Asset Management Plan – SCADA and Communications

Power and Water Corporation

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Executive Summary

Power and Water Corporation (Power and Water) owns and operates the electricity transmission and distribution networks in the Northern Territory (NT) of Australia. Included in the networks are Supervisory, Control and Data Acquisition (SCADA) and Communication assets performing the critical function of providing visibility of the network to System Control which allows Power and Water to efficiently and safely operate the network. For brevity, this plan will refer to all assets within the specified scope as SCADA.

SCADA Assets only contribute a very small proportion to the total asset base *– and age compared to expected life is not a great concern.*

SCADA assets make up 2.3% of the total network value of the asset base and contribute to around 2.8% of the total operating expenditure. The asset fleet is positioned well with an average age of 13 years for long-term fixed infrastructure (shelters, structures and communication linear assets) with an average age of seven years for all remaining assets. The majority of the asset class is located in the Darwin-Katherine region, with the remainder distributed across the Alice Springs and Tennant Creek regions.

The scope of this AMP does not include other assets such as protection relays, circuit breakers, current and potential transformers or IT systems.

Assets operate across a diverse environment *– temperature, humidity, rainfall, termites, soil types present different challenges to managing the assets.*

The Power and Water power network is subject to unique environmental and operational challenges ranging from the coastal tropical environments prone to cyclones, high temperatures and humidity, and high annual rainfall, to desert environments subject to high ambient temperatures, occasional flooding, droughts, dust storms, and surrounding factors including high termite infestation and aggressive soil conditions. This unique environment results in a more rapid rate of asset deterioration, and lower worker productivity compared to peer distribution businesses.

There are five key challenges that require management *– asset obsolescence, asset management due to environmental challenges, IT/OT convergence, data collection, and adapting to rapid technological change.*

A key asset challenge is asset obsolescence related to end-of-vender support and meeting functionality standards required by Power and Water, NER and the Technical Code.

Diverse environmental conditions also result in many additional asset management challenges for ensuring that a reliable SCADA system is available at all times. Assets in less accessible areas of the network have an increased level of importance; as such additional battery capacity as well as the availability of mobile assets is required. Furthermore, some assets such as battery systems which operate in non-air-conditioned structures have a reduced expected life when operated in high ambient temperatures.

The integration of older SCADA assets with newer digital technologies into one cohesive system is an on-going issue for Power and Water. There is a long-term strategic goal to have LAN centres at all zone substations. These LAN centres will be installed alongside major development projects to reduce system downtime and the costs associated with asset augmentation/renewal projects.

Power and Water also acknowledges that they are in the process of maturing their approach to asset management and need to improve their asset data collection processes. The two key challenges are; the lack of comprehensive asset condition data, and that not all SCADA assets are recorded in Maximo (asset database). These data sources are required to fully understand the asset fleet and the impact that deterioration of assets has on the operational integrity and functionality of the assets. Power and Water plans include all assets in Maximo to develop suitable asset condition parameters and start recording asset condition data on a consistent basis.

***Investment programs are targeted to manage the key challenges** – directed replacement.*

The following asset renewal programs are proposed for the 2019-20 to 2023-24 regulatory period to address key asset challenges:

- SCADA and Communications Networks Technical Code Compliance [NMSC4]
- Battery system replacement [NMSC2]
- SCADA and communications asset replacement program [NMSC1]
- DKTL - Secondary systems upgrade of 132 kV substations at Manton, Pine Creek and Katherine [PRD32117]
- Energy Management System (EMS) Replacement Project [PRD33134]
- Zone substation and key asset replacement programs with SCADA components
  - Berrimah ZSS replacement
  - Humpty Doo ZSS
  - Centre Yard ZSS
  - Cosmo Howley transformer replacement
  - Weddell transformer replacement

The renewal programs have been developed with the objective of maintaining risk over time. To achieve this, an asset health and criticality framework was developed that provides for a consistent method of assessing assets and making value based investment decisions. The health and criticality framework was central to establishing the targeted SCADA investment programs focusing on the highest risk assets as a priority. The SCADA investment programs are summarised as follows:

Table 0.1: Summary of SCADA investment programs over the coming regulatory period

Investment category	2019-20 ($ million)	2020-21 ($ million)	2021-22 ($ million)	2022-23 ($ million)	2023-24 ($ million)	Total ($ million)
Renewal	$1.52	[redacted]	[redacted]	[redacted]	$0.84	[redacted]
Augmentation	$0.53	$0.53	$0.53	$1.53	$0.53	$3.65
Maintenance Plans	$2.22	$2.22	$2.22	$2.22	$2.22	$11.10
Total	$4.27	[redacted]	[redacted]	[redacted]	$3.59	[redacted]

The increase in expenditure in 2021-22 is due to the replacement of the obsolete Energy Management system.

Benefits from the investment programs *– maintain reliability.*

The investments are expected to maintain reliability of SCADA assets at current levels. The investment program targets the highest risk assets with consideration of other works as appropriate to optimise workforce scheduling and address priority defects. The program is expected to materially impact the risk profile of SCADA assets.

The investment will also meet the longer-term strategy to improve operational monitoring and control that will enable improved operational performance of network assets.

Network risk – *as related to investment & improvement programs.*

Network risk is the combination of asset health and criticality. This identifies that there are 97 SCADA assets with a moderate risk rating and no assets assessed as either high or extreme risk. Most assets are of low or very low risk.

Table 0.2: SCADA asset health - criticality matrix for discrete asset categories

	H1	H2	H3
C1	728	49	59
C2	0	0	0
C3	38	0	0

Table 0.3: SCADA asset health - criticality matrix for communication linear assets (km)

	H1	H2	H3
C1	376,061	0	0
C2	0	0	0
C3	0	0	0

Risk legend				
Very low	Low	Moderate	High	Extreme

The assets driving the moderate risk are either non-critical assets which have exceeded their expected life (C1 & H3) or critical assets with an acceptable health rating (C3 & H1), these assets are listed below alongside a summary of Power and Water's risk mitigation plan.

C1 & H3 moderate risk assets:

- 23 RTU's; with the following to be decommissioned as part of these programs;
  - 4 - DKTL secondary systems upgrade (section 9.4)
  - 4 - planned asset replacements (2018/19)
  - 2 - decommissioning of the West Bennet and Austin Knuckey switching stations
  - 1 - Humpty Doo ZSS upgrades (section 9.5)
  - 1 - Berrimah ZSS upgrades (section 9.5)
- 22 UHF systems
  - All to be decommissioned in 2018
- 8 battery systems
  - 2 – planned asset replacement (2018-19), with another 4 being considered for replacement.

- 4 teleprotection assets
  - All to be replaced as part of the DKTL secondary systems upgrade program outlined in section 9.4.
- 1 power supply
- 1 PDH multiplexor

The remainder of these assets are to be placed on Power and Water's asset life extension policy.

C3 & H1 moderate risk assets (these assets are to be carefully monitored to help minimise the potential for asset failure):

- 20 master station assets (6 process coolers, 7 UPS, 7 EMS hardware / software assets)
  - EMS assets will move into the H3 category over the coming regulatory period. Power and Water has planned the EMS replacement project (section 9.5) to ensure that this critical system is safe, reliable, and improves functionality to meet Power and Water's developing asset management program.
- 18 structures

The risk profile snapshots have been based on the current understanding of SCADA asset's age, condition, and operating environment. The risk profile is expected to evolve as ongoing condition and performance monitoring, methodical inspections, and improved data collection practices provide for better quality data and asset insights.

Performance indicators have been established for Operational Performance, Health & Safety, People & Culture, and Financial Performance. Targets are currently being met.

1 Purpose

The purpose of this asset management plan (AMP) is to define Power and Water's approach to managing SCADA equipment. It frames the rationale and direction that underpins the management of these assets into the future:

- Short Term (0-2 years): Detailed maintenance and capital works plans for the upcoming financial year based on current asset condition.
- Medium Term (3-7 years) 2019-24 Regulatory Period: Strategies and plans based on trends in performance and health indicators.
- Long Term (8-12 years) 2024-29 Regulatory Period: Qualitative articulation of the expected long-term outcomes.

The SCADA and communications assets are managed to comply with the broad external requirements of legislation, codes and standards. This is achieved within an internal framework of policy, strategy and plans that are enabled through interrelated documents, systems and processes that establish the Power Networks asset management practices. The asset management system is summarised.

