to be determined.

Table 1 - Pole by Material Type

RIN Category	Number of Asset	Percentage of Fleet
Wood	187,608	47%
Concrete	123,942	31%
Steel	87,005	22%

3.2.1 Asset Population by Type

3.2.1.1. Wood Poles

AusNet Services purchase wood poles to Australian Standard AS 2209-1994[3], which classifies wood species according to its code. The strength group and durability class are listed in Asset Inspection Manual 30-4111[4]. The wood poles specification can be found in DES 10-18[5].

[1] 2017 AusNet Services (distribution) Category Analysis

[2] 2017 AusNet Services (distribution) Annual Reporting Statement

[3] Australian Standard AS 2209-1994 Wood Poles for Overhead Lines

[4] Asset Inspection Manual 30-4111 Issue10

[5] Wood Poles Specification – Electricity Distribution Specification

There are approximately 187,600 wood poles in the network. The proportion of species within this fleet is shown in Figure 1.

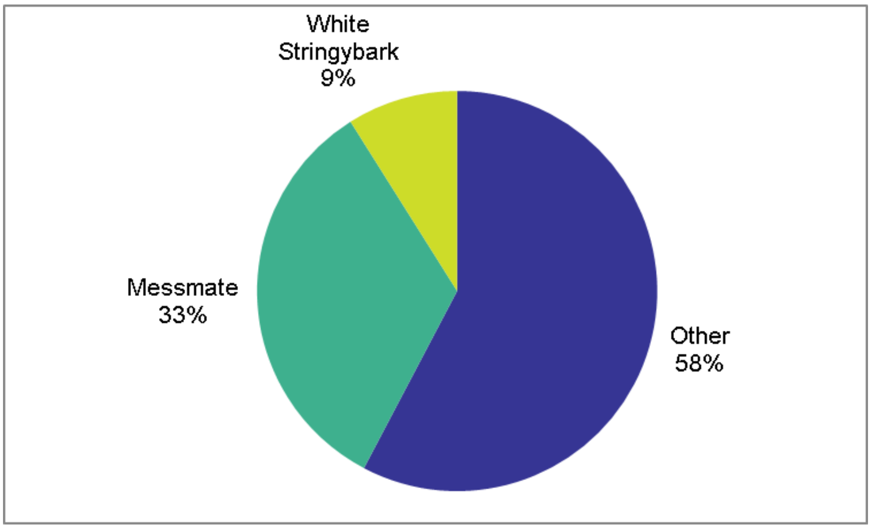

Figure 1 - Wood Poles by Wood Species

Messmate and White Stringybark poles make a significant proportion of wood poles accounting for 33% and 9% respectively. Since 1993, Class 1 wood poles are regal species wood, often dressed octagonally by suppliers. Class 2 wood poles usually have a natural round profiles. The entire Class 3 poles are creosote pressure treated. The Copper chromiumarsenate (CCA) treated Class 1 and 2 wood poles were introduced in 1992, which represent a small proportion of the overall wood pole population.

3.2.1.2. Concrete Poles

There are approximately 124,000 steel reinforced concrete poles[6] in service, which have been used in Victoria since the early 1970s. They are electrically conductive and require additional engineering of insulation and earthing systems to provide a safe and reliable performance.

Figure 2 shows a typical 22kV and LV circuit concrete pole.

[6] Australian Standard AS/NZS 4676-2000 Structural Design Requirements for Utility Services Poles

Figure 2 - Concrete Pole

3.2.1.3. Galvanised Steel Pole

Galvanised steel poles have been predominately used as street light poles within the electricity distribution network. Similar to concrete poles, galvanised steel poles are electrically conductive and require additional engineering of insulation and earthing systems to ensure safety and reliability. There are approximately 87,000 galvanised steel poles supporting public-lighting lanterns in eastern part of Victoria.

Figure 3 shows a typical galvanised steel pole.

Figure 3 - Galvanised Steel Pole

3.3 Asset Age Profile

The historical expansion of the distribution network has resulted in considerable infrastructure installations and replacements causing the asset age profile to be sporadic. The service age profile of all poles on the distribution network is shown in Figure 4. Approximately 2% of the poles have a service age exceeded 75 years. These poles are currently subjected to data review.

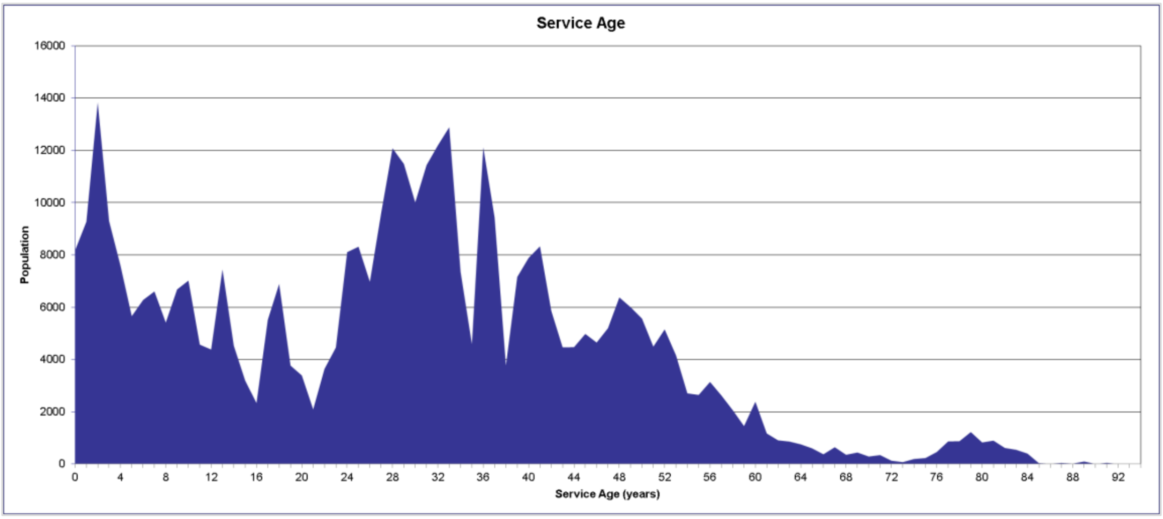

Figure 4 - Pole Age Overview

3.3.1 Age Profile by Pole Type

The service age profile can be segmented into age bands and pole types. Figure 5 illustrates the introduction of concrete poles over recent years and the increase in steel public lighting poles population.

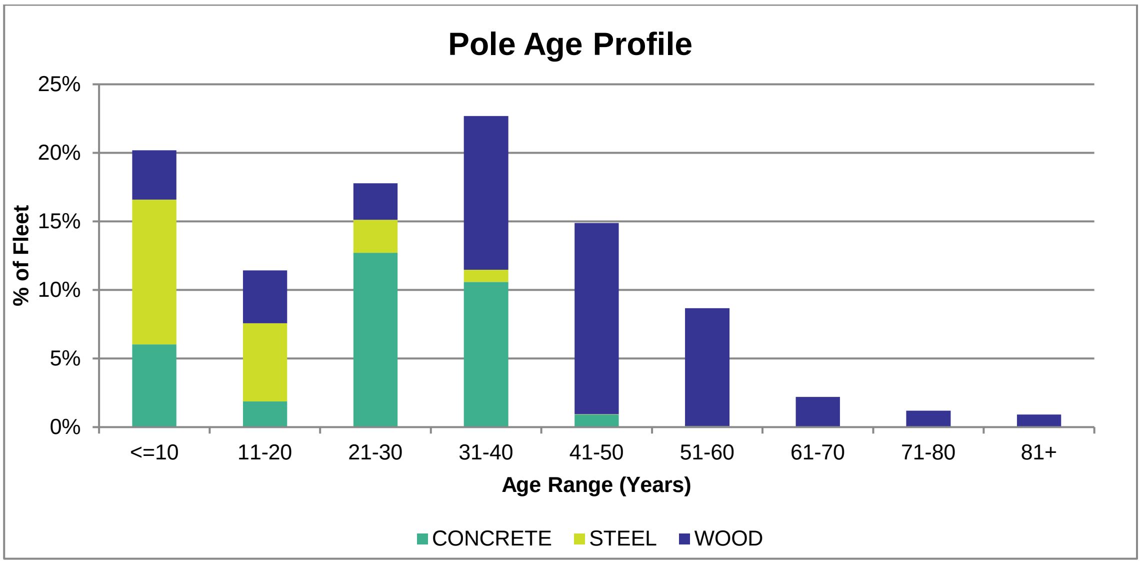

Figure 5 - Segmented Pole Age Overview

The average service age for the overall pole population is 29 years, with the standard deviation of 18 years. The average service age for wood, concrete and galvanised steel poles are given in Table 2.

