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Transmission Line Renewal and Maintenance Strategy

AMS Asset Class Strategy

2021/2022

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Table 1 – Change from previous version

Revision no	Approved by	Amendment
9	Andrew McAlpine A/Head of Asset Management	2021 calendar review. Formatting Update Document now exclusively for prescribed assets. Nominal lives for conductor and earthwire fittings added.
8	Lance Wee Head of Asset management	2020 calendar review. Network Asset Strategy Summary Network Asset Strategy figures updated Failure Mode Analysis table added
7	Lance Wee Head of Asset management	Formatting update. 2019 calendar review. 50-year OPEX forecast removed. Asset Management Stagey and Objectives has been replaced with Network Asset Strategy – Asset Management System Boundary, KPI's Overarching business objective and Asset Strategy objectives updated.
6	Lance Wee Head of Asset management	Formatting update. 2018 calendar review.
5	Mark Jones A/Manager/Asset Management	2017 calendar review. Updated to be consistent with 2017FY RIN submission – asset descriptions and quantities all sections Multiple new, emerging issues and renewal and maintenance strategies raised since last issue. New renewal and maintenance strategies added – all asset classes. Updated to align with new Asset Management Strategy and Objectives: New objectives, new KPI's, new Asset Management System Document Hierarchy.

Revision no	Approved by	Amendment
		Renewal and Maintenance initiatives (many tables) updated. Future Outlook updated
4	Lance Wee Group Manager/Asset Planning	Formatting update.
3	Lance Wee Group Manager/Asset Strategy	Review and update to deliver the 2016/17 Business Plan and further enhance the strategy. Update to new template.
2	Lance Wee Group Manager/Asset Strategy	Review and update to deliver the 2015/16 Corporate Plan and further enhance the strategy.
1	Garrie Chubb Group Manager/Asset Performance	Updated to reflect the continual improvement in the 'top down' approach for the line of sight to the Asset Management Strategy and the Corporate Plan and an enhanced description of the asset management decision process and the strategic initiatives to be undertaken.

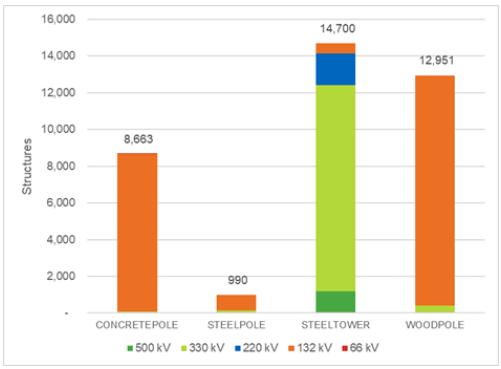
A printed copy of this document may not be the current version. Please refer to the Wire to verify the current version.

Executive Summary

Transgrid's transmission line network is made up of assets ranging from 66 kV to 500 kV dating back to 1940. The ageing asset base and increasing costs required to sustain the network are presenting ongoing challenges. Asset condition information is being collected to better model asset health and ensure corrective and replacement activities are performed at an optimal time and cost.

Asset Review

Transgrid's transmission line network covers a route length of 11,315 km strung on 37,578 structures across NSW and the ACT. A breakdown of transmission line asset structure types is shown in below.



Achievements

In FY2021 Transmission Lines achieved significant goals including:

- Replacement of deteriorated poles on Lines 9U3, 9UH and 99D with concrete or steel poles.
- Remediation of Line 993 low spans by installing steel poles. Project also included replacing of an earthwire with OPGW. There are now no wood pole structures remaining on Line 993.
- Lines 4 and 5 grillage tower remediation.
- Line 959/92Z tower refurbishment complete.
- Successful completion of AER bushfire pass-through submission.
- Update to health index, bushfire and public safety risk models.
- Initiation of various needs for replacement and refurbishment of transmission lines asset for the next regulatory period

Challenges

- The average age of the assets continues to increase requiring further monitoring and data capture to manage the safety and reliability of the assets.
- The ageing wood pole assets are causing increased defect maintenance spend.
- Achieving cost reductions and efficiencies with an aging asset base.
- Optimising replacement and operating programs based on the data obtained in the inspection program and limited condition information.

Initiatives

- Wood pole replacement program to extend the life of 132 kV assets.
- Steel tower refurbishment, insulator replacement, conductor replacement, and grillage foundation remediation program.
- Managing hazard tree risk.
- Initiate an Early Fault Detection trial to detect, locate, and diagnose asset failure before adverse outcomes occur (ex conductor and insulator).
- Initiate a Public Safety Camera trial on "High Risk Location" to manage public safety risk.
- Improving asset data collections methods to better model asset health and ensure maintenance and replacement activities are performed at optimal cost.

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1. Foreword

1.1. Foreword

This document defines the renewal and maintenance strategies for Transgrid's Transmission Line assets. In doing this, it applies the overarching Network Asset Strategy, and relevant Lifecycle Strategies. This strategy document covers all prescribed transmission line and easement assets owned and maintained by Transgrid. Non-prescribed assets are excluded from this strategy document.

The document identifies the emerging issues with Transgrid's Transmission Line assets, and details the renewal and maintenance initiatives to be implemented in response to these issues. The output of the strategy is the asset management program of works, which is derived via distinct paths as follows:

- The renewal and disposal initiatives are considered through the Prescribed Capital Investment Process and managed by the Head of Asset Management, which then leads to the resource-optimised capital works program.
- The maintenance initiatives directly drive the maintenance regimes which are detailed within the relevant Maintenance Plans. The maintenance plans are then resource-optimised through Transgrid's Enterprise Resource Planning (ERP) system, Ellipse and supporting applications such as TRAC.

The population reviews and strategies in this document cover prescribed assets only for a five year period from December 2021. Non-prescribed assets are covered in Non-prescribed Renewal and Maintenance Strategy.

1.2. Overview

Transgrid's transmission line network is made up of assets ranging from 66 kV to 500 kV dating back to 1940. The ageing asset base and increasing costs required to sustain the network are presenting ongoing challenges.

The collection of detailed condition data in conjunction with span by span risk ratings has allowed for targeted CAPEX and OPEX to achieve the best outcome for the transmission line assets with the funds available, managing asset risk As Low As Reasonably Practicable (ALARP). Condition related issues being addressed include wood pole deterioration, corrosion of steel structures, conductors, and fittings and insulator deterioration.

Easement maintenance has seen the successful implementation of risk based maintenance, delivering sustainable efficiencies now and in to the future.

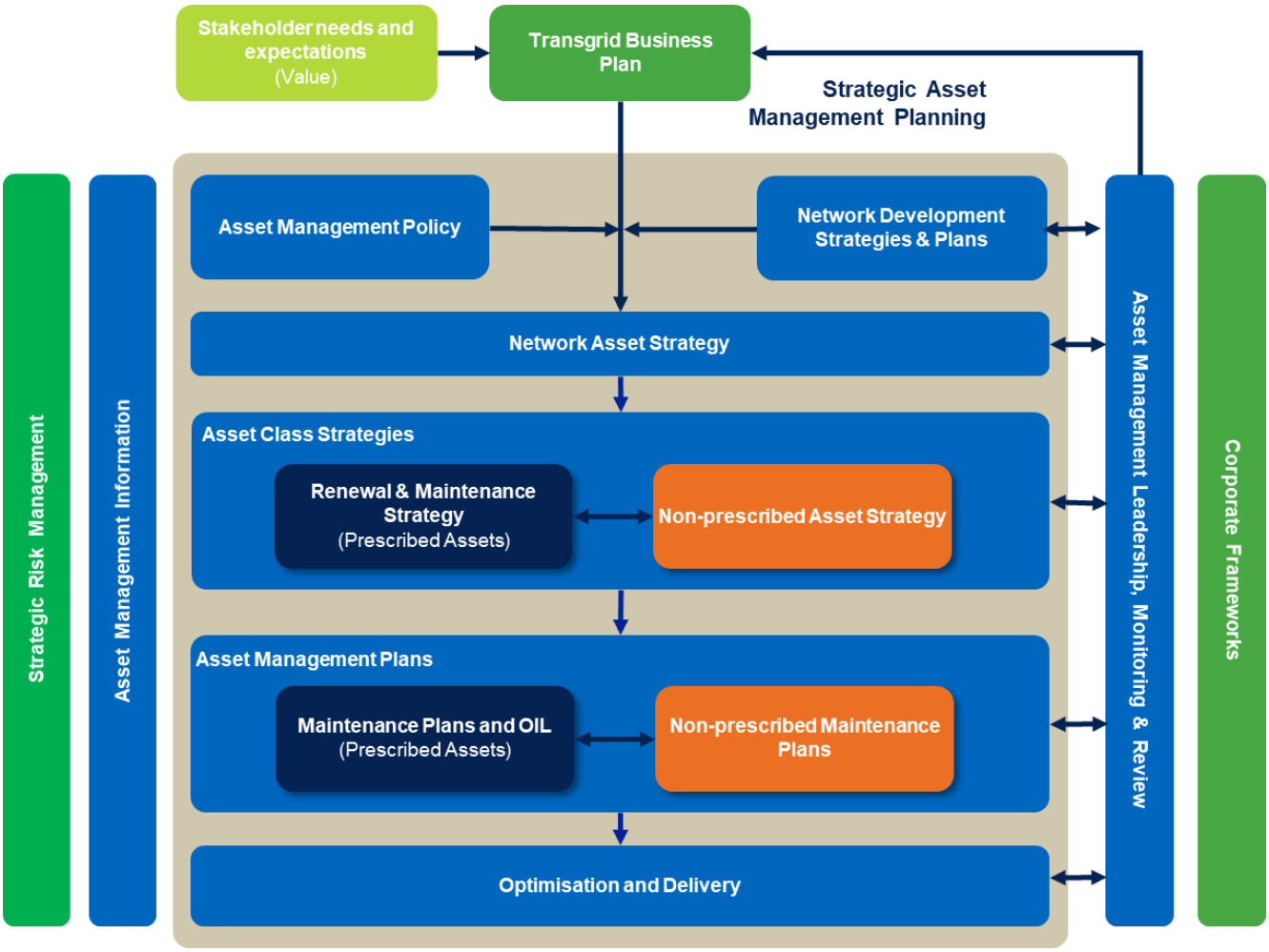
AEMO's Integrated System Plan identified a number of transmission line projects to address the radical changes occurring in both the demand requirements and supply mix in the NEM. Should Transgrid deliver these links, the increase on the transmission line asset base would be substantial. It is important that these new assets are designed, procured and constructed in a manner which leads to the lowest lifecycle cost and incorporate new innovations to ensure efficient solutions are delivered.

2. Context and Background

2.1. Relationship to Asset Management Systems

This Renewal and Maintenance Strategy (RMS) document is one of several that comprise the Asset Management Strategies within Transgrid's Asset Management System. This document sits below the Network Asset Strategy document as shown in Figure 1.

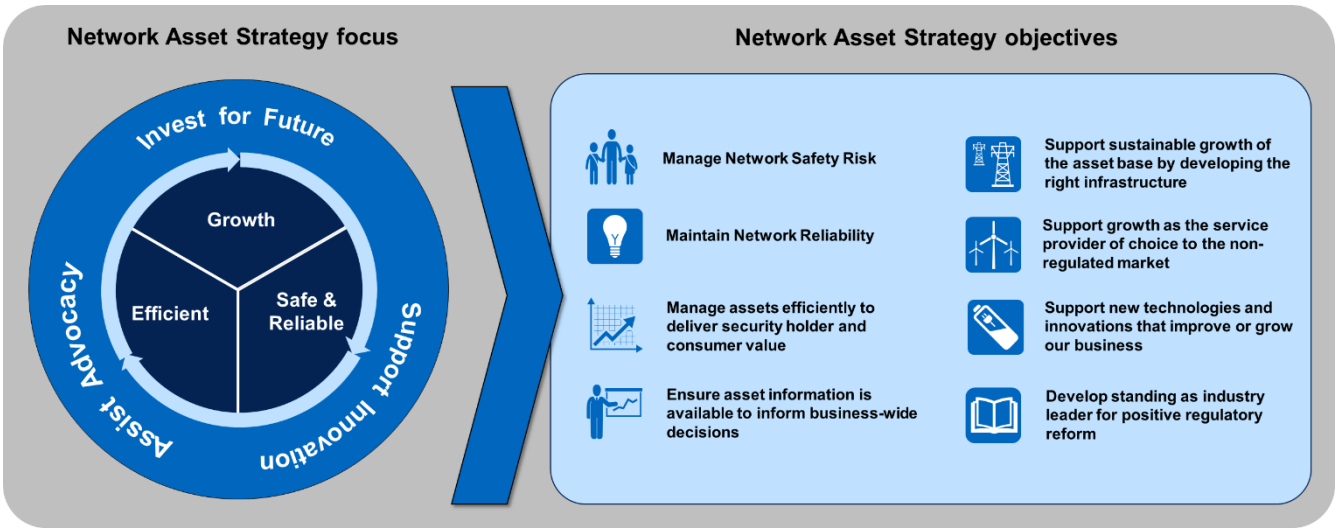
Figure 1 – Asset Management System Hierarchy



2.2. Asset Management Line of Sight

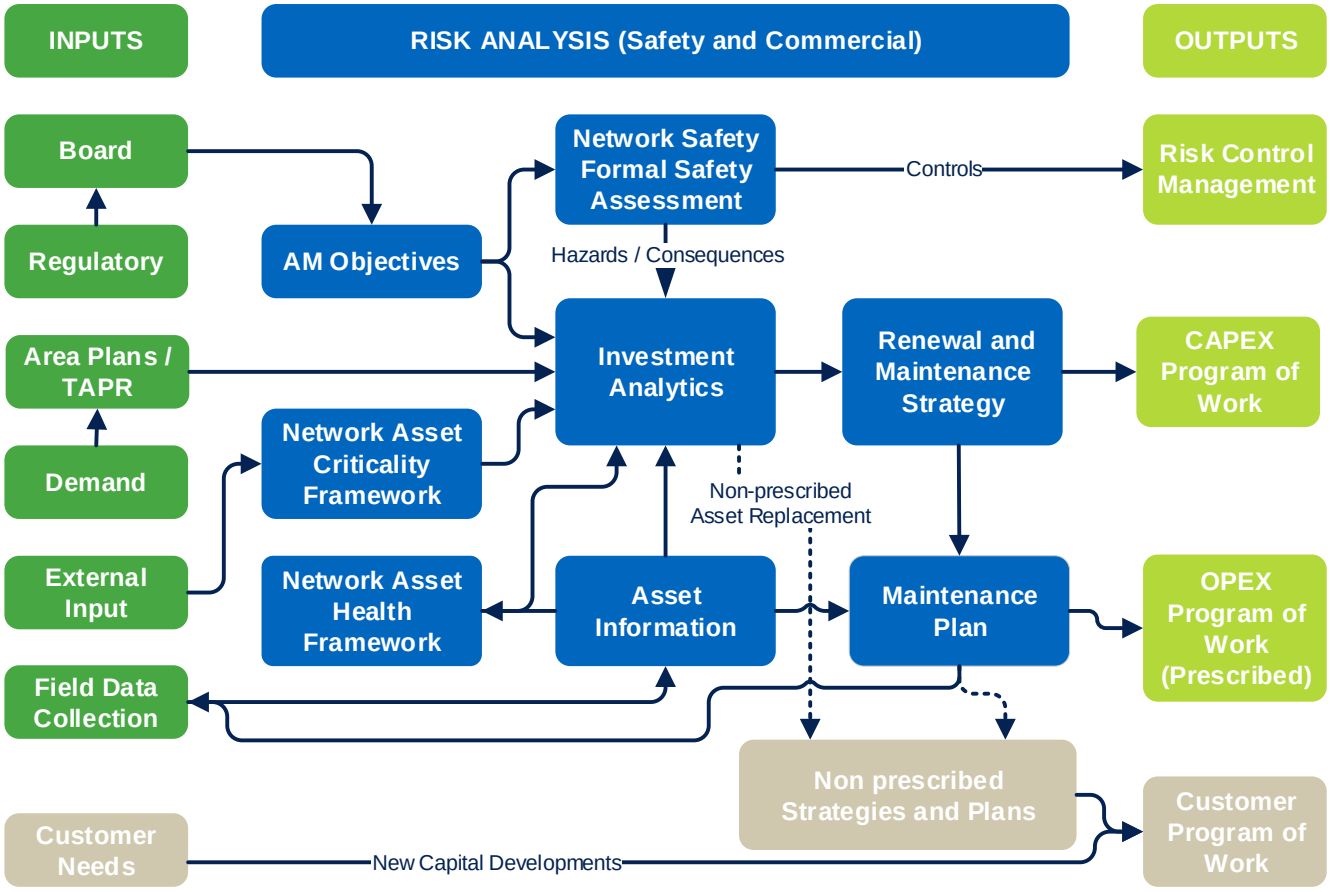
The renewal and maintenance strategic initiatives set out in this document support the achievement of the strategies set out in the Network Asset Strategy. The strategic alignment of the initiatives in this document to the Network Asset Strategy is based on meeting its strategic themes.

Figure 2 – Asset Management Strategy Key Themes



2.3. Renewal and Maintenance Process Overview

Figure 3 – Investment Development Framework



2.4. Asset Overview

2.4.1. Scope of Assets

The following assets are within the scope of this strategy:

- 500 kV Transmission Line Assets
- 330 kV Transmission Line Assets
- 220 kV Transmission Line Assets
- 132 kV Transmission Line Assets
- 66 kV Transmission Line Assets
- Associated Easements and access tracks

The following assets are outside the scope of this strategy:

- Strung busbars within substations.

- Distribution Network Service Providers (DNSP) 132 kV Transmission Lines which are tee connected to Transgrid's transmission lines. The transmission line sections owned by DNSP's are not covered within the scope of this document.
- Conductors, insulators and fittings on Line 888 on Transgrid's double circuit towers 888/97K. This is an Essential Energy owned line strung on Transgrid's double circuit towers.
- Conductors, insulators and fittings on Line 971 (shares a structure with 976/2 outside of Yass Substation). This is an Essential Energy owned line strung on Transgrid's double circuit tower.

2.4.2. Asset Base

Transgrid has over 12,900 km of transmission line circuit within its prescribed network which are supported by around 37,300 structures. The total route length is greater than 11,200 km.

Their locations vary from coastal to rural, sub-tropical to dry-desert, sea level to high altitude. Structures consist of steel lattice towers and pole structures made out of timber, concrete and steel.

Transgrid also manages non-prescribed transmission line assets and assets owned by Transgrid Services.

A snapshot of the transmission line asset base is provided in Table 2. Quantities exclude non-prescribed and Transgrid Services assets. Non-prescribed assets are described in 'Non-prescribed Renewal and Maintenance Strategy'

Table 2 –Asset Base

Asset	Total Circuit Length	Quantity	Description
500 kV Transmission Lines and associated easements.	1,023 km	• Steel structures: 1,178	• 500 kV transmission lines are located within the Northern, Southern and Central Regions. • There is a total of 1,023 km of circuit length which are all supported by steel lattice structures.
330 kV Transmission Lines and associated easements.	5,478 km	• Steel structures: 11,390 • Concrete poles structures: 70 • Wood poles structures: 405	• 9,465 single circuit and 2,400 double circuit structures. • There population consists of: - Steel structures (includes lattice and pole) – 96% - Wood pole – 3% - Concrete pole – <1%
220 kV Transmission Lines and associated easements.	681 km	• Steel structures: 1,790 • Concrete pole structures: 13	• 220 kV transmission lines are located in the South West NSW. • The population consists of: - Steel lattice structures – 94% - Steel pole – 5% - Concrete pole – 1%

Asset	Total Circuit Length	Quantity	Description
132 kV Transmission Lines and associated easement.	5,709 km	• Steel structures: 1,421 • Concrete pole structures: 8,575 • Wood pole structures: 12,546	• 2,129 single circuit and 1,413 double circuit structures. • There are a total of 5,792 km of dual and single circuit length supported by: - Wood pole – 56% - Concrete pole – 38% - Steel pole and Steel lattice structures – 6%
66 kV Transmission Lines. No 66kV easements (on Transgrid property)	21 km	• Concrete pole structures: 5	These are located at Molong and Glenn Innes. The majority of the circuits share dual circuit structures with another Transgrid 132 kV circuit. There are a small number of single circuit 66 kV structures (on Transgrid property) connecting the 66 kV lines bays in the respective substations to the dual circuit structures.
33kV	39 km	Installed on 132 kV double circuit concrete poles with Line 9C8	This is Transgrid owned conductor with multiple Essential Energy connection points on the section of double circuit between Brandy Hill and Stroud.

The nominal lifespan of a transmission line varies depending upon its individual components. The individual components can be broadly categorised as electrical conductors, supporting structures and fittings. The nominal lifespan for transmission line components are provided in Table 3. Note that these lifespans are different to the timeframes are used for depreciation.

Table 3: Nominal Lifespan of Transmission Line Components

Component	Sub-component	Nominal Lifespan (years)
Steel Lattice Structure	Steel Tower – Low Corrosion (zones C1 & C2)	94
	Steel Tower – Moderate Corrosion (zone C3)	75
	Steel Tower – Severe Corrosion (zone C4)	57
	Tower Refurbishment	35
	Climbing Deterrent	30

Component	Sub-component	Nominal Lifespan (years)
Poles	Wood Pole	63
	Concrete Pole	85
	Steel Pole – Low Corrosion (zones C1 & C2)	85
	Steel Pole – Moderate Corrosion (zone C3)	75
	Steel Pole – Severe Corrosion (zone C4)	55
Guys	Guy Wires and anchors	50
Conductor	Conductor	90
	Cond Fittings – Very Low Corrosion (zone C1)	80
	Cond Fittings – Low Corrosion (zone C2)	70
	Cond Fittings – Moderate Corrosion (zone C3)	55
	Cond Fittings – Severe Corrosion (zone C4)	45
Earthwire	Earthwire – All SC/GZ	50
	Earthwire – All within 10 km of coast	50
	Earthwire – not SC/GZ and greater than 10 km from coast	90
	EW Fittings – Very Low Corrosion (zone C1)	65
	EW Fittings – Low Corrosion (zone C2)	60
	EW Fittings – Moderate Corrosion (zone C3)	45
	EW Fittings – Severe Corrosion (zone C4)	40
Insulators	Porcelain and Glass disc insulators	50
	Composite longrod insulators	25

2.5. Spares

The overarching document *Spares Policy – All Asset Streams* provides the framework for the development of spares plans for each asset stream. High level requirements for the storage and management of spares by Delivery are also included.

The *Transmission Lines Spares Plan* aims to cover appropriate minimum maintenance spares requirements for Transgrid transmission lines. The plan only covers the key transmission line components and does not cover ancillary items such as bolts, nuts, split pins, etc.

Transmission Line Emergency Structures – provides guidance in establishing appropriate minimum emergency structure spares for Transgrid transmission lines.

Spares levels have been set for the prescribed assets only, unless where a specific agreement is in place. Spares noted in those documents shall not be used on non-prescribed or other utility assets where the use will bring holdings below the minimum. In exceptional circumstances the Executive Manager / Network Planning and Operations, with an appropriate risk assessment, can approve the release of further spares to the non-prescribed business or other utilities with appropriate financial treatment.

3. Current Performance

3.1. Review of Previous Renewal, Disposal and Maintenance Strategies

This section discusses the performance of the current asset base.

3.1.1. Historical Expenditure

3.1.1.1. Renewal Initiatives

There were a number of renewal initiatives completed in FY2021 as detailed in Table 4. Average efficiencies of 1% were achieved in the delivery of these projects compared to their DG2 estimate.

Table 4 – Completed Renewal Initiatives FY2021

Renewal Item	Need Reference	DG2 Estimate ($million)	Actual ($million)
Line 993 Gadara-Wagga OPGW Low Spans	DCN131	12.03	14.23
TL 99D Yanco - Darlington Pt Wood Poles	1558	7.52	7.83
TL9U3 BGE-GN2 TL9UH BGN-NB2 132k Wood	1558	12.98	11.12
Line 4 and 5 Grillage Condition	1523	9.146	9.193
999 Collapsed Tower Restoration	N2557	3.193	2.822

3.1.1.2. Maintenance Initiatives

There were a number of maintenance initiatives completed as detailed in Table 5.

Table 5 – Completed Maintenance Initiatives FY2021

Maintenance Initiative	Reference	Estimate ($)	Actual ($)
96F Waterway Crossing Signs	N2027	150K	180K
Analysis of Line 86 Defective Wood Poles	N2344	25K	25K
Line 10 and 11 OHEW Thimble fitting investigation	Line	45k	$27k
TL Coastal Conductor Condition	N2341	350K	150K
TL Composite Insulator Testing	N2256	180K	175K
Hazard Tree Removal	N2227	545k	262k

3.1.2. Review of Renewal and Maintenance Initiatives

3.1.2.1. Renewal Initiatives

Delivery of the existing Renewal and Maintenance Initiatives has continued to target the refurbishment and/or replacement of assets assessed to be at risk of failure based on analysis of condition data where:

- The investment can be shown to be in the best interest of consumers

- The investment is required to meet Transgrid's regulatory obligations

The following renewal initiatives completed in FY2021:

- The replacement of deteriorated wood pole structures with timber were completed on Lines 99D, 9U3 and 9UH. In total, 160 wood pole structures were replaced.
- The completion of low spans remediation on Line 993 completed the RP1 low span remediation.
- Line 4 and 5 towers were built with grillage foundations. The project remediated the grillage foundation through installation of concrete micropiles, installation of sacrificial anodes and installation of additional tower bracing.
- In December 2020 a storm collapsed six lattice structures on Line 999. The two adjacent structures were also damaged. The section was completely rebuilt with 14 concrete pole structures and new conductor and earthwire.