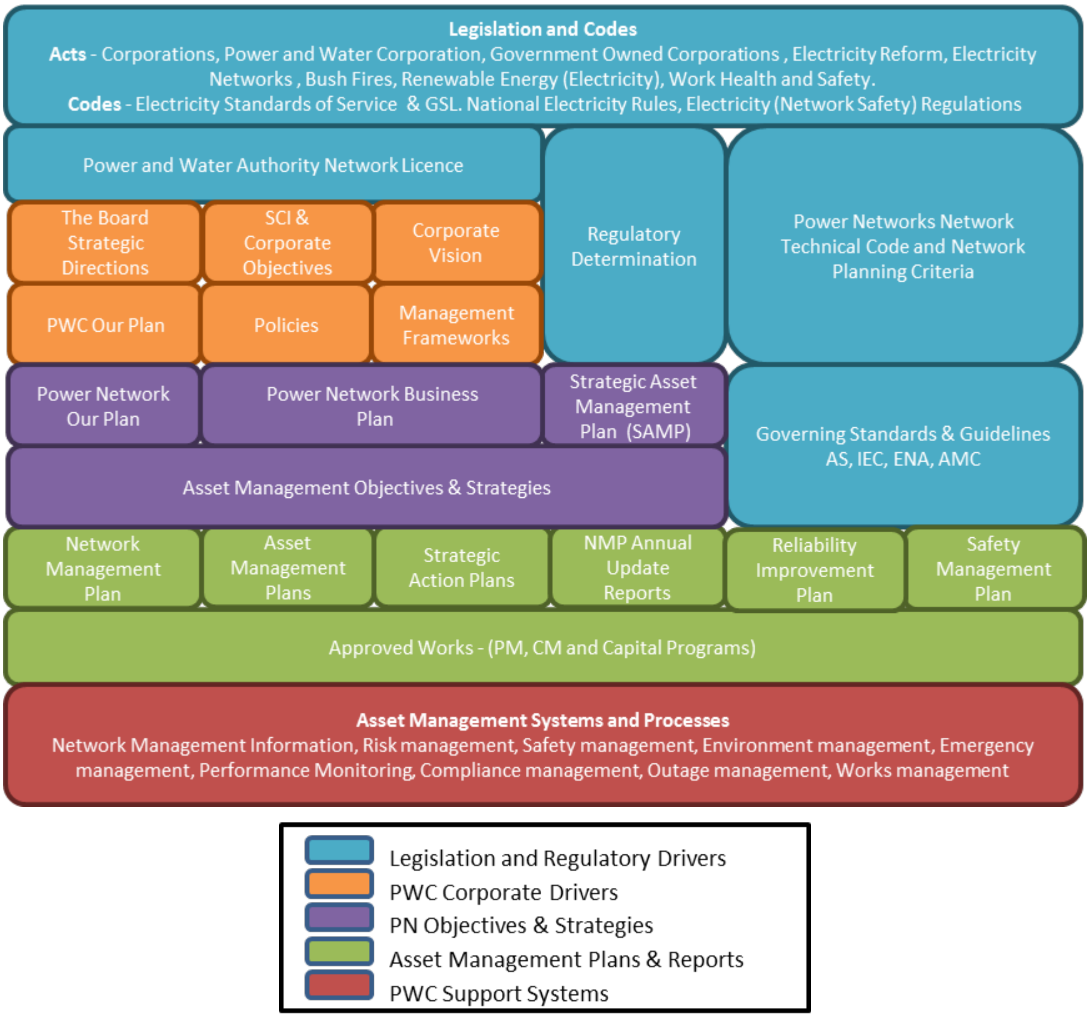


Figure 1.1: Asset Management System

2 Scope

2.1 Asset class overview

This AMP covers all supervisory control and data acquisition (SCADA) and communications assets located throughout Power and Water's power network. Table 2.1 provides an overview of the in-scope asset fleet separated into their respective asset categories. The scope does not include other assets such as protection relays, circuit breakers, current and potential transformers, or IT systems. A full description of all asset types is provided in section 4.2.

Non-regulated assets amount to a negligible proportion of Power and Water's SCADA and communications assets, all of which are located at the Jabiru, Ranger and Yulara zone substations. Therefore, the analysis throughout this AMP combines regulated and non-regulated SCADA assets unless otherwise specified; for brevity, this AMP will refer to all assets within the specified scope as SCADA.

Table 2.1: Overview of in-scope regulated assets

Asset category	Asset description	Quantity	Average age (years)	Average nominal lifespan (years)	Percentage exceeding lifespan
Field devices	RTUs	111	9.47	15	20.72%
Communications network assets	Management systems	8	3.50	6	0%
	Microwave links	54	4.96	15	0%
	DWDM systems	5	5.60	15	0%
	SDH multiplexors	63	6.33	15	0%
	PDH multiplexors	149	7.78	15	0.67%
	UHF system	61	12.20	14.08	36.07%
	Telemetry systems	65	5.83	15	0%
	Teleprotection systems	74	9.00	16	5.41%
Master station assets	EMS	7	3.00	6	0%
	Server/equipment room	13	6.92	15	0%
Communications site infrastructure	Power supply	78	5.67	15	0%
	Battery systems	107	5.92	12.08	0%
	Solar system	22	6.95	20.45	0%
	Shelters	28	20.46	40	0%
	Structures	18	20.28	50	0%
Communications	Fibre cable	291,282(km)	11.50	40	0%

Asset category	Asset description	Quantity	Average age (years)	Average nominal lifespan (years)	Percentage exceeding lifespan
linear assets	Pilot cable	84,779(km)	26.16	50	0%
Other	Substation LAN	11	2.36	15	0%

Power and Water's SCADA assets are distributed throughout its network footprint, which covers three regions of the Northern Territory (NT): Darwin & Katherine, Alice Springs and Tennant Creek.

Table 2.1 shows that many SCADA assets are relatively new and have been replaced in tandem with zone substation renewal projects undertaken within the past 10 years. However, there are some asset types such as, RTUs, UHF systems and teleprotection systems that have reached, or are approaching, end of life and should be monitored carefully over the coming regulatory period.

The asset base, health and criticality, and key challenges are discussed in detail in sections 4, 5 and 6 respectively. Asset augmentation, renewals and maintenance are discussed in sections 8, 9 and 10; these sections are used to show how the performance targets, which are outlined in section 7 and 10.2, will be met. The remaining appendices provide in depth supplementary information.

2.2 Asset class function

SCADA is critical in providing visibility of the network to System Control which allows Power and Water to efficiently and safely operate the network. SCADA is comprised of multiple assets classes which gather information regarding voltages, currents and the status of assets. The information is displayed visually to System Controllers, enabling them to take appropriate actions during system faults or incidents, and allows them to work with operational staff to conduct day-to-day activities.

Faults are isolated allowing for the restoration of the network to occur in a timely manner whilst minimising the risk of significant system outages and ensuring the electrical assets are not significantly overloaded.

SCADA assets provide the following functions:

- Enable isolation of faults and restoration of supply following an unplanned outage
- Undertake network switching for planned outages
- Secure operational data communications to enable effective and efficient day to day operations
- Ensure safe work practices through a coordinated network management system
- Provide systems which can continually monitor and control the network and network loading.
- Provide communications services for the teleprotection systems between sites
- Site security through site access controls and monitoring.

2.3 Asset objectives

The AMP provides a framework which steers the management of the asset class in a manner that supports the achievement of Power and Water's broader organisational goals. The Asset Management strategies are listed in the Strategic Asset Management Plan (SAMP) and are aligned to the Asset Management Objectives and implemented in through Asset Management Plans (specific to asset class) or Strategic Asset Plans as shown in Figure 2-1.

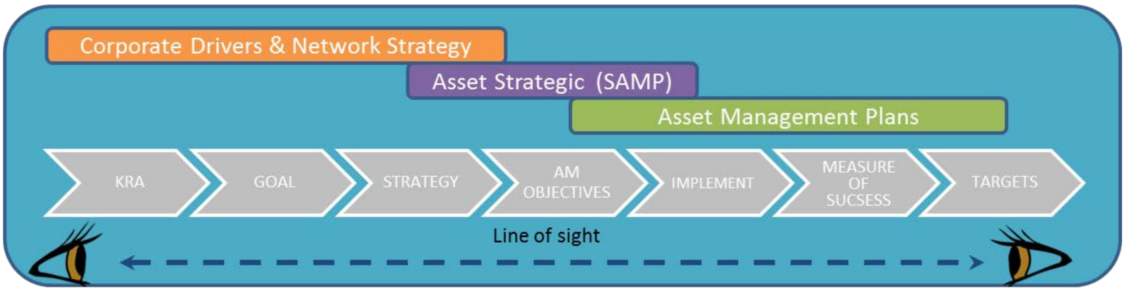


Figure 2-1: Asset Management Line of sight from Corporate and Network strategies through the Asset Management objective to the targets in the asset management plan.

Table 2.2 provides the asset management objectives from the strategies that are relevant to this asset class along with the measures of success and the targets. This provides a 'line of sight' between the discrete asset targets and Power and Water corporate Key Result Areas.

Table 2.2: Asset Management Objectives, Measures of Success and Targets

Objectives	Measures	Targets
• Network related operation and maintenance tasks are quantified in terms of risk and used to inform investment decisions that affect Health and Safety outcomes for the organisation	• Total asset class specific safety incidents	• Total asset class specific safety incidents not exceeding TBA
• Ensure that the systems and processes provide sufficient and appropriate data and information to drive optimal asset and operating solutions. • Minimise disruption to supply availability and quality in the event of system faults or abnormal operating conditions	• Asset class contribution to system SAIDI • Asset class contribution to system SAIFI • GSL contribution per year Guaranteed Service Levels	• SAIDI to be no more than 0.26% for this asset class. • SAIFI to be no more than 0.6% for this asset class. • GSL contribution per year TBA
• Ensure that the systems and processes provide sufficient and appropriate financial data • Understand the financial risks associated with asset management	• Variance to AMP forecast CAPEX • Variance to AMP forecast OPEX	• Variance to AMP forecast CAPEX +/-10% • Variance to AMP forecast OPEX +/-10%
• Develop systems and data that facilitate informed risk based decisions • Ensure that works programs optimise the balance between cost, risk and performance • Ensure the effective delivery of the capital investment program	• Network risk index quantified (Y/N) • Health and Criticality Parameters defined (Y/N)	• Achieved
• Identify, review and manage operational and strategic risks • Prioritise projects, programs and plans to achieve efficient and consistent risk mitigation. • Achieve an appropriate balance between cost, performance and risk consistent with	• Critical spares analysis completed for asset class • Operator/Maintainer risk assessment completed for asset class and risk register updated	• Achieved

Objectives	Measures	Targets
regulatory and stakeholder expectations. • Define and communicate the level of risk associated with the investment program		
• Ensure that electricity network assets are maintained in a serviceable condition, fit for purpose and contributing positively to Power Networks business objectives.	• All staff are trained and hold appropriate qualifications for the tasks they undertake. • Peer benchmarking, i.e. a reasonableness test of underlying unit costs (capex, opex) • Compliance breaches with the relevant legislation / regulation / standards. • Asset class preventative maintenance completion	• Achieved
• Provide for appropriate and timely responses to system outages and disruptions through automation or the efficient dispatch of field staff. • Manage operational and associated systems securely and in-line with best practice	• Annual SCADA service interruptions (minutes)	• Annual SCADA service interruptions (minutes) TBA
• Provide communication services with levels of availability and reliability appropriate for our operations. • Manage operational and associated systems securely and in-line with best practice.	• Availability of communications backbone • Number of cyber security breaches	• TBA

3 Context

3.1 Roles and responsibilities

Power and Water operates using an "Asset Owner / Asset Manager / Service Provider" business model. Although there is extensive collaboration and interfacing between the roles, generally:

- The Asset Owner establishes the overall objectives for the assets
- The Asset Manager develops the strategies and plans to achieve the objectives
- The Service Provider performs activities on the ground to deliver the plans.

