PWC Asset Class Management Plan

Underground cables

January 2023

PowerWater

Version control

This document has been approved in accordance with the Delegation of Authority (DoA) as evidenced by signatures and dates contained herein.

Rev	Date	Description	Author	Endorsed	Approved
1	17/01/2023	Revised and moved to new template	M Van Doornik Asset Engineer	B Kaye Manager Asset Strategy and Risk	S Eassie Senior Manager Asset Management

Contents

1. Introduction

ISO 55000 defines an Asset Management Plan (AMP) as documented information that specifies the activities, resources and timescales required for an individual asset, or a grouping of assets, to achieve the organisation's asset management objectives.

1.1 Purpose and context

The purpose of this Asset Management Plan (AMP) is aligned to the requirements specified in ISO 55000. This AMP:

- Defines what is included and exclude from its scope
- Describes the asset class being managed
- Defines how this asset class will contribute to achieving the Asset Management Objectives that are defined in the Strategic Asset Management Plan (SAMP)
- Identifies the challenges we are expecting to encounter over the AMP planning horizon
- Sets out the projects and programs that we will invest in to ensure we achieve the AM Objectives and address the identified challenges
- Quantifies the risk posed by this asset class with and without the proposed projects and programs of work

By reviewing this AMP and reassessing asset performance on an annual basis, we will ensure that any emerging issues are identified and can be addressed prior to becoming a significant risk. The outcome of the annual review will support the annual update of the Statement of Corporate Intent (SCI) and provide an input into the annual Transmission and Distribution Annual Planning Report (TDAPR).

1.2 Scope of the AMP

This AMP covers underground cables, including transmission, high-voltage (HV), low-voltage (LV), and service cables. It also covers the cable tunnel structures used to house underground cables.

The AMP excludes:

- Non-regulated assets that are managed by Power and Water, noting that performance and emerging issues are common across these asset populations, and improvement plans are also applicable
- Other ground network assets such as ground mounted equipment

This AMP will avoid, as far as practicable, repeating information that is contained in other documentation. Instead, it will provide a reference to the relevant document or data source.

1.3 Timeframe of the AMP

This AMP is focused on a 10-year planning horizon, with respect to expenditure forecasts, that aligns with the requirements of the SCI and TDAPR. However, when assessing future challenges and emerging trends we may consider longer timeframes and will comment by exception if any longer-term issues are expected to arise.

1.4 Asset management framework

Power and Water has a Strategic Asset Management System[1] which sets out the framework for asset management and the hierarchy of documents. This provides line of sight from the corporate objectives through to the asset objectives and how management of this asset class will contribute to achieving those objectives. Figure 1 highlights how the AMP fits in with the overall asset management system.