3.1.2.2. Maintenance Initiatives

The following maintenance initiatives completed in FY2021:

- Line 96F waterway crossing signs were completed on the section of line handed over from Ausgrid. Transgrid review found that not only were signs required, but the crossing over the Hunter River has insufficient clearance for the expected maximum vessel height. Signage installation has been completed. Augmenting the Hunter River crossing to apply for sufficient clearance would require 36 metre tall structures. This was considered for inclusion in the RP3 submission along with the 9W0 crossing of the Clarence River but it was determined that the investment could not be justified.
- An assessment of composite insulator condition through high resolution photography thermography, and corona sensitive camera was completed. A sample of composite insulators sent for testing to understand the asset condition. The sample test results have shown a large reduction in hydrophobicity (ie ability of the insulator to resist the ingress of moisture), reduction rod to housing adhesion and corona activity at the end of fitting to housing interface due to degradation and older design of this interface.
- A Smart Aerial Imaging Processing (SAIP) completed on selected conductor on coastal location to detect signs of corrosion and other condition issues.
- Line 86 required the replacement of some deteriorated composite wood poles. The nature of this transmission line means that wood pole structure replacement is not routine like it is for 132 kV transmission lines and the two piece composite pole arrangement makes condition assessment difficult and unreliable. Indeed a structure failed during high winds events in April 2020. Line 86 is expected to continue to require material maintenance attention until the renewal initiative to rebuild the line is undertaken.
- Hazard trees continue to be inspected and managed in accordance with the plan set out in the Maintenance Plan - Easements and Access Tracks.

3.1.3. Review of Maintenance Program

Routine maintenance regimes are reviewed annually and adjusted to minimise total cost including risk cost.

Table 6 below shows the comparison between actual versus annual budget for transmission line asset

Table 6 – Transmission Line OPEX FY2021

	Actual $	Budget $	Variance $
Routine Maintenance	813,140	951,240	138,100
Inspections	5,424,070	6,303,208	879,138
Condition	1,099,456	995,000	(104,456)
Defect	6,953,417	6,500,000	(453,417)
TOTALS	14,328,926	14,749,477	420,521
2019/20 Bushfire response (FY2021 costs)			
Pass-through	**5,416,046**		

The transmission line OPEX spend for FY2021, excluding bushfire works, was $14.29 million, an under spend of $459K on the overall lines budget. Defect works were 7% overspent due to increase in wood pole defect replacement.

Table 7 below shows the comparison between actual versus annual budget for easement and access tracks.

Table 7 – Easements and Access Tracks OPEX FY2021

	Actual $	Budget $	Variance $
Inspections	2,456,180	2,894,797	438,617
Condition	8,147,879	9,772,069	1,629,353
Defect	2,690,374	1,900,000	(795,248)
TOTALS	13,294,144	14,566,866	1,272,722
2019/20 Bushfire response (FY2021 costs)			
Pass-through	**828,067**		

3.1.4. Past Performance – Asset Management Performance Indicators

In November 2019 the Network Asset Strategy was issued. Performance against these KPIs is shown in Table 8. They demonstrate the effectiveness of this Renewal and Maintenance strategy to mitigate the network related safety, reliability environment, financial, compliance and reputational risks in support of the achievement of the asset management targets and objectives are the number of Key Hazardous Events. These measures have been maintained at a low level historically, indicating the Renewal and Maintenance strategies have been effective at mitigating the risks and achieving the asset management objectives. The updated KPI's are shown in section 4.1.

Table 8 – Network Asset Strategy KPI's – Transmission Lines FY2021

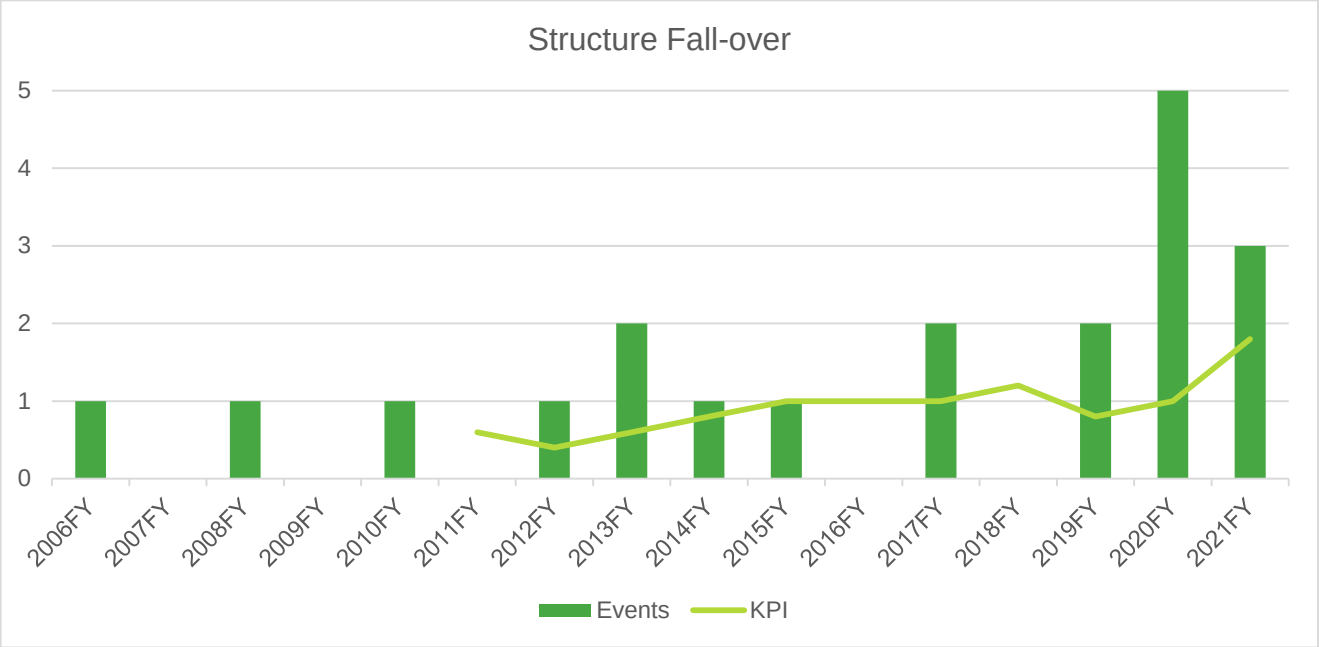
• **Asset Management Objective**	• **Asset Management Performance Indicators**	• **Past Performance**
• Manage network Safety Risk	• Maintain 5 yr. average of key hazardous (loss of control) events:	• There have been three structure fall-overs in FY2021, exceeding the five yearly average.

• Asset Management Objective	• Asset Management Performance Indicators	• Past Performance
	- Conductor drop - Structure failure - Unauthorised entry	• There were two conductor drop events in FY2021 exceeding the five yearly average. • There was one unauthorised entry event in FY2021 exceeding the five yearly average. BARC Reporting: • Nil red results • Nil vegetation fire start by since 2016 • Nil network fire start since 2018
• Manage network Safety Risk	• No red reports in key result indicators regarding Bushfire, Reliability and Public Safety Principal Risk Dashboards	BARC Reporting • Nil red results • Nil vegetation fire start by since 2016 • Nil network fire start since 2018.
• Maintain network reliability	• Maintain 5 year average level of loss of supply events due to line faults	• Achieved.
• Maintain network reliability	• Better than average performance of the STPIS measures: • Achieve CY2020 STPIS result of $7.0m • Achieve CY2021 STPIS result of $8.3m	• CY2020 STPIS target was met. • STPIS Performance is forecasting on track to meet target
• Manage assets efficiently without compromising security holder or customer value	• Gain efficiencies in OPEX expenditure	• FY21 AMPOW annual budget achieved through prioritisation of work. • For asset class refer to section 3.1.3.
• Manage assets efficiently without compromising security holder or customer value	• Achieve efficiency on regulated capital spend FY2021	• Targeted capital efficiency was achieved in FY2021 and reinvested into the business

3.1.4.1. Past Performance – Structure Fall-over

There were three fall over events in FY2021. All occurred during high wind. One of the three events was due to deteriorated pole and was scheduled for replacement as part of an in progress project. The other two lines failed during the same storm. Available weather data suggests that the wind gust may have been in excess of the line's design capacity. These events cause the KPI to not be met. The historical structure fall-over performance is shown in Figure 4.

Figure 4 – Structure fall-over events

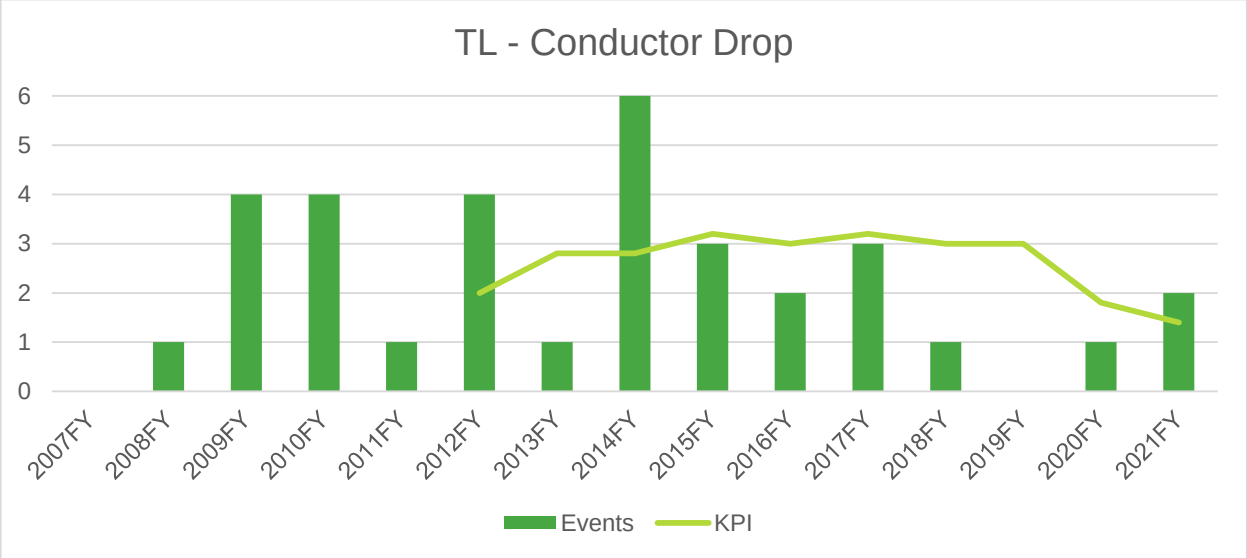


3.1.4.2. Past Performance – Conductor Drop

There were two conductor drop events in FY2021, so the KPI was not met. The two events were related to helical deadend earthwire fittings failure. One was already in the maintenance program for replacement, the other was assumed to be a compression arrangement (Cherry deadends) in previous desktop reviews. The Cherry deadends remediation have since been added to the maintenance program.

The historical conductor drop performance is shown in Figure 5.

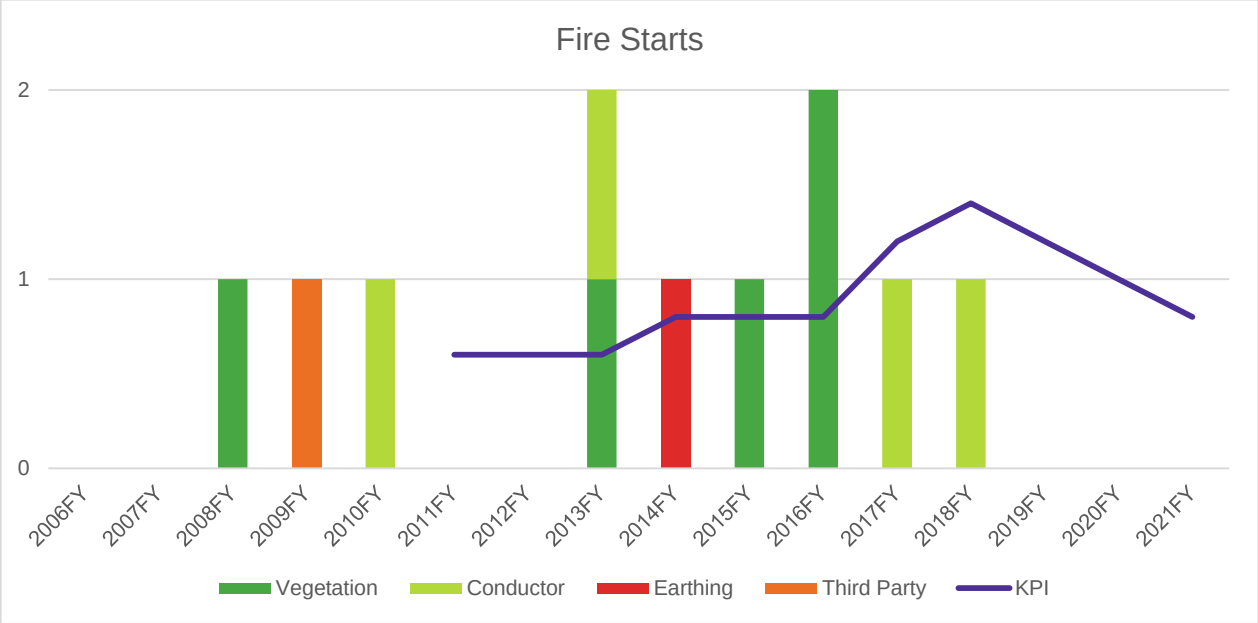
Figure 5 – Transmission Line conductor drop events



3.1.4.3. Past Performance – Fire Starts

There have been no fire starts attributed to the transmission lines asserts since FY2019. The KPI for FY2021 has therefore been met. The historical fire start performance is shown in Figure 6.

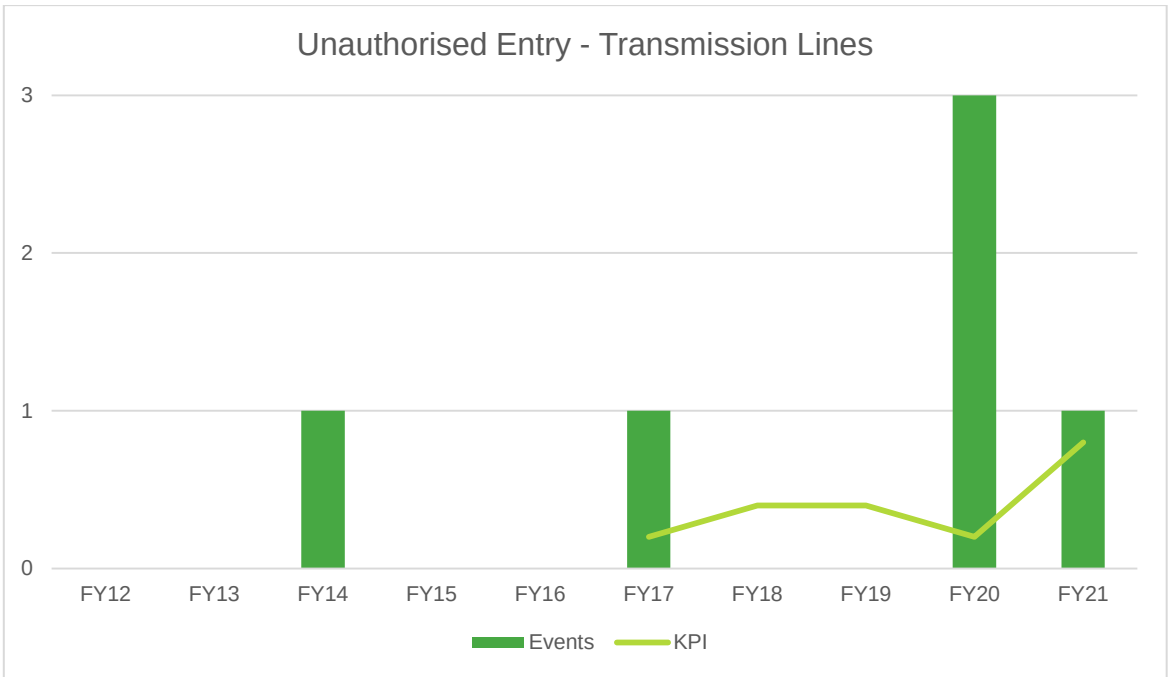
Figure 6 – Fire starts



3.1.5. Past Performance – Unauthorised Entry

'There was one unauthorised entry event in FY2021, a video was posted on Youtube of children climbing towers on what was believed to be Line 27. The KPI was not met. The criteria for identifying 'High Risk Tower' has since been reviewed.

Figure 7 – Unauthorised Entry



3.1.6. STPIS Performance

STPIS performance in CY20 was lower than previous years but aligned with strategic targets. This was due to many outages associated with upgrading numerous lines and substations associated with QNI. This was an expected result due to the large amount of critical work which needed to be completed.

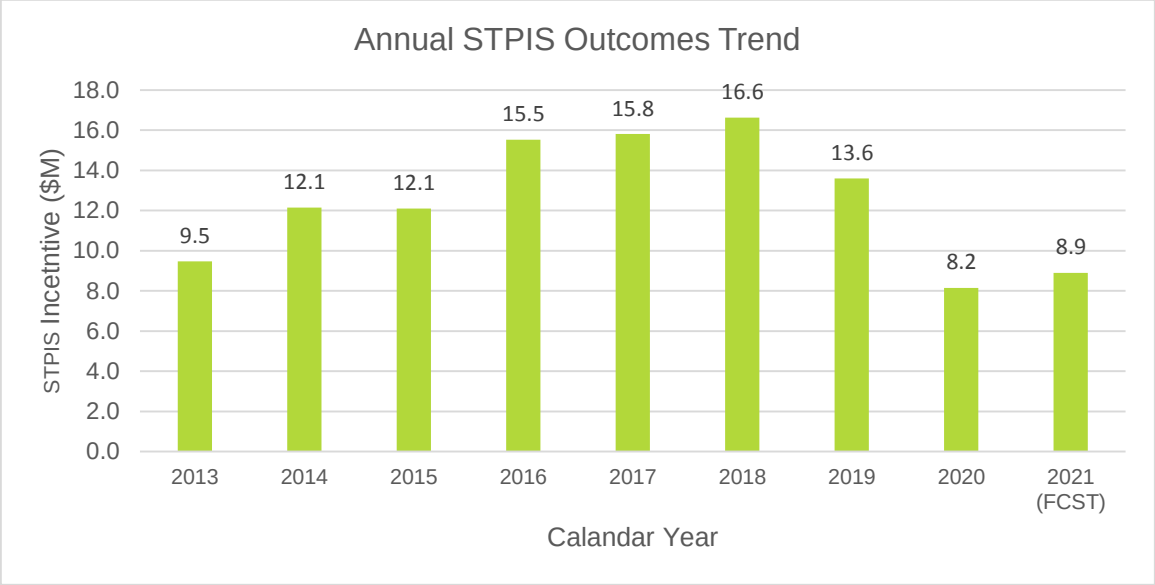
The effectiveness of our Asset Management program has contributed to STPIS performance by:

- Strategically targeted asset replacement programs for defective components of substation equipment, transmission lines, and digital infrastructure to improve asset reliability.

- Improved monitoring of assets and incident response by Asset Monitoring Centre and coordination with network planning for outage management.

- Maximising value achieved from Capital and Operating investment in our assets and minimising outages incurred

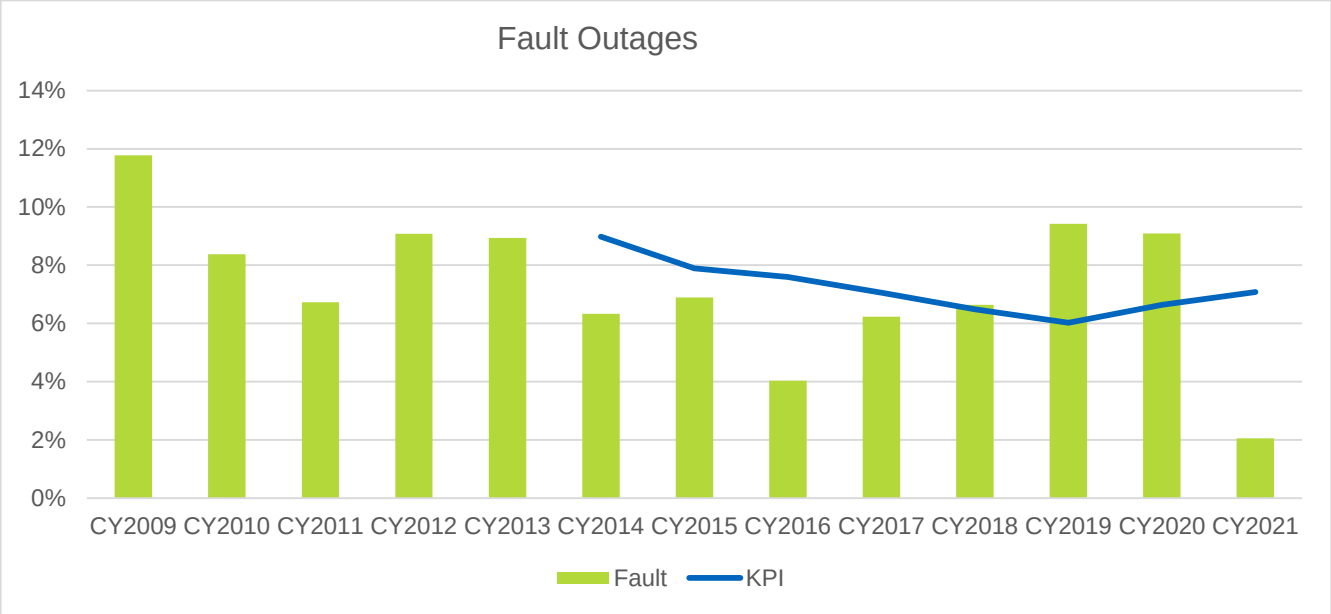
Figure 8 – Transgrid Annual STPIS outcomes



3.1.7. Past Performance – Fault Outage Rates

When the AER refers to “fault outage’, they are essentially referring to what TransGrid consider a “forced outage” These events include outages from all causes including emergency events and extreme events.

Figure 9 – Transmission Line Fault Outage Rates

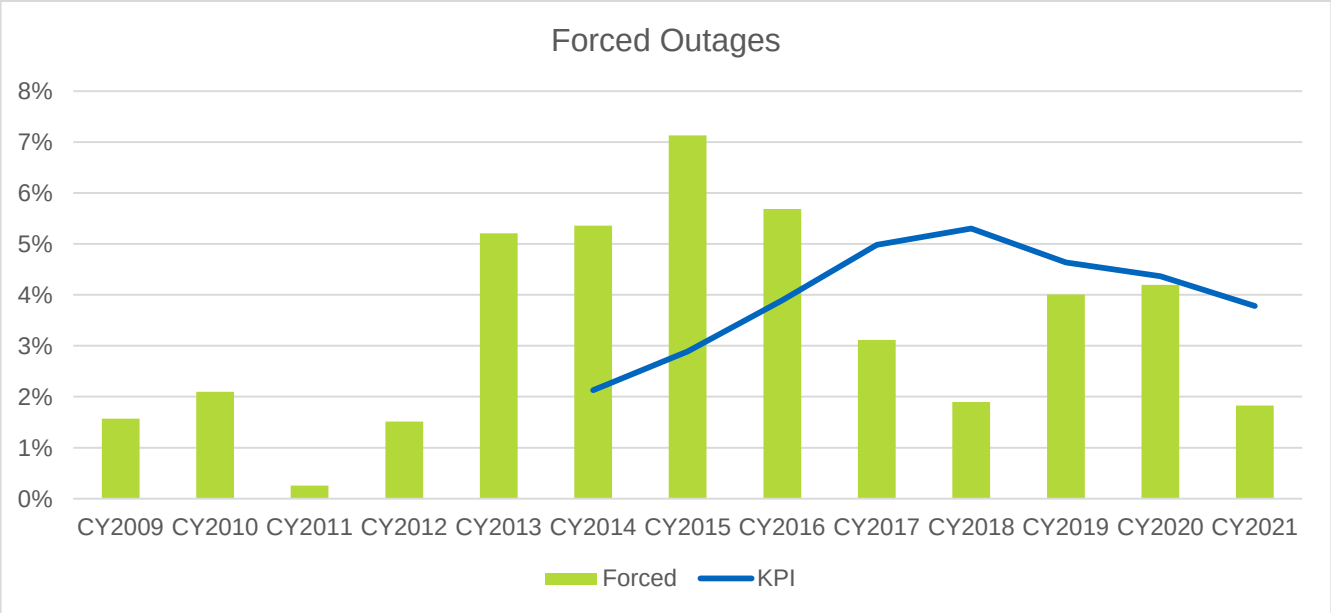


3.1.8. Past Performance – Forced Outage Rates

When the AER refers to “forced outage” they are essentially referring to what Transgrid considers and emergency outage’. The AER definition of “forced outage” is as follows:

> *Force outage means the urgent and unplanned reduction in the availability of defined circuits that occurs as a necessary consequence of the identification of the actual or imminent occurrence of an event that poses, or has the potential to pose, an immediate threat to the safety of persons, hazard to any equipment or property or a threat to power system security.*

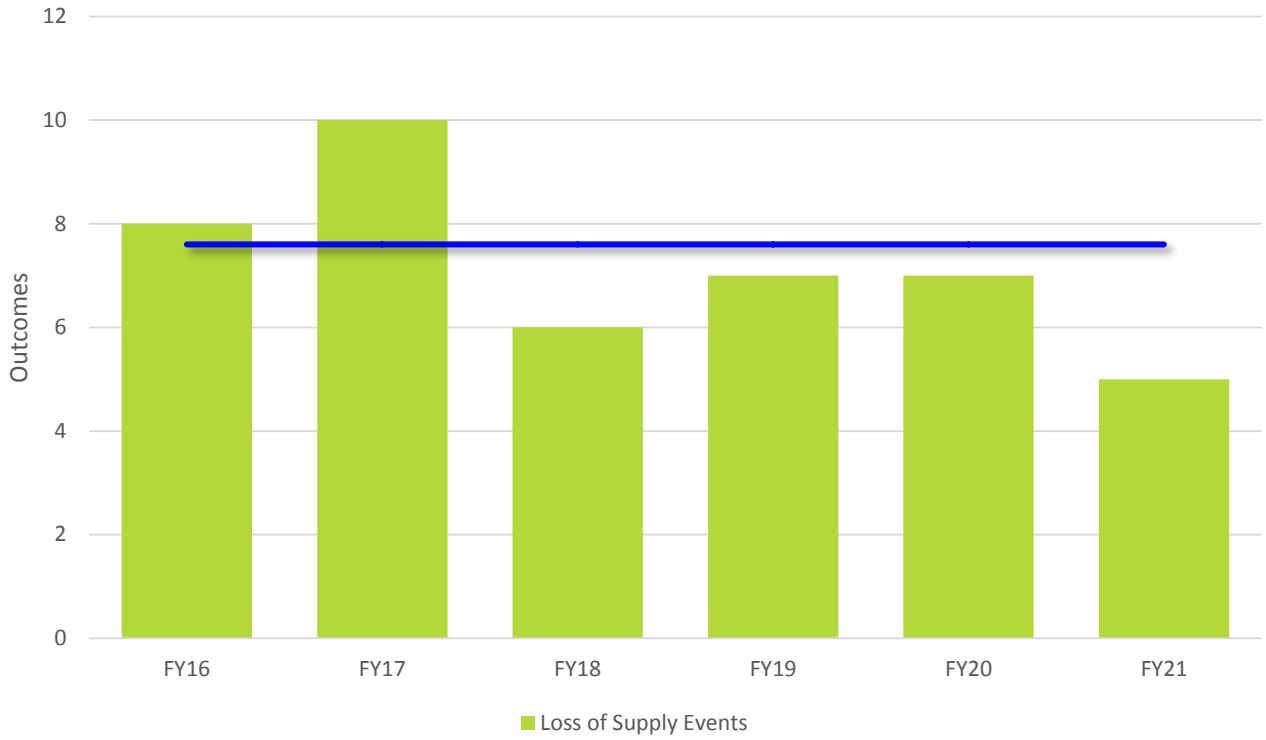
Figure 10 – Transmission Line Forced Outage Rates



3.1.9. Energy Not Supplied Events

There were five energy not supplied in FY2021. The KPI for FY2021 was met.