3.2 RACI

The Responsibility, Accountability, Consulted, Informed (RACI) matrix for the poles and towers asset class is provided in Table 3.1.This defines the roles and accountabilities for each task by allocating to specific roles/personnel in Power and Water.

Table 3.1: RACI matrix for SCADA

Process	Exec GM Power Networks	Group Manager Network Assets	Chief Engineer	Network Planning Manager	Major Project Delivery Manager	Group Manager Service Delivery	SCADA & Communications Manager	Works Management Manager	Strategic Asset Engineering	Asset Quality & Systems	Business and Information Systems	System Control
Establish Condition Limits		A	C	C		I	C/I	I	R	I		
Performance and condition data analysis	I	A	I	I		I	I	I	R	I		C/I
Plan capital works (Options, costs, BNIs, BCs etc)	I	R	A		C/I	R	R	R	R	I	C/I	C/I
Execute maintenance plans	I	I	I			A	R	R	C/I	I		C/I
Deliver identified major projects and programs	I	C	A	C	R	R	R	C/I			C/I	C/I
Manage asset data (data entry, verify data)		A	I	I			R		C/I	R		
Monitor delivery of capital plans and maintenance	I	A	I	I	I	R	R	R	R	R		
Cyber Security Management	I	A	I			I	R		I	I	C/I	

- *Accountable **(A)** means the allocated person has an obligation to ensure that the task is performed appropriately*
- *Responsible **(R)** means the allocated person must ensure the task is completed*
- *Consulted **(C)** means the allocated person must be included in the process for input but do not necessarily have specific tasks to do*
- *Informed **(I)** means this person must be kept up to date with progress as it may impact other parts of their responsibilities or accountabilities.*

4 Asset base

4.1 Overview

SCADA components are critical to providing visibility of the electrical network which allows system control to efficiently and safely conduct day-to-day switching of the network.

Power and Water's SCADA assets vary by type, model, function, age, location and many other factors within the network. This variety results in unique risk profiles, and thus unique expenditure and management implications. Descriptions of SCADA asset types are outlined below.

4.2 Asset types

A brief description of all in scope asset types is provided below within their respective asset category.

4.2.1 Field devices

Remote Terminal Units (RTU)

Remote Terminal Units (RTUs) typically exist at substations and are the interface between the substation assets such as Circuit Breakers and Transformers and the Master Station. The RTU monitors digital and analogue inputs and can control digital outputs. The RTU provides the status of these points back to the Master Station for display to the operator. Operators can also change the status of a device via the Energy Management System (EMS), such as opening or closing a Circuit Breaker.

RTU assets include Human Machine Interfaces (HMI): A display device in the substation which provides local monitoring and control of the substation assets via the RTU.

RTU assets include GPS Clocks: Provides a highly accurate (sub millisecond) time signal to ensure all RTUs are operating in synchronisation. This is critical when analysing protection events on the system by ensuring that common time reference exists.

Management systems - Communications Network Management System (CNMS): Timely response to faults ensures tele-protection, SCADA and two-way radio voice systems are returned to service a quickly as possible; currently a reliance on 'user' reporting of failures still exists. This reliance is steadily decreasing. The CNMS system also allows remote configuration of equipment leading to a reduction of the requirement to attend sites to make minor system changes. Increasingly IT standards for equipment and systems are being adopted within the utility sector to ensure standardisation of service delivery and quality.

Key functions of the CNMS include:

- Monitors the health of the majority of the operational telecommunications network (OTN)
- Provides early alerts to faults or deterioration in the OTN
- Allows timely response to faults within the OTN

- Provides the tools for efficient configuration and deployments of equipment and services to defined standards.

Microwave links – includes antennas and feeders: Antennas and associated coaxial feeders are key components of microwave and UHF radio systems. Periodic assessment of these components is required to ensure the ongoing operation of the associated system.

Dense Wave Division Multiplexor (DWDM) systems: A communications system capable of providing very high capacity communications services. It multiplexes different wavelength light signals onto one fibre optic pair. It is very useful where limited fibre optic cable capacity exists.

Synchronous Digital Hierarchy (SDH) multiplexors – includes GPS clocks: SDH Multiplex systems provide high capacity communications services. They combine a large number of lower bandwidth services (2 megabit) into a high capacity service which typically uses fibre optic cables as the bearer. They also have some inherent features which are very useful for high reliability communications such as automatic fault switching when configured in a ring topology.

Plesiochronous Digital Hierarchy (PDH) multiplexors: A low capacity multiplexor (2 megabit) which combines up to 30 * 64kbit/s services. The output of the PDH multiplexor is typically an input into a SDH multiplexor to allow further aggregation.

Services typically provided by a PDH multiplexor include:

- Teleprotection
- SCADA
- Serial data circuits for telemetry to field devices
- Access to Digital Data Recorders
- Low through-put Ethernet services for OTN system monitoring
- UHF radio site interlinking services
- Corporate IT access to substations
- Some POTS (telephone) services and hot-lines.

UHF systems - includes core sites and repeater sites: a number of UHF radio based systems exist:

- A UHF 2 Way radio system is used to manage operational activities within the electrical network and for crew dispatch to faults. The UHF radio system consists of a server based central core and the 2-way radio transceivers and associated ancillary equipment.
- A number of UHF radio based telemetry networks exist. These are typically point to multipoint UHF radio systems which allow the monitoring and control of field devices via an interface back into the SCADA EMS.

Power Line Carrier (PLC): provides a small number (two to three) of dedicated tele-protection circuits between zone substations. PLC uses the transmission line wires as its communications bearer. PLC is not suitable for high capacity communications but is sometimes used as one of the duplicate independent tele-protection circuits provided. Typically a PLC and microwave or fibre system may be used where the provision of two microwave systems, two fibre systems or a fibre and microwave system is not economically feasible.

Teleprotection systems

Teleprotection systems provide a high speed signal between two substations protection systems where the protection scheme used requires it. A number of teleprotection systems are used with legacy equipment:

- RFL;
- DIMAT (TPD15); and
- Nokai (TPS64).

The current standard teleprotection equipment in use is the DIMAT DM1200.

4.2.2 Master station assets

Energy Management System (EMS)

The Energy Management System (EMS) is the system that provides the user interface and data visualisation for System Controllers. Using the EMS, system controllers can locate any specific asset, view its status and remotely operate it. The EMS also records all operations for reporting purposed and enables advanced planning of network operations.

The EMS consists of:

- Software applications used to visualise and manage the electrical network
- Software applications used to configure, manage and maintain the EMS applications and the hardware
- Computer servers which host the various software applications and ancillary software applications required to configure, manage and maintain the EMS.

Server/equipment room – Uninterruptible Power Supply (UPS) and process coolers

This ancillary equipment is required to provide a stable environment for the EMS equipment to operate within.

4.2.3 Communications site infrastructure

Power supply - includes rectifiers, converters

Power supplies convert AC power to DC power to maintain the batteries in a fully charged state. In some sites, converters are required to convert one DC voltage to another; e.g. 48VDC to 12VDC where the equipment operating voltages require it. The longer term aim is to have all equipment with the same operating voltage (48VDC).

Battery systems

Communications battery systems are a critical sub system for the correct operation of the OTN. They provide the power supply to the electronic SCADA devices so that they continue to operate if there is a network outage. Battery systems are duplicated to ensure the reliability of the network.

Solar systems - includes frames

Solar panels systems are used to charge batteries in remote locations. Solar panels arrays are located at:

[redacted]

Shelters – stand-alone communication sites

In remote areas where SCADA is required but cannot be located within a zone substation, it can be housed in dedicated stand-alone communication sites. Several different types of shelters exist:

- Steel clad foam sandwich prefab of various sizes (passively cooled)
- Steel clad foam sandwich prefab of various sizes (not passively cooled)
- Concrete block construction
- Shipping containers for battery rooms

Structures (towers and masts)

The structures category includes towers and masts as well as other associated assets, such as access roads or tracks and compound equipment (security fencing), that are required for the operation and maintenance of the towers and masts.

The majority of guyed towers in use were installed around 1988-1989 and the designed wind loading was for gridpack parabolic antennas suitable for low data capacity microwave radio systems and omni-directional antennas for 2-way radio systems. In subsequent years, the guyed towers have been re-designed and strengthened to support additional wind loads as larger diameter and/or solid parabolic antennas and additional omni-directional antennas were required to support increases in the system capacity and availability.

4.2.4 Communications linear assets

Fibre cable – Underground and Optical Pilot Ground Wire (OPGW)

Fibre optic cables (underground and OPGW) are used to connect network devices to the master station. The fibre optic cable is fully owned by Power and Water and Power and Water leases the majority of the fibre cores to Optus. In Alice Springs, Power and Water utilises [redacted] in some locations.

Pilot cable

Pilot (copper) cable is used primarily for analogue differential protection schemes.

4.2.5 Other

Substation Local Area Network (LAN)

The substation LAN allows all substation equipment to be remotely accessed to allow configuration management and post event data to be accessed.

4.3 Breakdown of asset population

SCADA assets vary greatly in make, model and type due to the diverse range of functions that are required for the reliable and safe operation of Power and Water's network.

4.3.1 Expected life of assets

The expected life of SCADA assets varies greatly due to the mixture of digital assets as well as long life fixed structures. A breakdown of the expected asset life of SCADA assets is shown in Table 4.1 and Table 4.2.