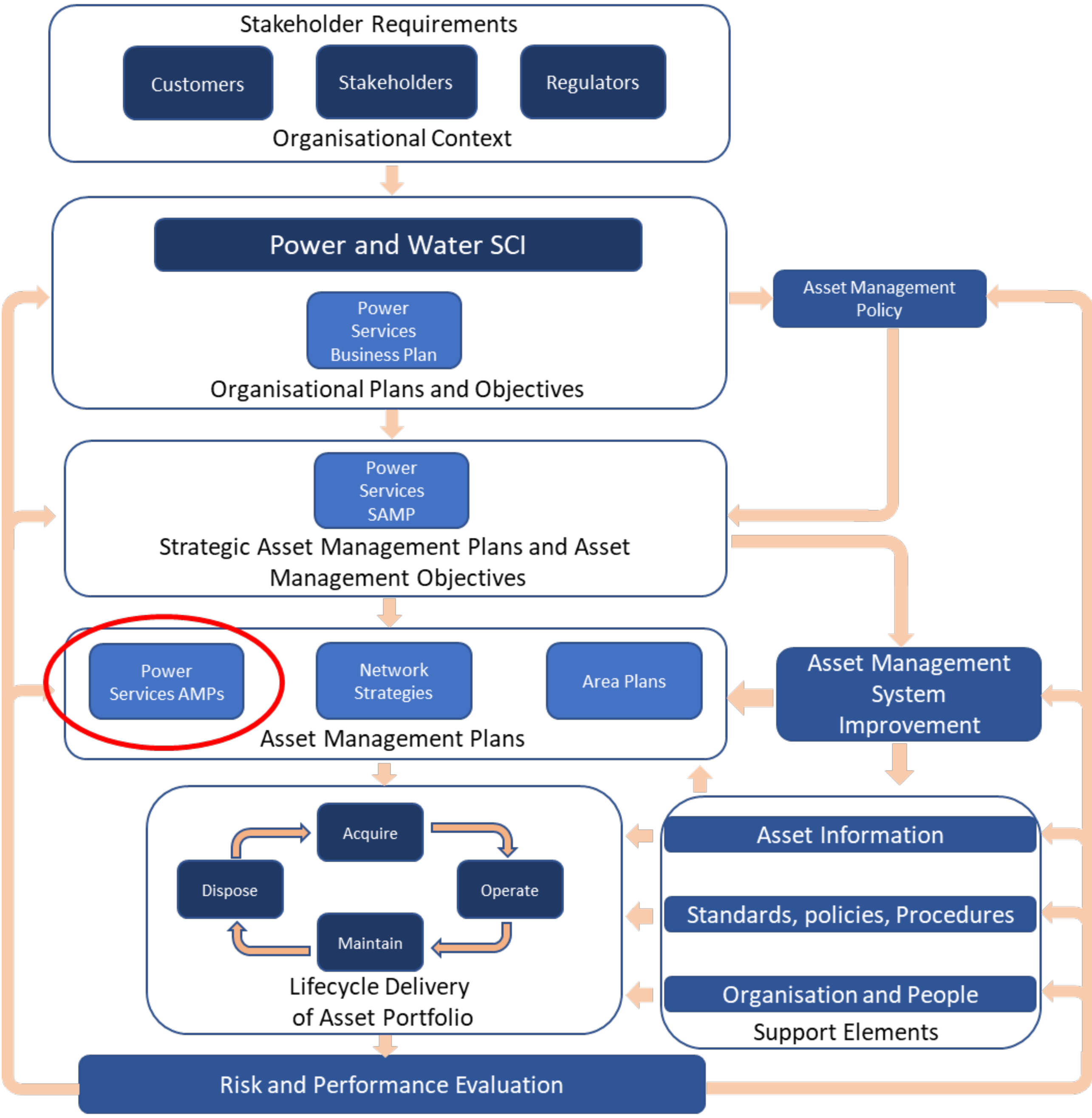

Figure 1: The AMP within the context of the Asset Management System

[1] CONTROL0548

1.5 Document structure

This document has been structured to align with the Power and Water Asset Management Standard and fits under the SAMP in the hierarchy of documentation. The document has been designed to be concise and provide the outcomes of detailed analysis with references, and not repeat the analysis in this document.

The purpose of each section is described below:

- **Asset profile** provides an overview of what the asset is to provide context to the reader of the asset's role in the electricity transmission and distribution network. It provides a breakdown by asset characteristics and volumes as well as the age profile which is an important input to asset management.
- **Asset objectives and performance** sets out the asset objectives and how they apply to this asset class. Any gaps or emerging trends are identified and linked to a project or program, if relevant, to address the issue and ensure the asset objectives are achieved.
- **Asset challenges and emerging issues** outlines any existing or emerging challenges that may impact the performance of the asset class or may otherwise impact the management of, or need for, the asset class.
- **Implementation plan** sets out the project and programs with expenditure per year for the 10-year planning horizon. This is a point in time assessment that is updated periodically so it may not align fully to the SCI and TDAPR if additional analysis has been completed subsequent to the AMP update.
- **Risk quantification and mitigation** describes the approach to risk-based investment decision-making and demonstrates the risk mitigated by the proposed implementation plan.
- **Asset lifecycle management** describes the asset management approach at each stage in the asset lifecycle.
- **Continuous Improvement** outlines the improvement plans related to the asset class.

2. Asset profile

Power and Water owns and maintains a portfolio of 2,597km of underground transmission and distribution cables distributed across the four regions of Alice Springs, Darwin, Katherine and Tennant Creek, with the largest population in the Darwin Region. These operate at voltages including LV (230V, 400V), HV (6.35kV, 11kV, 22kV), and transmission (66kV). The population includes feeders of entirely underground cable as well as mixed overhead and underground feeders.

The portfolio consists of a variety of cable types, with XLPE type cables comprising the majority. Different types have been used depending on the preferred technology at the time of installation, or functional requirements such as different voltage levels. Each cable type presents different challenges, with the associated risk and expenditure implications.

Furthermore, Power and Water owns and maintains a portfolio of six kilometres of cable tunnels, mostly located in the Darwin CBD area. The cable tunnels are mainly of box culvert design and follow key cable routes throughout Darwin.

2.1 Fleet characteristics

In-scope assets include Power and Water's transmission, high-voltage (HV), low-voltage (LV), and service cables. Table 1 provides an overview of the asset class.

Asset type	Quantity	Voltage	Average age	Nominal lifespan
Transmission cables	39km	66kV	18 years	55 years
HV cables	890km	6.35-22kV	25 years	55 years
LV mains cables	706km	400V	26 years	55 years
LV service cables	962km	230/400V	31 years	35 years
Total	**2,597km**	**-**	**-**	**-**

Table 1 - Overview of in-scope assets

The underground cable asset class is increasing in overall significance as a proportion of Power and Water's assets and activities. This is because much of the growth in new areas is supplied using underground assets.

An overview of the different cable types is provided in Table 2.

Cable type	Period of installation	Challenges	Expenditure/ risk implications
Oil filled	1967 – 1981	• Technology becoming obsolete.	• Skills to maintain and repair the cable diminishing. Longer repair times during fault conditions.
XLPE	1959 – present	• Older cables prone to water ingress and earthing screen failure.	• Older XLPE cables are prone to moisture ingress and early failure

PowerWater

PILC	1961 – 2013	• Ageing cable type being phased out in the industry by XLPE type cables for most applications.	• Loss of jointing skills. Longer repair times during fault conditions.
PVC	1961 – present	• Mostly applied in LV applications. • Being phased out in the power distribution industry.	• Loss of jointing skills. Longer repair times during fault conditions.
Cable tunnels	1973 – present	• Mostly located in the greater Darwin City area. • Generally, in good health.	• Emerging structural degradation, water leaks and vegetation ingress.