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Table 2 - Pole Age Summary

Asset Type	Average Service Age	Standard Deviation
Wood	40.1 years	17.5 years
Concrete	24.5 years	11.4 years
Steel	11.1 years	9.3 years

3.3.1.1. Wood Poles

The service life of a wood pole can be extended by using wood preservatives, termiticide, and pole reinforcement techniques.

Figure 6 shows the age profile of wood pole.

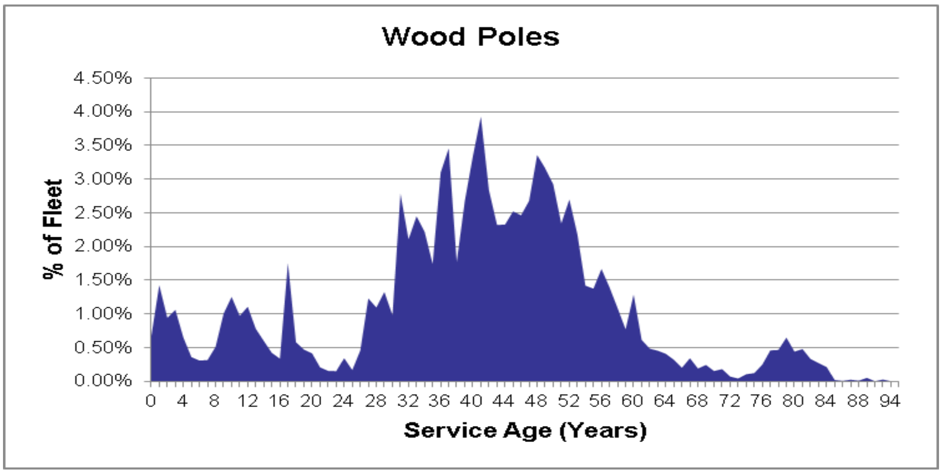


Figure 6 - Wood Pole Age Profile

3.3.1.1.1. Wood Poles Reinforcement

Approximately 12% of the wood pole population have been reinforced through pole staking. Poles that have been staked are expected to have their serviceable life extended by an additional 10 to 15 years. Pole re-butting is another pole reinforcement technique applied to extend the service life of a pole. Pole reinforcement procedures and criteria can be found in the Standard Maintenance Guidelines SOP 70-03[7].

The service age profile of staked wood poles shows an average age of 51 years with a standard deviation of 12 years. In contrast, un-staked wood poles have an average age of 40 years with a standard deviation of 18 years. This suggests that on average, staked wood poles have extended their service life by 11 years.

[7] Standard Maintenance Guidelines – Distribution and Sub-transmission Lines and Associated Assets – Standard Operating Procedures

3.3.1.2. Concrete Poles

Less than 1% of the concrete pole fleet are exhibiting signs of external corrosion; this is being monitored and currently has no effect on the serviceability of these poles. As the fleet increases in population and age, the understanding of the asset class will develop to a level equivalent to that of wood poles.

Currently the technical life for concrete poles has not been determined; however, with the oldest installations approaching 45 years and fewer than ten have been replaced due to deterioration, it is expected to last beyond 60 years and may well achieve a mean service life of 100 years. This will be determined through the ongoing inspection and condition assessment regime and analysis of deterioration and replacement rates.

Figure 7 shows the increased usage of concrete poles from late 1970's to the 90's due primarily to the shortages in wood pole availability.

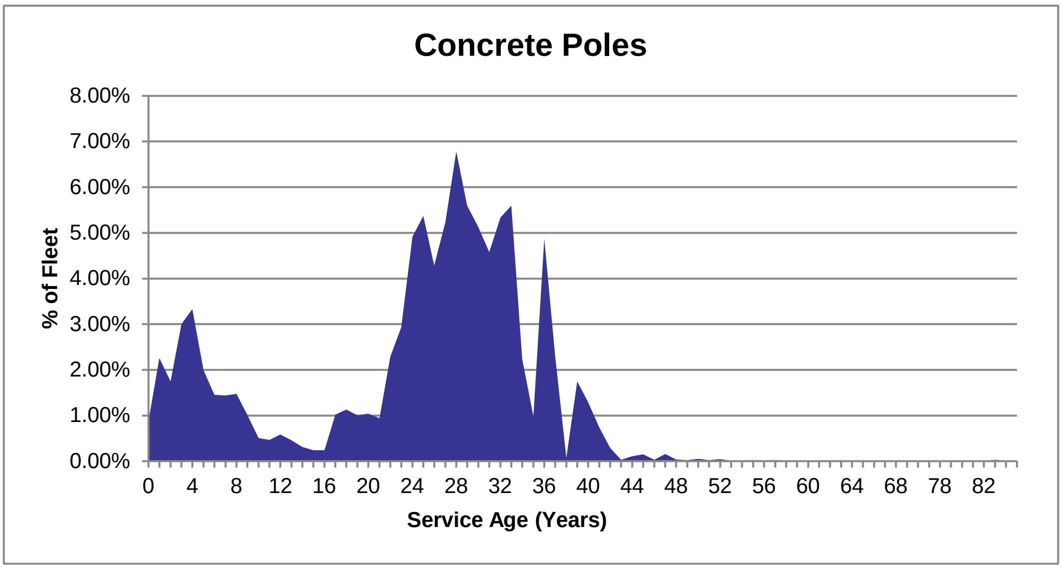


Figure 7 - Concrete Pole Age Profile

3.3.1.3. Galvanised Steel Poles

Galvanised steel poles have an expected service life of 35 years and a standard deviation of 6 years when employed as utility poles in the Electricity Distribution Network.

However due to the application of the below ground anti-corrosion coatings and improved galvanising techniques, it is expected that galvanised steel poles installed after the 1990s should have an estimated expected life of nearing 50 years.

Figure 8 shows the age profile for the current population of galvanised steel poles.

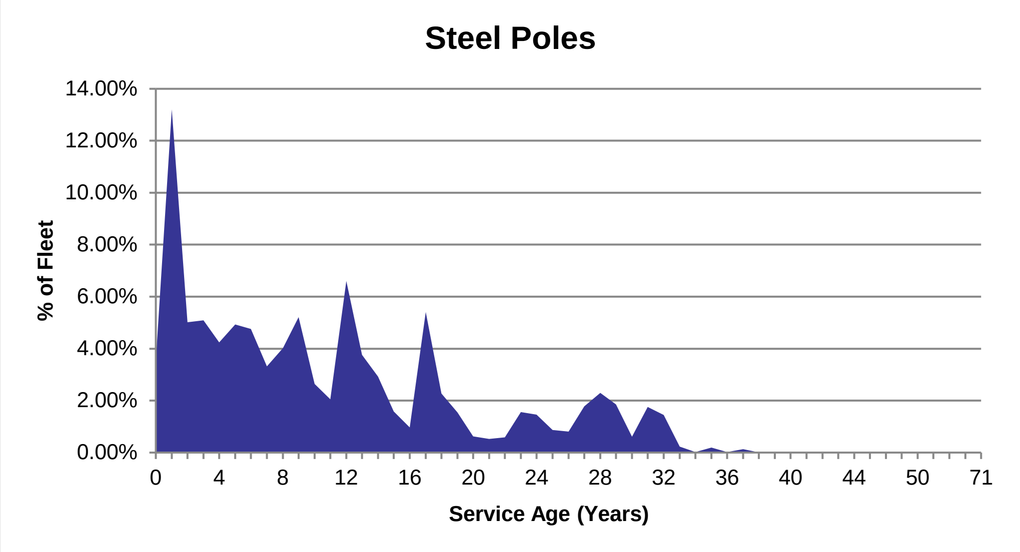


Figure 8 - Steel Pole Age Profile

Reinforcement works such as staking galvanised steel poles are currently applied to extend the service life of a pole.

Staking criteria and procedures can be found in the Standard Maintenance Guidelines SOP 70-03[7].

3.4 Asset Condition

To provide a consistent assessment of the condition of the whole asset group, a common condition scoring methodology has been developed. This methodology uses the known condition details of each asset and grades that asset against common asset condition criteria.

There are 5 different condition scores that have been applied to each distribution pole, ranging from "Very Good" (C1) to "Very Poor" (C5). Table 3 describes the attributes, which determine the condition score rating.