Table 4.1: Expected life of SCADA assets

Equipment type	Asset life (years)
Towers/masts	50
Pilot (copper) cable	50
Fibre cable	40
Shelters	40
Solar panels	30
PLC line plants (teleprotection)	30
Power supplies	15
Solar regulators	15
PDH multiplexors	15
DWDM terminals	15
SDH equipment	15
Teleprotection	15
Telemetry devices	15
RTU	15
Process coolers/UPS	15
UHF radios (base stations and mobiles)	15
Microwave equipment	15
UHF radios (handhelds)	10
UHF core servers and networking equipment	7
Network Management Hardware	7
Network Management Software	5

Table 4.2: Expected life of SCADA batteries

Batteries	Asset life (years)
7OPzV600	18
8OPzv960	18
A600/720	15
SBS580	15
SBS320	15
A406/165	12
UXF-150-12	10
PS1270	10
G85	10
A212 / 9.5	10
SB6330	7

4.4 Asset profiles

4.4.1 Asset installations profile

The number of new SCADA assets installed each year since 2010 is shown in Table 4.3. The key drivers for new asset installations have been the augmentation or renewal of zone substations and power transformers. These figures also include asset replacement due to failure and targeted replacement programs.

Table 4.3: SCADA discrete asset installations

	2010	2011	2012	2013	2014	2015	2016	2017
Number of installations	98	64	45	48	59	51	73	42

Table 4.4: SCADA communications linear asset installations (km)

	2010	2011	2012	2013	2014	2015	2016	2017
Number of installations	71,766	856	17,414	16,292	19,134	39,765	9,472	240

Since 2010 Power and Water has carried out a number of zone substation renewals. These substations typically contained old SCADA assets that were at, or approaching, their end of life. Therefore, Power and Water aligned the replacement of the SCADA equipment with the substation renewal. This approach has two key benefits; it ensures both asset compatibility and cost-efficiency.

4.4.2 Age profiles

Asset age profiles provide an overview of the SCADA asset fleet in its current state.

All SCADA assets

It is important to note that electronic/digital SCADA assets have relatively short functional lives (such as CNMS or the Energy Management System) whereas structures, shelters, and cables have expected lives of up to 50 years.

Figure 4.1 shows the age profile of all discrete SCADA assets on the network and Figure 4.2 shows the asset age of the communication linear assets by length of cable (km). These figures highlight that 54.92% of the assets fleet has been installed within the past 10 years.

It is important to note that electronic/digital SCADA assets have relatively short functional lives (such as CNMS or the Energy Management System) whereas structures, shelters and cables have expected lives of up to 50 years.

Figure 4.1: Asset age profiles for discrete asset categories

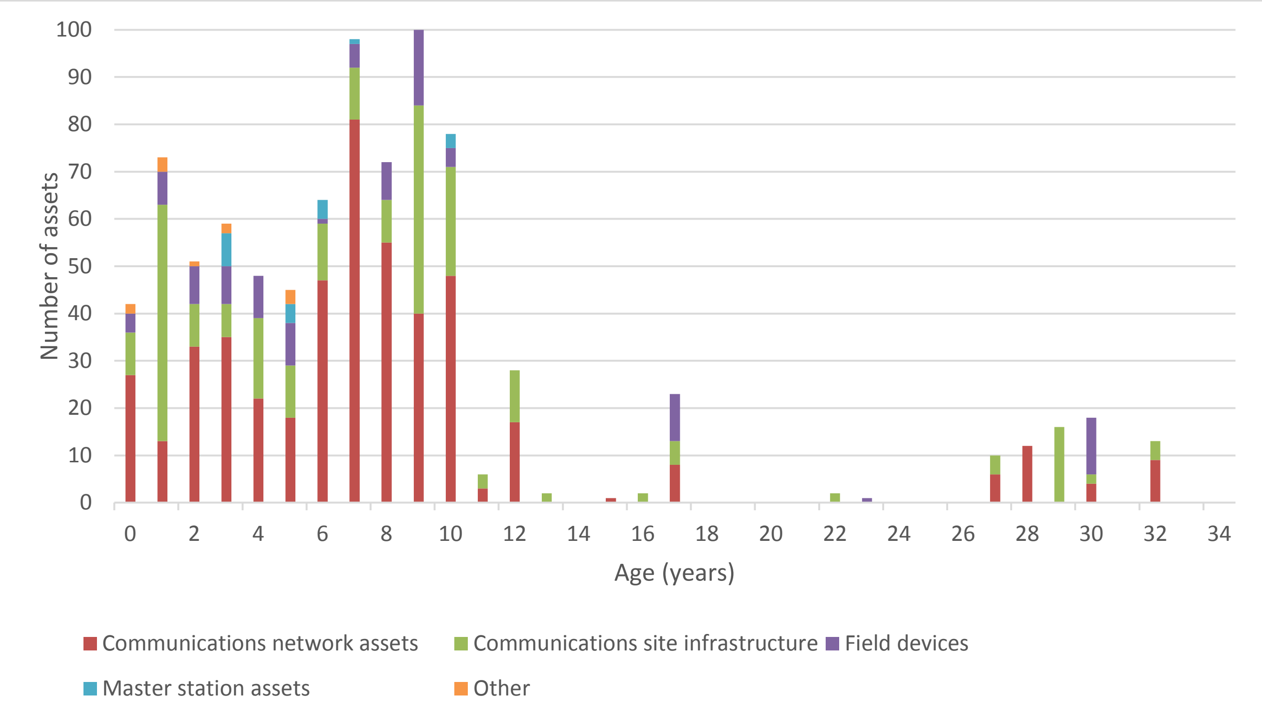
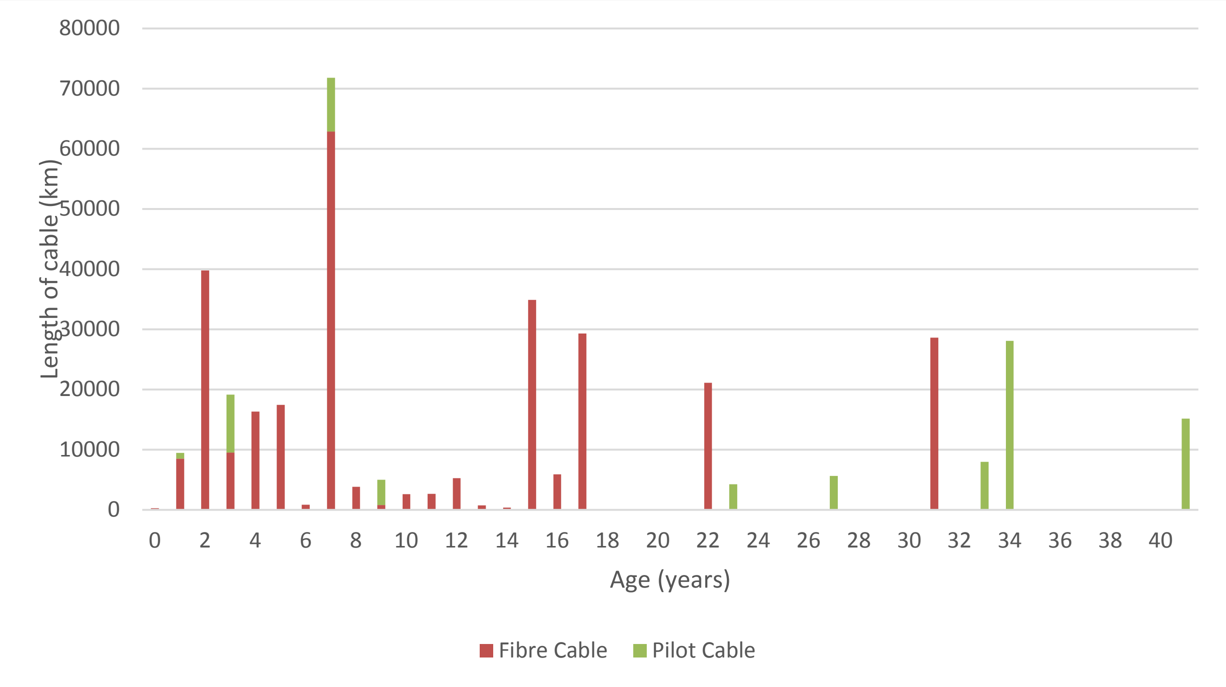


Figure 4.2: Communications linear assets age profile



Further age profiles broken down into asset categories as well as their respective asset types are provided in Appendix B – Asset data.

5 Health and criticality profiles

This section discusses the health and criticality of SCADA assets and the resulting network risk. This analysis informs the priorities for Power and Water with respect to where they should focus further condition assessments and future network investments.

The health and criticality framework provides the basis for calculating the risk associated with SCADA assets. Risk is the product of the probability of an event occurring (determined by asset health) and the consequence should it occur (determined by asset criticality). Network risk can be reduced though improving the condition of assets (opex or repex) and/or by reducing the consequence of failure through changing the network topology/configuration.

Power and Water manages network risk so it can operate the network safely and reliably at the lowest cost to customers.

5.1 Asset health

This section discusses the health of the asset fleet. Power and Water currently assesses asset health by the relative age of an asset compared to its expected life. Overall, SCADA assets are performing reliably with only a few assets replaced each year due to failure. This aligns with experience of other DNSPs in Australia.

To aid in the future assessment of asset health, field crews will begin undertaking condition assessments during routine inspections focusing on batteries and non-electronic assets such as cables and shelters. Power and Water engineers are further assessing the viability and potential value of developing conditional assessments for electronic assets; if prudent Power and Water will begin to collect this data over the coming regulatory period.

This will improve Power and Water's ability to extend the life of assets which remain in good condition whilst replacing those which have deteriorated faster than expected. This process will improve network reliability, minimise risk and reduce asset management costs.

5.1.1Asset performance (reliability)

SCADA asset performance and network reliability is measured by tracking the number of asset failures, as well as analysing SCADA's SAIDI and SAIFI contribution to network performance. These measures are discussed below.