Table 2 - Asset types comprising the underground cable population

A breakdown of the cable tunnel assets is provided in Table 3. There are five cable tunnel networks covering a total of 6km. The key challenges in maintaining the condition of the cable tunnels are corrosion of the cable support structures and water and vegetation ingress. Holistic condition assessment is required to better understand the future requirements to maintain their integrity for the foreseeable future given their criticality to supporting Darwin CBD development and reliability.

Distribution area	Length (m)	% of asset population
Archer	231.7	3.8%
Darwin City	4,620.7	76.6%
Driver (associated with Palmerston City tunnel)	259.2	4.3%
Palmerston City	843.3	14.0%
Woolner	80.4	1.3%
Total	**6,035.2**	**100.0%**

Table 3 - Cable tunnels

2.2 Age profile

The age profile provides an early indication of expected asset condition and potential life extension or renewal investment requirements. The asset age profile for underground cables is shown in Figure 2.

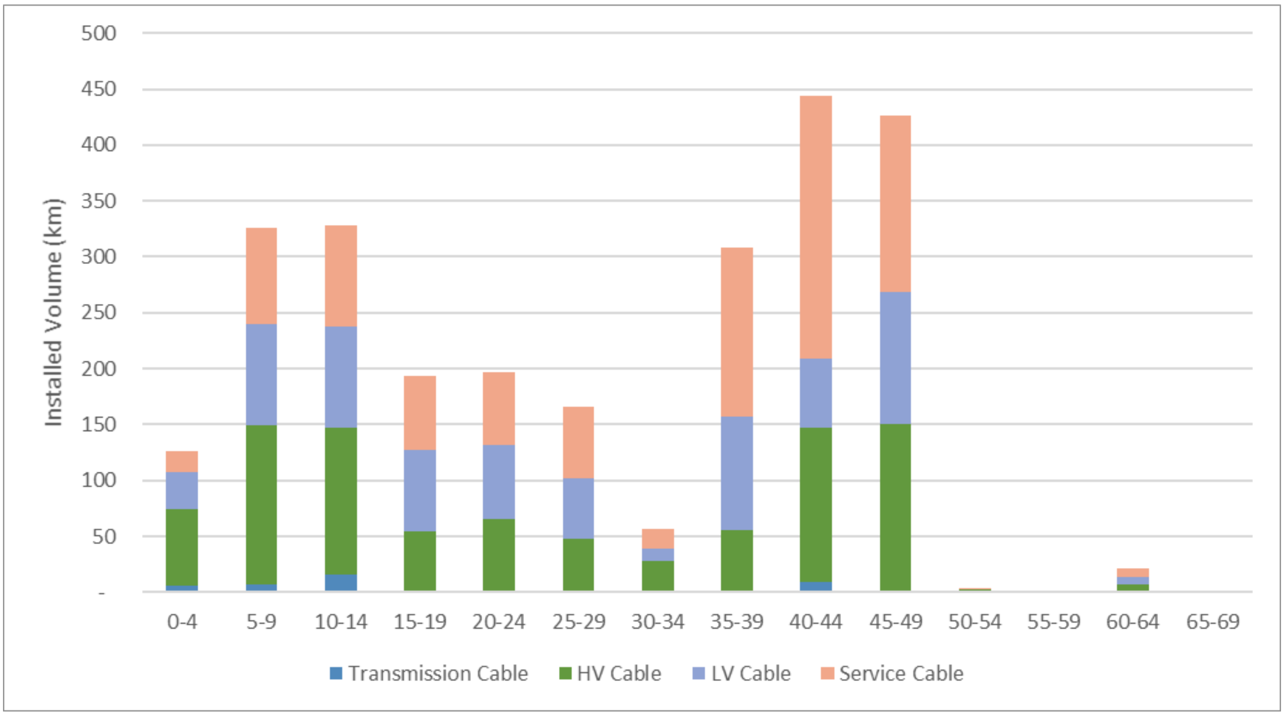

Figure 2 – Age profile by cable type

With the exception of service cables, the cable age profile shows a relatively young asset group, with relatively few assets currently exceeding the nominal life of 55 years. The service cable asset data is lower quality due to less reliable historical replacement information captured during faults that were not recorded in our systems. The volume of fault replacement is very low and immaterial to the age profile.

There has been a steady growth in cable installations across the network since they began to be widely used in the distribution network in the 1970's. Significant cable installations were made in the Darwin region following Cyclone Tracy in 1974, with the establishment of several new suburbs in Darwin's north. As a result, there is a large volume of cables approaching end of life over the next 10 years. In addition, a type issue with the XLPE cables installed in the northern suburbs is resulting in their premature failure and a replacement program is underway to address this issue.

2.3 Criticality

Power and Water has established a Risk Quantification Procedure for Investment Decision Making to assess the overall risk posed by the asset fleet. However, when undertaking detailed scheduling and prioritisation of assets within the fleet for specific tasks, such as testing and inspection or replacement, we consider the localised characteristics of individual assets to account for relative criticality within the fleet.