Table 3 - Pole Condition Scoring Methodology

Condition Scoring Methodology			
Condition Score	**Condition Description**	**Summary of Condition Score**	**Remaining Life**
C1	Very Good	Generally, in excellent operating condition with no history of significant defects or failures. Routine inspection and condition monitoring is recommended.	95%
C2	Good	Includes assets in better than average. Does not require intervention between scheduled inspections nor do they show any trends of deterioration in condition or performance.	70%
C3	Average	This category includes assets which are in an average condition for its material type. These assets typically require some maintenance activity. The assets demonstrate typical	45%

		deterioration in condition or performance.	
C4	Poor	Includes assets which are in worse than average condition. Specialist work is required to manage specific defects, may be classified as 'Limited Life' depending upon the material type.	25%
C5	Very Poor	This category includes assets which are inspection and maintenance intensive. These assets are approaching the end of economic life. The asset is now considered 'Limited Life' and is being managed through to the 'Unserviceable' condition and replacement. There are currently no economical alternatives to asset replacement.	15%

For further detailed information regarding the condition assessment framework, specific issues, conditional maintenance activities and discussion of fails, refer to AHR 20-70 - Pole Asset Health Report[8].

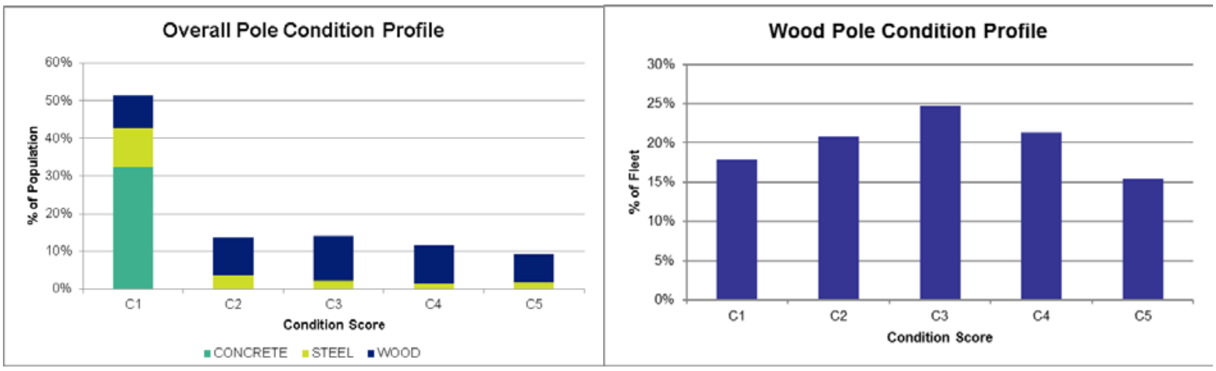
3.4.1 Pole Condition Summary

Table 4 provides a summary of condition all poles.

Table 4 - Condition Summary for all Poles

Condition	Wood	Concrete	Steel	Total
C 1	8.6%	32.3%	10.5%	51.3%
C 2	10.0%	<0.01%	3.7%	13.7%
C 3	11.9%	<0.01%	2.2%	14.1%
C 4	10.3%	<0.01%	1.4%	11.7%
C 5	7.4%	<0.01%	1.8%	9.2%

Figure 9 illustrates the overall pole condition profile and condition scores for each pole type.



[8] AHR 20-70 Poles

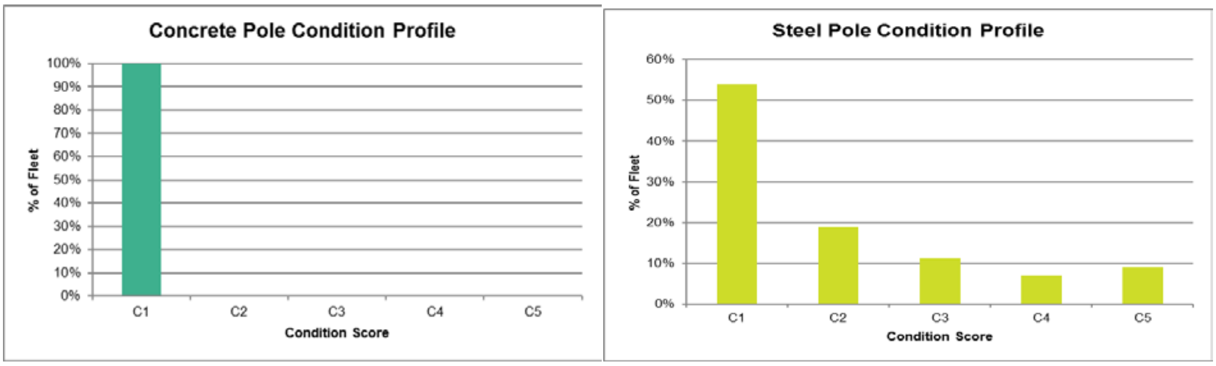


Figure 9 - Pole Condition by Type

It is observed that over 65% of the pole population is in “Good” or “Very Good” condition.

3.4.2 Pole Condition by Pole Type

This section discusses pole condition by each pole type.

3.4.2.1. Wood Poles

Condition Summary for wood poles is shown in Table 5. Approximately 15% of wood poles are in condition C5, which may subject to replacement or reinforcement. The condition 4 and 5 of Wood Poles “Others” consist of more than 20 different wood species.

Table 5 - Condition Summary of Wood Poles by Species

Condition	Messmate	White Stringybark	Others	Total
C 1	1.8%	0.2%	15.8%	17.8%
C 2	9.5%	2.1%	9.3%	20.8%
C 3	9.3%	4.2%	11.2%	24.7%
C 4	7.8%	1.4%	12.1%	21.3%
C 5	4.9%	1.1%	9.4%	15.4%

Figure 10 shows the overall condition scores for all wood poles and by wood species. Historically White Stringybark poles have been the single largest species of poles requiring replacement. However, since 2009 when a significant drought throughout Victoria ended, there has been a substantial increase in the number of Messmate poles approaching the end of their serviceable life.

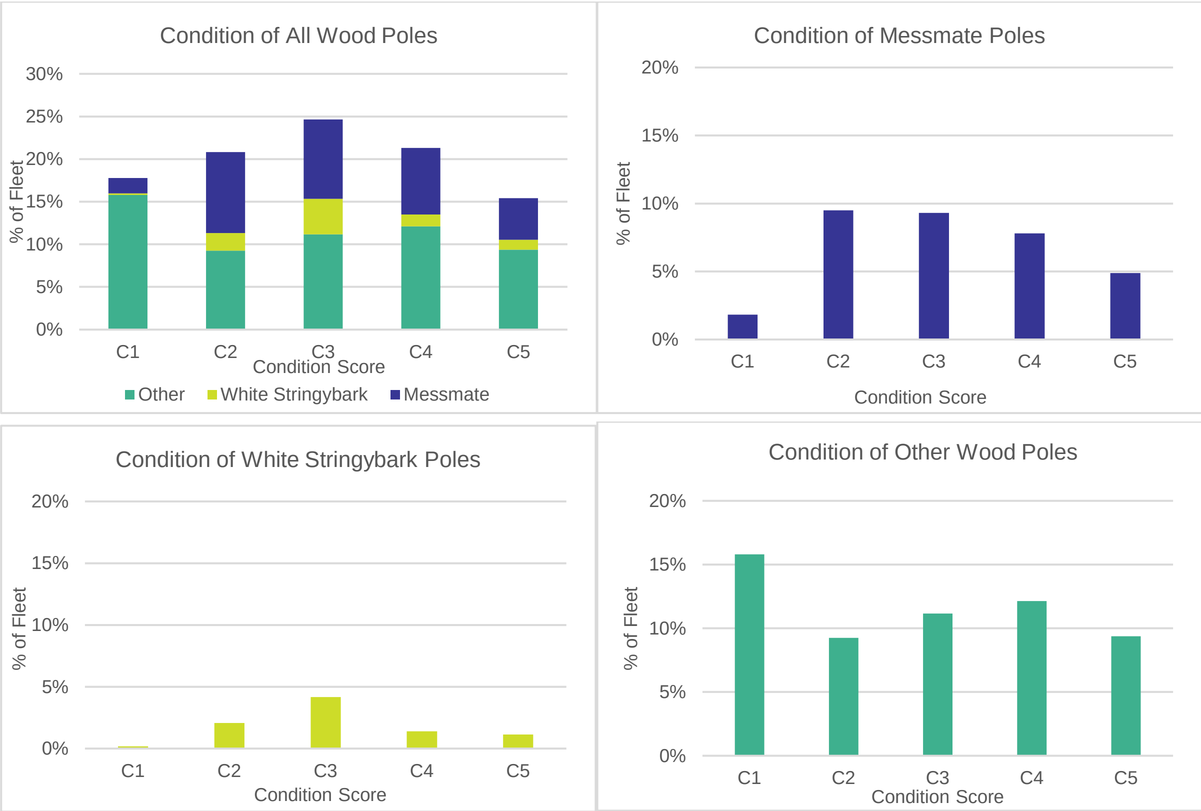


Figure 10 - Condition Profile for Wood Poles by Species

Figure 11 shows the service status of wood poles by species. The majority of wood poles are in the serviceable service status. It is observed that the White Stringybark poles have been extensively staked, which is a leading indicator of increasing replacement rates over the next decade. In order to postpone the increasing replacement rates of wood poles, development and implementation of new wood pole life-extension techniques, including alternative staking, rebutting and pole head reinforcement systems will be required.