Figure 5.1: SCADA's contribution to NT SAIDI / SAIFI

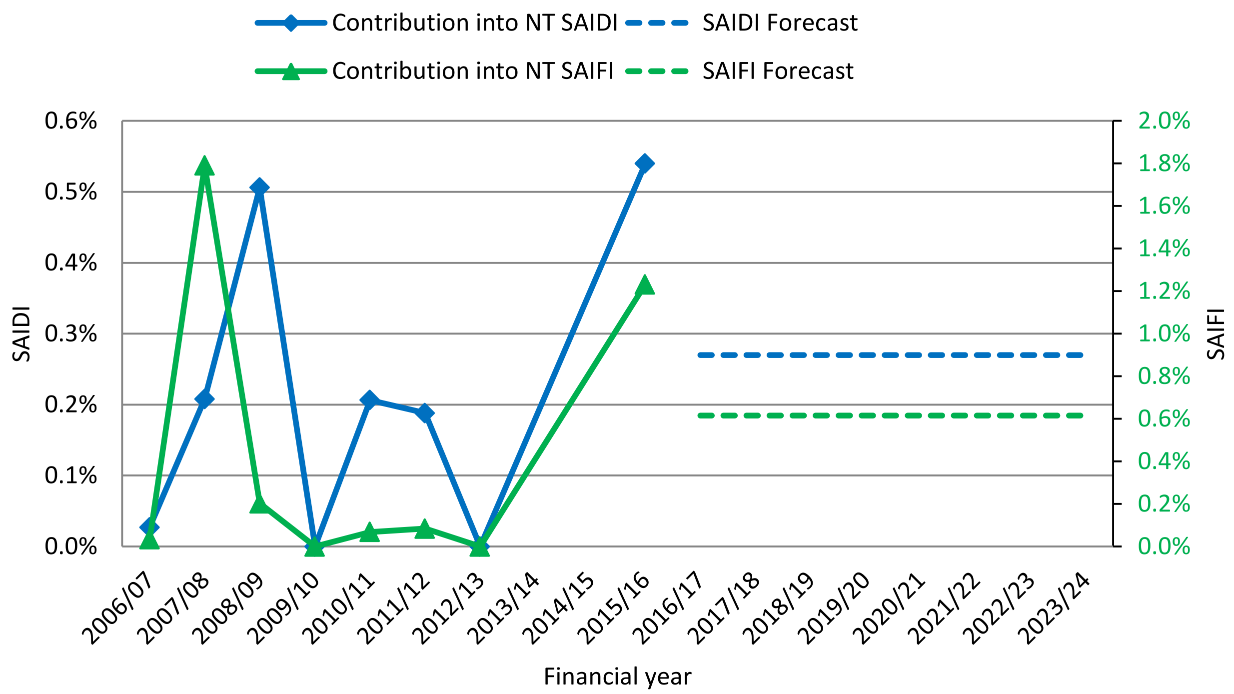


Figure 5.1 shows that the contributions of SAIDI and SAIFI are volatile without a clear trend between periods/across time, hence it is prudent to look at a simple average of the data when considering historical performance. These charts show that there is a material contribution of SCADA assets to NT SAIDI and SAIFI.

The dashed lines in Figure 5.1 are the forecasted contribution of SCADA assets into SAIDI and SAIFI based historical average. Further analysis of historical outages and correlation with the age, condition or type of equipment that caused the outage is planned to gain a better understanding of reliability drivers.

Figure 5.2: SCADA – number of failures & contribution to NT SAIFI

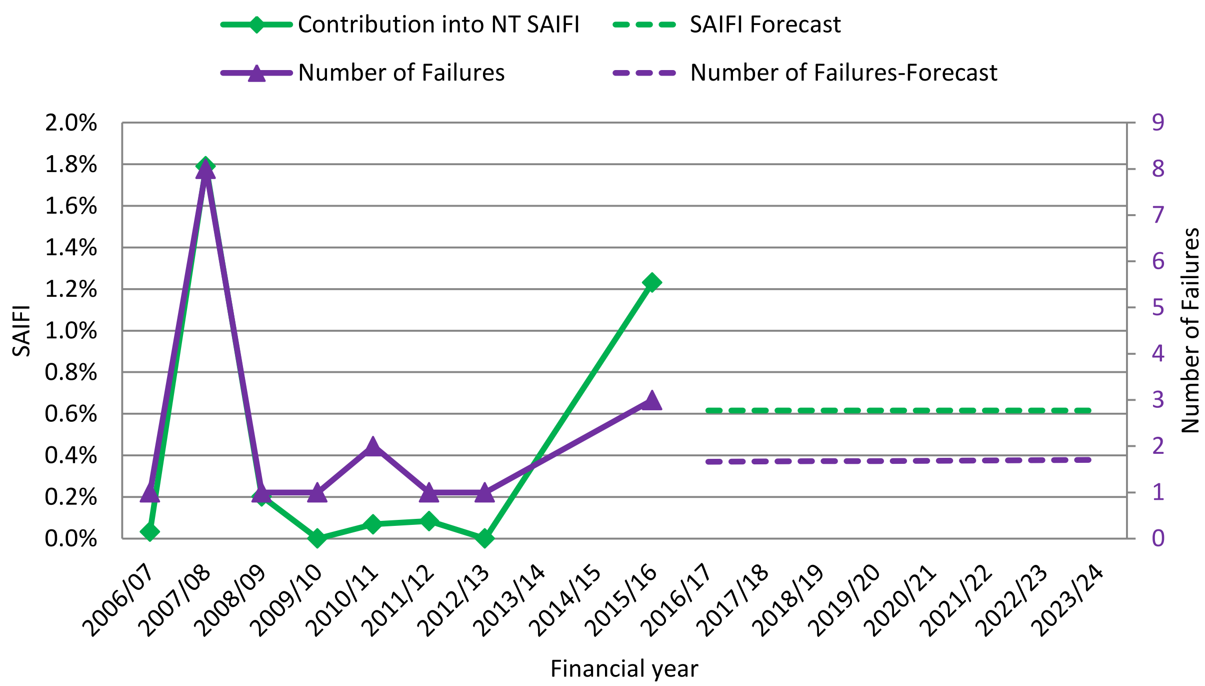


Figure 5.3: SCADA – number of failures & and contribution to NT SAIDI

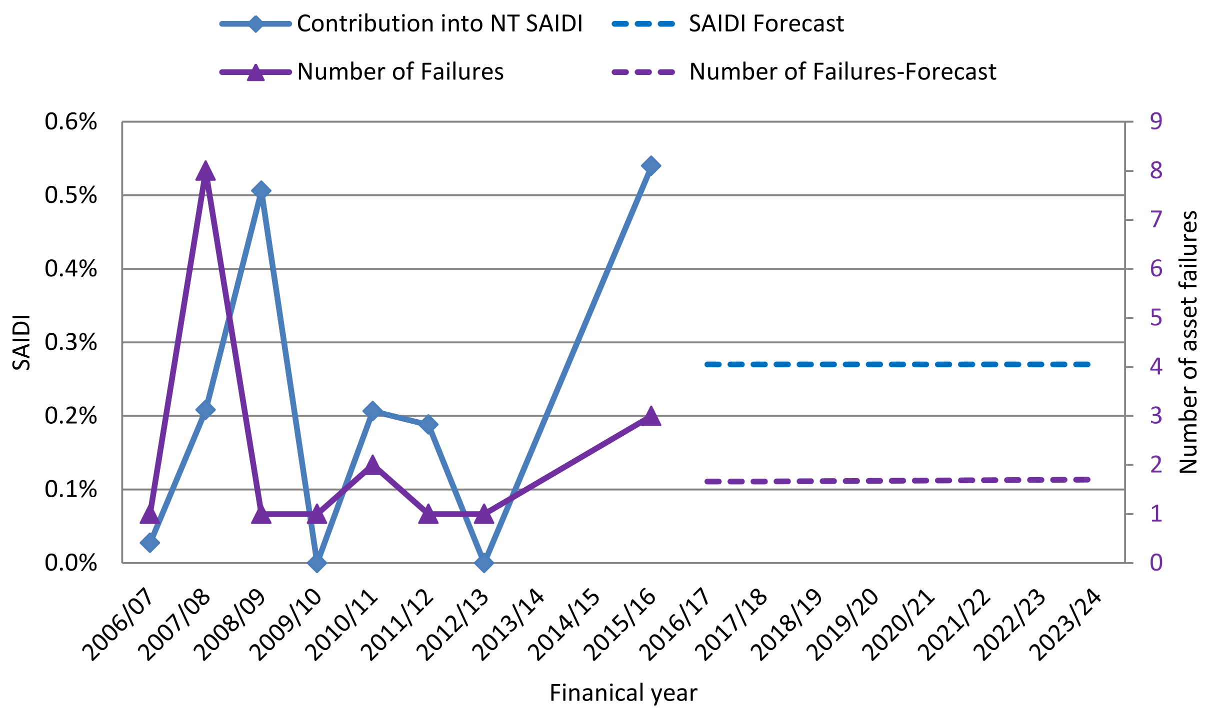


Figure 5.2 and Figure 5.3 display the relationship between asset failures and SCADA's contribution to NT SAIFI and SAIDI. The majority of SCADA assets operate with dual redundancy schemes, meaning most asset failures do not impact supply; however, at times these failures do result in outages to customers.

Power and Water experienced 18 recorded SCADA asset failures since 2007, after taking into account the missing 2013-14 and 2014-15 data this is an average of 1.8 per year. Power and Water is working to improve their data recording practices over the coming regulatory period.

The relative magnitude of asset failure is also important; this is displayed in 2008-09 where there was only one asset failure which resulted in a NT SAIDI contribution rate of 0.612%. To reduce the magnitude of outages Power and Water assesses SCADA asset criticality and implements asset management strategies to reduce the risk of asset failure of highly critical assets. This methodology is discussed in section 5.2.

The clear link between asset failures, outages and the contribution of SCADA assets to NT SAIFI is displayed in Figure 5.2. The augmentation and renewal projects outlined in sections 8 and 9 will improve the future performance and reliability of SCADA assets. Further information regarding NT SAIDI, NT SAIFI, and asset failures is provided in Appendix B – Asset data.

5.1.2 Remaining life

The effective remaining life of SCADA assets is calculated based on the current life of the asset compared to the estimated expected life of the asset. The following factors are used in calculating an asset's expected life:

- Technical data sheets
- Power and Water SCADA engineer expertise in combination with asset condition assessments
- Environmental factors
- Design life specified by the vendor.