The criticality assessment considers the diversity of the network including impact on public safety, service disruption (reliability) or environmental incidents. The location of an asset has a significant impact on the likelihood and severity of the consequences.

Details of the criticality assessment approach can be found in our Health and Criticality Method (D2018/72550).

3. Asset objectives and performance

The Strategic Asset Management Plan (SAMP) defines the Asset Objectives and how they support Power and Water achieving the corporate objectives. This section shows how the Asset Objectives are supported by this asset class by establishing the measures and targets to assess if the Asset Objectives are being achieved, and any gap in performance that needs to be addressed.

Table 4 states the asset management objectives from the SAMP, identifies whether they are relevant to this asset class, and defines the measures of success, targets and performance gaps. This provides a 'line of sight' between the discrete asset targets and Power and Water corporate Key Result Areas.

The performance shown here represents the historical performance of the asset class to date. It is expected that benefits from investments proposed in the next regulatory period will manifest as benefits in these key objectives.

Objectives	Measures	Targets	Performance
Ensure appropriately skilled and qualified staff are employed to meet the current and future needs of the network. Embed a fit for purpose Asset Management System across the business that is consistent across Regulated, Non-Regulated and IES.	A capability development plan will include the requirements to ensure each asset class has defined capability requirements to enable effective management and performance. The development of our Capital and Operational Works Plan (COWP) will define capacity requirements across different capabilities to achieve asset management objectives.		
Maintain the safety of customers, community and staff demonstrated by reducing worker and public safety incidents and implementing public incident reporting metrics into asset plans.	Public injuries	0	0
	Worker injuries	0	0
	Km cable replaced (NMP1)	As per program (approx. 7.5km pa)	4.3km in FY22
Reduce by 50% the number of feeders and communities exceeding performance targets by more than 100% by 2025. Enable greater visibility of planned and unplanned interruptions to customers through improved online services for all networks and improve accuracy and transparency of	SAIDI and SAIFI targets.	Target by feeder type as set by the Utilities Commission.	Targets achieved. Refer to section 3.2

reliability performance metrics for isolated remote communities.			
Implement risk quantification for all regulated network (system) capital investment decisions by Jan 2023, and extend for remote generation and networks by 2025.	Implementation of risk quantification for decision making.	Use of Risk Quantification to assess investment needs for all aspects of the asset fleet.	Achieved.
Implement by EOFY 2023 asset criticality process to support granular prioritisation of corrective works based on public safety, reliability, security and other factors, and implement in the AMS and supporting systems by 2025	A quantitative criticality assessment criterion that can be integrated into defect management processes and supported by our ICT systems to be developed for all asset classes.		
Preparing our network and systems to be ready for the future, including building in flexibility for future uncertainty, maximising hosting capacity for customer DERs and enabling the energy transition to reviewable energy according to the governments targets.	Development of specific capability requirements for various asset classes is a key focus of our Future Networks Strategy to support increased utilisation of DER while maintaining safety and reliability performance.		

Table 4 - Asset Management Objectives

3.1 Reliability performance

The Utilities Commission requires Power and Water to report performance against targets for SAIDI and SAIFI, by feeder category and network region. Power and Water does not disaggregate the feeder category targets by asset class. Instead, assess the performance of each asset class to identify trends that require further analysis, and to determine if a specific program of works is required to support achievement of our targets at the feeder category level.

From a whole of system perspective, Power and Water has continued to improve its performance, although there has been mixed performance in each feeder category and region. These trends are discussed in the SAMP and are the subject of the network reliability performance improvement strategy.

Figure 3 shows the historical and forecast performance of the cable asset class. The data shows that the average duration of interruptions experienced by customers due to cable failures has varied significantly from year to year, with some years having much higher or lower values compared to others. However, the overall trend is slightly downward.

The volatility and high SAIDI contributions were mainly due to the failure of high-voltage cables in the northern suburbs. The failures are related to a type-issue that results in accelerated deterioration of insulation and earth screen. To address the issue, Power and Water has implemented proactive cable replacement in the northern suburbs, using a risk-based prioritisation approach that takes into account the condition of the testing results as well as criticality based on demand and proximity to the public. This strategy is likely to reduce the number of cable faults and their SAIDI contribution over the next regulatory period.

Also contributing to high SAIDI were multiple failures of cable joints which were attributed to the one-off use of a particular type of HV joint kit. Most of these joints have since been replaced.