Figure 11 – Energy not supplied events



3.2. Review of Strategic Initiatives

The status of relevant strategic initiatives from the Network Asset Strategy and other asset class specific strategic initiatives is provided in Table 9.

Table 9 - Strategic Initiative Status

Network Asset Strategy Objectives	Initiatives / Reference	Status
Deliver Safe Reliable Power		
Manage Network Safety Risk	Update bushfire and public safety models to better reflect asset criticality and risk appetite	Completed.
Manage Network Reliability	Review and revise Risk Assessment Methodology and Asset Criticality assessment to ensure our ability to demonstrate that network safety risk is managed ALARP on a data driven basis.	The Risk Assessment Methodology has been updated to match current Business As Usual processes.

Network Asset Strategy Objectives	Initiatives / Reference	Status
Manage Network Safety Risk	Refer to Section 5	
Maintain network Reliability		
Create an efficient high performing business		
Ensure asset information is available to inform business-wide decisions	Continued collection of detailed asset condition data in AIM. Ready access to this data and integrating into the AAIT should empower the Asset Manager to make informed decisions.	Transgrid is achieved 85% of transmission line condition data at the end of FY2021. Ongoing.
Invest in Transmission to support the energy transition		
Support sustainable growth of the asset base by developing the right infrastructure	Supporting the development of the Integrated System Plan and Renewable Energy Zone projects	Ongoing – provided trusted advice for the development, procurement, and design of new asset to achieve lowest lifecycle cost
Seek new innovations and technologies		
Support new technologies and innovations that improve or grow our business	Investigate combining aerial inspections and LIDAR into the one helicopter flight. Aerial inspections would be detailed photography in lieu of Transgrid inspector.	Combining aerial and LIDAR into the one flight was determined not to provide acceptable outcomes.
	Investigate a 3 in 1 inspections (Combined photographic, infrared, and corona camera inspection) for insulators.	Trial has been completed and provided an acceptable outcomes.
	Use of Smart Aerial Image Processing (SAIP)	Recent SAIP run completed on coastal transmission lines. Possible uses for structure, insulator and fittings condition assessment is being investigated
	Trial public safety camera on high ‘fun seeker’ risk structures to manage public safety risk.	Investigation on vendors and technology feasibility are in progress
	Trial IoT early fault detection devices to detect early failure on asset.	Investigation on vendors and technology feasibility are in progress
	Investigate the use of drones for inspections and condition assessment.	Trial of drone inspection as an alternative climbing inspection completed. Assessment to be completed to ensure it provides cost effective solution.
	Trial the use of Distributed Acoustic Sensing (DAS) for Dynamic Line	Not Started.

Network Asset Strategy Objectives	Initiatives / Reference	Status
	Rating (DLR) alternatives and conductor vibration	

4. Strategy

4.1. Strategy and Objectives

All strategic initiatives with respect to Transgrid's Transmission Line assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Maintenance Plans, and the referenced governance documents. The Asset Management Objectives and performance indicators were refreshed in November 2021. The applicable Transmission Line objectives is shown in Table 10.

Table 10 – Asset management objectives and performance indicators – Transmission Lines

Business Objective	Network Asset Strategy Objective	Asset Management Performance Indicators
Deliver safe reliable and low cost power	• Manage network safety risk	• Maintain Network Safety LTIs and Fire Starts at Zero • 5 year average level of Key Hazardous Events: - Conductor drop - Structure failure - Unauthorised Entry • No red reports in key result indicators regarding Bushfire, Reliability and Public Safety Principal Risk Dashboards
Deliver safe reliable and low cost power	• Manage Network Safety Risk	• Maintain 5 year level of environmental incidents
Deliver safe reliable and low cost power	• Maintain network reliability	• Maintain 5 year average level of loss of supply events
Deliver safe reliable and low cost power	• Maintain network reliability	• Target improvements to performance of the STPIS measures
Create and efficient, high performing business	• Manage assets efficiently without compromising security holder and customer value	• Achieve +/- 5% performance in Program of Works Budgets. • Delivery Capital Program within +/-5% • Target capital efficiency improvements

To implement the strategic renewal and maintenance initiatives stemming from this document, actions are to be established via the:

- Maintenance Plan – Transmission Lines Assets: The maintenance plan outlines the routine maintenance tasks and frequencies for each asset type.

- Maintenance Plan – Easements and Access Tracks: The maintenance plan outlines the routine maintenance tasks and frequencies for each asset type.
- Capital Works Program – The capital works program outlines the approved asset renewal and disposal projects.

The Transmission Line and Cables Asset Manager is responsible for preparation of the maintenance plans and referring the renewal and disposal initiative to the network investment process. Delivery is responsible for delivering the maintenance plans and the renewal and disposal initiatives detailed in the approved capital works program.

5. Renewal and Maintenance Initiatives

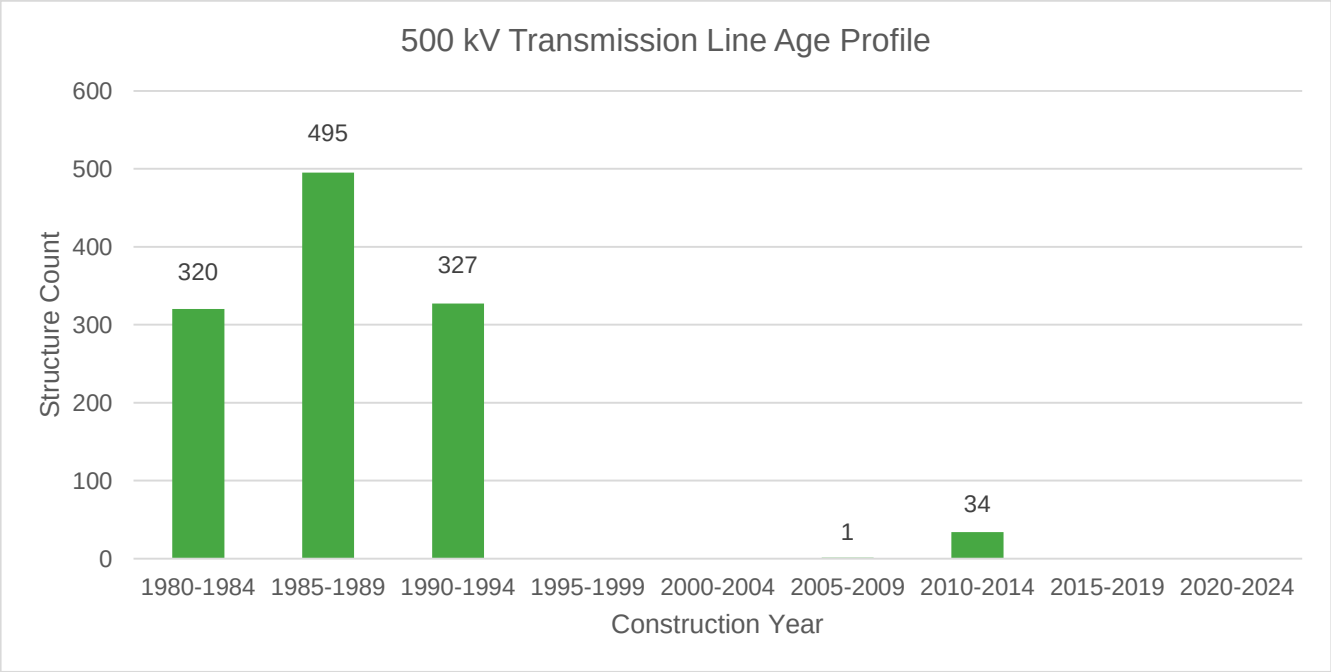
5.1. 500 kV Transmission Lines Asset Review

5.1.1. Population Review

The 500 kV network makes up approximately 9% of Transgrid's transmission line asset base by circuit kilometres. It has approximately 510 km of transmission line route which are supported by over 1,100 structures. The 500 kV network is mostly located inland and is entirely supported by steel structures, which have a nominal lifespan of 90 years. Twenty six structures are classified as coastal. The first elements were commissioned in 1982 and all assets remain within the first half of their nominal lifespan. The 500 kV network is relatively young compared to Transgrid's other steel structure transmission lines and is showing minor signs of deterioration on a small number of structures and spans.

The age profile of Transgrid's 500 kV transmission line assets is shown in Figure 12.

Figure 12 – 500 kV Transmission Line Age Profile



5.1.2. Emerging Issues and Renewal and Maintenance Initiatives

5.1.2.1. 500 kV Transmission Line Emerging Issues

The specific issues relating to the 500 kV transmission lines is discussed below with respect to the three main transmission line elements listed below.

Fittings

The current and emerging issues relating to 500 kV fittings are as follows:

- Insulator corrosion and staining: Corrosion of the base caps has led to rust staining of some V- String Suspension Insulators on the 500 kV 5A1/5A2 Eraring - Kemps Creek transmission line. Analysis indicates that electrical discharge (known as 'corona') at the base of the cap has caused localised deterioration of the zinc coating leaving these areas exposed to corrosion. The corrosion could eventually lead to mechanical failure of the insulators.

Electrical conductors

The current and emerging issues relating to 500 kV electrical conductors are as follows:

- Conductor damage: The 5A1/5A2 Eraring - Kemps Creek transmission line suffered damage to strands of the aluminium conductors following poor installation of 'Quad Spacer Dampers' during construction. Spacer dampers separate the conductors to prevent loose cable damage and also absorb physical vibrations in the lines. The installation issues were rectified; however, the damaged conductors remain in service. Further analysis found that the damage only affected the outer aluminium strands and not the galvanised steel wire which provides mechanical strength; as such the mechanical integrity of the conductors is thought to remain uncompromised. Inspection of these conductors with SAIP will enable accurate identification of these spacer defects. Failing quad spacers and associated conductor damage has also been observed on 5A6/5A7 and are addressed as appropriate under defect management. This issue will require ongoing monitoring to avoid a conductor drop event.

Structures

In general, the 500 kV structures are in a good condition overall and no current or emerging issues have been identified. General issues on structures are as follows:

- Soil covered concrete foundations: On some steel structures with concrete foundations, the top of the concrete pedestal is below ground line due to soil wash-ins. This can result in corrosion at groundline where moisture and oxygen in the soil aid oxidation.
- Transmission line earthing assessments, completed in January 2016 to assess high risk (publicly frequented) structure earthing found approximately 10% of structures tested did not comply with the requirements of AS7000. Further earthing assessments in publicly frequented areas will assess earthing arrangements of the wider transmission line network to determine compliance with AS7000.
- A public safety incident on 5A1/5A2 has triggered a review into the climbing deterrent effectiveness on 500 kV towers. The climbing deterrent installed on this tower was inconsistent with the standard at time of construction.

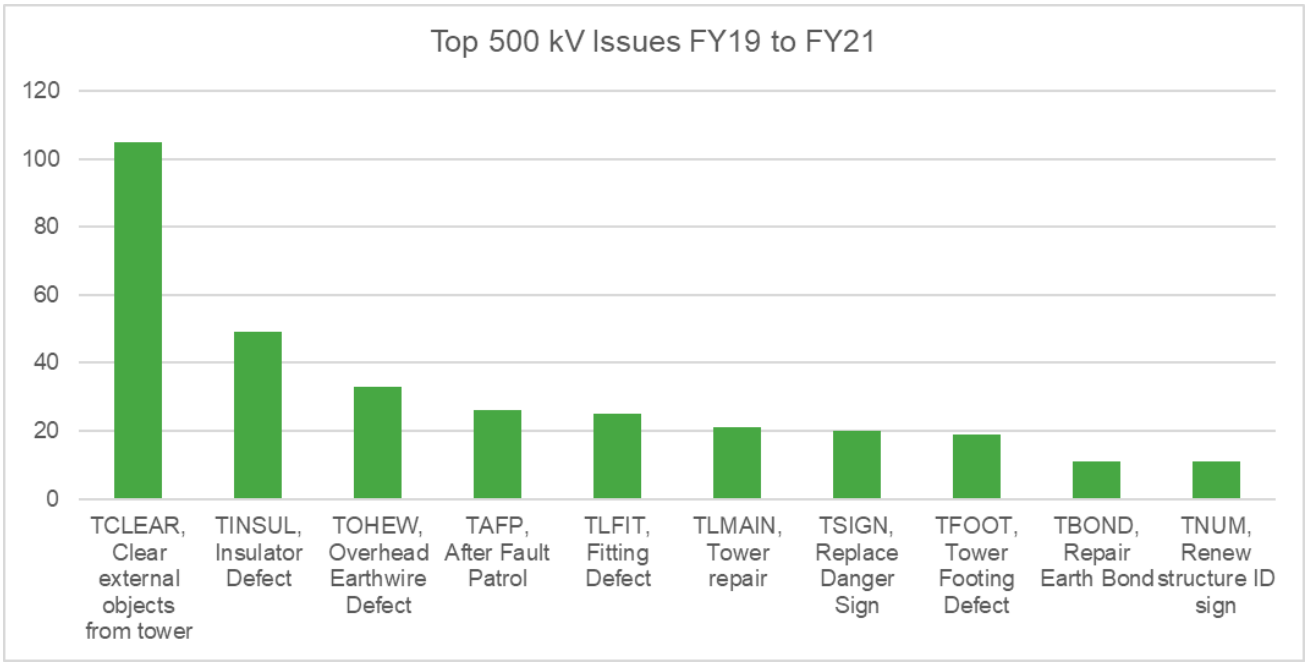
General Issues Commentary

An analysis of issues raised on the 500 kV network is shown in Figure 13. The greatest proportion of defects on 500 kV lines are due to fading structure numbers. These would not lead to a key hazardous event, but can make identifying the assets during an emergency difficult.

Fitting repair and insulator replacement is related to the spacer and insulator corrosion issues discussed above and would have the potential to drop conductors if left unaddressed.

Birds' nests on 500 kV towers continue to be an ongoing issue and result in a number of trip and reclose events each year due to suspected 'streamers'. This is particularly problematic on tension towers due to the gap from the V-string and the structure being minimal. The streamers from the nest location is more likely to cause an outage. ROTOMARKAs will be trialled on the earthwire on problematic structures. These are used for aerial markers and bird deterrents. It is hypostasised that the spinning marker will deter the bird from nesting below.

Figure 13 – Issue Quantities by Type (Top 10)



5.1.2.2. 500 kV Renewal Initiatives

A targeted renewal of the towers on Line 5A1/5A2 was included in the 2018-23 revenue proposal submission addressing issues with corrosion to tower steelwork at groundline due to soil coverage, replacement of a small number of tower bolts, damaged earth straps and poor condition insulator strings. The timing of this renewal has been adjusted to the RP4 or onwards based on the condition of the asset, risk and optimal timing of intervention.

5.1.2.3. 500 kV Maintenance Initiatives

During routine inspections the following emerging issues are monitored (Issued found will be actioned under corrective maintenance):

- Corrosion and residue build up on V-String Suspension Insulators.
- Damage to aluminium conductor strands around Quad Spacer Dampers.

Emerging issues on associated easements are:

- Hazard trees on easements.
- Unauthorised easement encroachments.

Climbing Deterrents

- Design review of tower contract drawings to identify any towers which may are not consistent with current design standards.
- Install climbing deterrent wires, diagonal wires and grid infills as per current standard and enhanced razor wire deterrents at road crossings.

5.1.2.4. 500 kV Disposal Initiatives

There are currently no 500 kV disposal initiatives.

Table 11 – 500 kV Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
All 500 kV lines	• Manage Network Safety Risk	• With the introduction of routine tower climbing to the Transmission Line Maintenance Plan there is increased exposure to EMF.	Engage EMF consultant to model the EMF exposure in the climbing corridors on the 500 kV towers. No actions recommended.	Completed	MISI_17_R031 Report
All 500kV Lines	• Manage Network Safety Risk	• Structure earthing not compliant with AS7000	• Assess earthing arrangements of the wider transmission line network to determine compliance with AS7000. • Reporting complete, action proposed and implemented. • Maintenance earthing testing results under review with detailed assessments to be undertaken as required.	Ongoing	IWR0088 IWR0191 Transmission Line Maintenance Plan
All 500 kV lines	• Manage Network Safety Risk • Maintain Network Reliability	• Damage to aluminium conductor strands around Quad Spacer Dampers	• Continue to inspect and monitor the identified issues through routine inspections and corrective maintenance. • The 500 kV network was inspected using aerial imagery and Smart aerial	Ongoing	Transmission Line Maintenance Plan

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			Image Processing (SAIP).		
All 500 kV lines	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion and residue build up on V-String Suspension Insulators.	• Continue to inspect and monitor the identified issues through defect management and defect maintenance • Unmanned aerial vehicle on select coastal structures with fog insulators.	Ongoing	Transmission Line Maintenance Plan IWR-N2401
All 500kV Lines	• Manage Network Safety Risk • Maintain Network Reliability	• Hazard trees causing transmission line faults	• Identification and scoping of hazard tree risk. • Removal of hazard trees as per Maintenance Plan.	Ongoing	Maintenance Plan – Easements and Access Tracks
All 500kV Lines	• Manage Network Safety Risk • Maintain Network Reliability • Manage assets efficiently without compromising security holder and customer value	• Unauthorised encroachments on easements present a safety risk to maintenance staff and the public	• Identify encroachments and order their removal where required.	Ongoing	Maintenance Plan – Easements and Access Tracks Living and working with electricity transmission lines
All 500 kV Lines	• Manage Network Safety Risk	• After a climbing incident on the 500 kV network in 2019, a review on the climbing	• Review effectiveness of climbing deterrents on	• Design is being	IWR0065 – complete

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Maintain Network Reliability • Manage assets efficiently without compromising security holder and customer value	deterrents is required.	the 500 kV network	reviewed. • Included in RP3 submission	IWR0121 – complete IWR0144 – complete N2425 – Public Safety Compliance
All Transmission Line Assets	• Manage assets efficiently without compromising security holder and customer value • Support sustainable growth of the asset base by providing the right infrastructure in the right place. • Enable accessible, relevant asset management information is available to inform business wide decisions.	• Asset condition data of insufficient quality and detail to support decision making.	• Improve asset data quality through Maintenance Plan and the implementation of AIM (Asset Inspection Manager). • AIM condition data available for 70% of 500 kV network at end of FY2021.	AIM has been rolled out to Transmission Lines. Contractors also have access. Data will become available progressively.	N/A
All Transmission Line Assets	• Manage Network Safety Risk • Maintain Network Reliability	• Long term performance of composite longrods is unknown • Hidden condition issues could lead to failure	Sample and analyse a selection of composite longrod to assess long-term performance. Longrods over 20 years old should be considered for	Complete.	IWR-N2256

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			replacement. Tests on aged longrods showed large reduction in hydrophobicity. No plans for 500 kV longrod replacements.		
Line 5A1/5A2	• Manage Network Safety Risk • Maintain Network Reliability • Manage assets efficiently without compromising security holder and customer value	• Corrosion of steelwork and components. • Reduction in security of supply.	Where required: • Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion. • Replacement of fasteners • Buried concrete foundations - Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of earth strap • Replacement of insulators	Deferred to at least RP4 $10.94M ($2021)	Need ID: 1278

5.1.3. 500 kV Maintenance Program

For the 500 kV Transmission Line assets, all structures are steel towers. There are no changes specific to 500 kV assets.

A Failure Mode Analysis was completed for all transmission tower types. The analysis is compared with the Transmission Line Maintenance Plan to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them. This is shown in Appendix A.

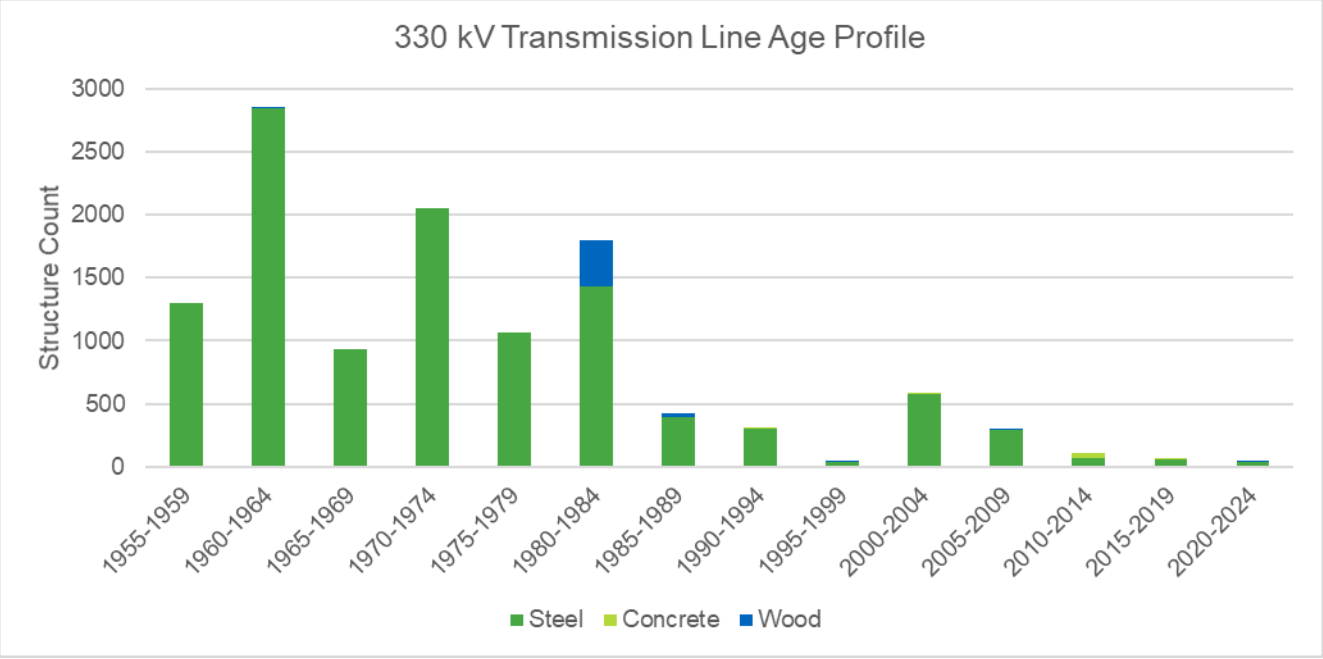
5.2. 330 kV Transmission Lines Asset Review

5.2.1. 330 kV Population Review

The 330 kV network makes up approximately 43% of Transgrid's transmission line prescribed asset base by circuit kilometres. It has over 4,600 km of transmission lines route (over 5,400 circuit km) which are supported by over 11,860 structures, 96% of which are steel structures. The first elements of Transgrid's current 330 kV network were commissioned in 1957 (originally at 132 kV then later uprated).

The age profile of Transgrid's 330 kV transmission line assets is shown in Figure 14.

Figure 14 – 330 kV Transmission Line Age Profile (prescribed assets)



5.2.2. Emerging Issues and Renewal and Maintenance Initiatives

5.2.2.1. 330 kV Transmission Line Emerging Issues

The specific issues relating to the 330 kV transmission lines are discussed below with respect to the three main transmission line elements listed.

Fittings and Insulators

The current and emerging issues relating to 330 kV fittings are as follows:

- Corrosion of nuts, bolts and insulator pins: This is a particular issue in coastal areas and ranges from minor to severe. Inspections of discs removed as part of recent refurbishment projects have shown that there can be significant pin corrosion and deterioration. The corrosion has been shown to significantly reduce the diameter of the pins, which compromises their structural integrity. A failure of a single pin will result in a conductor drop event.
- Porcelain insulator testing has also revealed that pre 1968 vintage insulators have reached end of life, with micro cracking forming within the porcelain that will eventually lead to electrical puncture.
- Composite insulators have been in service for over 20 years and may be reaching end of life. The sample test results have shown a large reduction in hydrophobicity (ie ability of the insulator to resist the ingress of moisture), reduction rod to housing adhesion and corona activity at the end of fitting to housing interface due to degradation and older design of this interface. Some of the findings are as follows:
    - Golden Phoenix insulator has shown quick reduction of hydrophobicity and weak adhesion core/housing after 2 years of in-service which will not provide reliable long-term performance.
    - Sediver insulator has shown crack around spacer ring which is well-known defect internationally. In addition, cracks perpendicular to insulator axis were found on this insulator which can be an entrance for moisture penetration into the interface and the core. Chalking was also observed, which naturally lead to their completely hydrophilic state of surface. A combination of possibility for moisture penetration and ingression via cracks in the housing and low quality of the core (some porosity, might be some cracks) is crucial for long-term performance and might lead to so-called “flashunder”, i.e. internal flashover, which may in turn lead to mechanical failure.
    - Xiangyang Guowang insulator (supplied by Zinfra) has shown low adhesion core/housing and high electric field close to the end of fitting which may accelerate internal deterioration in the interface core/housing.