Figure 5.4 shows the SCADA fleet by asset category. To understand network health, it is important to know how many assets are likely to reach their end of life in the near future so appropriate steps can be taken to address the risk. For the SCADA asset classes, 10% of their life is typically 4-5 years for structures, shelters, and fibre and pilot cables, whereas 10% of digital assets are typically assessed to be only one year. This has been used as a threshold for identifying the number of assets likely to reach the end of their life within the next regulatory period. This is useful for assessing network risk.

Figure 5.4: Remaining life for discrete asset categories

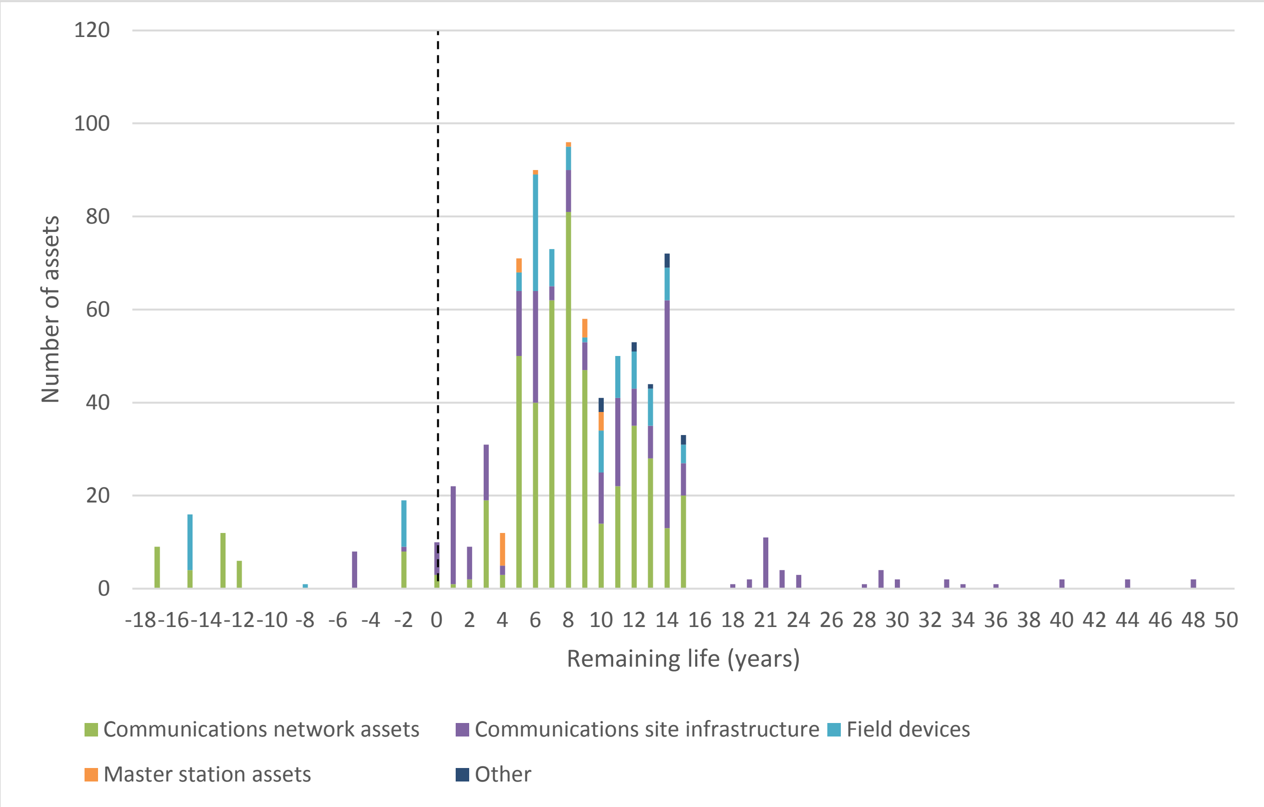
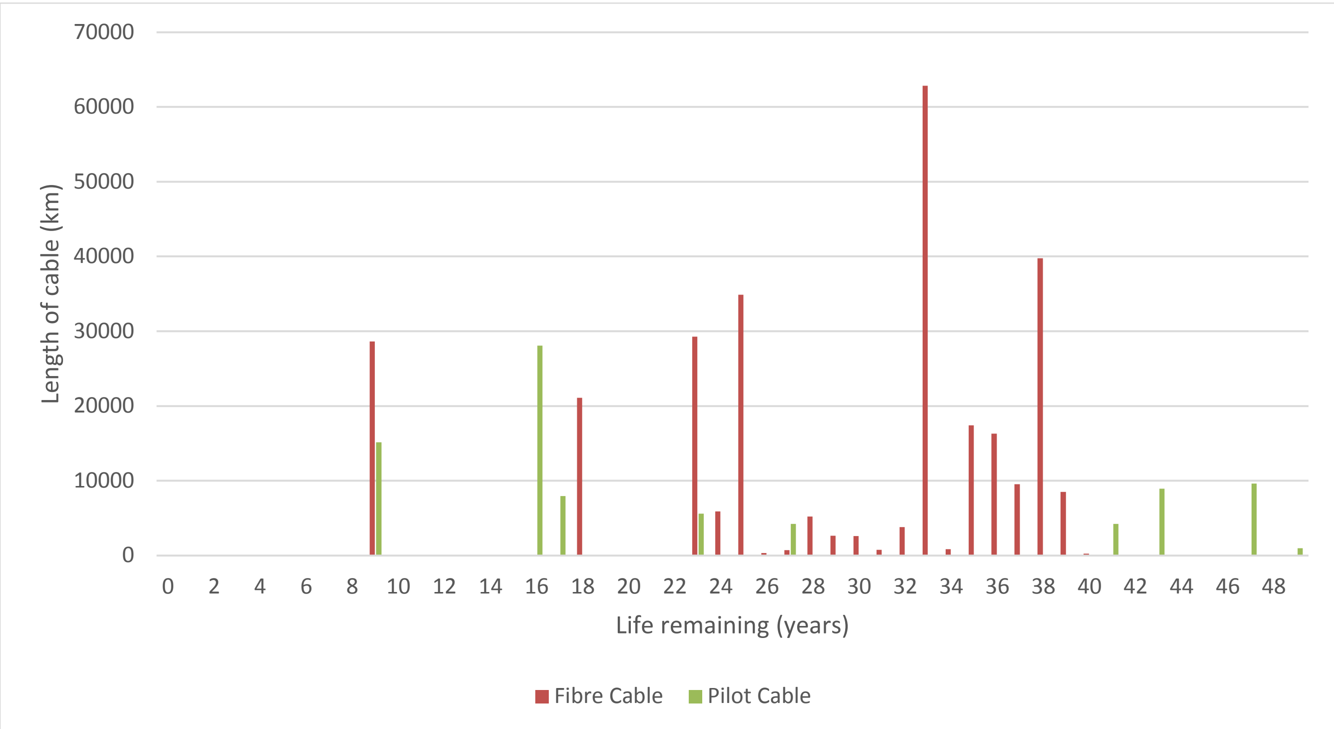


Figure 5.5: Remaining life for communication linear assets (km)



Based on asset age compared to expected life, the following assets have either less than 10% of their life remaining (5.61% of total assets) or have already exceeded their expected life (6.75% of total assets):

- 23 RTU's
- 22 UHF systems
- 38 battery systems
- 16 teleprotection assets
- 3 solar systems
- 2 PDH multiplexors
- 2 management systems
- 1 power supply
- 1 DWDM system.

Further details regarding the expected life of all SCADA assets are provided in Appendix B – Asset data.

5.1.3 Health assessment matrix

The remaining life of assets is used to develop an Asset Health Score. The Health Score identified the assets that are considered to have the highest risk of failure. There are three categories[1]:

- Acceptable - greater than 10% of the expected asset life remaining.
- Caution / monitor – within the last 10% of the expected asset life remaining.
- Urgent – the asset has exceeded its life expectancy.

Table 5.1 & Table 5.2 display the output of the health assessment - this assessment is made directly from the age of the asset as it is currently the best indicator of health for SCADA assets.

Table 5.1: Health score results for discrete assets

Condition Rank	Condition	Number of SCADA assets
H1	Acceptable	766
H2	Caution – monitor	49
H3	Urgent	59

Table 5.2: Health score results for communications linear assets

Condition Rank	Condition	Length of cable (km)
H1	Acceptable	376,061
H2	Caution – monitor	0
H3	Urgent	0

[1] Due to the different lives of various sub-classes, the standard remaining life approach for Health of SCADA assets has been modified to represent proportion of asset remaining life, rather than a specific timeframe.

5.2 Criticality

Power and Water's SCADA engineers have categorised assets as critical if they pose a high risk to the network should they fail, and non-critical if they will not have a major impact on the network if they fail. Based on these categorisation criteria, any asset that has redundancy is considered non-critical.

The criticality assessment identified the following high risk assets:

- Structures and towers which are relied upon by the communications network. The time taken for Power and Water to repair/replace these assets would cause considerable downtime of critical systems.
- Master station assets including; server/equipment room assets (UPS and process coolers), EMS server hardware, and cybersecurity systems.

Table 5.3 shows there are 38 assets that are considered to have high criticality.

Table 5.3: Criticality for discrete asset categories

Condition Rank	Number of SCADA assets
C1	836
C2	0
C3	38

Table 5.4: Criticality for communication linear assets

Condition Rank	Length of cable (km)
C1	376,061
C2	0
C3	0

As part of their asset management improvement plans, Power and Water plans to undertake a more comprehensive FMECA analysis of these assets over the coming regulatory period. To achieve this, Power and Water needs to improve their asset data, including entering all assets into their asset management system database (Maximo). Refer to section 6.4 for further information.

The full criticality analysis is shown in Appendix B – Asset data.