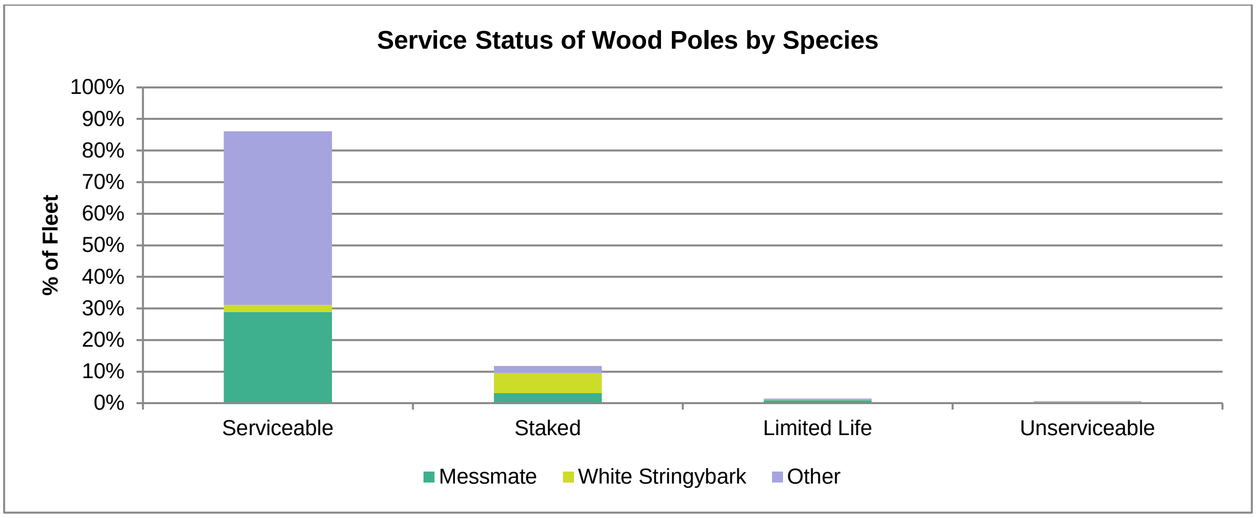


Figure 11 - Service Status of Wood Pole by Species

3.4.2.2. Concrete Poles

Concrete poles have thus far required very little maintenance in comparison to wood poles. Visual condition assessments have identified significantly less than 1% of the concrete pole population as being unserviceable or limited life. Therefore, more than 99% of the concrete poles are in “Very Good” condition.

The damage to unserviceable or limited life concrete poles has primarily been caused by the action of third parties, for example vehicle impact. The classification placed upon these assets and the ongoing inspection regime is expected to be adequate to monitor any increase in the level of degradation prior to failure. There have been very few planned concrete pole replacements due to the deterioration of the concrete structure.

Overall, the population is considered to be in a “Very Good” condition as illustrated in Figure 9. The existing maintenance inspection regime will continue until such time that future deterioration trends emerge.

3.4.2.3. Galvanised Steel Poles

Galvanised steel poles require relatively little maintenance. The current cyclical visual inspection of steel poles can identify surface corrosion at or just below ground level of a steel pole.

Figure 9 shows approximately 16% of galvanised poles are in “Poor” or “Very Poor” condition. The use of reinforcement works such as staking deteriorated galvanised steel poles has been a business as usual process since 2016.

There is no programmed remediation approach currently employed for below ground corrosion of a steel pole. The use of Non-Destructive Testing (NDT) is currently under investigation to see whether it can provide a better assessment of the serviceability of steel poles.

3.5 Asset Criticality

3.5.1 Failure Modes Effects Critical Analysis (FMECA)

Failure Mode, Effects and Criticality Analysis (FMECA) is a technique for analysing and evaluating a life-cycle strategy to ensure that the function has the desired reliability characteristics by managing critical failure modes through redundancy, maintenance, refurbishment or replacement.

FMECA includes a criticality analysis, which charts the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

3.5.2 Wood Pole Failure Modes

The failure modes of wood poles include:

- Wood Rot;
- Termites;
- Pole Fires; and

- Damage by motor vehicle or third party impact.

3.5.2.1. Wood Rot

Wood rot is the principal cause of wood pole downgrading. Rot occurs both internally and externally in the vicinity of the ground line. Rot reduces the cross-sectional area of sound wood and thus the structural strength of the pole over an extended time. The extent of sound wood can be assessed by drilling and probing the wood. On average the first signs of deterioration occur after 25 to 30 years' service. The 'warning time' (or P-F interval[9]) from when rot is first detected until when the pole becomes unserviceable can be as short as five years but is typically 20 years. The use of boric-acid based fungicides is effective in slowing the progression of rot, but the act of drilling for inspection and treatment can further reduce the strength of the pole.

3.5.2.2. Termites

Termites are insects that may be found in trees, logs, poles and most wood products. In Victoria, termites usually enter the pole from just below ground to the base of the pole. Several types of termites have been found in network poles. Examples include subterranean termites destroying sound wood, damp wood termites found in decaying wood and ambrosia beetles that may have riddled the tree with numerous galleries before significantly undermining the structural strength of the wood pole.

Termites have been found in approximately 3% of all wood poles across the network. Damage varies from being confined to a gallery in the middle of the pole, destroying a wood cross arm, up to a full nest within the pole. Termite attack is difficult to predict in wood poles and early detection is challenging for asset inspectors. Structural failure can occur within months of infestation and well within a single five-year inspection cycle. However, termite damage in new poles is rare.

3.5.2.3. Pole Fires

Pole top fires occur in fog, dew, drizzle or light rain, and in most cases, this follows a long period of dry weather in which airborne pollutants have coated the insulators.

Pollutants include diesel fumes, coal dust or dust from roads or agriculture, fertilisers, or airborne salt spray in coastal areas. The pollution facilitates the passage of leakage currents from the phase conductor to ground via points of concentration where the insulator is fastened to the cross arm or where metal braces attach to the cross arm. At these points of concentration, the current density is sufficient to ignite the wood cross arm which smoulders and then becoming flames. If unattended, the fire will destroy the cross arm and pole top.

Pole fires rarely develop into grass fires or bushfires, as they usually occur at times of high humidity and generally do not occur at times of high ambient temperature.

On December 2016, the Victorian Government published the "F-Factor Scheme order 2016" (the 2016 order). It targets incentives towards fire ignitions that pose the greatest risk of harm via ignition risk units (IRUs), which fire is weighted by a "location factor" and a "fire risk factor"[10]. Currently, 54% of poles are located in a High Bushfire Risk area. AusNet Services has implemented programs targeting fire ignitions which have resulted in a decline in Asset Fires as shown in Figure 12.

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[9] Reliability Centred Maintenance (2nd Edition), Chapter 7, J Moubray, 1997.

[10] Electricity f-factor scheme 2016-20 for Victorian electricity distribution network service providers

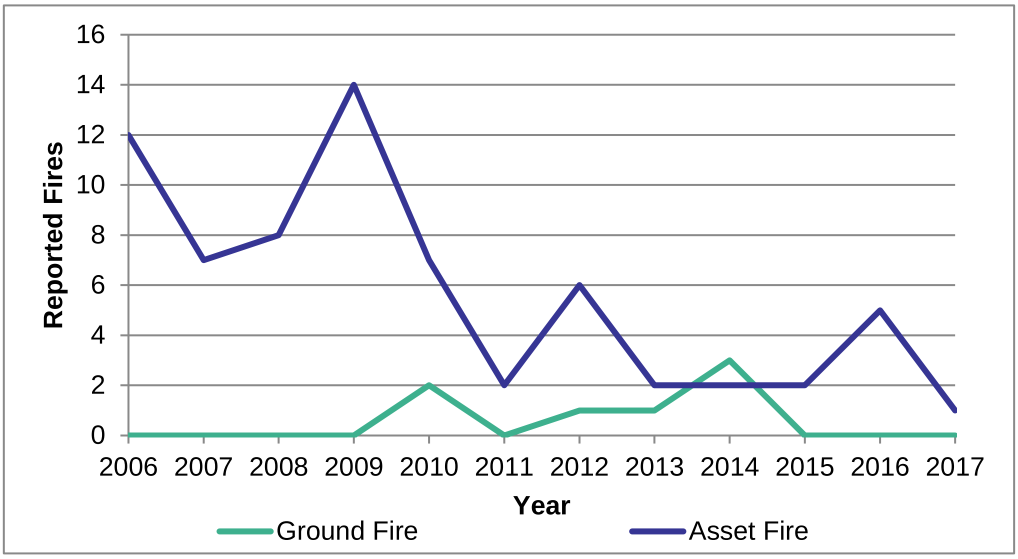


Figure 12 - Pole fires

Eight asset fires occurred in the past 3 years, with six were located in HBRA areas. All ground fires occurred in HBRA areas. Since the introduction of the “F-Factor Scheme” AusNet Services has an average of less than a single ignition per annum due to pole failure leading to a ground fire.