    The strategy to replace these type of insulators already in service is being developed.
- Ineffective Stockbridge vibration dampers – Stockbridge vibration dampers are installed on most 330 kV lines across the network. Old dampers are showing signs of droop and are not providing adequate performance.
- Failure of Silmalec Mid Span Joints (MSJ) – There have been three mid span joint failures on transmission lines with Silmalec AAAC conductor. Failures have been through the centre of the joint and may be due to compression of the joint tube in the centre with a gap between the conductors to be joined. All MSJ which are accessible from EWP have been replaced. The remaining outer phase MSJ’s on the higher tension sections were replaced via helicopter platform. The middle phase was to be remediated by helicopter longline, which is no longer possible due to the ban. The alternative is to restring, which is currently not economical.
- Failure of Silmalec deadends – In February 2015 a deadend on transmission line U7 failed. Metallurgical examination found that the failure was a progressive (fatigue) failure that was initiated from the lower corner of the first crimp.
- Ineffective vibration dampers on Silmalec conductor –ELGRA vibration dampers from Sweden were installed on the first 330 kV lines emanating from the Snowy Hydro Electric scheme from the late 1950s. These dampers have been found to be ineffective worldwide.

- There has been an increasing trend in hot joints on both the 132 kV and 330 kV network. This included a conductor drop event on Line 11 in 2016 due to deadend failure.
- The 2019/20 bushfires caused widespread damage to spiral vibration dampers. A total of 224 330 kV spans were identified with vibration damper fire damage. Scattered quantities of insulators and aerial marker balls were also damaged. Replacement of these insulators and fittings were included in the AER pass-through application.

Conductors and Earthwires

The current and emerging issues relating to 330 kV conductors and earthwires are as follows:

- Various inspections, including Smart Aerial Image Processing (SAIP) in early 2020, have been carried out on selected lines, supported with sampling and material testing. These have confirmed that multiple spans within line segments have issues including broken strands, probable conductor corrosion, and probable annealing of conductor.

  The main factors that impact conductor condition are:

  - Bushfire exposures. High temperatures can impact the mechanical integrity of conductors in multiple ways such as annealing of the aluminium alloy reducing tensile strength, loss of grease/galvanising layer from the inner steel strands of conductor. Both of which then reduces the corrosion performance.
  - Corrosive operating environment. Conductors which are operating in the coastal regions are subject to harsher operating conditions and therefore higher rates of corrosion than conductors situated away from the coastline. In particular, corrosion and subsequent metal loss of the steel strands in ACSR/GZ conductor and galvanised steel earthwire reduces tensile strength. Once the level of corrosion has reached a certain threshold, the earthwire is at an increased risk of failure.
  - Conductor type. Prolonged exposure to Aeolian vibration results in fatigue and/or fretting of conductor strands, and TransGrid's earlier legacy fleet of conductor attachments utilise bolted suspension clamps which lack effective vibration control.
  - Mid-span joints, once installed, form part of the conductor system, depending upon the operating environment and conductor type, these may impact the expected conductor life. In addition, There is a particular issue of galvanised steel earthwire in coastal areas ranging from minor to reduction in cross section. Options where strategic replacement of earthwire with OPGW provides economic benefits are considered.
- Low hanging conductor spans. These are spans with low electrical clearances which do not meet design standards (grandfathered to date of construction). Stage 1 of the low span remediation program has been completed. Stage 2 to progress in RP2.
- During the scoping of the Line 22 refurbishment project, Transgrid identified that the earthwire near Sydney North substation was undersized. It is possible that other lines have the same issue. They would have been suitable at time of construction but became undersized when the grid was augmented over time. On further investigation this issue was found to be quite widespread.
- The 2019/20 bushfires caused significant damage to conductors in the Snowy Mountains. A total of 51 spans require remediation, which will be completed by FY2023. Further spans were damaged, but not to extent that requires remediation in the near term. These spans will be monitored during routine inspections.

Structures

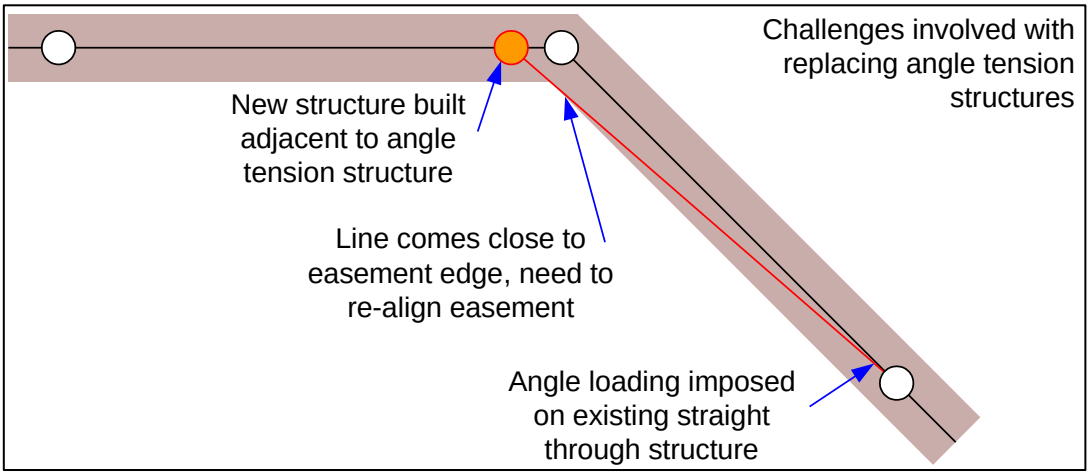
The current and emerging issues relating to 330 kV structures are as follows:

- Corrosion of steel tower members: A number of steel towers have degraded through loss of zinc coating and subsequent corrosion of the steel. The towers located in coastal and industrial areas have suffered the greatest deterioration. This affects the structural integrity and reduces the transmission line security of supply.
- Corrosion of nuts, bolts and fasteners on steel towers: This is a particular issue in coastal areas and ranges from minor to severe. Routine inspections on lines in the Newcastle, Central Coast, Sydney and Dapto regions have indicated that there is significant corrosion on bolt heads and blown nuts, which compromises the structural integrity of the steel tower structure and/or conductor fittings. This reduces the transmission line security of supply.
- Corrosion of steel footings: A large number of the steel tower structures constructed prior to the late 1960s were installed with buried steel 'grillage' foundations. A chemical reaction occurs due to contact with the soil which leads to deterioration of the zinc coating and corrosion of the underlying steel. The majority of grillage foundation towers were fitted with sacrificial magnesium anodes. A review has found these anodes to be ineffective in a number of locations where severe soil corrosion conditions exist. This reduces the transmission line security of supply.
- Soil covered concrete foundations: On some steel structures with concrete foundations, the top of the concrete pedestal is below ground-line due to soil wash-ins. This can result in corrosion due to contact with the soil which leads to corrosion of the zinc coating and the underlying steel. This can reduce the transmission line security of supply.

These corrosion issues are being addressed through refurbishment projects as per the methodology below:

- The refurbishment can include selected member and fastener replacement and selective blast and paint to the affected areas. Where corrosion is extensive, whole tower blast and paint may be required. It has been determined that it is more economical to replace at end of life where the tower is a simple suspension structure. In the time taken to reach end of life, a painting regime would normally require multiple refurbishments, and would still require that in perpetuity. Tension and space constrained suspension structures will require a blast and paint regime.
- Structure replacement works are considered suitable for straight line suspension structures, as a new structure can be built adjacent to the old structure, and the conductors transferred prior to the removal of the old structure. Compared to a suspension tower, a tension tower is significantly more difficult and expensive to replace due to the need to anchor conductor tensions during transfer to a new structure, and the fact that these towers are generally much more robust with larger footprints, requiring replacement structures to be built further away.
- Where the structure is an angle structure (generally a tension tower), the conductor alignment is likely to change, possibly requiring easement adjustment or imposing a conductor angle on the adjacent structures that will require assessment for strength suitability. This is illustrated in the below diagram. As a result, tension towers are not considered suitable for replacement, and must be life extended by painting, prior to the loss of structural integrity from further corrosion.

Figure 15 – Challenges involves with replacing angle tension structures



- Damage to tower earthing: A number of earth straps on steel tower structures have been compromised, affecting earthing performance and presenting a people safety risk.
- D-String impacts on structural integrity – It was identified during the Lines 4 and 5 Low Spans project that tower strengthening is required to ensure structural integrity is maintained on towers where D-strings are being installed. This highlights the issue of D-strings installed at other locations where no strengthening has taken place.
- Collapsible crossarms on some suspension towers: These crossarms have been deemed not suitable for supporting a worker to carry out maintenance tasks on the tower. Design for reinforcements has been completed. The intention is to install only when required prior to works.
- Tower Asbestos Paint: Asbestos containing paint has been identified on steel towers across Transgrid's transmission network. The paint is generally limited to the lower part of the tower legs, however there are a few towers identified as having been completely painted with the asbestos paint. The extent of this issue across the network is still under investigation, but is believed to affect all tower lines constructed pre-1980. The paint has been found to be in poor condition, generally flaking and peeling from the structure.
- Emergency Structures: Lines 3 and 6 have had emergency wood poles structures installed after storm failures of the original steel towers. The Line 3 structure is suitable for permanent use, it just requires the additional maintenance of a timber structure. The Line 6 structures are designed as temporary structures to lower design criteria compared to the original permanent line effectively reducing the expected life of these emergency temporary structures. They were always expected to be a temporary solution only and do not have the full design capabilities of the steel tower structures they replaced reducing the transmission line security of supply. Despite this there are no near-term plans to address the Line 6 structures.
- Transmission line earthing assessments, completed in January 2016 to assess high risk (publicly frequented) structure earthing found approximately 10% of structures tested did not comply with the requirements of AS7000. Further earthing assessments in publicly frequented areas will assess earthing arrangements of the wider transmission line network to determine compliance with AS7000 with implementation of solutions to follow on a progressive basis. Inadequate or inappropriate earthing on transmission lines can cause hazards to the public or start fires. The pole top failure of Line 944 in 2014 resulted in two fire starts in separate locations; none were at the structure failure site. Routine

inspections have also flagged multiple fences within the easement that are not in accordance with design standards.

- Corrosion of steel poles at the lead up to Sydney South substation (transmission lines 12/76, 13/78, 76/78) have been found with corrosion at the joins between the sections of the steel poles, corrosion at groundline, and corrosion of the earthing straps.
- Older single circuit transmission line structures were designed to the standards at that time, but were found to be deficient in some circumstances (skew wind) with a lower set of design criteria compared with newer structures. Following a number of structure failures in extreme wind events, investigations found single circuit suspension towers had design deficiencies in the governing load combinations when compared to more recent design philosophies and standards.
- Strengthening of structures with utilisation over 85% at road crossings and public areas has occurred. However, groups of structures on different lines in close proximity which may impact system stability if damaged (such as near major generator substations) may not have been strengthened, representing a potential weakness in the security of supply.
- During the scoping for the QNI project (impacting Lines 84 and 88) it was discovered that some structures not only failed the current design criteria but also was not built to the design standard at the time. During extreme wind or storm events, these structures will have a higher probability of failure.

Climbing Deterrents

A public safety incident on Line 27 of a youth climbing the tower has triggered further review on climbing deterrent adequacy. This structure was identified in the PESA plan as high public exposure and the high-security razor wire rings were in-place at the time of the incident.

Line 86

Tamworth to Armidale Line 86 was constructed using mostly composite wood poles. It is the only 330 kV wood pole line. Wood rot beneath the composite pole joint sleeve is becoming more prevalent throughout the line, affecting their structural integrity. This was highlighted by the failure of structure 22 in April 2020, where the both poles snapped at this point during a storm. This wood pole transmission line was designed to a lower set of design criteria than steel tower transmission lines which reduces the security of lines providing supply between the major generation at Newcastle, the Tamworth/Armidale region and Queensland.

Four structures replaced over a period of two days in August 2019 resulted in a $3.5M STIPS impact, which highlights the critical nature of Line 86 and the impact on the NEM should a structure fail.

Design for bracing, which goes over the steel sleeve, has been formalised, allowing short term deferral of structure replacement in some situations with additional inspection to be done on annual basis to ensure there is no deterioration on the pole condition. Additional structures have been condemned in FY2021 and the first half of FY2022. Two structures were replaced in November 2021 with concrete pole structures.

Whilst this line was not affected by the 2019/20 bushfires, the NSW review into the events recommended that this line be made more resilient bushfires. The review saw the resilience of the line was not in alignment with its importance in the NEM.

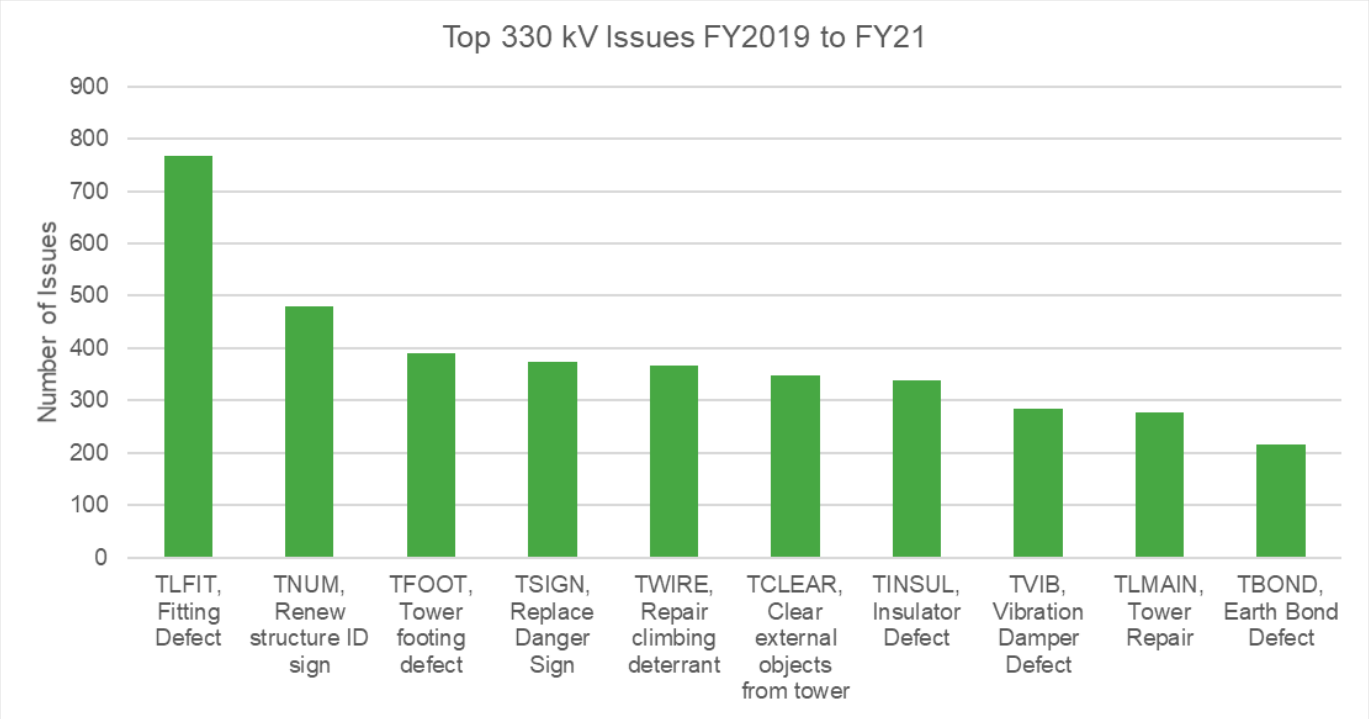
A RIT-T is being progressed for uprating Line 86. Should those works proceed, these wood pole structures will be removed.

General Defect Commentary

An analysis of defects raised is shown in Figure 16. The greatest quantity of issues was nearby unearthed fences or gates. During a fault, dangerous voltages can be induced on these items. This could leave to a fire start or death/injury if a person was nearby. Other safety issues such as anti-climber replacement, warning signs and structure leg bonding are also prominent.

Fitting, footing and tower leg repairs and insulator replacements are indication of an ageing asset base, particularly in coastal areas. Fittings and insulators if left unaddressed could lead to conductor drop.

Figure 16 – 330 kV Issue quantities by type (top 10)



5.2.2.2. 330 kV Renewal Initiatives

Transgrid utilises a health index methodology to identify those assets with the highest risk of failure. The analysis takes into account actual age and effective age (based on recorded condition) in individual transmission line components, applies an appropriate weighting to give an overall health score for each major structure component.

The overall risk cost for that component is determined by the probability of failure of the item with that health score, the likelihood of key hazardous event and the cost of that event at that particular location.

Where investment is to proceed the components worse than a set condition replaced are replaced or refurbished.

The following renewal initiatives are planned. Details on the specific assets are noted in Table 12:

- Line 86 rebuild (contingent project). Subject to regulatory approval start RP3, finish RP4.
- Targeted replacement of insulators with pin corrosion.
- Targeted replacement of Stockbridge vibration dampers with excessive droop.
- Targeted replacement of SC/GZ earthwire with consideration for replacement with OPGW where there is a strategic benefit.
- Corrosion of steel tower members:
  - Targeted minor member replacement
  - Targeted corrosion remediation - abrasive blast cleaning to remove any corrosion product and application of Zinga paint.
  - Targeted whole tower corrosion remediation
  - Targeted replacement of corroded steel tower nuts, bolts and fasteners.
- Grillage foundations corrosion remediation:
  - Testing programme of soil sampling to classify areas by soil aggressivity,
  - Proof test if aggressivity model by excavating the grillage foundation.
  - Structures which have been classified as located in areas of aggressive soils are to have the grillage foundation dug out, and the footing steel work repaired, or reinstated where required, then concrete encased.
  - Installation of new or additional sacrificial anodes elsewhere.
- Soil covered concrete foundations:
  - Clear soil from buried tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel
  - Clear soil from buried tower legs, scabbling of concrete footing, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion
- Replacement of corroded or damaged earth straps to the current standard.
- Conductor replacement program
- Line 11 – Sydney South – Dapto – Targeted suspension structure and conductor replacement.
- Line 23 – Munmorah Power Station – Vales Point Power Station – Targeted suspension structure replacement.
- Silmalec Conductor Mid Span Joints (MSJ) replacement of reinforcement. Lines with generally higher conductor tensions (> 48kN) were prioritised for completion by June 2018. These works have been delayed multiple times with the banning of works from helicopter being the latest setback. All remaining spans stage 1 and stage 2 were due to be completed by June 2023. The cost to complete these works by other methods is disproportionate to the conductor drop consequence, so these problematic mid-span joints will remain until the ban is revoked.

- Silmalec Conductor dead end replacement of reinforcement. Lines with generally higher conductor tensions (>48kN) have been completed. Remaining work deferred until further notice.
- Replace all ELGRA vibration dampers (Silmalec AAAC conductor).
- Removal of transmission structure asbestos paint using solvents (after verification of asbestos presence) – high and very high risk structures remediated in RP2; medium and low will be remediated in RP3.
- Low Spans - Transgrid's low span strategy is to prioritise spans for remediation using a risk based approach. Line temperature during credible contingency scenarios have been calculated and the low spans at this temperature are then determined. A risk assessment is then conducted on these spans taking into account traverseability, land use and extent of clearance violation (both violation height and violation area). The high and medium risk spans will then be remediated to the design temperature while the low and very low risk classifications will only be remediated if the cost of doing so is not disproportionate to the benefit gained. Where low spans are not remediated, engineering and administrative controls will be implemented.
    - A grandfathering principle applies when determining the clearance requirements (older 330 kV lines have a 7.7 m clearance requirement, current standard are 8 m). They do not have to comply with new clearance requirement.
    - Stage 1 of the low spans project is now complete. Stage 2 is due in RP2.
    - Lines 1, 2, 3L, 4 and 5 are planned in RP3.
- There are several past and current initiatives with respect to steel tower climbing deterrents as per the followings:
    - Provide designs for high risk locations (complete)
    - Modification of double circuit tower modification of around K-members on high exposure towers (complete).
    - Single circuit towers high exposure – razor wire modification (complete).
    - 'High risk' location criteria defined (complete).
    - Additional high exposure towers – require updating as appropriate (razor wire design to be reviewed) and remediated.
    - Towers without infills and/or inadequate spreaders to be remediated to current design.
    - Spike type climbing deterrent to be replaced with updated design.

A Failure Mode Analysis was completed for all transmission tower types. The analysis is compared with the Transmission Line Maintenance Plan to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them. This is shown in Appendix A.

5.2.2.3. 330 kV Disposal Initiatives

The Bayswater to Mount Piper 500 kV link was built in 1982 but was operating at 330 kV up until 2009. Short sections of 330 kV wood pole lines were constructed to connect the 330 kV switchyards became redundant after 500 kV operation. The structures at the Mount Piper end have been dismantled. The structures at the Bayswater end remain.

Table 12 – 330 kV Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
All 330 kV lines	• Manage Network Safety Risk	• With the introduction of routine tower climbing to the Transmission Line Maintenance Plan there is increased exposure to EMF.	Engage EMF consultant to model the EMF exposure in the climbing corridors on the 500 kV towers. No actions recommended.	Completed	MISI_17_R031 Report
All 330 kV Lines	• Manage Network Safety Risk	• Structure earthing not compliant with AS7000	• Assess earthing arrangements of the wider transmission line network to determine compliance with AS7000 • Reporting complete, action proposed and implemented. • Maintenance earthing testing results under review with detailed assessments to be undertaken as required.	Ongoing	IWR-0088 IWR0191 Transmission Line Maintenance Plan
All 330 kV Lines	• Manage Network Safety Risk	• Unearthed fences within easements	Inspect fences during routine inspections for earthing in accordance with Transgrid guidelines. Issues to be managed by Property and Environment.	Ongoing	Line 944 failure report. 'Transgrid Fencing Guidelines' public document.
All 330kV Lines	• Manage Network Safety Risk • Maintain Network Reliability	• Hazard trees causing transmission line faults	Identification and scoping of hazard tree risk. Removal of hazard trees as per Maintenance Plan.	Ongoing	Maintenance Plan – Easements and Access Tracks

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Manage assets efficiently without compromising security holder or customer value				
All assets – Conductors and fittings	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of fittings and conductors	• Continue to inspect and monitor the identified issues. • Include in regulatory submissions for renewal when appropriate.	• Ongoing during routine maintenance. • Selected fitting replacements included in RP2 Revenue proposal as part of line refurbishments.	Transmission Line Maintenance Plan Transmission Line and Easement Condition Data Collection
All 330kV Lines	• Manage Network Safety Risk • Maintain Network Reliability • Manage assets efficiently without compromising security holder or customer value	• Unauthorised encroachments on easements present a safety risk to maintenance staff and the public	Identify encroachments and order their removal where required.	Ongoing	Easement development guidelines
Line 82/95	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2026 • Planned for FY2027 • Estimate - $4.26 million	Need ID: N2505

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
				($2021)	
Line 76/78	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues. Remediation of corrosion at joints.	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2024 • Estimate - $3.67 million ($2021)	Need ID: 1723 withdrawn due to ORPS project changes Need ID: N2477
Line 25/92	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2026 • Planned for FY2028 • Estimate- $3.59 million ($2021)	Need ID: N2502
Line 29/26	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2028 • Estimate - $4.54 million ($2021)	Need ID: N2525

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line 90/92	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed and planned for FY2025 • Estimate - $1.40 million ($2021)	Need ID: N2526
Line 9W/96	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2027 • Estimate - $1.36 million ($2021)	Need ID: N2499
Line 92/93	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed and planned for FY2025 • Estimate - $2.44 million ($2021)	Need ID: N2527
Line 94/96	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2028	Need ID: N2501

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
				• Estimate - $5.29 million ($2021)	
Line 95	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2026 • Estimate - $2.17 million ($2021)	Need ID: N2504
Line 24/90	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Included in RP3 submission. • Optimally timed for FY2029 • Planned for FY2024 • Estimate - $1.16 million ($2021)	Need ID: N2520
Line 13/78	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steel pole and towers • Line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2024 • Estimate - $4.56 million ($2021)	Need ID: N2724

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line 12/76	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steel pole and towers • Line components at end of life.	Option B preferred: Refurbish all asset components that have been identified as having condition issues	• Structure 76/77-311 remediated under IWR. • Included in RP3 submission. • Optimally timed for FY2026 • Planned for FY2024 • Estimate - $5.66 million ($2021)	Need ID: N2476
QNI Refurbishments: • 8C/8E • 8C/8J • 8L/8M	• Manage Network Safety Risk • Maintain network reliability	• Circa 2001 NCIs are approaching end of life. • Deteriorated condition of marker balls, bonding and climbing deterrent	• NCI Insulator replacements • Other refurbishment where required.	• 8C/8E and 8C/8J included in RP3 submission. Planned for FY2028 • 8C/8J and 8L/8M optimally timed in FY2026, 8C/8E FY2028. • 8L/8M deferred to RP4 Estimates: • 8C/8E – $18.76 million ($2021) • 8C/8J – $8.28 million ($2021) • 8L/8M – $6.52 million ($2021)	Need ID: N2496, N2497, N2498,

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Non-Ceramic insulator (NCI) replacements 24 25/26 81 90	• Manage Network Safety Risk • Maintain network reliability	• NCIs installed in 1990's early 2000's located in coastal environment near heavy industry.	• Tests have been conducted which confirms degraded condition, so these NCI's need to be replaced. • Insulators on Lines 24 and 90 will be completed under the RP2 project. • Insulators on Line 25/26, 81 and 2M will be replaced under IWR. • Insulators on Line 22 will be replaced under the Line 22 conductor replacement	• Line 24 – Est. $2.77 million ($2021). Planned FY23 completion under existing refurb need • Line 90 – Est. $1.20 million ($2021). Planned FY23 completion under existing refurb need. • Line 25/26 – Est. $6.82 million ($2021). • Line 81 – Est $6.13 million ($2021). • Line 22 – Est. $1.29 million ($2021). • Line 2M – Est. $1.14 million ($2021).	Need ID: N2623 Need ID: 1328 (TL24 refurb) Need ID: 1347 (TL90 refurb) IWR: To be issued. Need ID : N2595
Conductor condition on the following lines: U1 U3 U5 U7 1 2 03 65 L1 L3 L5 M11 M13 64	• Manage Network Safety Risk • Maintain network reliability	End of life due to the following: • Corrosion • Annealing due to bushfire exposure • Fretting and fatigue caused by Aeolian vibration.	• Like for like conductor replacement, includes replacement of all conductor compression fittings, suspension clamps/AGSU, jumper connections, spacers and vibration dampers. • Lines 21 and 22 planned for RP3 remediation. • Line 11 included in str replacement • When Silmalec remediation is actioned, it is to be replaced with	• Lines 21 and 22 are included in RP3 submission. • TL21 planned for FY2026 • TL22 planned for FY2027 • TL21 and TL22 estimate - $14.58 million ($2021). • The following lines are planned for RP4 and beyond:	Need ID: N2595