5.3 Network risk

Network risk is the combination of asset health and criticality. It is shown in Table 5.5 using a risk matrix approach. This identifies that there are 97 SCADA assets with a moderate risk rating and no assets assessed as either high or extreme risk. Most assets are of low or very low risk.

Table 5.5: SCADA asset health - criticality matrix for discrete asset categories

	H1	H2	H3
C1	728	49	59
C2	0	0	0
C3	38	0	0

Table 5.6: SCADA asset health - criticality matrix for communication linear assets (km)

	H1	H2	H3
C1	376,061	0	0
C2	0	0	0
C3	0	0	0

Risk legend				
Very low	Low	Moderate	High	Extreme

The assets driving the moderate risk are either non-critical assets which have exceeded their expected life (C1 & H3) or critical assets with an acceptable health rating (C3 & H1); these assets are listed below alongside a summary of Power and Water's risk mitigation plan.

C1 & H3 moderate risk assets:

- 23 RTU's; with the following to be decommissioned as part of these programs;
    - 4 - DKTL secondary systems upgrade (section 9.4)
    - 4 - planned asset replacements (2018/19)
    - 2 - decommissioning of the West Bennet and Austin Knuckey switching stations
    - 1 - Humpty Doo ZSS upgrades (section 9.5)
    - 1 - Berrimah ZSS upgrades (section 9.5)
- 22 UHF systems
    - All to be decommissioned in 2018
- 8 battery systems
    - 2 – planned asset replacement (2018/19), with another 4 being considered for replacement.
- 4 teleprotection assets
    - All to be replaced as part of the DKTL secondary systems upgrade program outlined in section 9.4.
- 1 power supply
- 1 PDH multiplexor

The remainder of these assets are to be placed on Power and Water's asset life extension policy.

C3 & H1 moderate risk assets:

- 20 master station assets (6 process coolers, 7 UPS, 7 EMS hardware / software assets)
    - EMS assets will move into the H3 category over the coming regulatory period. Power and Water has planned the EMS replacement project (section 9.5) to ensure that this critical system is safe, reliable, and improves functionality to meet Power and Water's developing asset management program.
- 18 structures

These assets are to be carefully monitored to help minimise the potential for asset failure.

Power and Water will continue to develop data recording processes and improved data granularity to further improve their ability to assess network risk and the corresponding risk mitigation strategies.

6 Key challenges

6.1 Environmental challenges

The network covers a range of environments and geographies which present different challenges for SCADA assets. Table 6.1 provides an overview of environmental challenges in relation to managing Power and Water's SCADA assets across its operating regions. Power and Water has unique requirements compared to other DNSPs around Australia due to climatic conditions; extreme temperatures, the wet season and cyclones.

Table 6.1: Environmental challenges in relation to SCADA asset management

Region	Environment	Challenges	Expenditure / risk implications
Alice Springs	Desert	• High temperatures contributing to the overheating of SCADA assets.	• Infant mortality / early life replacement due to technical failure. • An increased dependence on temperature control / air-conditioning at zone substation control centres and SCADA shelters.
Darwin	Coastal/Tropical	• High humidity possibly resulting in damage to internal components of assets. • High temperatures contributing to the overheating of SCADA assets if air conditioners within substation control rooms are damaged/fail. • Access to SCADA communication asset sites and the ability to work on these assets during the wet season – heat and rain/flooding (safety issue and detrimental to assets). • Cyclonic or storm events resulting in frequent / prolonged power outages- resulting in blocked / flooded roads • Managing personnel and prioritising issues during severe weather events. • Providing adequate emergency communication services in the event of a major system weather related event. • Corporate resiliency assessment and mitigation requirements against extreme weather events	• Increase in maintenance frequency. • Increased importance of maintenance to address leaks. • An increased dependence on temperature control / air-conditioning at zone substation control centres. • Public and Power and Water employee safety is reduced if assets fail to operate as intended. • Ensuring sufficient battery capacity so that sites remain in operation during severe weather events or periods of prolonged inaccessibility. • Ensuring solar power sites have sufficient battery capacity to maintain load during adverse weather conditions – such as monsoonal conditions where there may be significant cloud cover for weeks at a time. • Functional fleet of mobile communication centres to allow additional / replacement capacity to be quickly deployed to support restoration efforts. • Assessment and management costs to ensure all Power and Water sites meet corporate resilience assessment and mitigation requirements
Katherine	Inland/Tropical	• as above	• as above
Tennant Creek	Desert	• High temperatures contributing to overheating of SCADA assets.	• Infant mortality / early life replacement due to technical failure. • Some of the batteries in use have seen a 50% reduction in life for every 10°C above 20°C • An increased dependence on temperature control / air-conditioning at zone substation control centres and SCADA shelters.

6.2 Operational challenges

SCADA faces several operational challenges which drive or influence asset management strategies adopted by Power and Water, these briefly include;

- Workforce capability and location driving up cost
- Technology changes shortening the asset life cycle and increasing difficulty to support legacy systems
- Increases in the reliability, availability and capability requirements from users and other systems.

These items are discussed below.

6.2.1Workforce capability and location

The majority of staff who are appropriately qualified to work on SCADA assets are located in Darwin. There is only one SCADA staff member located in Alice Springs and none located in Tennant Creek. As a result, the time and cost of undertaking routine inspections or simple replacement tasks has a high cost. The climate also has a significant impact on the accessibility of assets.

The distance and time required for specialised staff to operate and maintain network assets has the following implications;

- Increased operational travels costs of maintaining and fixing the SCADA assets.
- Increased battery costs (capex) associated with an increase in battery capacity and reliability to ensure Power and Water sites remain operational during severe weather events or periods of prolonged inaccessibility.
- Outages which can last for a prolonged period due to travel times to reach the site or accessibility constraints during the wet season.

Power and Water is assessing new technologies (for example, local area networks in substations) that may be able to mitigate some of the costs associated with these problems.

6.2.2 Rapid technological change

The rapid pace of technological change is an on-going challenge for personnel who manage SCADA assets. The continued upskilling of personnel is problematic for an ageing workforce. The changes in technology and the ever increasing inability to undertake repairs of complex equipment is forcing maintenance into a 'black box' replacement methodology. This is further exacerbated by the requirement to have a very broad breath of knowledge and skills to maintain the various legacy systems in use and compatibility issues between modern and legacy systems.

Power and Water is considering alternative approaches to managing this ongoing change in technology. An option is to moving to a methodology where only one or two subject matter experts exist rather than having all staff trained and skilled in the systems being maintained. However, this creates a 'key person' risk and may not be appropriate.

6.2.3 Increases in Reliability, Availability and Capability requirements

An increasing customer expectation of highly available and reliable power supply is seeing an increased requirement for highly available and reliable SCADA assets. As the capacity to remotely monitor and control devices further into the network beyond the traditional point of the substation is required to provide greater network visibility and control, SCADA systems need to be developed to support these needs. The investigation into the use of the Digital Mobile Radio system to provide this access is planned.

The capability of SCADA systems to provide data into the corporate network and other systems is also increasing. Another growing demand is for remote access for maintenance and support of these systems. These requirements have a significant effect of the cyber security requirements for the SCADA systems to ensure that the risk of cyber incidents is at an acceptable level.

6.3 Asset challenges

There are six primary challenges in relation to Power and Water's SCADA assets:

- Obsolescence – end of vender support
- Obsolescence – functionality standards required by Power and Water, NER & the Technical Code
- Cyber-security
- Weather challenges – temperature, cyclone resilience & wet season accessibility
- Personnel – breath of knowledge and skill sets required.

Refer to Appendix B – Asset data sections 14.2.1-14.2.5 for a breakdown of these asset challenges into their respective asset type.

6.4 Asset management challenges

This section discusses the key challenges associated with managing SCADA assets in terms of informational requirements and business processes.

Data deficiencies

Two key asset management challenges are:

- A lack of comprehensive asset condition data
- Not all SCADA assets are recorded in Maximo.

These data sources are required to fully understand the asset fleet and the impact that deterioration of assets has on the operational integrity and functionality of the assets.

Power and Water acknowledges that they are in the process of maturing their approach to asset management and need to improve their asset data collection processes. They have republished plans to include all assets in Maximo (their asset database), to develop suitable asset condition parameters and start recording asset condition data on a consistent basis.

IT/OT convergence - Integration of asset technology into a cohesive system

The integration of older SCADA assets with newer digital technologies into one cohesive system is an on-going issue for Power and Water. There is a long-term strategic goal to have LAN centres at all zone substations. These LAN centres will be installed alongside major development projects to reduce system downtime and the costs associated with asset augmentation/renewal projects.

The implementation process of this strategy will take place over the medium-long term as a short-term roll out across all zone substations is not cost efficient. In the meantime, the management of differing technology systems into a cohesive system will remain an on-going issue for Power and Water's SCADA engineers.

7 Performance indicators

The performance of SCADA assets against the specific objectives and measures identified in section 2.3 are provided here. The performance indicators represent 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. The projected investment outcomes in relation to past performance trends are provided in section 10.2.

7.1 Operational Performance

Table 7.1 Operational performance objectives

Description	Targets	Actual
SCADA's annual NT SAIDI (five-year average)	Under development	0.457
SCADA's annual NT SAIFI (five-year average)		0.011
SCADA's annual contribution to total NT SAIDI (five-year average)		0.261%
SCADA's annual contribution to total NT SAIFI (five-year average)		0.600%
Annual in-service asset failures		2
Availability of core SCADA services		N/A
Availability of Communications Backbone		N/A
Number of obsolete or no longer supported assets without strategic spares		17

7.2 Health and Safety

Table 7.2 Health and Safety performance objectives

Description	Target	Actual	Gap
Number of safety incidents (near misses, injuries, fatalities).	0	0	0

8 Growth requirements

Increases to the SCADA asset fleet are driven by expansion of the network due to customer demand or compliance requirements. This can include new substations, additional transformers installations, or other network security requirements. The key drivers are listed below.

8.1 Optus fibre cable shared asset installation [NMSC3]

Refer to the Business Needs Identification – Optus fibre cable shared asset installation, document number NMSC3, for details of this program.