3.5.2.4. Damage by Motor Vehicle or Third Party Impact

Pole may subject to shock loading due to motor vehicle or third party impact, which exceeds the design loading for the pole. The structure of the pole is damaged as a result.

3.5.3 Concrete Pole Failure Modes

Concrete pole failure modes include:

- Concrete Cracking;
- Steel corrosion; and
- Damage by motor vehicles.

3.5.3.1. Concrete Cracking

Some of the aggregate used for poles has contained pieces of iron or iron bearing stone, either of which can cause dense rust spots on the surface. In most cases, these are not structurally harmful. Pole deterioration by rusting of reinforcing steel can result in the prominence of vertical cracks and rust stains, which may reduce the service life of a pole. These are usually seen above ground to a height of one metre on the north side of the pole.

3.5.3.2. Steel Corrosion

High salinity ground water accelerates the corrosion of the steel reinforcing in concrete poles, leading to concrete spalling and subsequent loss of structural strength near ground level. In the 1980s, stainless-steel plates were introduced to seal the hollow butt of concrete poles and slow the rate of corrosion of the internal steel reinforcing cage. Mechanical damage to the outer layer of concrete can also expose the steel reinforcing of concrete poles to corrosion and subsequent concrete spalling, which, if undetected or uncorrected, may ultimately cause structural failure of the pole.

3.5.3.3. Damage by Motor Vehicle and Third Party Impact

Pole may subject to shock loading due to motor vehicle or third party impact, which exceeds the design loading for the pole. The structure of the pole is damaged as a result.

3.5.4 Galvanised Steel Pole Failure Mode

Ground-line corrosion is the primary failure mode of direct buried galvanised steel poles. Many factors determine the rate of ground-line corrosion, including soil type, soil contaminants, moisture content and ground-water salinity.

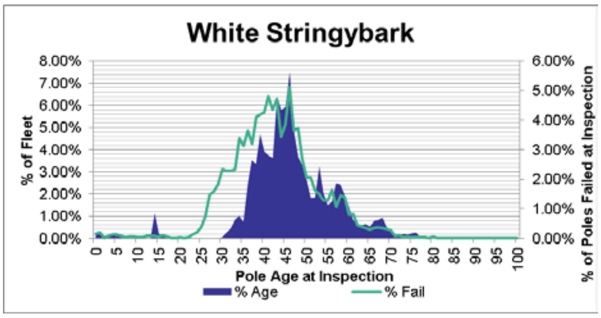
Poles installed prior to 1990 were directly buried with no protective coatings for the relatively thin steel walls, and structural failures due to ground-line corrosion have occurred after service life of 10 years. Direct buried poles now have bitumen-mastic surface coatings applied to the below-ground portion of the pole to slow the corrosion rate.

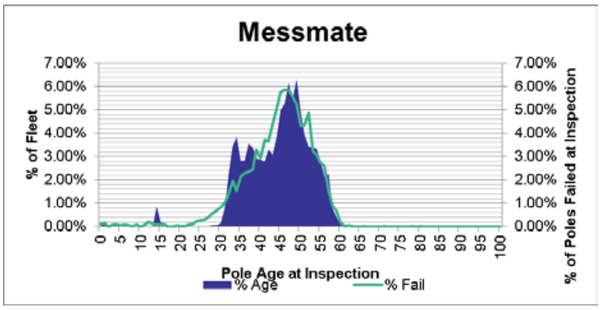
Plate-set galvanised steel poles have not exhibited ground-line corrosion, but have shown mechanical damage from vehicles, structural cracking, cracked base-plate welds, and missing or rusted base-plate fasteners.

3.6 Asset Performance

3.6.1 Wood Pole Failure Frequency

Poles have a different deterioration rates depending on their age and species. Figure 13 compares the three prominent wood pole cohorts namely, White Stringybark, Messmate and the remaining “Other” wood species. It provides an overview of the overall population breakdown and the corresponding historical failure characteristic.





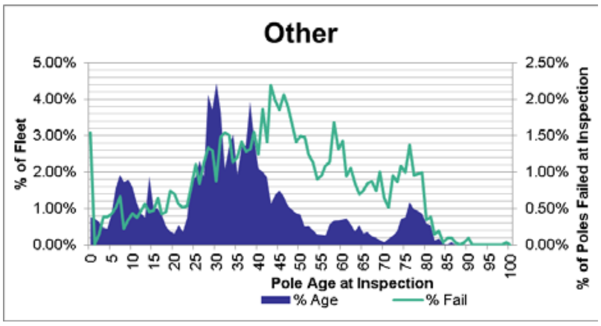


Figure 13 - Wood Species Age Profile with Historical Failure Characteristics

The following sections provide detailed analysis for the 3 prominent wood pole species.

3.6.1.1. White Stringybark Wood Pole Analysis

White Stringybark poles make up 9% of the entire wood pole population and are mainly located in the eastern part of the network, as shown in Figure 14.

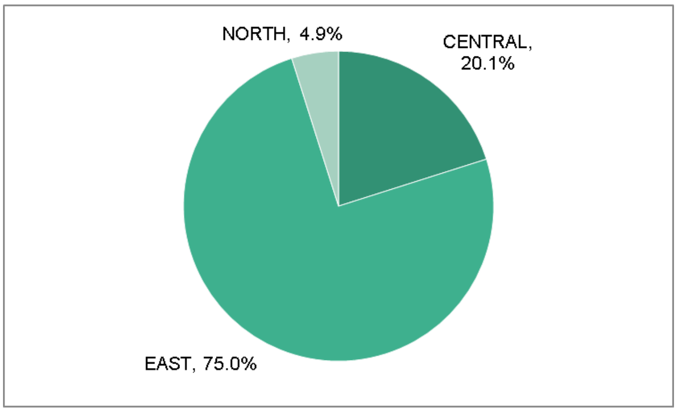
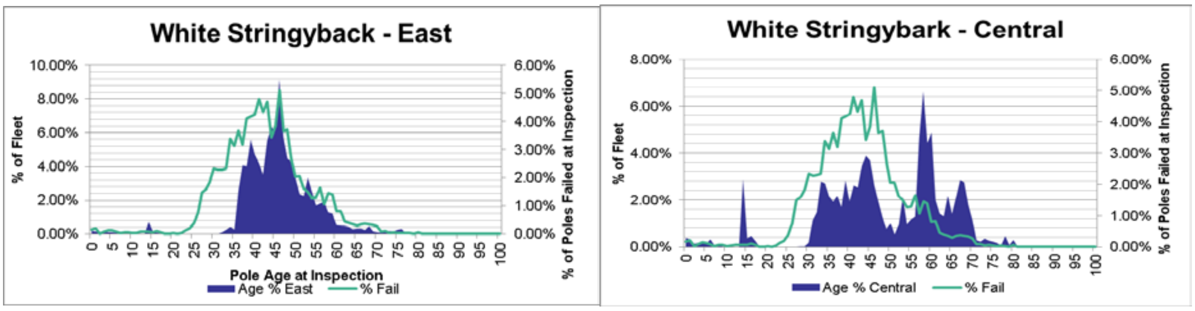


Figure 14 - White Stringybark Poles by Region

Each region shows a different White Stringybark age profile (Figure 15).



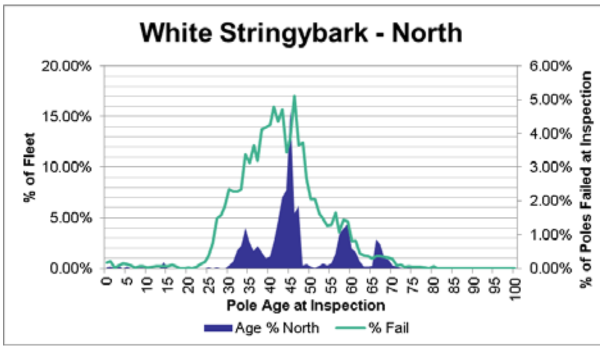


Figure 15 – White Stringybark Age Profile per region

White Stringybark failed at inspection in an average age of 46 years with a standard deviation of 11 years.