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
11 18 21 22 2M 10 22 23 17 21 90 81 26 25 M3			the ASCR equivalent bundled conductor.	- Line 65 - Line 2M - Line 17 - Line 90 - Line 81 - Line 93 - Line 25/26 - Line 99Z - Line 994	
Line 3H Storm Damage remediation	• Manage Network Safety Risk • Maintain network reliability	• Two towers on Line 3H collapsed December 2020. Line was restored with emergency which have lower design criteria.	Restore line with permanent steel pole structures.	• PAD cost: $1.43 million • December 2021 forecast completion.	Need ID: N2558
Lines with bushfire damage, hazard trees impacted by fire, blocked or eroded access track as result of bushfires.	• Manage Network Safety Risk • Maintain network reliability	• Conductor damage has occurred on a number of lines in the Snowy Mountains. • Spiral vibration dampers on many earthwire spans have been melted and are ineffective. • Bushfire has	• Assess risk from damaged conductors. Replace or repair conductor where work will comply with ALARP, prioritising the higher risk spans. • Replace melted aerial marker balls. • Monitor spans not planned for repair or replacement during routine inspections.	• Pass-through application submitted to AER. AER considered Northern fires as a separate event so were excluded from final determination. • AER final determination - $49.8 million (All assets).	AER Pass-through application IWR-N2466

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		increased the quantity of hazard trees which need action. • Access track condition has worsened by fallen trees or increased erosion.			
TL81 Structure 649A	• Manage Network Safety Risk • Maintain network reliability	• Severe ground subsidence has badly buckled tower members.	• Install bypass and Dismantle failed tower--IWR0157 • Install new structures – Capital Need 1268 • Dismantle bypass – IWR0174	• IWR-0157 – $754K • Need 1268 – additional $2.187M • IWR-0174 - $84K	IWR-0157 Need 1268 IWR-0174 PCR-1268
Line 21 Hawkesbury River crossing	• Manage Network Safety Risk	• Aerial marker balls may not be compliant with AS 3891.	• Sydney Seaplanes requested marker balls be installed on Line 21 crossing of the Hawkesbury River. Marker balls were installed but fewer than the standard requirements due to tower capacity. • Investigations on requirements to make spans compliant to be investigated. • December 2017 findings from TL&CD determined that the SC/GZ earthwire was able to withstand additional marker balls	• IWR0150 – total spend $10K. • Further investigations found that Sydney Seaplanes was requesting markers on an Ausgrid line. Item closed.	IWR0150

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			to be compliant with AS 3891.		
Selected lattice tower lines	• Manage Network Safety Risk	• Climbing deterrent enhancement. • Aerial marker ball installation and replacements	• Selected double circuit structures noted in the PESA plan and other structures located in areas noted as 'backyard', school and 'public' to have augmented climbing deterrents, including razor wire installed by 30 June 2018. One structure remaining (property owner refusing access) • Upgrade spike type climbing deterrents. • Upgrade climbing deterrents with without diagonal wires and grid infills and installations with inadequate spacers. • Replace faded aerial marker balls and install additional markers where required by AS3891.1	• Current design needs review before it can be used. • Climbing deterrents included in RP3 submission – Est cost $25 million ($2021). • Aerial markers ball replacement is still being investigated.	IWR0065 – complete IWR0121 – complete IWR0144 – Complete IWR N2240 – on hold Need: N2425
Structures with D-String insulators	• Manage Network Safety Risk • Maintain Network reliability	• Structures with D-String insulators installed may require strengthening to maintain structural integrity.	• Identification of existing structures which have had D-strings installed, and those which have been proposed for the installation of D-strings and Undertake a structural assessment of the identified structures to confirm structural	• $67K for investigations. • Delivery overdue – was due Dec 2017 • A list of D-string structures has been provided.	IWR0152

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			integrity. • Where the structural assessment identifies any deficiencies in the structure, a tower strengthening solution is to be designed in accordance with current standards.	• Next stage of assessing these structures and if fails designing remediation only complete for high risk road crossings.	
Line 86	• Manage Network Safety Risk • Maintain Network Reliability	• Twin wood pole 330 kV Line with composite poles. Rot can occur under the metal cylinder. This line is critical for the transmission of electricity between QLD and NSW. • Bushfire resilience of critical interconnectors	• Rebuild line with double circuit structures. • The Final Report of the NSW Bushfire Enquiry recommended the replacement of these wood poles with structures that are more resilient to fire.	• RIT-T for rebuild to commence FY2022. • If approved, construction would commence in RP3 for commissioning in RP4. • Four structures were replaced in August 2019 under OPEX. • Two structures replaced in FY2021	Need ID: 1555
Line 81	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Structure 649A permanent replacement – Complete. • Ground line corrosion – Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion • Buried concrete foundations –	• $11.02 million PAD approved (P90). • Commissioning planned FY2023.	Need ID: 1268

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of earth straps • Replacement of rusting steel tower members • Replacement of corroded fasteners. • Replacement of damaged Stockbridge conductor vibration dampers. • Replacement of damaged earthwire dampers. • Replacement of faulty or damaged insulators and corroded conductor fittings with new composite longrods and fittings. • Replacement of corroded earthwire and earthwire fittings.		
Line 3W	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	Where required: • Replacement of tower members, nuts & bolts and structure ladders; works on tower leg earthworks and encasements; and tower leg painting	• Works in progress. • Budgeted $8.43 million. • Planned commissioning FY2022.	Need ID: 1269

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			• Repairs of cracked concrete footings; restoration of soil erosion including draining improvements. • Replacement of insulators, including hot and cold end fittings. • Replacement of earthwire fittings • Replacement of vibration dampers • Replacement of tower earthing.		
Line 12	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of earthwire and line components at end of life.	Option C preferred: Refurbish all asset components that have been identified as having condition issues, and replace the existing earthwire on the line, including one with OPGW.	• Assessed in RP2 deferred to RP3. Included in RP3 submission. • Optimally timed and planned for FY2025 • Estimate - $4.20 million ($2021)	Need ID: 1271
Line 13	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	Option B preferred: Refurbish all asset components that have been identified as having condition issues.	• Assessed in RP2 deferred to RP3. Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2024	Need ID: 1272

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
				• Estimate - $3.06 million ($2021)	
Line 27	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion remediation • Corrosion of fasteners and replacement of steel members • Replacement of damaged and corroded earth straps. • Replacement of insulators, including corroded hot and cold end fittings • Replacement of corroded earthwire fittings	• Planned FY23 commissioning. • Estimate - $2.6M	Need ID: 1273
Line 28	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion remediation • Buried concrete foundations –Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of damaged and corroded earth straps. • Replacement of corroded earthwire fittings including damaged spiral vibration	• Planned FY23 commissioning. • $4.9M Estimated	Need ID: 1274

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			dampers. • Replacement of insulators, including corroded hot and cold end fittings		
Line 14	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Buried concrete foundations –Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of corroded earthwire fittings including damaged spiral vibration dampers. • Replacement of corroded or damaged insulators with new composite longrods. • Replacement of corroded conductor fittings. • Restringing of corroded SC/GZ earthwire.	• Planned commissioning FY2023. • $5.3M Estimated (BoE pre-PAD P50)	Need ID: 1280
Line 21	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Replacement of tower members • Replacement of fasteners • Replacement of damaged of corroded insulators, conductor fittings and vibration dampers.	• Planned for Jan 2023. • Estimate - $14.83 million	Need ID: 1333

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			• Replacement of corroded earthwire, earthwire fittings and damaged spiral vibration dampers.		
Line 8	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Corrosion of tower members – 12 towers – Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint – entire tower • Corrosion of fasteners – Replace 5% of fasteners on 9 towers • Corrosion of conductor fittings – 33 sets of fittings replacements • Corrosion of earthwire fittings – 21 sets of fittings replacements • Corrosion of insulators – 286 sets of insulator replacements • Corrosion of earthwire – replacement of 4km of earthwire • Damaged Stockbridge vibration dampers – 209 damper replacements • Remediate asbestos	• In construction. • Forecast completion FY22. • Estimate - $7.73 million – Tower refurbishment • Estimate - $1.95 million – Asbestos remediation	Need ID: 1341
Line 90	• Manage Network Safety Risk • Maintain Network	• Corrosion of steelwork and line components at end	• Ground line corrosion remediation • Buried concrete foundations –Dig	• Estimate - $2.4 million (DG1). • Planned completion	Need ID: 1347

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	Reliability	of life. • Reduction in security of supply.	out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of fasteners. • Replacement of suspension and tension insulators with composite longrods.	FY23.	
Line 24	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion –Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion • Buried concrete foundations –Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of corroded tower members • Abrasive blasting towers and painting with Zinga – partial and whole towers • Replacement of corroded	• Estimated P90 cost $9.2 million. $2.7M Estimated (DG1). • Planned for FY2023 commissioning.	Need ID: 1348

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			fasteners. • Replacement of insulators with corroded pins or shed damage with composite longrods. • Replacement of corroded SC/GZ earthwire.		
Line 22	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion – Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion. • Buried concrete foundations –Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Corroded earth straps – Replacement of earth straps in line with current standard • Corrosion of tower members – Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint • Replacement of corroded	• $11.54 million estimated. • Forecast completion in FY2022	Need ID: 1349

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			fasteners • Replacement of insulators with corroded pins or shed damage with composite longrods. • Replacement of corroded conductor fittings. • Replacement of corroded earthwire fittings • Replacement of earthwire like for like SC/GZ • Replacement of damaged conductor and earthwire dampers.		
Line 25, 26 and 25/26	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion – Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion • Replacement of rusting steel tower members • Buried concrete foundations – Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel	• PSCR issued • Forecast completion FY22. • Estimate cost - $26.89 million	Need ID: 1350

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			• Replacement of corroded fasteners. • Replacement of corroded or damaged insulators with new composite longrods. • Replacement of corroded conductor fittings. • Replacement of corroded or damaged earth straps • Replacement of damaged Stockbridge conductor vibration dampers. • Replacement of damaged earthwire dampers.		
Line 18	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Buried concrete foundations –Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of corroded tower members • Abrasive blasting towers and painting with Zinga – partial and whole towers • Replacement of corroded or	• In development. Completion planned for RP2. • $9.33 million PAD approved	Need ID: 1351

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			damaged earth straps • Replacement of corroded or damaged insulators with new composite longrods. • Replacement of corroded conductor fittings. • Replacement of corroded SC/GZ earthwire and fittings. • Replacement of conductor vibration dampers.		
Line 17	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion – Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion • Buried concrete foundations – Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of corroded fasteners. • Replacement of corroded or damaged insulators and corroded conductor fittings with new	• RIT-T Complete • $6.68 million Estimated • Forecast FY2023 completion.	Need ID: 1352

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			composite longrods and fittings. • Replacement of corroded earthwire fittings.		
Line 16	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	Option B Preferred – Refurbish all asset components that have been identified as having condition issues	• Was planned for RP2. Deferred to RP3. • Optimally timed and planned for FY2025. • $8.9 M Estimated ($2021).	Need ID: 1353
Line 93	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	• Ground line corrosion –Abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and concrete encasement to prevent future corrosion • Buried concrete foundations –Dig out tower legs, abrasive blast cleaning of steelwork to remove any corrosion product, application of Zinga paint and establishment of drainage channel • Replacement of corroded fasteners. • Replacement of insulators with pin corrosion with composite longrods.	• Planned commissioning FY2023. • Estimate: $0.87 million	Need ID: 1407

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line 23	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life. • Reduction in security of supply.	Option C preferred: • Replace all suspension structures with concrete or steel pole. • Replace the wood pole structure with a concrete or steel pole. • Replace all conductor and earthwire components, hardware, fittings and insulators • Replace the existing phase conductor and earthwire	• Line reviewed in RP2, included in RP3 submission. • Optimally timed for FY2026. • Planned for FY2025. • Estimate $12.24 million ($2021).	Need ID: 1408
Snowy Lines: 01, 2, 64, 65, U1, U3, U5, U7	• Manage Network Safety Risk • Maintain Network Reliability • Leverage AM to support new technologies and innovations that improve or grow our business.	• Mid span joint failures on Silmalec conductor	• Develop systems to allow reinforcement of mid span joints from helicopter using longline method. • Reinforce mid span joints.	• All mid span joints that can be reasonably accessed from ground have been replaced. • The ban on works from helicopter has put further works on hold. • Remediating these mid span joints via restringing is be disproportionate to the failure consequence. The remaining problematic fittings will remain until the ban is revoked.	Need ID: 1290 (2016 – 2018) and 1590. On Hold

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Snowy Lines: 01, 2, 64, 65, 66, L1, L3, L5, M1, M3, M5, M7, M9, M11, M13, U1, U3, U5, U7	• Manage Network Safety Risk • Maintain Network Reliability • Leverage AM to support new technologies and innovations that improve or grow our business.	• Deadend failure on Silmalec conductor	Develop systems to allow replacement or reinforcement of deadend on Silmalec conductor.	• Easily accessible dead ends have been replaced. • Scoping of replacement/ reinforcement options and methodology been completed. • Some replacements complete. The ban on works from helicopter has put further works on hold.	Need ID: 1290 (2016 – 2018) and 1590 (On Hold)
Snowy Lines: 01, 2, 64, 65, 66, L1, L3, L5, M1, M3, M5, M7, M9, M11, M13, U1, U3, U5, U7	• Manage Network Safety Risk • Maintain Network Reliability	• 'ELGRA' Vibration dampers on Silmalec conductor are ineffective.	Replace vibration dampers on Silmalec conductor.	• Cost included in Deadends and midspans stage 1. • Some replacements complete. The ban on works from helicopter has put further works on hold.	Need ID: 1290 (2016 – 2018) and 1590 (On Hold)
Lines with collapsible crossarms	• Manage Network Safety Risk	• Collapsible crossarms may not be adequate to support maintenance loads	• Determine maximum loadings. • Design reinforcements. • Order an appropriate number of reinforcement sets that will be kept in the store (Spares Plan to be updated). The reinforcements will then be installed as and when	• Reinforcement designs has been approved. • IWR to be issued for design alteration.	Safety Alert 10/09/18 Maintenance Delivery RDS IWR0213

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			required. • These designs have not been well received.		
Lines with grillage structures: 10 4 U3 11 5 U5 16 65 U7 17 66 21 18 8 24 2 88 2M 90 9 35	• Manage Network Safety Risk • Maintain Network Reliability • Leverage AM to support new technologies and innovations that improve or grow our business.	• Ground line and buried steel tower corrosion • Reduction in security of supply.	• Concrete encasement or micropiles of buried steel in aggressive soil corrosion areas are currently being scoped. • Replacement/installation of sacrificial anodes in other areas. • Installation of tower bracing	Ongoing	Need ID: 1523 IWR0146 IWR0110
Lines with asbestos paint	• Manage Network Safety Risk	• Asbestos paint in poor condition presents people safety and environment risk	• Progressively remove asbestos paint using a risk-based approach using solvents after testing verifies the presence of asbestos. • Very high and high risk structures remediated RP2; medium and low remediated in RP3.	RP2: Remediate high risk structures – Est. cost $40.1 million. RP3: remediate medium and low risk structures – Est. cost $25.3 million	Need ID: 1164 Asbestos Management Plan Asbestos Register
330 kV lines with SC/GZ earthwire	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steel earthwire	• Continue to inspect and monitor the identified issues with steel earthwire corrosion. • Include in regulatory submissions for renewal when appropriate.	Ongoing during routine maintenance. Selected earthwire replacements included RP2 and RP3 Revenue proposal as part of line	Transmission Line Maintenance Plan Transmission Line and Easement Condition Data Collection

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			• Remove SC/GZ from the Transmission Line Design Manual (replace with SC/AC).	refurbishments.	
330 kV lines strung with OPGW	• Manage Network Safety Risk • Maintain Network Reliability	• Excessive fitting wear on OPGW 'swing' fittings.	• Monitor during routine climbing inspections. • New design fittings installed.	Ongoing	Transmission Line Maintenance Plan Transmission Line and Easement Condition Data Collection
Lines 10, 11, 2M	• Manage Network Safety Risk • Maintain Network Reliability	• Improperly designed "thimble wrap" earthwire fittings • Fittings installed an OHEW for some line refurbishments are poorly designed and have resulted in several failures.	• Design appropriate fitting and replace and install in place of the thimble wrap fittings.	In Progress	IWR N2533
Low spans on 330 kV assets	• Manage Network Safety Risk	• Low spans with clearances that breach design standards at credible line loads.	Remediate low spans as per guideline 'Low Span Assessment – Risk Management Approach'. Transmission line modifications are to be to design temperature with AS7000 clearances.	• RP1 all works completed 2018/19. • RP2 works yet to be developed. • RP3 – Low spans on Lines 1, 2, 3L, 4 and 5. • Estimated Cost - $17.7	• Need No's: RP1: - DCN532 - DCN533 - 593 - 595

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
				million ($2021)	- 597 - RP2: - 1556 • RP3: N2609 • 'Low Span Assessment – Risk Management Approach'
Lines 3 and 6	• Manage Network Safety Risk • Maintain Network Reliability	• Emergency wood poles are designed as temporary structures to lower design criteria reducing line security of supply	• Replace emergency structures with new permanent structures. • Line 3 has been confirmed suitable for long term use.	Monitor during inspections	Need ID: 1686 withdrawn due to ORPS project changes.
Structures with non-standard design criteria 89 21/2M 12/76 13/78 76/77 76/78	• Manage Network Safety Risk • Maintain network reliability	• Structures designed to a lower wind speed than their location	• Equivalent Region B Wind Speed (TL89) • Structures to be upgraded to an Equivalent 330 kV Wind Speed Criteria (remaining).	Reviewed for RP3 but will not proceed.	N2618
Remaining lines with condition issues: 3J 84 85	• Manage Network Safety Risk • Maintain Network Reliability	• Corrosion of steelwork and line components at end of life.	Monitor condition. Defect replacements where necessary. Consider refurbishment program for RP4 onwards.	Lines reviewed for RP3 but not progressed due to not being economically or ALARP justified.	Need ID Numbers: TL: 38/32 — Need ID: N2478

Assets			Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents	
38/32	61	5					3J	N2507
3H	6	051					84	N2564
9	83	88					85	N2514
31/32	39	30					61	N2509
96/9W	82	7					3H	N2508
3L-4	37	3					6	N2516
62	2						5	N2517
							9	N2519
							83	N2563
							051	N2515
							31/32	1275
							39	1276
							88	1317
							94/9W	N2500
							82	N2506
							30	N2541
							37	N2542
							3L	N2537
							4	N2524
							62	N2572
							76/77	N2493

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
					25/93 N2503 1 N2522 2 N2521 3 N2523 7 N2620
Some older 330 kV lines	• Manage Network Safety Risk • Maintain Network Reliability	• Undersized earthwire near substations	Review of substation fault levels and earthwires of connected lines.	• Earthwire capacity technical review report completed. • Fault study report and required replacement scope planned Q3 FY21.	N2295
All Transmission Line Assets	• Ensure accessible, relevant asset management information is available to inform business wide decisions	• Asset condition data of insufficient quality and detail to support decision making.	• Improve asset data quality through Maintenance Plan and the implementation of AIM (Asset Inspection Manager) • AIM condition data available for 86% of the 330 kV network as and end of FY2021. • Investigate the remaining condition data gap,	AIM has been rolled out to Transmission Lines. Data will become available progressively.	N/A

5.2.3. 330 kV Maintenance Program

For the 330 kV Transmission Line assets, the maintenance program consists of the following:

- Routine inspections
- Corrective (or 'defect') maintenance addressing out of specification conditions. The need to conduct corrective maintenance is usually identified during a routine inspection. Where possible and practical, these defects are addressed at the same time as the inspection. Otherwise, these are prioritised on the basis set out in the 'Maintenance Plan - Transmission Line Assets'.

Easement maintenance is as detailed in the Maintenance Plan – Easements and Access Tracks.

A Failure Mode Analysis was completed for all transmission tower types. The analysis is compared with the Transmission Line Maintenance Plan to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them. This is shown in Appendix A.

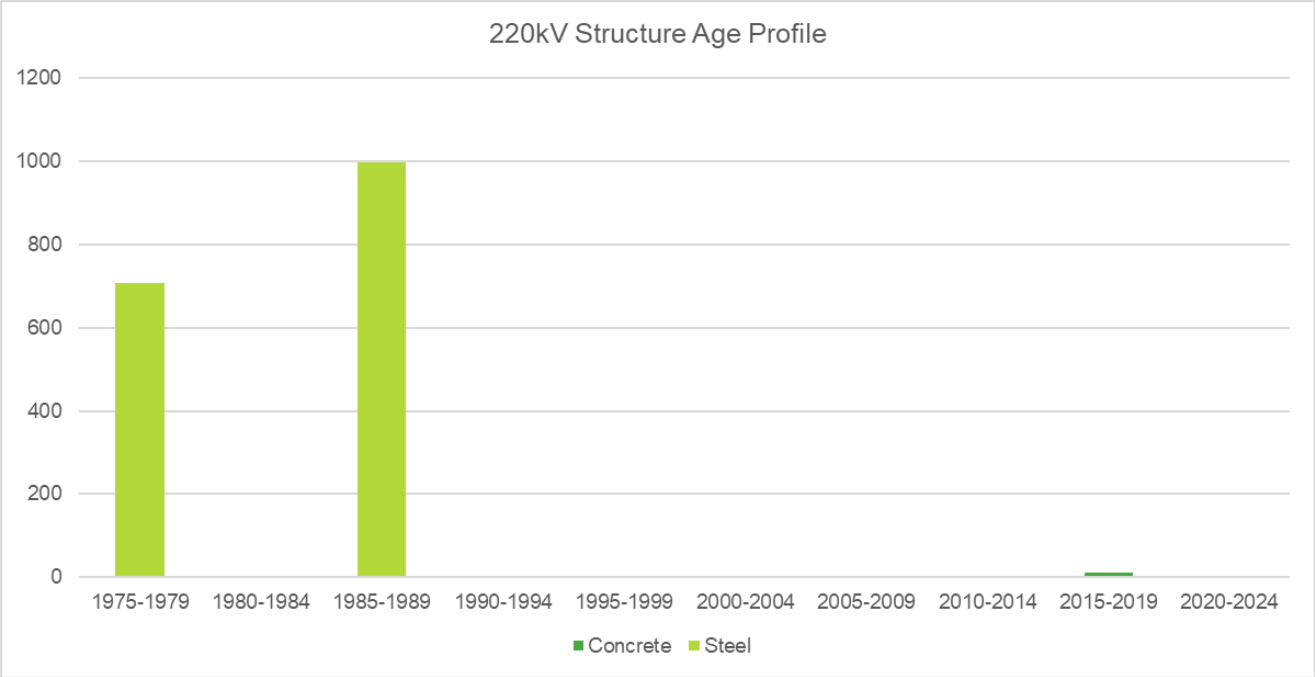
5.3. 220 kV Transmission Lines Asset Review

5.3.1. Population Review

The prescribed 220 kV network makes up approximately 7% of Transgrid's transmission line asset base by circuit kilometres. It has approximately 670 km of transmission lines that are supported by over 1,700 structures. The 220 kV network is located inland and is almost entirely supported by steel tower structures, which have a nominal lifespan of 94 years. The first elements of Transgrid's current 220 kV network were commissioned in 1975. The 12 structures installed in 2015-19 are concrete pole structures, installed after replacing emergency wood pole structures erected after three separate storm incidents between 1988 and 2011. They were classified as major operating project so did not change the regulated asset base.

The age profile of Transgrid's 220 kV transmission line assets is shown in Figure 17.

Figure 17 – 220 kV Transmission Line Age Profile (prescribed assets)



5.3.2. Emerging Issues and Renewal and Maintenance Initiatives

5.3.2.1. 220 kV Transmission Line Emerging Issues

The specific issues relating to the 220 kV transmission lines are discussed below with respect to the three main transmission line elements:

Fittings

The 220 kV fittings are in a good condition overall and no current or emerging issues have been identified.

Electrical Conductors

The 220 kV fittings are in a good condition overall and no current or emerging issues have been identified.

Structures

The current and emerging issues relating to 220 kV structures are as follows:

- The 220 kV structures are in a good condition overall and no current or emerging issues have been identified with respect to health, obsolescence or compliance. Line X2 was built with black steel, resulting in surface rust remaining constant over the past 35 years, but there has been little loss of member cross-section.
- These lines were designed as a bare-bones lowest cost option of that time.
- The 220 kV structures have a history of failures since construction. 13 structures have failed over three separate events. Failures have been the result of extreme wind events, reaching or exceeding the original tower design wind speed. A review at the time of the failures determined that these towers required additional bracing, resulting in strengthening of 147 structures at road crossings and public

areas. Given the criticality of the radial line to Broken Hill, the transmission line may potentially benefit from additional strengthening works to address the design deficiency to increase the security of supply.

- Transmission line earthing assessments, completed in January 2016 to assess high risk (publicly frequented) structure earthing found approximately 10% of structures tested did not comply with the requirements of AS7000. Further earthing assessments in publicly frequented areas will assess earthing arrangements of the wider transmission line network to determine compliance with AS7000.

General Defect Commentary

An analysis of issues raised is shown in Figure 18. Easement issues have been excluded. Surprisingly, even on the 220 kV network, which is exclusively in the South-West of the state, the greatest proportion were for blowout, detected by LiDAR. When easement issues are excluded the greatest quantity of issues was 'clear external objects'. These are normally birds' nests and can impact on line reliability when they are built directly above the insulator string.

The next two most frequent issues, structure renumbering and warning sign issues would not result in a key hazardous event, but impacts the ability to identify assets in an emergency.

The issues that could result in a key hazardous event (damper maintenance, tower members, insulators, etc.) are low in proportion.

A large number of auto generated issues relating to steelwork condition was excluded. This was due to Line X2 being built with black steel.