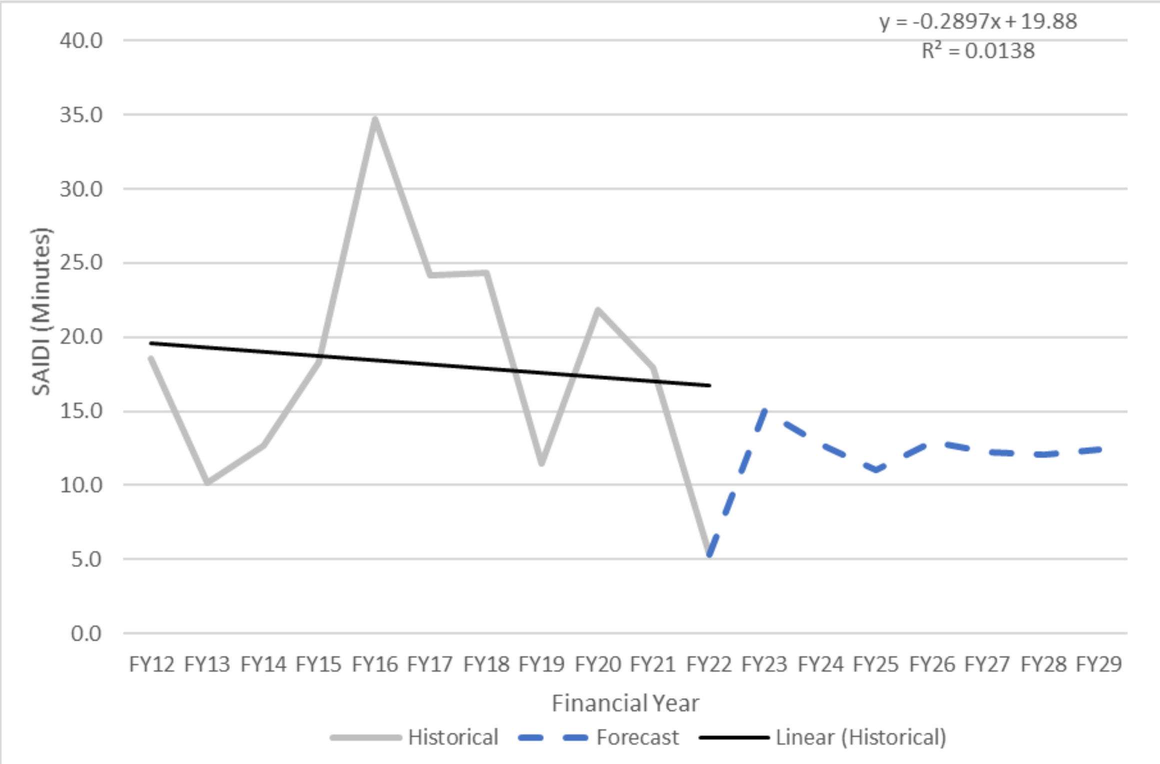

Figure 3 SAIDI performance of the cable asset class

3.2 Asset safety

The frequency of incidents involving cable damage associated with excavations is a key safety concern, especially considering the screen deterioration in the northern suburbs of Darwin. Cable screens ensure the fault return path is low impedance, enabling protection systems to operate as fast as possible to prevent injury or death to equipment operators, observers, bystanders, etc. Without continuous healthy screens, adjacent equipment or infrastructure are more likely to become part of the fault return path. As discussed, in sections 3.1 and 4.1, Power and Water have begun a risk-based replacement program to replace the affected cable.

There have also been a number of incidents resulting in an electric shock to members of the public, both in their residences and when contacting our assets. This has been largely due to high impedance neutral connections. To mitigate this safety risk, Power and Water have begun a review into testing and condition assessment requirements for neutral bonding, and this is expected to result in the implementation of a new maintenance strategy.

The number of safety related events associated with underground transmission and distribution cables for the past 10 years are documented in Table 5.

Category	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	Total
Dig in	1	4	8	5	3	4	11	8	3	6	**53**
Exposed	0	5	0	3	0	3	3	1	2	0	**17**
Shock	0	0	0	2	0	1	2	0	2	1	**8**

Table 5 - Safety incidents in the last 10 years

4. Asset challenges and emerging issues

4.1 Darwin northern suburbs HV XLPE cables

There are unique issues affecting XLPE cables installed in the Power and Water network. XLPE undergoes a degradation process called water treeing and an accelerated corrosion of the earth screen when exposed to moisture and electrical stress.

This is a particular issue for Power and Water, especially in the Darwin region, due to prolonged wet periods. Power and Water's XLPE cable fleet consists predominantly of the standard XLPE cable type (not tree-retardant). These cables are also unique in the fact that the screen conductors are aluminium which corrodes more readily than copper.

Significant cable failure contributions to reliability performance from the HV cable network in the northern suburbs of Darwin, combined with consistent reports from field crews on poor cable condition affecting the reparability of these cables, resulted in the launch of an investigation into the cause of these issues. The investigation confirmed the consistent poor condition of the cables and moisture ingress issues.

Cable tests undertaken as part of the investigations confirmed a widespread issue with cable earth screen continuity failures. Screen corrosion, as a result of water ingress and oxidisation of the aluminium screens, was identified as the main cause of the screen degradation. A strong correlation was also found between screen corrosion and cable fault events. The extent of the screen degradation will compromise the earthing system integrity in the northern suburbs, of which HV screens are the most critical part.

The cable issues significantly increase reliability and safety risk associated with cable failures and the absence of a reliable low impedance fault current path limiting the risk to people, equipment and system operation to acceptable levels.

A replacement program is already underway to address this issue.

4.2 LV cable network condition at Cullen Bay and Bayview

Investigations undertaken during 2016 and 2017 identified that the low voltage cables in the Cullen Bay and Bayview areas were of particularly poor condition with consistent sheath and insulation deterioration. The poor cable insulation condition has accelerated moisture ingress and the incidental development of calcium adipate. The level of deterioration of such a large proportion of cables is unprecedented based on their age and is considered a type issue unique to the cable installed.