Table 6 shows that approximately 80% of White Stringybark poles in the Eastern region have been staked to increase the average expected service life. A noticeable difference in the service status per region is observed.

Table 6 - White Stringybark Service Status per Region

Service Status	East	Central	North
Serviceable	17%	42%	69%
Defective, Unserviceable or Limited Life	3%	6%	11%
Staked – Defective, Unserviceable or Limited Life	4%	4%	1%
Staked - Serviceable	76%	48%	19%

3.6.1.2. Messmate Wood Pole Analysis

Messmate poles are predominately located in the Central region as illustrated in Figure 16.

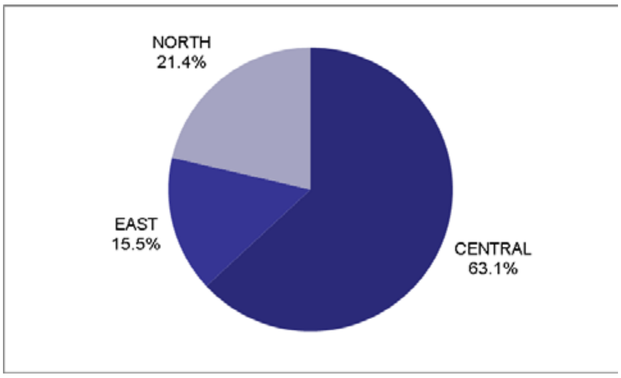


Figure 16 - Messmate Poles by Region

Figure 17 shows the age profiles for Messmate in each region.

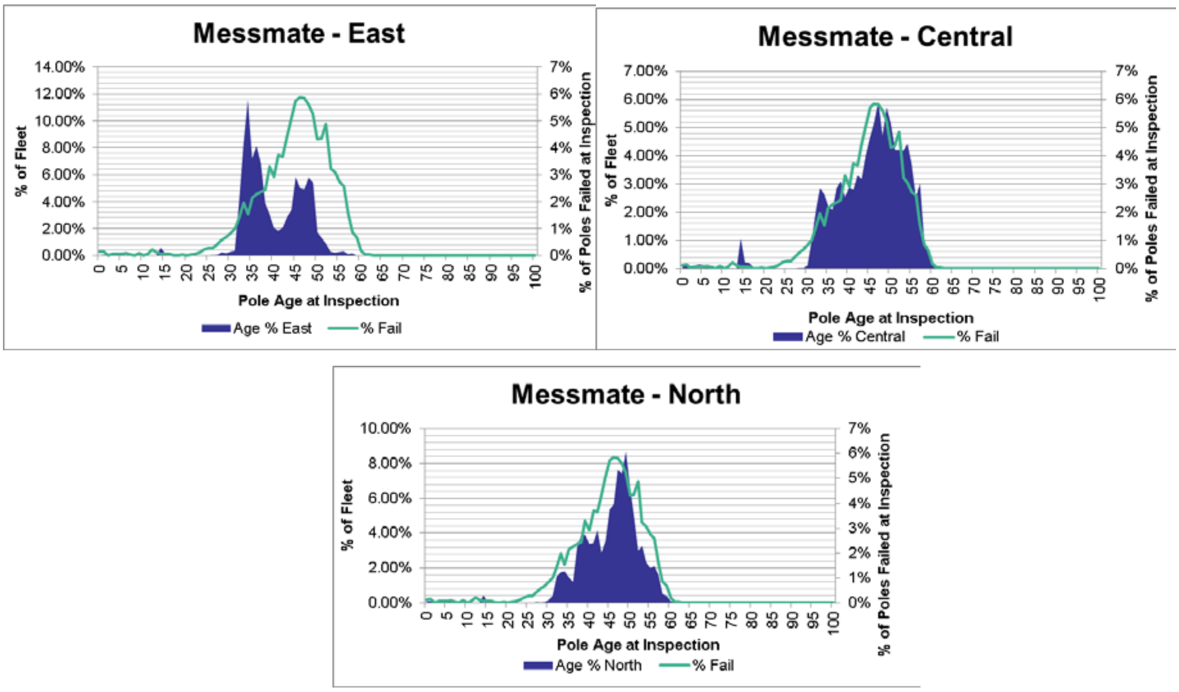


Figure 17 - Messmate Poles Age Profile per Region

The average service age of Messmate poles failed at inspection was at 44 years with a standard deviation of 9 years.

The environmental operating conditions are fundamentally different between the East, North and Central regions which influence the expected service life of a Messmate pole. Messmate poles in the East were made “Unserviceable” at an average age of 40 years with a standard deviation of 7 years. In contrast, Messmate Poles in North and Central regions were both made “Unserviceable” at an average age of 45 years, with a standard deviation of 7 and 9 years respectively.

Table 7 shows that majority of Messmate poles are in Serviceable status with relatively low levels of staking. This implies that there is opportunity to extend the expected service life of Messmate poles by using a proven staking technique or introducing new staking, rebutting and head reinforcement techniques.

Table 7 - Messmate Pole Status per Region

Service Status	East	Central	North
Serviceable	91%	86%	85%
Defective, Unserviceable or Limited Life	2%	4%	4%
Staked – Defective, Unserviceable or Limited Life	0%	1%	1%
Staked - Serviceable	7%	9%	9%

3.6.1.3. Remaining “Other” Wood Pole Analysis.

Figure 18 shows approximately 45% of the remaining “other” wood population is located in the Central region. The North and East region contributes to 21% and 34% respectively.

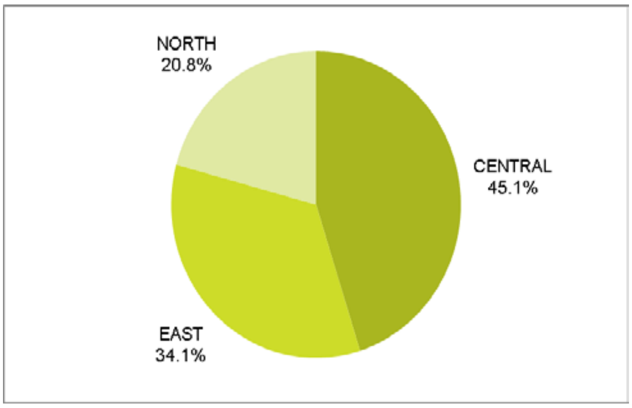


Figure 18 - Regionalised Population of Remaining "Other" Poles

The age profile for each region is different as shown in Figure 19.

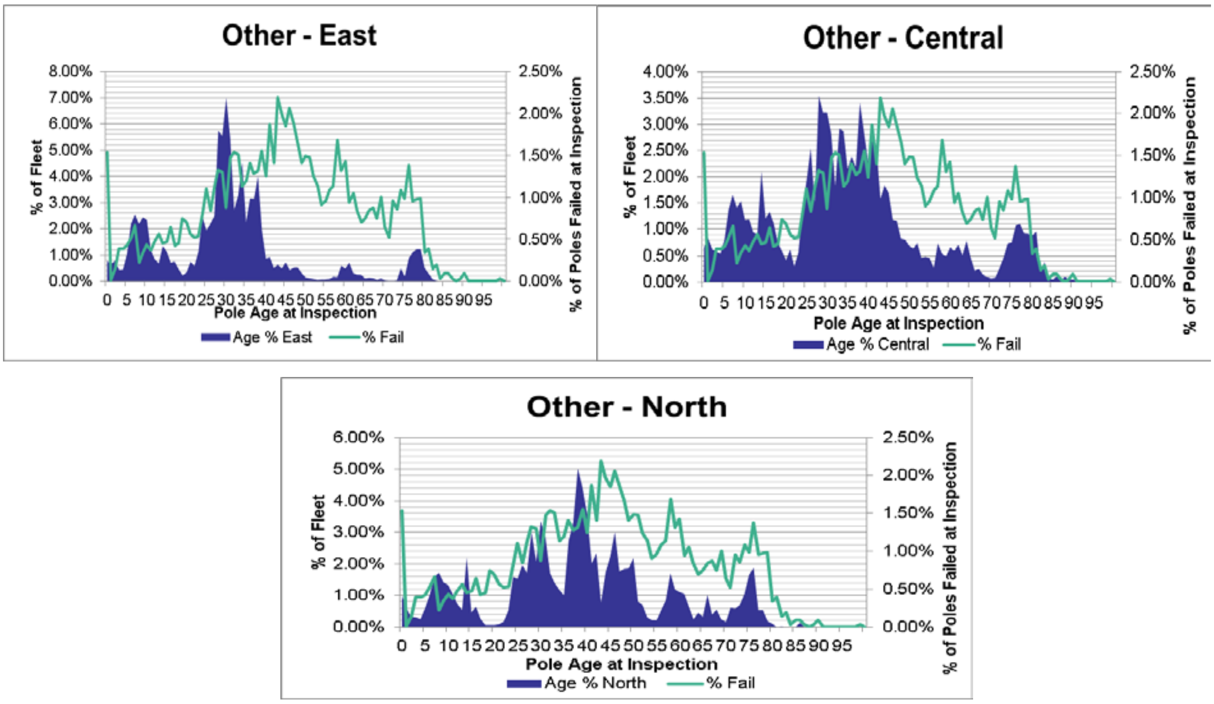


Figure 19 - Remaining "Other" Pole Age Profile per Region

It is observed that the age profile and the historical failure characteristic is less uniform and more sporadic compared to White Stringybark and Messmate poles. The average service age of poles that failed at inspection was at 35 years with a standard deviation of 19 years. This large standard deviation value indicates that the fail at inspection age were widely distributed from the mean.