Figure 18 – 220 kV Issue Quantities by Type

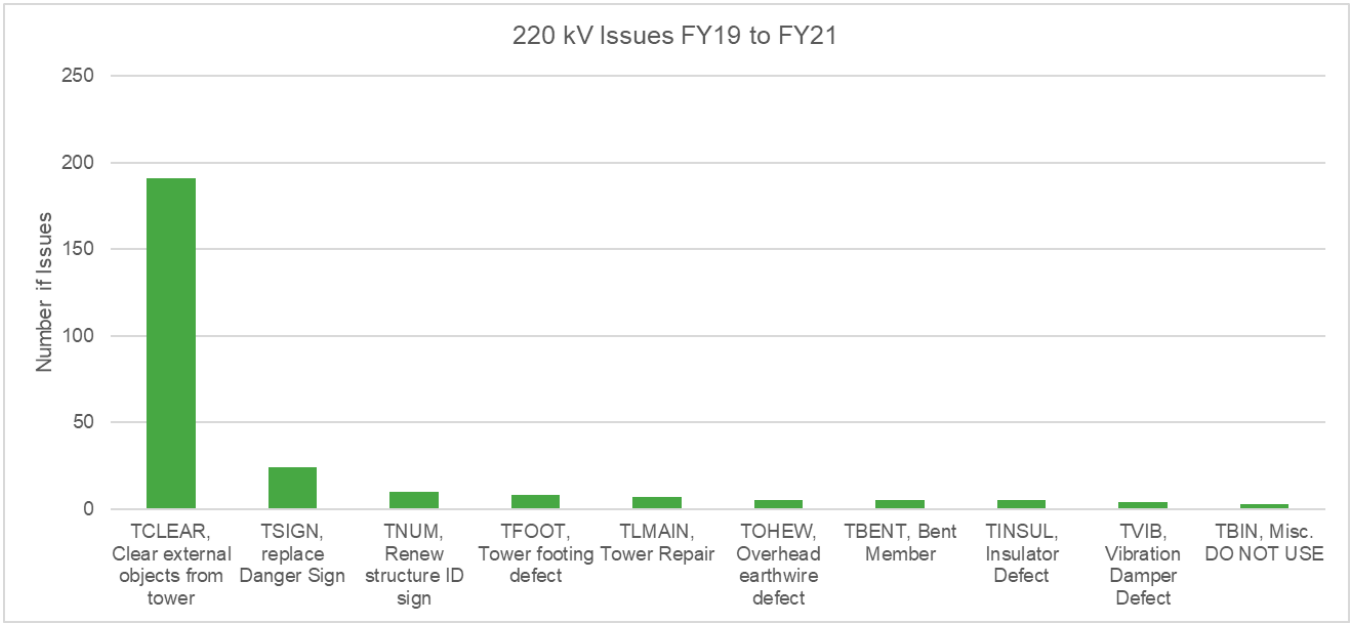


Table 13 – 220 kV Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
All 220kV Lines	• Manage Network Safety Risk	• Structure earthing not compliant with AS7000	Assess earthing arrangements of the wider transmission line network to determine compliance with AS7000	$70K	IWR0088 IWR0191
All 220kV Lines	• Manage Network Safety Risk • Maintain network reliability	• Structure failures in high wind events exceeding design capacity. • Reduction in security of supply.	Strengthening of structures as deemed appropriate	Ongoing	
All 220kV Lines	• Manage Network Safety Risk • Maintain network reliability • Manage assets efficiently without compromising security holder or customer value	• Hazard trees causing transmission line faults	Identification and scoping of hazard tree risk. Removal of hazard trees as per Maintenance Plan.	Ongoing	Maintenance Plan – Easements and Access Tracks
All 220kV Lines	• Manage Network Safety Risk • Maintain network reliability • Manage assets efficiently without compromising security holder or customer value	• Identify encroachments and order their removal where required.	Unauthorised encroachments on easements present a safety risk to maintenance staff and the public	Ongoing	

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
All Transmission Line Assets	• Ensure accessible, relevant asset management information is available to inform business wide decisions	• Asset condition data of insufficient quality and detail to support decision making.	Improve asset data quality through the implementation of AIM (Asset Inspection Manager). AIM condition data is available for 94% of the 220 kV network as of end of 2021FY.It was expected to have 100%.	AIM has been rolled out to Transmission Lines. Data will become available progressively.	N/A

5.3.3. 220 kV Maintenance Program

The following maintenance initiatives are planned from the date of this plan until June 2023.

- Strengthening of structures to increase reliability of supply, as deemed appropriate.

Emerging issues on associated easements are:

- Hazard trees on easements.
- Unauthorised easement encroachments.

A Failure Mode Analysis was completed for all transmission tower types. The analysis is compared with the Transmission Line Maintenance Plan to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them. This is shown in Appendix A.

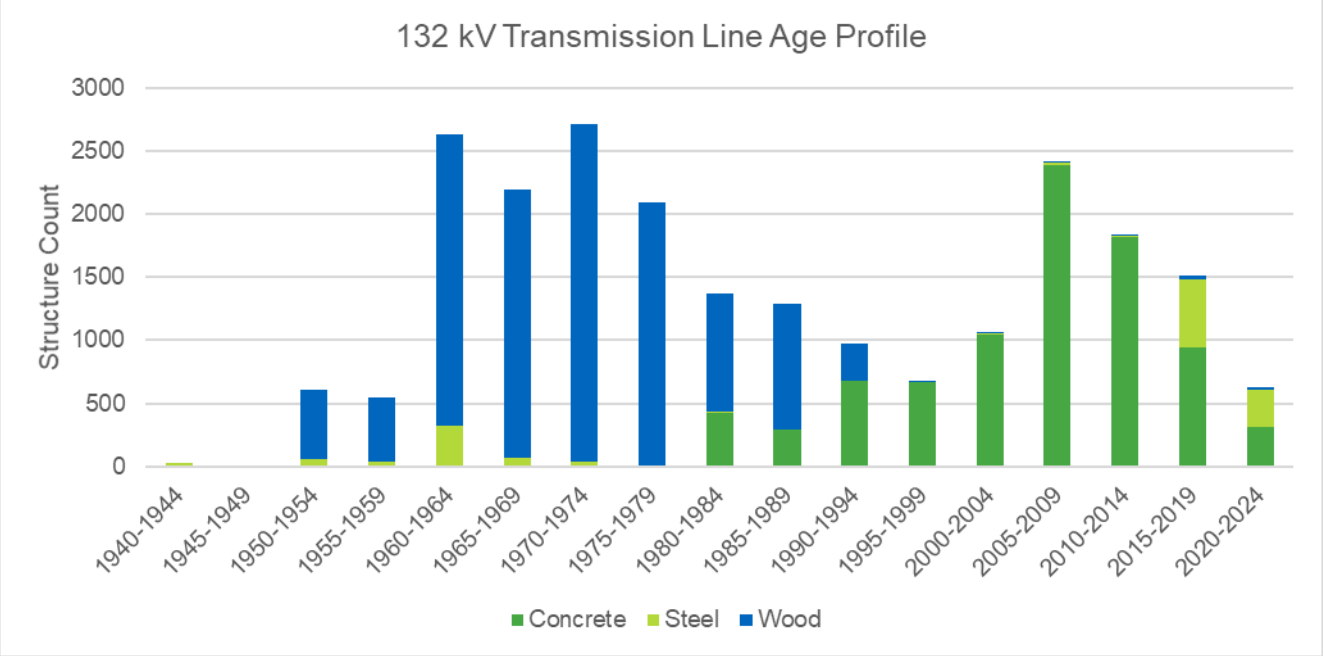
5.4. 132 kV Transmission Lines Asset Review

5.4.1. Population Review

The prescribed 132 kV network makes up approximately 44% of Transgrid's transmission line asset base by circuit kilometres. It has over 5,700 km of transmission lines that are supported by over 22,500 structures. The network is comprised of a combination of structures including 1,421 steel structures, 8,575 concrete pole structures and 12,546 wood pole structures. The first elements of Transgrid's current 132 kV network were commissioned in 1940.

The age profile of Transgrid's 132 kV transmission line assets is shown in Figure 19.

Figure 19 – 132 kV Transmission Line Age Profile (prescribed assets only)



5.4.2. Emerging Issues and Renewal and Maintenance Initiatives

5.4.2.1. 132 kV Transmission Line Emerging Issues

The significant issues that have been identified with the 132 kV network predominantly affect the wood pole transmission lines. The nominal lifespans analysed above do not consider localised effects that also affect these networks. These include:

- Coastal and high pollution environments: Steel structures are subject to corrosion. Although the wood poles themselves are not subject to corrosion issues, the conductors and fittings comprising the wood pole transmission lines are subject to corrosion issues in these environments.
- Termites: Termites are a significant threat to wood poles and in certain areas where termites are prevalent, the life expectancy of the poles is significantly reduced.
- Rot: Wood poles can also be affected by rotting and in areas of high rainfall and/or high water tables, the life expectancy of the poles is also significantly reduced.

During FY2020 a significant increase in wood pole defect expenditure have occurred, mostly due to the defect replacement with concrete poles structures. A total of $2.3 million was spent in FY2020 on wood pole replacements. This continued into FY2021 with $3.0 million spent on pole replacements.

The specific issues relating to the 132 kV transmission lines is listed in with respect to the three main transmission line elements discussed below.

Fittings

The current and emerging issues relating to 132 kV fittings are as follows:

- Corrosion issues range from minor to severe, where severe corrosion is more prevalent with those lines located in coastal or high pollution areas.
- On some older lines, fittings exist that do not meet current design standards. The following three issues have been identified:
    - The use of ‘U-bolts’ as a conductor clamping mechanism. This creates a stress-point at the clamp which is known to damage the conductors when exposed to prolonged conductor vibration.
    - The use of eyebolts rather than pole bands on some ‘flying angle’ and ‘tension’ constructions. Eyebolts are prone to pulling through under high tension, particularly when poles begin to be affected by rotting issues.
    - Corrosion of underground components: A number of fittings such as guy anchors and earth straps are buried in soil and suffer from corrosion problems. This is more prevalent in areas with high water tables and significant salt content, corrosive soils and marine clays.
- There have been a number of failures of helical earthwire deadends. Electrical current can pass through the thimble instead of the earthwire jumper causing excessive heat, particularly under fault conditions. The issue is more pronounced closer to substations due to the higher fault level.
- Older timber tension/flying angle structures have insulators attached to the pole using eyebolts. As the pole deteriorates it is possible for the eyebolt to ‘pull through’, dropping the conductor to the ground. The use of a ‘pole band’ attachment point would eliminate this failure mode as the insulator attachment is now supported by the entire annulus.

- There has been an increasing trend in hot joints. On January 2018, a hot joint on Line 99P resulted in a fire start.

Electrical Conductors and Earthwire

The current and emerging issues relating to 132 kV conductors and earthwires are as follows:

- Corrosion issues range from minor to severe, where severe corrosion is more prevalent with those lines located in coastal or high pollution areas.
- Low hanging conductor spans. These are low electrical clearance spans which do not meet design standards (grandfathered to date of construction). Only spans low at credible line loads are required to be considered. All the Stage 1 low span remediation works have been completed. Stage 2 is yet to be developed.
- Early 'Panther' (imperial predecessor of 'Lemon') may have issues with the welding of the individual steel wires. There were two conductor drops in the early 2000's on 1950's Panther conductor supplied by BICC. Quality issues with the welding of the steel cores were suspected. If there was insufficient space between the welds of different individual wires this could become a weak point. This is the reason for the conductor tension working restrictions on Panther conductor. Subsequent non-destructive inspection in the 2000's failed top pick up further issues. Conductor samples taken from Line 966 found slight reduction in mechanical properties on the external aluminium strands, just below the minimum requirements.
- Where Line 9W0 crosses the Clarence River it has been identified that the maximum height of vessels using the river may be taller than the safe navigable clearance, The RMS are currently duplicating the Grafton bridge, which will have similar navigation clearances. Transgrid reviewed this crossing with the RMS in 2018. It was determined that the current structures and signage was acceptable and that the crossing be reviewed again in 2023. The RMS requested in the 2018 review that any future installations or upgrades have a navigable clearance of 29.4 m. Remediation options were assessed for the RP3 submission. To achieve the stated 29.4 m clearance would require structures at least 82 metres tall. An underground option was also assessed. The remediation was not included in the RP3 submission as the costs are disproportionate to the risk reduction.
- The river crossings on section of Line 96F which Transgrid acquired from Ausgrid do not have signage according to AS 6947. Ausgrid appeared to have used incorrect survey data in their risk assessment, which concluded that signage was not required. Signage has been installed. The crossing of the Hunter River has a lower navigable clearance than the maximum expected vessel height. Remediation would require the installation of 36 m structures, significantly taller than the existing structures. The remediation was not included in the RP3 submission as the cost are disproportionate to the risk reduction.
- Line 959/92Z and 963 conductor are impacted by the following:
    - Bushfire exposures. High temperatures can impact the mechanical integrity of conductors in multiple ways such as annealing of the aluminium alloy reducing tensile strength, loss of grease/galvanising layer from the inner steel strands of conductor. Both of which then reduces the corrosion performance.
    - Corrosive operating environment. Conductors which are operating in the coastal regions are subject to harsher operating conditions and therefore higher rates of corrosion than conductors situated away from the coastline. In particular, corrosion and subsequent metal loss of the steel strands in

ACSR/GZ conductor and galvanised steel earthwire reduces tensile strength. Once the level of corrosion has reached a certain threshold, the earthwire is at an increased risk of failure.

- Prolonged exposure to Aeolian vibration results in fatigue and/or fretting of conductor strands, and TransGrid's earlier legacy fleet of conductor attachments utilise bolted suspension clamps which lack effective vibration control.

Structures (wood poles)

Wood pole structures are susceptible to termite, rot and fungal decay. Additional inspections are required to check poles for deterioration. Deteriorated poles can result in a structure fall-over during winds that the line would have otherwise been designed for.

Lead-times for supply of hardwood poles in the lengths and strengths Transgrid require have increased significantly (at least eight months). This has been exacerbated by the worldwide timber shortage and the 2019/20 bushfires. Given current defect rates, completing like-for-like for all replacements is not sustainable and could lead insufficient stocks in the event of emergency.

The newer wood poles do not appear to be as resilient to termite and rot attack compared to the poles used in the 1950's and 60's.

Wood poles are also prone to bushfire damage. In the November 2019, bushfires burnt out 11 structures on Lines 964, 965 and 966. A further 19 wood pole structures on Line 993 were rendered unserviceable by fire in January 2020. Replacing wood poles with concrete pole structures improves resilience to fire, which could become an increasing issue with climate change.

Structures (others)

The current and emerging issues relating to 132 kV structures (others) are as follows:

- Corrosion of steel tower members: A number of steel towers have degraded through loss of zinc coating and subsequent pitting of the steel. The towers located in coastal and industrial areas have suffered the greatest deterioration.
- Transmission line earthing assessments, completed in January 2016 to assess high risk (publicly frequented) structure earthing found approximately 10% of structures tested did not comply with the requirements of AS7000. Further earthing assessments in publicly frequented areas will assess earthing arrangements of the wider transmission line network to determine compliance with AS7000 with implementation of solutions to follow on a progressive basis. Inadequate or inappropriate earthing on transmission lines can cause hazards to the public or start fires. The pole top failure of Line 944 in 2014 resulted in two fire starts in separate locations; none were at the structure failure site. Routine inspections have also flagged multiple fences within the easement that are not in accordance with design standards.
- D-String insulators impacts on structural integrity – It was identified during the Lines 4 and 5 Low Spans project that tower strengthening is required to ensure structural integrity on towers where D-strings are being installed. This highlights the issue of D-strings installed in other locations where no strengthening has taken place.
- Deterioration of grillage footings: The early steel lattice towers (before late 1960's) often used grillage foundations. A chemical reaction occurs due to contact with the soil which leads to deterioration of the zinc coating and corrosion of the underlying steel. In addition on some lines, the base of the grillage is

actually made of timber. Condition of these timber bases is unknown. For the steel components of a grillage footing, a chemical reaction occurs due to contact with the soil which leads to deterioration of the zinc coating and corrosion of the underlying steel. The majority of grillage foundation towers were fitted with sacrificial magnesium anodes. A review has found these anodes to be ineffective in a number of locations where severe soil corrosion conditions exist. This reduces the transmission line security of supply.

- There appears to be an increasing trend in guys being found broken or ineffective.

With respect to concrete poles, early (non-prestressed) concrete poles on 99K have issues with internal steel reinforcement corrosion on line 99K.

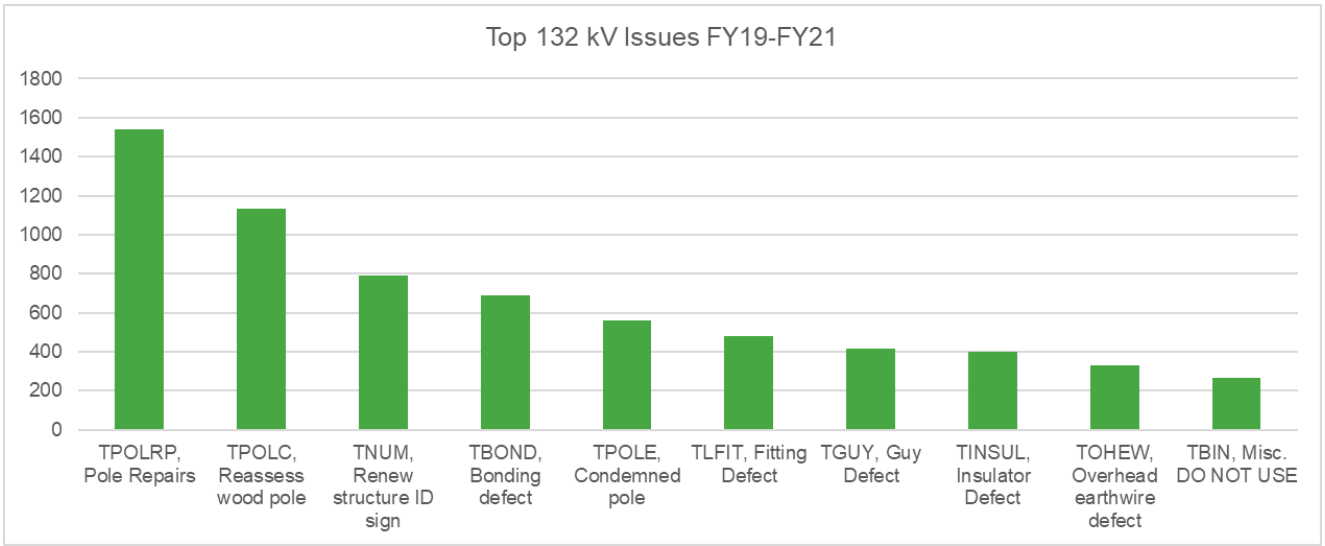
General Defect Commentary

An analysis of issues raised is shown in Figure 20. Easement issues have been excluded.

The greatest quantity of issues was “pole repairs” which usually are timber battens remediation. The timber battens cover the earth down lead on wood pole structures. These is only a safety issue on poles with a high public exposure. Otherwise they are replaced at ‘next maintenance’. These batten would be impacted by termites before the pole, so could be seen as leading indicator to upcoming termite deteriorated poles in the future, which will require replacement. An earthing study has been completed and based on Risk Based earthing covered under ‘ENA EG-0 Power System Earthing Guide’ and it was determined that a significant portion of wood pole structures do not require the cover batten to be remediated.

The large proportion of ‘TPOLC - wood pole reassessments’ is to assess the condition of deteriorated wood pole (‘conditionally serviceable’). These structures will deteriorate until the structure becomes condemned (TPOLE). Works requiring pole replacements, whether under capex or opex, is going to increase.

Figure 20 - 132 kV Issue quantities by type – top 10



5.4.2.2. 132 kV Renewal Initiatives

The following renewal initiatives are planned. Details on the specific assets are noted in Table 14.

- Wood Poles Replacement:
  - Replacement of forecast defect wood poles with concrete or steel poles on lines exceeding their economic life. A total of 200 wood pole structures will exceed their nominal 63 year life by 2023. This accounts for approximately 8% of Transgrid's 132 kV wood pole population. Based on historical defect rates, it is estimated that around 1,000 wood poles will require replacement in the 2019-23 regulatory period to extend the life of their respective transmission lines. By 2028 an additional 2,161 132 kV wood poles will exceed their 63 year nominal life. As the number of ageing wood poles is increasing, it is imperative that replacement of forecast defective poles commence before the quantity becomes unmanageable, which will increase network risk.
  - Wood poles are strategically replaced with concrete or steel (where local conditions permit) poles. Concrete and steel poles have a longer expected life than wood poles, have predictable deterioration patterns (i.e. do not suffer from termites, rot and fungal decay) and as such have reduced maintenance requirements and lower risk of failure. Newer chemically treated wood poles do not have the same expected life that older natural wood poles have, with significant increases in defect rates noted from 20 years of age. Concrete or steel poles also provide greatly improved fire resilience. With climate change increasing the frequency and intensity of bushfires, the use of wood poles is becoming increasingly unsuitable for use in transmission networks.
  - Staking transmission wood poles is only suitable in limited circumstances for short term life extension. Transgrid have used them in situations where wet weather has restricted access to heavy plant in order the replace the wood pole. Staking requires sufficient good wood at 1 m above ground. Unlike most distribution poles, transmission structures have earth connections. Introducing a stake into this system can cause touch potentials, which is a public safety risk. The poles used in distribution are shorter and have lower loads than the 132 kV transmission poles, the principles the distributors use in the use of pole staking are not completely transferrable.
- Steel lattice tower lines:
  - Lines 99X/9R5, 993/99W, 994/996 – Given the age of these line sections, condition issues are possible.
- Grillage structures:
  - Structures which have been classified as located in areas of aggressive soils are to have the grillage foundation dug out, and the footing steel work repaired, or reinstated where required, then concrete encased.
  - Installation of new or additional sacrificial anodes elsewhere.
  - Determine extent of timber grillage deterioration and determine appropriate solutions.
- Low Spans – All stage 1 low spans works have been completed. Whilst the Stage 2 of the low spans project only includes the 330 kV network, priority temperatures have now increased due to renewable generator connections. Some lines previously remediated now require further remediation. Some 132 kV lines were not included in stage 1 due to the unavailability of a PLSCADD model at the time. Some of these lines require remediation.
- Panther conductor lines – Improvements in technology may be able to infer any steel core deterioration or weak points, allowing for targeted replacement of conductor. Non-destructive testing options will be

evaluated. Early fault detection will be trialled on some Panther lines. Targeted replacement will be evaluated based on risk and consequence of conductor failing. Stringing tensions, previous exposure to fire, wind exposure, etc. will be considered. There was a further failure on Line 977/1 September 2021. This failure occurred on the same span as the previous Line 977 failure.

- Line 959/92Z and 963 have been impacted by several previous bushfires causing them to potentially have corrosion issues as described in 5.4.2.1. Impacted sections are planned to be restrung with new like for like ACSR conductor.