The LV neutral earthing system in Cullen Bay is also compromised. The LV neutral conductor connection between a substation and the network being supplied is one of the fundamental components of the TN-C-S (Australia's MEN) network configuration, as described by AS/NZS 3000. As such, an LV neutral conductor is reticulated to all locations of the supplied LV network (Protective Earth and Neutral PEN). Throughout Australian utilities, this is generally achieved through the installation of a neutral conductor with each LV circuit leaving a substation, to ensure redundancy and interconnectivity of the MEN system. This is not the case in Cullen Bay where Neutral conductors are "shared", creating many single points of failure. Unlike the rest of Power and Water's LV network, Cullen Bay also lacks a dedicated LV earthing conductor which exacerbates this issue; since, in the event of a neutral failure, the current return path is restricted to local earth rods resulting in potentially hazardous voltages in the LV earthing system.

A replacement program has is already underway to address this issue.

4.3 66kV oil filled undersea cable to Mandorah

One of the two 66kV undersea oil filled cables supplying Mandorah failed in 2013 and was unable to be repaired. The cable was formally decommissioned in 2016, although Power and Water still retains the liability for the 7,000L of oil contained in the cable. The remaining in-service cable is in good condition for its age; however, the technology is becoming obsolete and skills to maintain and repair the cable are diminishing. Power and Water is fully reliant on interstate and potentially overseas support should a failure occur on this cable. The nature of oil-filled cable construction requires an immediate response to maintain oil pressure if a failure occurs, pumping large volumes of insulating oil into the cable at pressure.

The most prevalent risks to the remaining cable are physical impacts from ship anchors or onshore earthmoving equipment and storm surges associated with high intensity cyclones. Multiple failures of these cables due to these external factors have occurred, the first being Cyclone Tracy in 1974. However, the supply risk associated with the cables are low, mainly as result of low demands and standby generation permanently installed at the remote end zone substation.

The cable is forecast to reach end of life in FY30, at which time an alternative supply to Mandorah will be required in the form of a standalone power system (SAPS) or an extension to the 22kV overhead network. Due to the time required to construct a network extension or SAPS, investment in the most efficient solution should commence in 2030. Compared to a 100km overhead line, a SAPS is considered a preferable solution to a from a customer reliability perspective and may be lower cost depending on opportunities to reduce energy costs through renewable sources. Replacement of the undersea cable is cost prohibitive, noting the previous large customer no longer exists at Cox Peninsula.

4.4 66kV oil filled cable replacement (feeder 66 DA-FB)

The 66kV oil filled cable provides a critical function in maintaining security of supply to Darwin CBD. The cable has reached the end of its economic life with the technology becoming obsolete and skills to maintain and repair the cable diminishing, as described above. The replacement of the cable will likely be required in the next 10 years; however, the supply risk associated with the cable is currently low, mainly as result of system redundancy. Furthermore, recent condition assessment has identified that the cable is in reasonable condition for its age. If the cable fails in-service, it is likely replacement with XLPE would be initiated rather than attempting a repair. Given the reliance on external support and equipment for an oil filled cable repair, a replacement with XLPE cable would likely be the least cost option.

4.5 66kV XLPE cable replacement (feeder 66 BE-LE)

This 66kV XLPE cable is forecast to reach end of life and require replacement in FY31. Recent condition assessment has identified that the cable is in reasonable condition for its age and replacement is not required in the short term. The asset condition will continue to be monitored as the asset approaches end of life and the precise replacement timing will be adjusted accordingly.

4.6 Port Feeder replacement

An increase in failure rates have been observed on the 11kV Port Feeder in recent years. An investigation initiated by Power and Water identified consistent sheath damage, damage to the earthing screens and water ingress. DC Insulation Resistance tests and outer sheath electrical integrity tests further identified the degradation of the internal insulation and the outer sheath. The majority of failures have occurred in two sections of the 8km cable, theses sections will be targeted for replacement.

4.7 CBD cable tunnel condition

The Darwin CBD is supplied by cables which are installed in underground tunnels constructed of reinforced concrete. These tunnels are typically more than 30 years old, and a recent survey identified significant deterioration that is causing some safety hazards for field crews. If not addressed these issues will cause continued deterioration of the tunnel, shortening its serviceable life.

The key issues identified include water ingress, overload of sump pumps, corrosion of the steel reinforcement, corroded cable racks, decommissioned cables that are not removed taking up valuable space, and non-standard cable installations causing obstruction in the main tunnels.

The cable tunnel condition needs to be addressed to ensure the ongoing serviceability, safety and useful life of the cable tunnels. This is highly important given its function and the reliance of the CBD on these tunnels for secure and reliable electricity supply.

5. Implementation plan

The following set of projects and programs have been developed to address the gaps in asset performance compared to the asset objectives and our long-term view to start planning for forthcoming asset challenges.

5.1 Replacement expenditure

Replacement expenditure is defined as work to replace an asset with its modern equivalent where the asset has reached the end of its useful life. Capex has a primary driver of replacement expenditure if the factor determining the expenditure is the existing asset's inability to efficiently maintain its service performance requirement.