3.6.2 Wood Pole Mean Time to Unserviceable Summary

Table 8 shows that White Stringybark and Messmate poles in the East region have a significantly lower expected service life compare to the other two regions.

The process used to derive these expected service life consists of three steps.

1. Derive the Weibull plots based on approximately 25,000 wood poles that were inspected and classified as unserviceable from January 1998 to March 2018.
2. From this data, hazard rate can be derived to calculate the probability density function.
3. From the hazard rate, average age that a pole expected to become unserviceable can be determined.

Table 8 - Mean Time to Unserviceable Status for Wood Poles

Species	East	North	Central
White Stringybark	37 years	51 years	50 years
Messmate	40 years	46 years	45 years
Other Wood Poles	50 years	44 years	48 years

3.6.3 Pole Failures

A pole failure or functional failure is when an asset is *unable to fulfil a function to a standard of performance which is acceptable to user*[11]. The function of a pole has been defined in Section 3.1. A functional failure of a pole can be broadly categorised as damage or broken. Damaged poles are where a failure has occurred, and remedial maintenance works can restore the pole to a serviceable status. In contrast, a broken pole refers to a pole which is deemed to be unserviceable and a replacement is the only option.

Since 2006, approximately 5,265 poles were damaged or broken, of which 26% resulted in sustained outages, and the remainder experienced momentary outages (Figure 20).

[11] Reliability Centered Maintenance, John Moubray

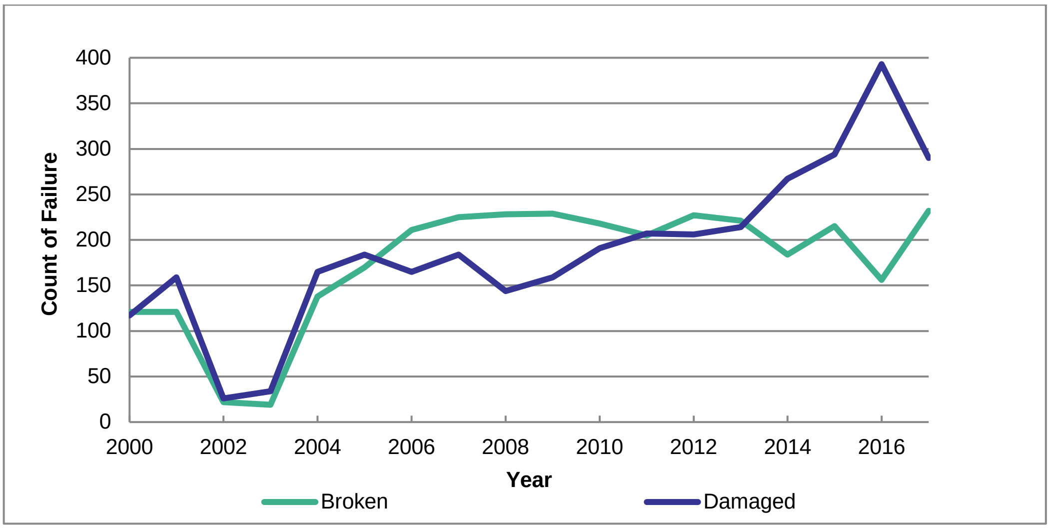


Figure 20- Pole Functional Failures

Figure 21 provides a breakdown of the causes of pole failures which resulted in an outage. 73% of outages were caused by Third Party incidents that AusNet Services has very little ability to control.

A customer might experience loss of supply due to unplanned interruptions caused by pole failures in an average of 7.6 minutes per year. This has resulted in an average of Service Target Performance Scheme (STPIS) penalty of $105K per incident per year.

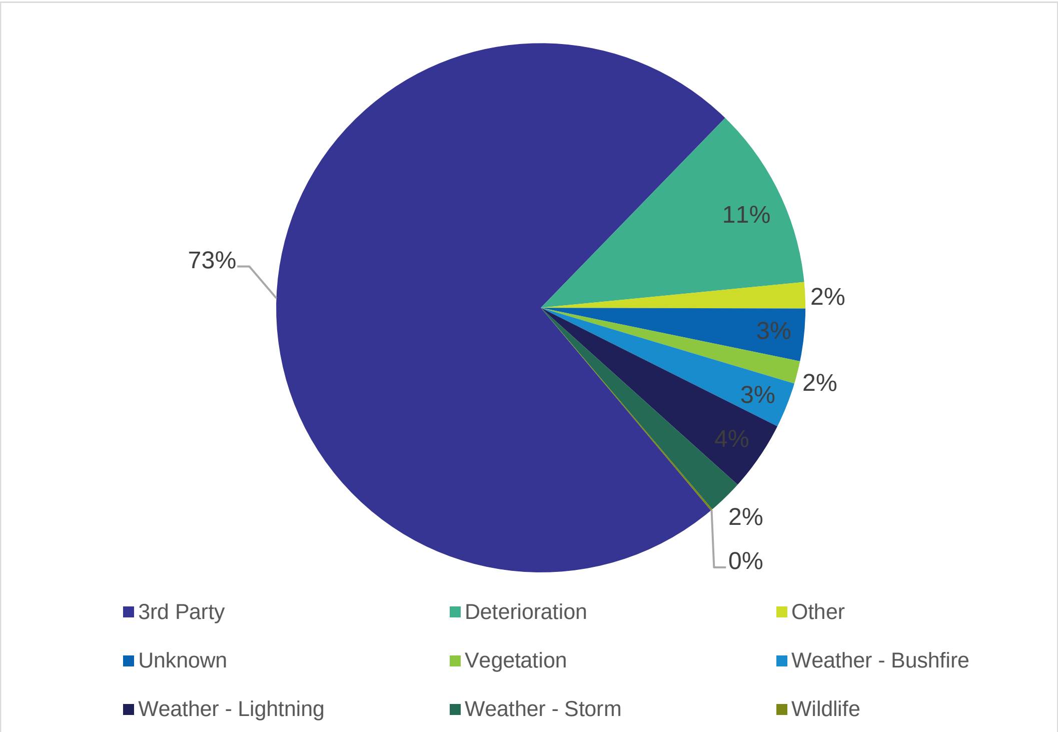


Figure 21 - Cause of Pole Failures

4 Other Issues

4.1 Inspection

The distribution pole inspection program is undertaken through a combination of ground (test and inspected) and aerial based inspection activities.

This combination of ground and aerial based inspection is approved by Energy Safe Victoria as satisfying the requirement for inspections and intervals contained in the Electricity Safety (Bushfire Mitigation) Regulations. Details of the inspection cycles can be found in the Bushfire Mitigation Plan- Electricity Distribution Network BFM 10-01 and the Bushfire Mitigation Manual BFM 21-79.

In order to collect a more precise wood measurement reading in an inspection, a non-invasive pole strength assessment has recently been introduced using a “Wood Scan” device. This advance technology can assist inspectors to determine the service status of a pole. Operating procedures and criteria can be found in the Asset Inspection Manual 30-4111[4].

4.2 Maintenance

4.2.1 Wood Poles

The key maintenance practices that are applied to wood poles are:

- Application of preservatives to control decay and rot;
- Treatments to control termites; and
- Correction of stay wires.

Since 1987, several different diffusing wood preservatives have been applied during pole inspections to control decay of the internal heartwood. Most of the products applied have slowed the rate of decay. The most successful product used is the “Polesaver” which uses a boric acid based fungicide to arrest decay. This product has contributed to the reduction in number of poles becoming “Unserviceable” each year.

If asset inspectors detect termites activity in a wood pole, the pole will be labelled and a specialist contractor is employed to treat the infestation. The Asset Inspection Manual 30-4111[4] details the treatment procedure. After the treatment, ongoing inspections will be performed to confirm the cessation of the termite activity.