Table 14 – 132 kV Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line 94M	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles	Replace deteriorated wood pole structures with steel or concrete pole structures, including fittings and insulators.	• Included in RP3 submission. • Optimally timed for FY2027 • Planned for FY2026 • Estimate - $6.78 million ($2021)	Need ID: N2580
Line 94U	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • Very high defect rate.	Replace all remaining wood pole structures with steel or concrete pole structures, including fittings and insulators.	• Included in RP3 submission. • Optimally timed for FY2026 • Planned for FY2028 • Estimate $18.62 - million ($2021)	Need ID: N2582
Line 99B	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles	• Replace deteriorated wood pole structures with steel or concrete pole structures, including fittings and insulators. • Replace eyebolts with pole bands	• Included in RP3 submission. • Optimally timed for FY2027 • Planned for FY2025 • Estimate -	Need ID: N2603

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
				$3.26 million ($2021)	
Line 99Z	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators. • Line already mostly replaced with concrete pole structures.	Replace all remaining wood pole structures with steel or concrete pole structures	• Included in RP3 submission. • Optimally timed for FY2025 • Planned for FY2024 • Estimate - $2.81 million ($2021)	Need ID: N2605
Line 992	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators.	Replace all remaining wood pole structures with steel or concrete pole structures, including fittings and insulators. The most deteriorated structures will be targeted for RP3 replacement with the remainder to be completed in RP4.	• Included in RP3 submission to begin in RP3 but complete in RP4. • Optimally timed for FY2030. • Planned for FY2030. • Estimate - $23.94 million ($2021)	Need ID: N2604
Line 963	• Manage Network Safety Risk	• Deterioration of wood poles.	• Remediate all identified condition issues. Deteriorated wood poles to be replaced with	• Included in RP3 submission.	Need ID: N2606

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Maintain Network Reliability	• Conductor impacted by fire.	concrete or steel pole structures. • Replace conductor between structures 442 and 463.	• Optimally timed for FY2026. • Planned for FY2026. • Estimate - $7.65 million ($2021).	
Line 964	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Remediate all identified condition issues. Deteriorated wood poles to be replaced with concrete or steel pole structures.	• Included in RP3 submission. • Optimally timed for FY2028. • Planned for FY2025. • Estimate - $2.69 million ($2021).	Need ID: N2607
Line 966	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings • Conductor impacted by fire • Panther conductor.	• Replace deteriorated wood pole structures with steel or concrete pole structures, including fittings and insulators. • Conductor work not able to be justified.	• Included in RP3 submission. • Optimally timed for FY2028. • Planned for FY2025. • Estimate - $13.08 million ($2021).	Need ID: N2599

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line 947	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Remediate all identified condition issues. Deteriorated wood poles to be replaced with concrete or steel pole structures.	• Included in RP3 submission. • Optimally timed for FY2028. • Planned for FY2028. • Estimate - $5.31 million ($2021).	Need ID: N2621
Line 977/1	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings • High connection interest could result in low spans becoming an issue.	• Remediate all identified condition issues. Deteriorated wood poles to be replaced with concrete or steel pole structures. • Remediate low spans.	• Included in RP3 submission. • Optimally timed for FY2028. • Planned for FY2026. • Estimate - $8.74 million ($2021)	Need ID: N2479
Line 959/92Z conductor.	• Manage Network Safety Risk • Maintain Network Reliability	Conductor end of life due to the following: • Corrosion • Annealing due to bushfire exposure • Fretting and fatigue caused by Aeolian vibration.	Like for like conductor replacement, includes replacement of all conductor compression fittings, suspension clamps/AGSU, jumper connections, spacers and vibration dampers.	• Optimally timed for RP3 and included the RP3 submission. • Planned for FY2027 and FY2028. • Estimate -	Need ID: N2595

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
				$16.83 million ($2021).	
All 132 kV Lines	• Manage Network Safety Risk	• Structure earthing not compliant with AS7000	Assess earthing arrangements of the wider transmission line network to determine compliance with AS7000	$70K	IWR0088 IWR0191
All 132 kV Lines	• Manage Network Safety Risk	• Unearthed fences within easements	Inspect fences during routine inspections for earthing in accordance with Transgrid guidelines. Issues to be managed by Property and Environment.	Ongoing	Line 944 failure report. 'Transgrid Fencing Guidelines' public document.
All assets – Conductors and fittings	• Manage Network Safety Risk • Maintain Network Reliability • Manage assets efficiently without compromising security holder or customer value • Ensure accessible, relevant asset management information is available to inform business wide decisions	• Corrosion of fittings and conductors	Continue to inspect and monitor the identified issues.	Ongoing during routine maintenance.	Transmission Line Maintenance Plan Transmission Line and Easement Condition Data Collection
All 132kV Lines	• Manage Network Safety Risk	• Hazard trees causing transmission line	• Identification and scoping of hazard tree risk.	Ongoing	Maintenance Plan – Easements and Access Tracks

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Maintain Network Reliability • Manage assets efficiently without compromising security holder or customer value	faults	• Removal of hazard trees as per Maintenance Plan.		Following IWR's: IWR0197 – priority removal. N2058 – 2020FY inspections. N2227 – Removal 2020FY and pre bushfire 2021FY. N2391– 2021FY inspections (costs in FY2022)
All 132kV Lines	• Manage Network Safety Risk • Maintain Network Reliability	• Unauthorised encroachments on easements present a safety risk to maintenance staff and the public	Identify encroachments and order their removal where required.	Ongoing	Transgrid guideline; 'Living and working with electricity transmission lines'
All Transmission Line Assets	• Ensure accessible, relevant asset management information is available to inform business wide decisions	• Asset condition data of insufficient quality to support decision making.	• Improve asset data quality through Maintenance Plan and the implementation of AIM (Asset Inspection Manager) • AIM condition data is available for 93.37% of the 132 kV network as of end of 2020FY. It is forecasted to have 98.32% at end of 2022FY.	AIM has been rolled out to Transmission Lines. Data will become available progressively.	N/A

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line • 99X/9R6	• Manage Network Safety Risk • Maintain network reliability	• Corrosion of steelwork and line components at end of life.	Replace fittings, earthwire, insulators and refurbish/ replace members where condition dictates.	• Evaluated for RP3 but not included in submission. Could not be justified. • Monitor through inspections and address issues through defect maintenance.	Need ID: N2566
Line 9W0 Clarence River and 96F Hunter River Crossings	• Manage Network Safety Risk	• Possible maximum vessel height higher than safe navigable vessel height.	• Assess options in conjunction with RMS in 2023. • Consider augmenting crossings to allow for safe navigation of tallest expected vessel. - 96F to use taller structure. - 9W0 would require minimum 83 m tall structure or underground cable to completely meet the need. A tower this high would result in significant community opposition.	• Line number 96H changed to 9W0. • The option with the cable remediation is $14.3 million.	Public Electricity Safety Awareness Plan Need ID: 460 Need ID: N2602
Line 96F River Crossings	• Manage Network Safety Risk	• Ex Ausgrid section of Line 96F does not have waterway warning signs.	• Install waterway crossing signage. • Assess options for crossing	• November 2020 – 7 of 8 signs installed. Property owner	IWR-N2027 Need ID: N2602

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		• Possible maximum vessel height higher than safe navigable vessel height.	augmentation if required.	access issues for remainder. Planned completion March 2021. • IWR estimate: $118K • Completed April 2021. Actual cost $109K. • Need N2602 for crossing augmentation.	
Structures with non-standard design criteria 966 967 96H 96L 9W0	• Manage Network Safety Risk • Maintain network reliability	• Structures designed to a lower wind speed than their location	• Improve network resilience by upgrading structures to region B Wind Speed	Reviewed for RP3 but will not proceed.	N2618
Wood poles and NCI's in locations of high bushfire risk 964 96L 963 976/2	• Manage Network Safety Risk • Maintain network reliability	• Wood poles and NCI insulators are less resilient to bushfires.	• Improve network resilience by replacing wood with concrete equivalent and NCIs to be replaced with glass equivalent.	Reviewed for RP3 but will not proceed.	N2618

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
976/1 977/1 96C 94M 94B 94X 948 96R 944 9W0					
High bushfire risk lines with hooked insulators without keepers. 944 94X 99A 949	• Manage Network Safety Risk • Maintain network reliability	• The lack of keepers may result in insulators becoming unhooked from the structure resulting in conductor drop and fire start.	• Improve network resilience by replacing insulator with hook attachments with glass insulators in line with the latest Transgrid standards.	Reviewed for RP3 but will not proceed.	N2618
Lines with Panther conductor	• Manage Network Safety Risk	• Panther conductor has potential manufacturing issues that could lead to conductor drop.	• Evaluate methods of assessment (e.g. SAIP) that could infer steel core deterioration. • Restring lines as required. • Evaluate use of non-destructive testing (eddy currents etc.) to determine location and deterioration of butt welds. • Investigate suitability of Early Fault Detection.	• Works over RP3 and RP4. Governance documents to be prepared. • No Panther conductor projects included in RP3 submission.	N2351
Selected 132 kV lines	• Manage assets efficiently without compromising security holder or customer	• Unique, no longer supported or low quantity of installed	Transmission Line Design to report on the following: • Availability of each defunct	$10,000	IWR-0138

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	value	conductor and earthwire increases spares requirements. Holdings currently inadequate.	conductors and fittings. • Electrical and structure suitability for conductor or earthwire replacement with a standard conductor or earthwire. • Develop arrangement that will provide mid-span joint functionality between non-standard and standard conductor/earthwire. Final report provided. Spares Plan updated.		
Line 96T and 96R	• Manage Network Safety Risk • Maintain network reliability	• Decay in timber earthwire risers can lead to failure. Multiple defects already addressed.	• Monitor only	Project cancelled, monitor condition.	Need ID: 1588 and 1589.
Helical OHEW deadends near substations	• Manage Network Safety Risk • Maintain network reliability • Manage assets efficiently without compromising security holder or customer value	• Leakage current through thimble causing deadend failure.	• Insulate deadend at pole to ensure fault current path down jumper, not through thimble or replace with compression deadend at structures close to substations by June 2023. • Other helical deadends will be monitored through routine maintenance.	• Project 1671 cancelled. • IWR-N2292 to be completed over FY21 and FY22. • Estimate - $714K	Need ID: 1671 IWR-N2292

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Wood pole tension / angle structures with eyebolts	• Manage Network Safety Risk • Maintain network reliability • Manage assets efficiently without compromising security holder or customer value	• Eyebolts can 'pull through' the timber pole dropping conductor or earthwire.	• Monitor during routine inspections. High risk spans monitored with compliance inspections. • Replace eyebolt fittings with pole band type fittings on identified high risk spans. • Remaining structures will be monitored through routine maintenance.	Included in associated RP3 wood pole line refurbishments where applicable.	Need development currently being undertaken
• Line 959/92Z	• Manage Network Safety Risk • Maintain network reliability • Support sustainable growth of the asset base by providing the right infrastructure in the right place.	• Corrosion of steelwork and line components at end of life. • Corrosion of steel earthwire. • Reduction in security of supply.	• Buried concrete foundations – Dig out tower legs, abrasive blast steelwork, treat with Zinga, install doubler plates and establish draining channel. • Replacement of corroded or damaged earth straps. • Replacement of corroded tower members. • Replacement of corroded conductor attachment fittings. • Replacement of corroded earthwire fittings. • Replacement of corroded earthwire, including OPGW on one side.	• Project completed. • $13.1 million • Outstanding issues with thimble wrap earthwire fittings to be resolved.	Need ID: 1346

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
			• Replacement of corroded conductor vibration dampers.		
Wood pole lines: • 94X • 99J • 948 • 966 • 993 • 995 • 9U3 • 9UH • 976/2 • ~~097B~~ • ~~97A~~ • 99P • 97L • 97G/3 • 96L • 96F • 94K • 99A • 99D	• Manage Network Safety Risk • Maintain network reliability • Manage assets efficiently without compromising security holder or customer value	• Wood pole structures at end of life • Reduction in security of supply.	• Allowance for replacement of forecast defect wood pole structures with concrete pole structures on lines at end of their economic life. An allowance of 966 structure replacements has been made. • Lines 995, 966, 97L, 99J, 976/2 and 97G/3 differed to RP3. • Lines 097B, 97A removed from scope	$86M Estimated Lines in various stages of scoping and delivery in RP2 Completed in 2021FY: • 9U3 • 9UH • 99D Remaining Lines • 99A • 94K	Need ID: 1558

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Lines with grillage structures: • 970 • 97K • 9R5/9R6 • 990/99X • 99X/9R5 • 99X/9R6	• Manage Network Safety Risk • Maintain network reliability • Leverage AM to support new technologies and innovations that improve or grow our business.	• Ground line and buried steel tower corrosion • Timber grillage foundations could have deteriorated. • Reduction in security of supply.	• Concrete encasement or micropiling of buried steel in aggressive soil corrosion areas is currently being scoped. • Replacement/installation of sacrificial anodes in other areas.	• Included in 2018-23 Revenue proposal • $16M Estimated ($46M for grillage program over both 132 kV and 330 kV) • 9R5/9R6, 990/99X, 99X/995, 99X/996 inserted back info program in FY2022.For completion by FY2023.	Need ID: 1523
Steel lattice towers	• Manage Network Safety Risk • Maintain Network Reliability • Manage assets efficiently without compromising security holder or customer value • Ensure accessible, relevant asset management	• Corrosion of steel towers to the extent that refurbishing is no longer possible.	Monitor corrosion of steel towers to ensure assets not suitable for replacement shall not get to condition where refurbishment is not possible	Ongoing	Asset Condition Data Collection

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	information is available to inform business wide decisions				
Line 99K	• Manage the following risks to ALARP as per Transgrid's Regulatory Obligations and Corporate Risk Appetite Statement • Public Safety • Bushfire • Minimise environmental harm and property damage • STPIS Performance. • Maintain network reliability • Improve OPEX Performance	• Corrosion of concrete pole internal steel reinforcement	Stage 1 • Development of an inspection methodology • Applying the methodology to inspect 34 concrete poles in a pilot study • Detailed investigation and reporting of selected poles, and Finalisation of the inspection procedure • Development and documentation of criteria for the design assessment of poles using inspection results Stage 2: Inspection and condition assessment of the remaining poles. Awaiting costs for inspection as per supplied methodology.	• Need 1724 withdrawn. • IWR Issued. • Stage 1: $130K • Stage 2: TBA.	Need ID: 1724 (withdrawn). IWR 0193 Need ID: 1327
132 kV Low Spans RP3: • 94K • 96R	• Manage Network Safety Risk	• New and planned generators have caused the priority temperatures used for RP1 low span remediation to	Remediate low spans as per guideline 'Low Span Assessment – Risk Management Approach'. Transmission line modifications are to be to design temperature with AS7000 clearances.	• Last of RP1 works low span works complete June 2020. • RP3 – OER complete.	Need ID: RP1: DCN129 DCN131 DCN243

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
• 9U3 • 9UH • 96L • 973 & 9GL • 996 • 994 • 949		increase. • Some lines not included in RP1 works (no PLSCADD model at the time) require remediation.		Included in RP3 submission. • Estimate - $22.04 million ($2021).	594 596 598 699 (Combined with OPGW installation) RP2: Nil RP3: N2616
Older 132 kV conductor	• Manage Network Safety Risk • Maintain Network Reliability	• Suspension clamp 'U-bolt' damages conductor under clamp.	Damaged conductor not an issue if contained within the suspension unit. If replacement poles are to be installed in a new location then conductor must be inspected before new suspension unit installed. Jobs shall plan for possible requirement for replacement of a length of conductor.	Ongoing during corrective maintenance and capital works.	Line 993 conductor sample TL&CD design advice
Line 965	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Remediate all identified condition issues. Deteriorated wood poles to be replaced with concrete or steel pole structures.	• Estimate - $9.95 million ($2021) • Optimally timed for FY2037.	Need ID: N2621
Line 968	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Rebuild entire line	• Estimate $115.8 million ($2021) • Optimally timed for RP4.	Need ID: N2574

Assets	Network Asset Strategy Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Line 97G	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Refurbish asset components that meet the primary condition criteria only	• Estimate $3.04 million ($2021) • Refurbishment evaluated. Not ALARP or NPV positive.	N2518
Line 97K	• Manage Network Safety Risk • Maintain Network Reliability	• Poor condition of crossarm attachments • Deterioration of wood poles.	Monitor condition.	• Not evaluated for RP3.	N2629
Line 991	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Rebuild the entire circa 1968 line, replacing wood poles with concrete or steel pole structures. The existing Panther conductor is to be replaced with Lemon ACSR/GZ.	• Estimate $68.27 million ($2021) • Optimally timed for FY2037.	N2581
Line 9R6	• Manage Network Safety Risk • Maintain Network Reliability	• Deterioration of wood poles. • End of life condition of insulators and fittings	Replace known wood pole structures exhibiting ground line degradation and those impacted by bushfire with steel or concrete pole structures only.	• Estimate $1.18 million ($2021) • Optimally timed for FY2037.	N2571
Line 963/96P	• Manage Network Safety Risk • Maintain Network Reliability	• High public exposure.	Refurbish all asset components that have been identified as having condition issues.	• Estimate - 1.18 million • Optimally timed for FY2038.	N2492

5.4.3. 132 kV Maintenance Program

Corrective Maintenance Process requires the Asset Manager to endorse all issues P3A and above. This has allowed the Asset Manager more input in remediation solutions. For example, on a number of occasions a condemned timber structure was able to be replaced with a concrete pole structure after seeking design input and assessing the risk of failure while the concrete pole was procured. The current strategy is to replace defective wood poles with concrete structures dependant on the nature of the defect, bushfire risk and termite zone. This improves bushfire resilience and termite and fungal attack. Wood poles will be kept for short notice replacements and situations where a concrete structure replacement is not feasible, allowing preservation of an increasingly scarce resource.

For the 132 kV Transmission Line assets the maintenance program consists of the following:

- Routine inspections
- Corrective (or 'defect') maintenance addressing out of specification conditions. The need to conduct corrective maintenance is usually identified during a routine inspection.

Where possible and practical, these defects are addressed at the same time as the inspection. Otherwise, these are prioritised on a basis as per 'Maintenance Plan - Transmission Line Assets'.

Easement maintenance is as detailed in the Maintenance Plan – Easements and Access Tracks.

A Failure Mode Analysis was completed for the steel towers lines. The analysis is compared with the Transmission Line Maintenance Plan to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them. This is shown in Appendix A.

5.5. 66 kV Transmission Lines Asset Review

5.5.1. Population Review

There are only five 66 kV structures in the Transgrid network. The structures are of concrete pole construction and formally transferred ownership to Transgrid after renewal of the connection agreements prior to the lease transaction in 2015. The structures are relatively young with the installation dates being 2002 (three structures at Molong) and 2012 (two structures at Glenn Innes).

The majority of the 21 km circuit length is strung on 132 kV double circuit structures with a Transgrid 132 kV circuit on the other side. These double circuit structures are covered under section 5.4.

5.5.2. Emerging Issues and Renewal and Maintenance Initiatives

5.5.2.1. 66 kV Transmission Line Emerging Issues

There are no emerging issues, renewal or maintenance initiatives for the 66 kV structures.

5.5.2.2. 66 kV Transmission Line Emerging Issues

There are no emerging issues, renewal or maintenance initiatives for the 66 kV structures.

5.5.2.3. 66 kV Maintenance Program

The maintenance on these structures will be as per a 132 kV concrete pole line.

5.6. 33 kV Transmission Lines Asset Review

5.6.1. Population Review

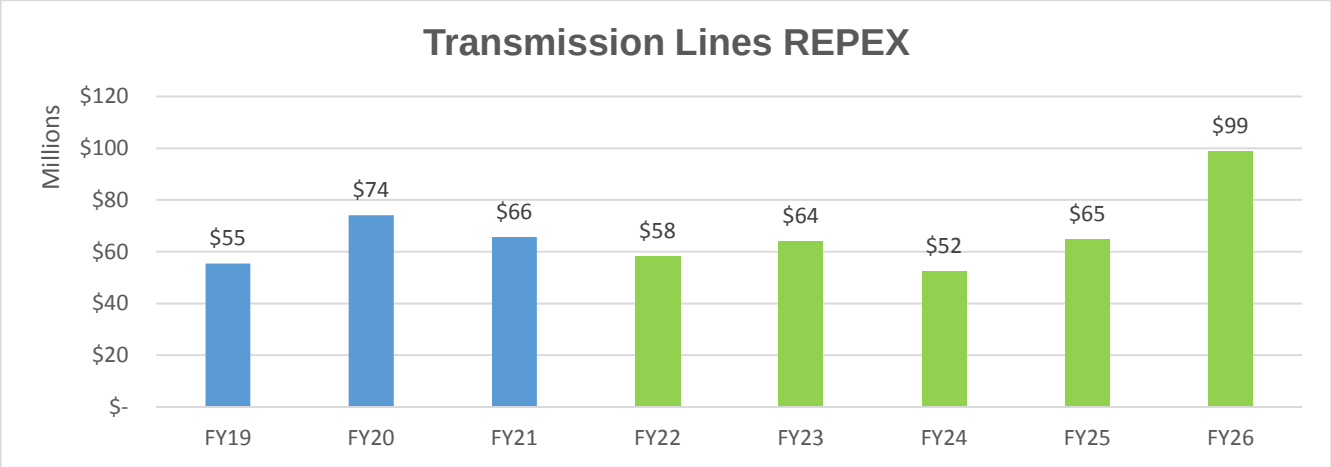
There are 28 kilometres of 33 kV conductor reported in the Regulatory Information Notice. This is entirely strung on 132 kV double circuit structures. These double circuit structures are covered under section 5.4.1.

6. CAPEX Forecasts

6.1.1. Five-Year CAPEX Profile

The five year CAPEX forecast for the Transmission Line portfolio REPEX is $338M. Augmentations have been excluded.

Figure 21 – Five Year REPEX forecast

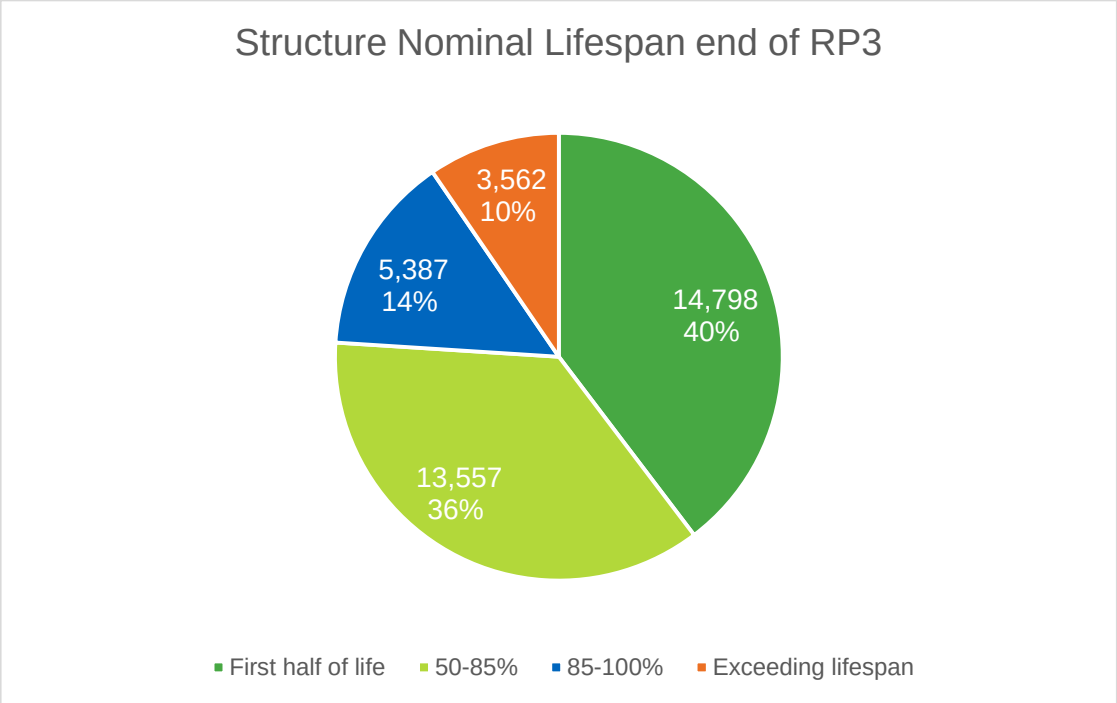


6.1.2. Anticipated Changes to the Asset Base

Anticipated changes to the transmission line asset base as at June 2023 will result in the lifespan profile as per Figure 22. Note that this figure uses nominal lives slightly different to Table 3, notably all steel structure nominal life 90 years.

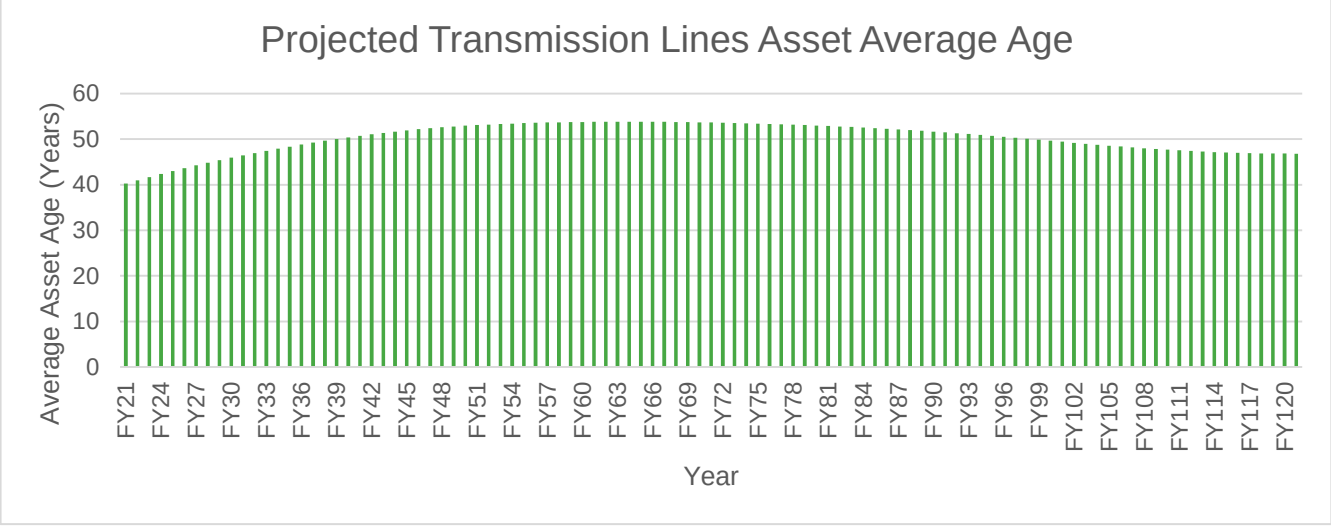
Significant increases in asset base due to augmentation are expected over the next five years. These include projects such as Project Energy Connect, Humelink, QNI Minor, and VNI minor. These have not been included in the figure below.

Figure 22: 2028 Forecast with proposed intervening actions



It is anticipated that the average age of transmission lines asset will increase at a moderate rate over the next few decades. This is due to continuing investment and advancement in technologies that will maintain the reliability of the aged asset in the future.

Figure 23: Projected Transmission Line Asset Classes Average Age



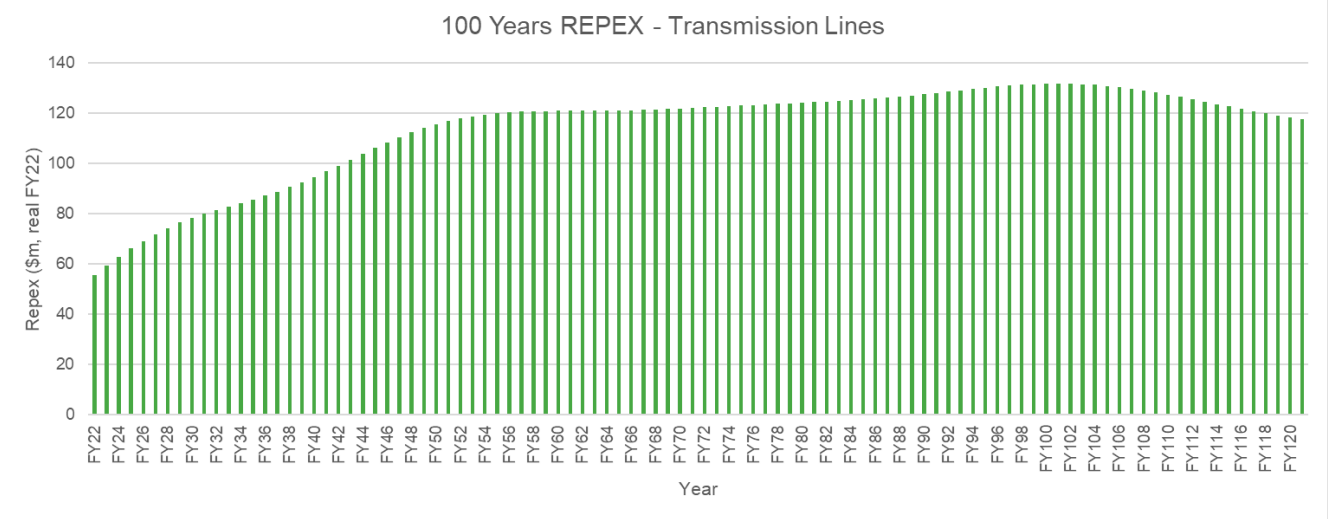
6.1.3. Long Term - REPEX Investment Framework

The 100 Year REPEX model is used by Transgrid to create a 100 year forecast, which is based on expected asset lives, standard deviations and unit costs. The assumptions within the model are based on industry standard information. This forecast includes REPEX volumes, costs and consequential average life profiles but no other consequential inputs/outputs (such as reliability and asset health). It also does not

include augmentation expenditure. An overview of the REPEX investment framework is shown in Figure 24 below.