The identified projects and programs are listed below. The indicative cost (real FY22) of the project or program for the 10-year horizon is provided and includes the entire project, not only the cable component:

- All regions condition and failure-based replacement program ($ 55.6 million)
- Darwin northern suburbs high voltage cable replacement program ($49.8 million)
- Cullen Bay and Bayview low voltage cable replacement program ($6.8 million)
- Replace Port feeder ($0.8 million)
- CBD cable tunnel refurbishment ($0.9 million)
- Darwin to Frances Bay 66kV oil cable replacement ($4.7 million)
- Casuarina to Leanyer 66kV cable replacement ($9.0 million)
- Alice Springs network reconfiguration ($4.3 million)
- Centre Yard power system ($9 million)

5.2 Augmentation expenditure

Augmentation expenditure is defined as work to enlarge the system or to increase its capacity to transmit or distribute electricity. It also includes work relating to improving the quality of the network, for example, to meet regulatory obligations.

The identified projects and programs are listed below. The indicative cost (real FY22) of the project or program for the 10-year horizon is provided and includes the entire project, not only the cable component:

- Design and planning projects ($4.2 million)
- Overloaded feeders / distribution augmentation program ($6.1 million)

5.3 Operational expenditure

The forecast annual expenditure on maintenance activities is outlined in Table 6 below.

Maintenance Type	All Assets	Cables
Routine Maintenance	$7.0	$0.0
Non-Routine Maintenance	$7.7	$0.3
Emergency Response	$7.6	$1.1
Total	**$22.3**	**$1.4**

Table 6 - Forecast annual maintenance expenditure ($ Million FY22)

5.4 Delivery plan

There have been a number of challenges during the current regulatory period that have resulted in under-delivery of capital plans. Power and Water have undertaken a detailed analysis of our internal processes and activities to identify the causes and compiled a detailed plan to address this issue. The analysis and resulting plan to enable delivery of the proposed program of works is described in our Capital Delivery Plan.

6. Risk quantification and mitigation

Power and Water has established a Risk Quantification Procedure for Investment Decision Making to assess the overall risk posed by the asset fleet. Our procedure considers the asset's condition and failure modes, the likely risks of failure on safety, security and reliability of services to customers, and the relative maintenance and capital costs. In some cases, our decision making will be influenced by demand growth or customer upgrade requirements. Essentially, our decision making is based on an economic assessment of risks, costs, and benefits.

Figure 4 below shows our forecast of risk on the network that is contributed by the cables asset fleet. The unmitigated risk shows increasing risk cost if no actions are taken to address known issues. The mitigated risk shows the decreasing risk cost incurred if the suite of proposed programs is implemented. The current risk level provides a reference to the current level of risk.

The northern suburbs cables are the key driver of increasing risk in the unmitigated case. By addressing the known defect we are able to reduce network risk for this asset class. Our risk based economic analysis demonstrates that implementing the northern suburbs cable replacement program and reducing the contribution of risk cost is efficient and has a net benefit to our customers.

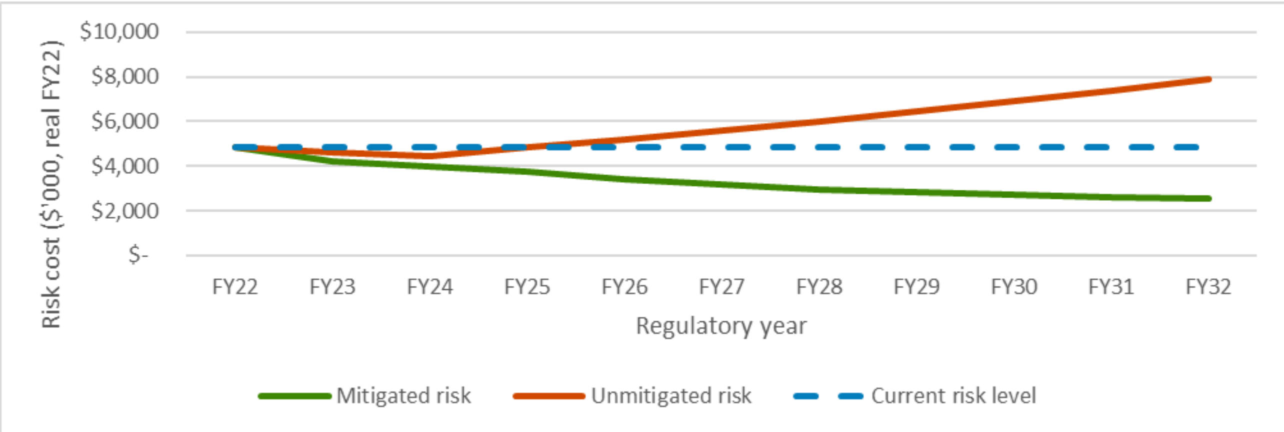

Figure 4 - Forecast total unmitigated and mitigated risk compared to the current risk level

7. Lifecycle asset management

Power and Water's asset management approach considers the entire asset lifecycle. This approach supports prudent asset management decision making to effectively balance risk, cost and performance over the life of the asset. The intended outcomes of a lifecycle approach are to:

- Maximise asset utilisation
- Minimise asset lifecycle costs
- Keep asset risk as low as reasonably practical
- Review and continuously improve asset management practices

The following sections detail Power and Water's lifecycle management activities.