In most recent years, there has been an increased effort in ensuring stay wires on poles are operating in the way in which they were first installed.

4.2.2 Concrete Poles

Concrete poles have required very little maintenance. A common requirement is the plugging of precast holes to prevent insect infestation.

Less commonly but more significantly, are repairs following impact from motor vehicles. Missing concrete and exposed steel reinforcing can result in structural collapse. Vertical cracking and rust staining often indicate that the concrete and steel reinforcing no longer offers mutual support, and concrete spalling is imminent. The loss of small areas of concrete, without damage to the steel reinforcing can be repaired. However, the loss of large sections could require replacement of the pole

4.2.3 Galvanised Steel Poles

A new surface coating can be applied when the ground line inspection of galvanised steel poles detects sign of corrosion or pitting on the surface of uncoated poles, or that the existing coating has deteriorated.

The coating type “Denso Ultraflex 1500” is applied to the pole in the vicinity of the oxygen rich ground line. This tape is supplied on a 400mm wide roll and consists of a high impact black PVC outer cover and a bitumen mastic adhesive, with an inner removable siliconized paper.

The “Denso Ultraflex” tape has become an on-going and intrinsic element of the rust prevention mechanism for steel poles. It is made to last in service when correctly applied unless either the physical capability of the product is compromised or mechanical damage has been inflicted.

4.3 Refurbishment

Reinforcement works such as staking can be performed as a preventative maintenance activity to reinforce the poles resulting in a safe extension of the useful life. The reinforcement criteria is detailed in the Asset Inspection Manual 30-4111[4].

Historical pole staking volumes can be found in the Electricity Network Works Program document[12]. Analysis[13] shows that where technically feasible, staking a pole is an economic solution if the service life of the pole can be extended by at least 2 years.

4.4 Replacement

The number of poles that are replaced per annum can vary from year to year depending on the inspection results. There are three variable factors determine the volume of poles replaced each year:

- Volume of poles made Unserviceable
- Suitability of Limited Life poles for economical remediation by staking
- Deteriorated poles that have already been staked.

AusNet Services are transitioning to increase, where it is economically practical and technically feasible, from the current staking rate. This approach is consistent to the industry trend as other power utility business have increased pole replacement rates moderately and significantly increased staking rates to keep pace with condemnation rates.

[12] Electricity Networks Works Program FY19-FY23

[13] Increasing number of degraded poles to be reinforced Issue 1

At the time of the writing, AusNet Services has commenced the trial of composite poles such as engineered cement (Titan) poles, for the use on distribution and sub-transmission networks. The titan poles are made from a mixture of cement, metakaolin and an acrylic emulsion reinforced with fibreglass. The performance and reliability of the engineered cement (Titan) poles are yet to be determined.

4.5 Research and Development

In order to economically extend the service life of a greater range of deteriorated poles, AusNet Services is continuously exploring alternative pole staking and rebutting techniques. This include new wood preservatives and new pole reinforcement techniques such as a new staking system, rebutting system and pole head reinforcement system.

5 Risk and Options Analysis

5.1 Overview

Pole inspection program is described in Section 4.1 which is approved by Energy Safe Victoria and compliance with the Electricity Safety (Bushfire Mitigation) Regulations.

During an inspection of a wood pole, “sound wood measurement” at ground level and 1m above ground level, as well as “girth measurement” are recorded in the Enterprise Asset Management System – SAP. This information is used to derive the service status and condition of the pole. Inspection procedures are detailed in the Asset Inspection Manual 30-4111.

The condition of a galvanised steel pole is based upon a visual inspection, at ground and below ground level. The extent and impact of the corrosion is assessed and the pole is considered as either “Serviceable” or “Unserviceable”.

For a concrete pole, the condition assessment relies upon a visual assessment along its length for cracking and rust staining to determine the overall condition of the pole.

Pole reinforcement such as pole staking is predominantly applied to wood and some steel poles, which act as a preventative maintenance activity to extend the expected service life of poles. If a pole is classified as a “Limited Pole” by a trained inspector and is considered as an unsuitable candidate for “staking”, the inspection frequency will be changed according to the Asset Inspection Manual 30-4111. When the extent of internal deterioration has increased and the pole attains the classification of “Unserviceable”, it will be scheduled for a replacement. “Limited Life” poles deem suitable to be staked will reinstate its “Serviceable” status.

The reinforcement and replacement criteria are described in detail in the Standard Maintenance Guidelines SOP 70.03. It serves as a purpose to clearly indicate the standards that shall be employed in the issue of planned work guidelines for the maintenance of distribution poles.

These rules have been developed using a risk based approach to reduce the risk of a pole failure “as far as practicable” as required by the Electricity Safety Act.

5.2 Replacement Forecast

5.2.1 End of Life

Historical pole inspection results are divided into a number of groups such as:

- Wood species; and
- Service status.

The result of the inspection is either a failure (pole made Unserviceable) or suspension (poles remain serviceable or limited life). These failures and suspensions data have been analysed in Isograph's Availability Workbench (AWB) software to obtain a Weibull probability distribution.

Poles are subjected to a 5-year ground inspection cycle. From the latest inspection date of the pole, the next inspection date can be estimated accordingly. Based on the result of the statistical analysis in AWB, poles that may become Unserviceable in the next inspection can be predicted.

5.2.2 Incident related Replacement

Poles that are damaged due to the action of third parties e.g. vehicle impact are reported in PowerOn Fusion Distribution and Outage Management System (DOMS). The incident related replacement forecast is estimated by historical faults recorded in DOMS.

5.2.3 Maintenance & Efficiency related Replacement

At any point, it may be efficient to replace a limited life pole in conjunction with other asset replacement works.

5.3 Summary

Table 9 summaries the economic contribution of poles forecast for replacement per annum over the 2022-2026 period.

Table 9. Pole Forecast for replacement

Identifier	Justification	Contribution per Annum
End of Life Replacement	Probabilistic replacement based from condition assessment	3,673
Incident related Replacement	Replacement due to damage by third parties, with volumes based on historic replacement rates	825
Proactive replacement	Replacement due to maintenance and efficiency	784
	Total	5,282

6 Asset Strategies

6.1 New Assets

- Monitor the availability, procurement costs, transport costs and supply of wood poles.
- Monitor the availability, procurement costs, transport costs and supply of concrete poles.
- Establish new public lighting installations on galvanised steel poles.
- Establish new service poles using CCA treated wood poles
- Establish new LV only circuits on CCA treated wood poles.
- Establish new simple MV structures on CCA treated wood poles.
- Establish new complex MV structures on concrete poles.
- Establish new sub-transmission structures on concrete poles.
- Effectively earth all conductive poles in accordance with published standards.
- Customer requests for certain pole materials will be considered.

6.2 Inspection

- All poles shall be subject to a cyclic inspection involving a condition assessment and any other visual inspections as per the criteria established in the Asset Inspection Manual 30-4111.
- Stay wires and rods shall be inspected at the same time as the pole.

6.3 Refurbishment

- Reinforce wood poles on condition.
- Reinforce galvanised steel poles on condition
- Where technically feasible all wood poles shall be reinforced to extend expected remaining life for a minimum of two years.
- Where technically feasible, reinforce Underground Residential Distribution (URD) steel poles in place of replacement.

6.4 Replacement

- Replace galvanised steel, concrete and wood poles on unserviceable condition.
- Replace deteriorated wood poles which have previously been treated for termite infestation with other pole types as per the Standard Maintenance Guidelines SOP 70-03.
- The selection of replacement poles shall follow the same guidelines as for New Assets.
- Replace stay wire and rod and as required, replace bed log when replacing deteriorated poles.

6.5 Research and Development

- Monitor trial and implement more economic materials and technologies for poles, staking and preservative treatments.
- Investigate alternative inspection techniques to monitor wood decay.
- Collect more accurate measurement of poles by using non-destructive technologies such as “Wood Scan”, to monitor pole deterioration rates.
- Investigate, trial and implement the use of non-destructive testing for steel poles
- Develop stay solutions for concrete poles.
- Establish guidelines for the economic extension of wood pole life using staking, rebutting and refurbishment of pole tops.
- Establish guidelines for economic replacement of poles when other assets are being replaced.
- Investigate safety issues of poles in relation to proximity of the carriageway, e.g. monitor effectiveness of the raptor trial, and solutions to streetlight poles on dangerous corners.
- Investigate, develop and implement new wood rot prevention techniques to protect staked wood poles and control decay at reinforcement attachment points.
- Investigate, develop and implement economic new wood pole life extension techniques including alternative staking, rebutting techniques and introducing longer stakes for wood poles.