For shorter term forecasting related to the next 5 year revenue determination period is performed using a bottom up approach through an asset analytics tool using a number of financial and non-financial (risk) inputs.

Figure 24: 100-Year Transmission Line REPEX Forecast



7. OPEX Forecasts

OPEX forecasts provided by Asset Analytics and Insights exclude the impact of augmentation projects. All costs are in actual dollars.

7.1. Discussion of significant changes to Maintenance Plan

The lines that were subject to wood pole replacement or refurbishment projects will require end of defects liability inspections. There are one-off tasks but are generally not captured in the forecast.

AEMO's Integrated System Plan indicates that there would likely be a significant increase in the transmission line network in NSW within the next five years.

7.2. 5 year OPEX Profile

The five-year OPEX trends for Transmission Lines is shown in Figure 25 and Figure 26 for Easements.

The following shall be noted:

- Support cost is included
- Volume of Corrective and Condition is maintained at the same level
- Escalation is as per CPI forecast provided by Transgrid Finance.
- Stretch target has not been included.

Figure 25: Five-Year Transmission Line OPEX Forecast

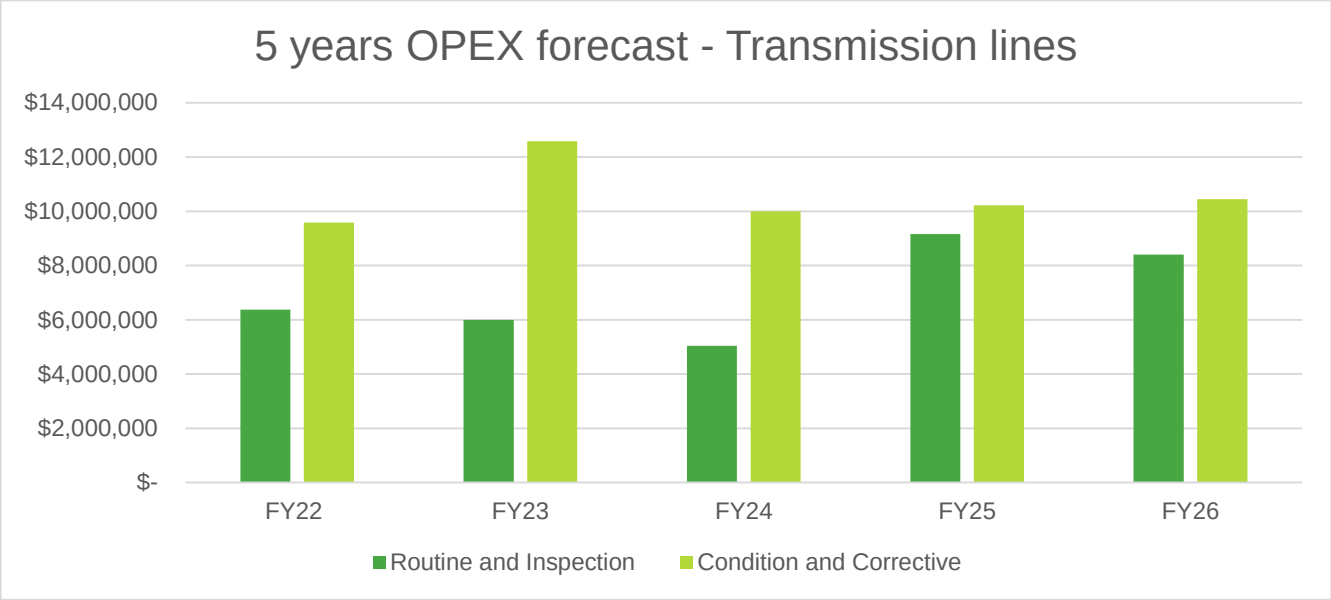
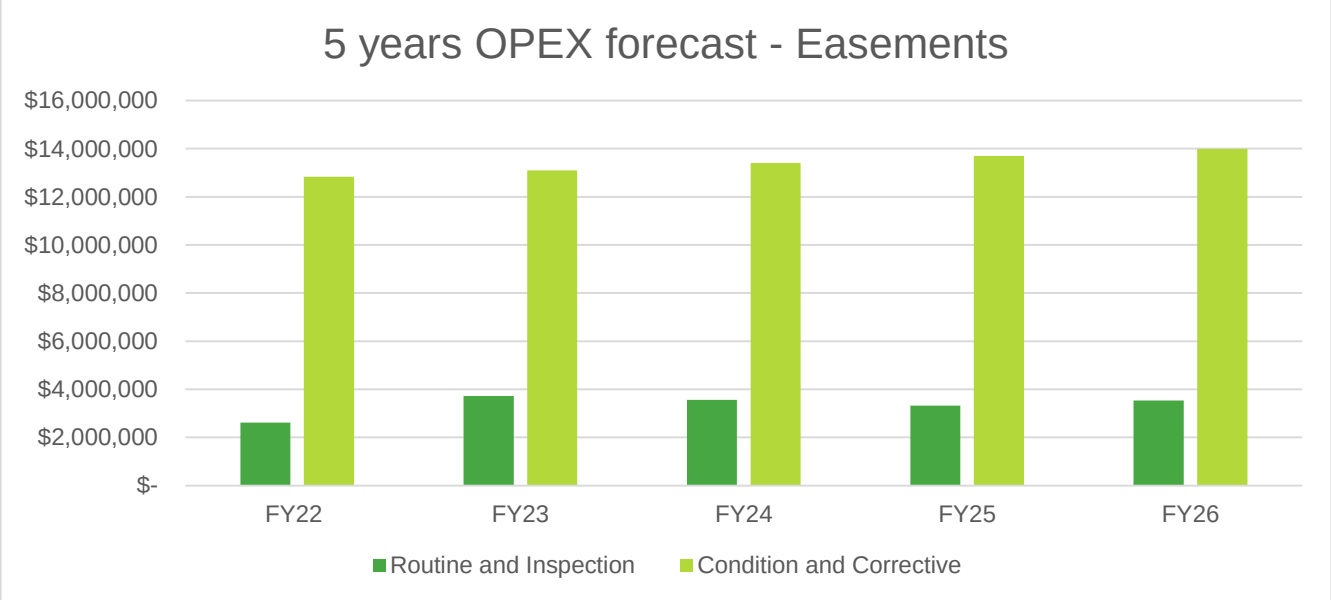


Figure 26: Five-Year Easements OPEX Forecast



8. Definitions

Term	Definition
Asset Management Objectives	• Specific and measurable outcomes required of the assets in order to achieve the Corporate Plan and objectives; and/or • Specific and measurable level of performance required of the assets; and/or • Specific and measurable level of the health or condition required of the assets; and/or • Specific and measurable outcomes or achievement required of the asset management system.
Key Hazardous Events	They events of most concern associated with the assets that prevent the achievement of the corporate and asset management objectives.
Emerging Issues	Newly identified issues with an asset that pose a risk to the achievement of the corporate and asset management objectives.
Fault Outage	AER defined term - Fault outages are unplanned outages (without notice) on the prescribed network from all causes including emergency events and extreme events.
Forced Outage	AER defined term - Forced outages are outages on the prescribed network where less than 24 hours notification was given to affected customers and/or AEMO (except where AEMO reschedules the outage after notification has been provided). Forced outages exclude fault outages.
Asset Management Plans	Documents specifying activities, resources, responsibilities and timescales for implementing the asset management strategy and delivering the asset management objectives.
RP1	Regulatory Period 2014/15 – 2017/18
RP2	Regulatory Period 2018/19 – 2022/23
RP3	Regulatory Period 2023/24 – 2022/28
RP4	Regulatory Period 2028/29 – 2030/33

9. Document Management

9.1. Monitoring and review

Implementation of the Transmission Line Renewal and Maintenance Strategy is monitored and reviewed by the Transmission Lines and Cables Asset Manager, the Head of Asset Management and Asset Management Committee annually.

9.2. Roles and Responsibilities to Develop this Asset Strategy

The roles and responsibilities of those responsible for the development of this asset strategy are as follows:

The Head of Asset Management is responsible for the approval of this strategy.

Transmission Line and Cables Asset Manager is responsible for the development and regular review of this strategy. The document will be reviewed biannually and as significant changes to investment needs become apparent.

9.3. References

Network Asset Strategy

Asset Management System Description

Maintenance Plan – Transmission Line Assets

Maintenance Plan – Easements and Access Tracks

Prescribed Capital Investment Process

Appendix A - Failure Mode Analysis and Effectiveness of Maintenance Tasks

The below table details the failure modes analysis completed for transmission line asset parts and sub-parts and identifies the primary maintenance task or tasks that are in place to detect each. A qualitative analysis has been carried out to assess the effectiveness of the maintenance tasks in detecting the failure mode.

These ratings where developed following a workshop with Works Delivery team members and where adjusted to take account of ergonomic factors, line of sight, main focus of inspection tasks, etc. The final rating gives the likelihood that the primary and /or secondary maintenance tasks will detect the failure mode (defect) in time to allow planning of mitigation works.

Those defects that are likely to be detected during multiple maintenance tasks have higher effectiveness ratings. Conversely those defects that are only likely to be detected by specifically targeted maintenance tasks and / or have a low likelihood of being detected during other maintenance tasks have a lower effectiveness rating.

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
Anti-Climber & Signage	Anti-Climbers	Corroded	Environment	Steel Tower	Compliance inspection Ground and Climbing Inspection	Effective
		Damaged	Human Interference	Steel Tower		Very Effective
		Inadequate	Design - General	Steel Tower		Effective
	Danger Signage	Deteriorated	Environment	All		Effective
		Missing/Damaged	Human Interference	All		Very Effective
			External Event	All		Very Effective
	Identification Signage	Deteriorated	Environment	All		Effective
		Missing/Damaged	Human Interference	All		Very Effective
			External Event	All		Very Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
Insulator – Composite	Insulator Longrod	Flashover	Contamination	All	After fault patrol Ground and Climbing Inspection Aerial photography	Effective
			Major Weather Event	All		Effective
		Deteriorated	Manufacturer Type Fault	All	Ground and Climbing Inspection Aerial photography	Effective
		Flashunder	Contamination	All	After fault patrol Ground and climbing inspection	Effective
	Insulator Posts	Fractured	Vibration	All	Ground and Climbing Inspection Aerial photography	Somewhat Effective
		Flashover	Contamination	All	After fault patrol Ground and climbing inspection	Effective
			Major Weather Event	All	After fault patrol Ground and climbing inspection	Effective
		Deteriorated	Manufacturer Type Fault	All	Ground and Climbing Inspection Aerial photography	Effective
		Flashunder	Contamination	All	After fault patrol Ground and climbing inspection	Effective
	Sheath/Sheds	Damaged	Animal Damage	All	Ground and Climbing Inspection Aerial photography	Effective
			Human Interference	All		Effective
		Worn	Environment	All		Somewhat Effective
	Insulator Base	Corroded	Environment	All	Ground and Climbing inspection	Effective
		Damaged	Major Weather Event	All	After fault patrol Ground and climbing inspection	Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
		Damaged	Design - General	All	Ground and Climbing inspection	Effective
	End fittings	Corroded	Environment	All	Ground and Climbing inspection	Somewhat Effective
		Damaged	Major Weather Event	All	After fault patrol Ground and climbing inspection	Effective
		Damaged	Design - General	All	Ground and Climbing inspection	Effective
	Corona Control Devices	Corroded	Environment	All	Ground and Climbing inspection	Somewhat Effective
		Loose	Design - General	All	Ground and Climbing Inspection Aerial photography	Effective
			Poor Installation	All		Effective
		Missing	Poor Installation	All		Very Effective
	Fasteners	Corroded	Environment	All	Ground and Climbing Inspection	Effective
		Loose	Poor Installation	All	Ground and Climbing Inspection Aerial photography	Effective
		Missing	Poor Installation	All		Effective
Insulator – Disc	Insulator	Flashover	Contamination	All	After fault patrol Ground and Climbing Inspection Aerial photography	Effective
			Major Weather Event	All		Effective
	Insulator Discs	Mechanical Separation	Wear	All	Ground and climbing inspection	Very Effective
		Damaged	Manufacturer Type Fault	All	Ground and climbing inspection	Effective
			Impact	All	After fault patrol Ground and Climbing Inspection Aerial photography	Effective
		Internal Puncture	Manufacturer Type Fault	All	Corona Inspection	Ineffective
	Insulator Pins	Corroded	Environment	All	After fault patrol	Somewhat Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
					Ground and Climbing Inspection	
		Cracked	Fatigue	All	Ground and climbing inspection	Ineffective
	Insulator Retaining Clips/ Pins	Loose	Poor Installation	All	Ground and climbing inspection	Somewhat Effective
			Design - General	All		Somewhat Effective
		Missing	Poor Installation	All	Ground and climbing inspection	Effective
			Design - General	All		Effective
Foundation	Concrete	Deteriorated	Environment	All	Ground and climbing inspection	Effective
		Cracked	Environment	All		Effective
	Reinforcement	Corroded	Environment	All	Ground and climbing inspection	Ineffective
		Corroded	Poor Installation	All	Ground and climbing inspection	Ineffective
	Buried Steel	Corroded	Environment	All	Ground and climbing inspection Grillage inspection	Somewhat Effective
	Ground	Structure Leaning	Design - General	Concrete Pole Steel Pole Wood Pole	Aerial photography Ground and climbing inspection Compliance inspection	Very Effective
		Collapse	Design - General	All	After fault patrol	Very Effective
		Erosion	Environment	All	Ground and climbing inspection Compliance inspection	Effective
		Movement	Environment	All	Ground and climbing inspection Compliance inspection	Effective
Fittings	Attachment	Worn	Design - General	All	Ground and climbing inspection	Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
		Corroded	Environment	All		Effective
	Conductor Saddle Clamp Connections	Loose	Vibration	All	Ground and climbing inspection	Effective
	Deadends	Cracked	Fatigue	All	Ground and climbing inspection	Effective
		Cracked	Environment	All		Effective
	Fasteners	Corroded	Environment	All	Ground and climbing inspection	Somewhat Effective
		Corroded	Design - Material	All		Somewhat Effective
		Loose	Poor Installation	All		Somewhat Effective
	Jumper Joint	Corroded	Environment	All	Ground and climbing inspection	Effective
	Split Pins	Loose	Poor Installation	All	Ground and climbing inspection	Effective
			Design - General	All		Effective
		Missing	Poor Installation	All		Effective
			Design - General	All		Effective
		Corroded	Environment	All		Somewhat Effective
		Corroded	Design - Material	All		Somewhat Effective
	Suspension AGSU	Damaged	Design - General	All	Ground and climbing inspection	Effective
	Conductor	Worn	Design - Material	All	Ground and climbing inspection	Somewhat Effective
		Broken Strands	Fatigue	All	Aerial photography	Very Effective
			Human Interference	All	Ground and Climbing Inspection Non-routine special inspection (e.g. SAIP)	Very Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
		Deteriorated	Design - Material	All	Non-routine special inspection (e.g. SAIP) Non-routine targeted metallurgical analysis under IWR.	Effective
		Corroded	Environment	All	Non-routine special inspection (e.g. SAIP) Non-routine targeted metallurgical analysis under IWR.	Somewhat Effective
		Damaged	Major Weather Event	All	After fault patrol (aerial and/or ground)	Effective
			Bushfire	All	After fault patrol (aerial and/or ground) Non-routine special inspection (e.g. SAIP) Non-routine targeted metallurgical analysis under IWR.	Effective
	Conductor Inner Steel Wire	Corroded	Design - Material	All	Non-routine special inspection (e.g. SAIP) Non-routine targeted metallurgical analysis under IWR	Somewhat Effective
	Aerial Marker	Deteriorated	Environment	All	Ground and climbing inspection	Effective
		Movement	Design - General	All	Ground and climbing inspection	Effective
		Missing/Damaged	External Event	All	After fault patrol (aerial or ground) Non-routine special inspection	Very Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
					(e.g. SAIP)	
	Spacers	Damaged	Fatigue	All	Aerial photography Non-routine special inspection (e.g. SAIP)	Effective
		Movement	Poor Installation	All		Somewhat Effective
			Design - General	All		Somewhat Effective
		Melted	Bushfire	All		Effective
	Vibration Dampers	Sagging/Broken	Human Interference	All	Aerial photography Ground and Climbing Inspection	Effective
			Fatigue	All		Effective
		Loose	Poor Installation	All		Effective
		Melted	Bushfire	All	After fire patrol (ground or aerial)	Very Effective
	Mid Span Joint	Failed	Poor Installation	All	Thermographic inspection	Very Effective
			Fatigue	All		Very Effective
			Internal Corrosion	All		Very Effective
OHEW / OPGW	Wire	Worn	Design - Material	All	Ground and climbing inspection	Somewhat Effective
		Broken Strands	Fatigue	All	Non-routine special inspection (e.g. SAIP). Ground and climbing inspection. Compliance inspection	Effective
			Design - Material	All		Effective
			Human Interference	All		Effective
		Deteriorated	Design - Material	All	Ground and climbing inspection Non-routine special inspection (e.g. SAIP). Non-routine targeted metallurgical analysis under IWR	Somewhat Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
		Corroded	Environment	All	Ground and climbing inspection	Ineffective
		Damaged	Major Weather Event	All	After fault patrol (aerial or ground)	Effective
			Bushfire	All	Non-routine special inspection (e.g. SAIP)	Effective
	Conductor Inner Steel Wire	Corroded	Design - Material	All	Non-routine special inspection (e.g. SAIP). Non-routine targeted metallurgical analysis under IWR	Ineffective
	OHEW Riser	Deteriorated	Timber Rot	Wood Pole	Ground and climbing inspection	Somewhat Effective
			Timber Defect	Wood Pole	Aerial photography Ground and climbing inspection Compliance inspection	Somewhat Effective
		Damaged	Major Weather Event	Wood Pole	After fault patrol (ground or aerial)	Effective
	Aerial Marker	Deteriorated	Environment	All	Ground and climbing inspection	Effective
		Movement	Design - General	All	Non-routine special inspection (e.g. SAIP)	Effective
		Missing/Damaged	External Event	All	After fault patrol (ground or aerial) Non-routine special inspection (e.g. SAIP)	Very Effective
	Vibration Dampers	Sagging/Broken	Human Interference	All	Aerial photography Ground and climbing inspection	Very Effective
			Fatigue	All		Very Effective
		Melted	Bushfire	All	After fire patrol (ground or aerial)	Very Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
	OHEW Bonding	Disconnected	Poor Installation	All	Thermographic inspection Ground and climbing inspection	Very Effective
			Overheating	All		Effective
	OPGW Joint Canister	Loose	Poor Installation	All	Ground and climbing inspection	Effective
			Human Interference	All		Effective
	OPGW Tail	Loose	Poor Installation	All	Ground and climbing inspection	Effective
			Human Interference	All		Effective
Earthing System	Earth Bond	Loose	Poor Installation	Wood Pole	Compliance Inspection Underground Inspection Ground and climbing inspection Earthing testing	Effective
			Human Interference			Effective
		Missing	Poor Installation	Wood Pole		Effective
			Human Interference			Effective
		Deteriorated	Environment	Wood Pole		Effective
		Damaged	Human Interference	Wood Pole		Effective
		Continuity Broken	Environment	All		Effective
	Structure Bonding at Earth Wire	Disconnected	Poor Installation	All	Ground and climbing inspection	Effective
			Overheating	All	Thermographic inspection	Effective
	Batten Cover	Loose	Poor Installation	Wood Pole	Underground Inspection Compliance inspection Ground and climbing inspection	Effective
			Human Interference			Effective
		Missing	Poor Installation			Very Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
			Human Interference			Very Effective
		Deteriorated	Timber Rot			Effective
			Termites			Effective
	Hardware Bonding	Loose	Poor Installation	Wood Pole Concrete Pole	Ground and climbing inspection Compliance inspection	Effective
		Missing	Poor Installation			Very Effective
	Structure Earthing - Refers to the bond to earth rod connection	Loose	Poor Installation	All	Compliance inspection Ground and climbing inspection	Effective
			Human Interference	All		Effective
		Missing	Poor Installation	All		Very Effective
			Human Interference	All		Very Effective
Pole - Wood	Pole	Deteriorated	Timber Rot	Wood Pole	Underground inspection Ground and climbing inspection	Effective
			Termites			Effective
		Damaged	Bushfire		After fire patrol (ground or aerial)	Effective
			Impact		After fault patrol Compliance inspection	Effective
			Major Weather Event		After fault patrol Aerial photography Ground and climbing inspection	Effective
		Split	Timber Defect		Underground inspection Ground and climbing inspection	Very Effective
	Cross Arms	Corroded	Environment		Ground and climbing inspection	Somewhat Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
		Damaged	Impact		After fault patrol Compliance inspection	Effective
			Seismic Event		After fault patrol (ground or aerial) Compliance inspection Aerial photography Ground and climbing inspection	Effective
	Fasteners	Corroded	Environment		Ground and climbing inspection	Effective
	Pole Cap	Missing/Damaged	Major Weather Event		Aerial photography Ground and climbing inspection	Very Effective
	Pole Joints	Deteriorated	Timber Rot		Ground and climbing inspection	Ineffective
		Corroded	Environment			Effective
	Pole Reinforcement	Deteriorated	Timber Rot		Underground inspection	Somewhat Effective
		Corroded	Environment			Effective
	Step bolts	Missing	Poor Installation		Ground and climbing inspection	Effective
			Human Interference			Effective
		Corroded	Environment			Effective
Pole - Concrete	Pole	Damaged	Impact	Concrete Pole	After fault patrol Compliance inspection	Effective
			Seismic Event		After fault patrol	Effective
		Collapse	Major Weather Event		After fault patrol	Very Effective
		Cracking	Environment		Ground and climbing inspection	Effective
			Design - General			Effective
	Cross Arms	Corroded	Environment		Ground and climbing inspection	Somewhat

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
						Effective
		Damaged	Impact		After fault patrol Aerial photography	Effective
			Seismic Event			Effective
	Fasteners	Corroded	Environment		Ground and climbing inspection	Effective
	Pole Cap	Missing/Damaged	Major Weather Event		After fault patrol Aerial photography	Very Effective
	Pole Joints	Corroded	Environment		Ground and climbing inspection	Effective
	Pole Reinforcement	Corroded	Environment		Ground and climbing inspection Concrete pole corrosion assessment (select lines only)	Ineffective
	Step bolts	Missing	Poor Installation		Ground and climbing inspection	Effective
			Human Interference		Compliance Inspection	Effective
		Corroded	Environment		Ground and climbing inspection	Effective
Pole - Steel	Pole	Damaged	Impact	Steel Pole	After fault patrol Compliance inspection	Effective
			Seismic Event		After fault patrol	Effective
			Major Weather Event		After fault patrol	Effective
		Corroded	Environment		Ground and climbing inspection	Effective
	Cross Arms	Corroded	Environment		Ground and climbing inspection	Somewhat Effective
		Damaged	Impact		After fault patrol Aerial photography	Effective
			Seismic Event			Effective
	Pole Joints	Corroded	Environment		Ground and climbing inspection	Effective
	Step bolts	Missing	Poor Installation		Ground and climbing inspection	Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
			Human Interference		Compliance Inspection	Effective
		Corroded	Environment		Ground and climbing inspection	Effective
	Access Ladder	Corroded	Environment		Ground and climbing inspection	Effective
	Footing/Rag Bolts	Corroded	Environment		Ground and climbing inspection	Effective
	Pole Buried Section	Corroded	Environment		Ground and climbing inspection	Somewhat Effective
Guy	Guy Rod	Damaged	Human Interference	All Pole Strs	Compliance Inspection Aerial photography Ground and climbing inspection	Effective
			Animal Damage	All Pole Strs	Aerial photography Ground and climbing inspection	Effective
		Corroded	Environment	All Pole Strs	Ground and climbing inspection	Effective
	Guy Wire	Loose	Poor Installation	All Pole Strs	Aerial photography Ground and climbing inspection	Effective
			Human Interference	All Pole Strs	Compliance Inspection Aerial photography Ground and climbing inspection	Effective
		Corroded	Environment	All Pole Strs	Ground and climbing inspection	Effective
	Guy Wire Earthing	Continuity Broken	Environment	All Pole Strs	Ground and climbing inspection	Effective
		Loose	Poor Installation	All Pole	Aerial photography	Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
				Strs	Ground and climbing inspection	
			Design - General	All Pole Strs		Effective
	Guy Sight Sleeve	Missing/Damaged	Human Interference	All Pole Strs	Compliance Inspection Aerial photography Ground and climbing inspection	Very Effective
			Animal Damage	All Pole Strs	Aerial photography Ground and climbing inspection	Very Effective
Tower – Lattice	Tower Frame	Corroded	Environment	ST	Ground and climbing inspection	Effective
		Damaged	Impact	ST	After fault patrols Compliance inspection Aerial photography	Effective
			Design - General	ST	Covers bent members.	Effective
			Major Weather Event	ST	Covers bent members.	Effective
			Seismic Event	ST	After fault patrol	Effective
		Collapse	Major Weather Event	ST	After fault patrol	Very Effective
	Tower Frame Fasteners	Corroded	Environment	ST	Fasteners keeps consistency and also encompasses washers, locking devices, etc.	Effective
	Step bolts	Missing	Poor Installation	ST	Ground and climbing inspection	Effective
			Human Interference	ST	Compliance inspection Ground and climbing inspection	Effective
		Corroded	Environment	ST	Ground and climbing inspection	Effective
	Access Ladder	Corroded	Environment	ST	Ground and climbing inspection	Effective

Part	Sub-Part	Failure	Cause	Asset Type	Maintenance Plan Task	Effectiveness
	Tower Stub Leg	Corroded	Environment	ST	Ground and climbing inspection Grillage inspection	Effective
		Inundated	Human Interference	ST	Compliance inspection Ground and climbing inspection	Very Effective
			Design - General	ST		Very Effective
			Environment	ST		Very Effective
	Tower Stub Leg-Coating	Deteriorated	Environment	ST	Ground and climbing inspection	Effective