7.1 Planning

Asset planning identifies the need for an asset, outlines its functional requirements, and identifies the lowest cost solution that maintains risk within tolerable levels. Key planning inputs include asset condition, performance, criticality, and forecast demand.

For cable assets, other planning considerations are route selection, capacity requirements and environmental and cultural heritage constraints.

7.2 Design

The design phase involves the detailed specification of the asset function and physical characteristics.

Power and Water develops and maintains standard designs and technical specifications for most distribution assets, including distribution cables, all new distribution assets installed in the Power and Water network must comply. Standardisation has many benefits, including staff familiarity, asset and component interchangeability, increased production and productivity, and standardisation of construction equipment and processes. This is especially the case for assets with a high volume of installation and replacement.

Continuous improvement in this design phase has been demonstrated in the change in cable standards and specifications over time, to adopt evolving technologies. Power and Water moved away from PILC cable to adopt XLPE cable as the new standard, the later inclusion of water blocking and termite protection layers, the change from aluminium to copper screens around the same time and the most recent change to water tree retardant XLPE (TR-XLPE).

Transmission cables have a relatively low volume and new assets are installed infrequently. As a result, Power and Water does not have standard designs for transmission assets. When required, we leverage the most recent industry standards and bespoke detailed designs for new transmission cables to optimise cable life and construction costs.

7.3 Maintenance

Asset maintenance involves the upkeep of assets to ensure they will function to their required capability in a safe and reliable manner from their commissioning through to their disposal. Maintenance requirements can evolve as the condition and performance requirements of the assets change throughout its life.

Maintenance activities can be classified into three distinct areas:

- **Preventative maintenance** involves the activities carried out to reduce the probability of failure or degradation of asset performance. It includes routine inspection and monitoring, upkeep and repair, testing and component replacements. Preventative maintenance requirements are documented in our Asset Strategies Procedure.
  - For cable assets, visual inspection of above ground assets such as switchgear, pillars and substations will include cable terminations, and thermography and partial discharge scans also identify defects.
- **Corrective maintenance** involves planned activities to repair defects or restore asset condition. Defects are typically identified during preventative maintenance and are prioritised for rectification based on the risk they pose to the network. Offline testing and condition assessment is also performed in response to failures.
- **Unplanned maintenance** involves activities to immediately restore supply or make a site safe in response to asset functional failure.

7.4 Renewal

Asset renewal is the establishment of a new asset in response to an existing asset's condition, or the extension of life of an existing asset. The need for asset renewal is typically identified during maintenance and is verified in the asset planning stage. Asset renewal aims to optimise the utilisation of an asset whilst managing the safety and reliability risk associated with the failure of the asset.

Where it is practical to do so, Power and Water has targeted asset replacement programs which aim to proactively replace assets when the risk of asset failure is higher than the cost of the replacement. In some cases, proactive replacement is not justified, and the asset is replaced upon failure.

Section 5 outlines the implementation plans relevant to underground cable assets.

7.5 Disposal

Assets are assessed for potential reuse prior to disposal. Where it is economical to do so, assets may be retained as essential spares or components of the asset salvaged for spare parts. This is particularly the case for legacy assets since like-for-like replacements may not be available. Assets with remaining value are offered for sale prior to disposal.

Unless required to be removed, cables are generally left in-ground when decommissioned. The civil works and disruption associated with removal of cables is cost prohibitive where direct buried. This approach is changing in cable tunnels as space required for new developments is constrained be decommissioned cables left in-situ. Cables are removed from conduits to enable re-use of the conduit and avoid extensive civil works for cable replacement wherever possible.

8. Continuous improvement

Table 7 below outlines the improvement plans related to the asset class.

Improvement Area	Today	Tomorrow / In Development	Future
Condition monitoring	Targeted and opportunistic cable testing including partial discharge, tan delta, screen integrity, insulation resistance.	Transmission cable preventative maintenance strategy improvements and online partial discharge.	Improved understanding of cable condition and forecasting end of life, particularly transmission cables
Asset inspection	Visual inspection of cable terminations, thermography and partial discharge scans.	Develop asset inspection manuals and training materials and competencies.	Improved defect categorisation and risk-based prioritisation
Defect prioritisation	Prioritisation using high level risk assessment and staff experience	Systemisation of asset criticality and improved failure codes	Risk based defect prioritisation supported by asset systems
Cable construction and installation	Industry standard construction Triplex configuration for cable replacement installation efficiency	Design review to identify improvement and cost efficiencies	Optimise cable construction and cost if possible to improve efficiency of cable replacement programs, new developments and potential undergrounding programs
Cable tunnel management	Limited inspection and maintenance regime Documentation gaps for storm water management	Condition assessment and documentation updates, including 3D scans and storm water integration mapping	Comprehensive life extension strategy and supporting documentation Improved resilience to extreme weather events and safer access

Table 7 - Asset improvement plan

Power and Water Corporation

Senior Manager Asset Management
Power Services
Phone 1800 245 092

powerwater.com.au