8.1.1 Overview

Power and Water has a contractual obligation to install fibre optic cable as and when required by Optus in Darwin only. Power and Water uses this fibre cable in its backbone communications system in Darwin.

The Optus contract is set to expire in 2020; Optus have indicated they would like to start renegotiation of the contract in the next six months with completion in 12-18 months.

8.1.2 Issues and options

In 2000 Power and Water entered into a commercial agreement with Optus to install fibre optic cable for Optus' network. As part of the commercial arrangement, Power and Water is gifted cores from each cable to use for their SCADA network. [redacted]

The existing contract ends during the first year of the next regulatory control period, however, Optus has approached Power and Water to renegotiate and extend the contract. Negotiations are expected to commence in Q2 of FY18. The outcome is expected to be known by Q2 FY19.

The contract does not specify a minimum volume to be installed annually or a unit rate. The actual installation is based on Optus' needs and a quoted cost per installation.

Preferred option:

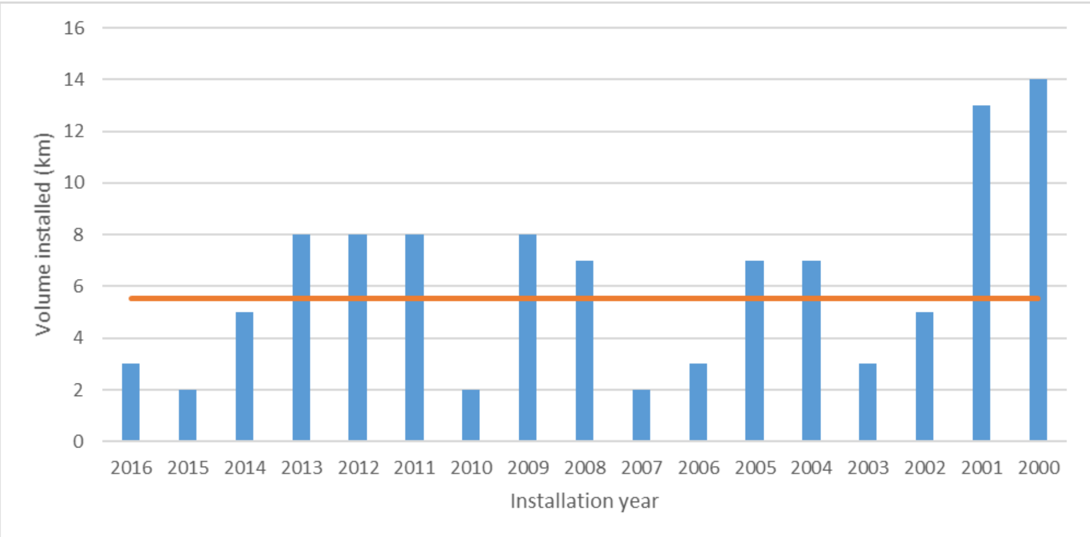
- Install the cable as required by Optus.

8.1.3 Asset management plan

Historical volumes and expenditure:

Figure 8.1 shows variation from year to year but the average annual installation volume for the period of 2003 to 2016 is 5.2km. The average unit rate during the same period has been $102,000 per kilometre, adjusted to FY18 dollars. These values have excluded 2000 to 2002 as they appear to be outliers in terms of volumes and unit cost.

Figure 8-1: Historical installation volumes (km)



This asset will be a shared asset, only the part of the asset value that is used for the distribution network can be rolled into the Regulated Asset Base (RAB). This is estimated to be 4.2% to 5.5% based on historical allocation of fibre cores.

Power and Water is expecting an ongoing investment by Optus of 5.2km per year or 26km during the next regulatory control period.

8.2 SCADA asset growth associated with new/augmented ZSS developments

8.2.1 Overview

Growth in SCADA assets is predicated on capital expenditures associated with new/augmented zone substations/substation assets.

8.2.2 Issues and options

SCADA assets are often replaced prior to end of life if they are intrinsically linked to zone substation/key asset augmentation projects. The reasons for this are;

- Reduces travel costs
- Reduces system downtime, thus reducing energy loss
- Align asset technology and capabilities for efficient and functionality gains.

8.2.3 Asset management plan

The growth in SCADA assets until the end of FY24, listed by zone substation augmentation/establishment is shown in Table 8.1.

Table 8.1: Asset growth associated with new / augmented zone substations

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Wishart new ZSS					2 RTUs 2 batteries 2 SDH multiplexors		
Archer 3rd transformer			nil				

8.3 Long-term (8-12 years) 2024-29 regulatory period

The demand forecast produced by AEMO shows that in general there is negative growth on the network. Growth corridors will be addressed by the augmentation and replacement programs that will be completed by the end of the next regulatory (2024). As a result, there is not expected to be significant growth in the SCADA network due to demand.

The only long term augmentation plan is the rollout of substation LANs. This is likely to occur as substations are renewed and/or on a cost benefit basis.

9 Renewal and maintenance requirements

The following sections provide an evaluation of renewal and maintenance requirements in relation to existing assets.

9.1 SCADA and Communications Networks Technical Code Compliance [NMSC4]

Refer to the Business Needs Identification – Safety and compliance program, document number NMSC4, for details of this program.

9.1.1 Overview

This program addresses needs identified on the network related to safety and compliance with respect to Technical Code.

9.1.2 Issues and options

Power and Water's Technical Code and Network Planning Criteria Section 2.9.2 require diverse protection systems for primary assets with operating voltages of 66kV or above. To meet this criterion with the protection schemes as used within Power and Water, diverse communications paths to these sites are required. The following sites have been identified as not complying with this requirement:

- Casuarina ZSS
- Marrakai ZSS
- Mary River ZSS
- Lovegrove ZSS
- Sadadeen ZSS

Three options have been identified to resolve the issues:

- Do nothing
- Complete the proposed program of works
- Reduced scope – only complete the compliance items.

9.1.3 Asset management plan

The preferred solution is **option 2** to undertake the complete program of works.

This will provide compliance with the Technical Code and make the protection schemes more resilient to a failure of a communications bearer.

Table 9.1: Replacement volumes

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Casuarina ZSS							1.4km of fibre
Marrakai ZSS					1 microwave link		
Mary River ZSS					1 microwave link		
Lovegrove ZSS						1.2km of fibre	
Sadadeen ZSS							1.2km of fibre

9.2 Battery system replacement [NMSC2]

Refer to the Business Needs Identification – Battery system replacement, document number NMSC2, for details of this program.

9.2.1 Overview

Many battery systems for SCADA assets have reached the end of their expected life and require replacement.

Batteries are critical to the operation of the telecommunications system. Without batteries of sufficient capacity, the telecommunications system will not operate correctly. Battery banks are most critical in power outages where they are the sole source of power to ensure continued operation of the SCADA network, and therefore to maintain control of the network.

This program includes solar panels that are installed for the purpose of charging SCADA asset batteries. This program does not include zone substation batteries that supply substation auxiliary devices.

9.2.2 Issues and options

The need to replace batteries is based on battery age. The sizes of the battery systems required are dictated by Power and Water's unique environmental circumstances and remote locations. These factors are explained below.

Loss of capacity with age

A well proven and understood characteristic of batteries is that they lose capacity as they age due to internal deterioration. This means that the amount of energy that batteries can store reduces over time, which results in the voltage output dropping below design levels more quickly than expected. When battery systems do not supply the required voltage levels, the connected devices will not operate correctly.

Impact of temperature

Battery life is affected by the conditions in which they are used. Experience and technical data sheets show that there is a 50% reduction in battery life for every 10^{o} C above 20^{o} C. The average temperatures in the Northern Territory range between a low of 23^{o} C and a high of 32^{o} C.

Old design standards in remote locations did not require batteries to be housed in air conditioned environments. Thus, they are expected to have a reduced life compared to other battery banks housed in air conditioned environments.

Due to the function of these assets, there are only a limited number of options that have been considered, these are:

1. Do nothing - allow the batteries to fail and do not replace. Manual operation of the network
2. Replace at end of life (age based) - replace batteries based on their design life, allowing for reduced life of batteries operated outside of air conditioned environments.
3. Proactive replacement (managed) - replace the assets prior to end of life by assessing performance and asset condition.

9.2.3 Asset management plan

Preferred option

The preferred option is **option 2: replace at end of life**. Batteries are critical assets for the communications network. Power and Water currently does not have the equipment or capability to effectively test battery banks (this capability will be developed over the coming regulatory period). Thus, the forecast for battery replacement is based on the design life of the batteries.

Table 9.2: Forecast replacement volumes

Type	FY18	FY19	FY20	FY21	FY22	FY23	FY24
7OPzV600						2	2
8OPzV960		1		2			
A602/720				2			
G85	4	17	2	1	2		4
PS1270		1	1				
SB6/330	2	2		6		2	
Total	**6**	**21**	**3**	**11**	**2**	**4**	**6**

9.3 SCADA and communications asset replacement program [NMSC1]

Refer to the Business Needs Identification – SCADA and communications asset replacement, document number NMSC1, for details of this program.

9.3.1 Overview

There are some SCADA assets that have reached the end of their expected life and are now using obsolete technology and/or are no longer supported by the vendor.

9.3.2 Issues and options

When equipment is at End of Support (EOS), the vendor support is no longer available and vendors do not sell spares or undertake repairs of faulty equipment. Power and Water has limited capacity and capability to address difficult technical issues related to programming and maintaining complex telecommunications systems. The issues needed to be resolved are more complex than the normal day-to-day activities experienced with a telecommunications network.

The following two key issues have been identified for the SCADA network:

- Assets have been identified as no longer supported by the vendor which is critical for equipment repairs, resolving software/firmware bugs, updating security patches to guard against cyber threats, and general overall support in programming and maintaining this equipment.
- Assets have been identified that will reach the end of their design life during the next regulatory period. Since these devices are solid state, Power and Water is not able to assess and monitor asset condition and the number of failures is expected to increase.

The options considered are:

- Do nothing - allow the assets to fail and do not replace

- Replace at end of life (replace at failure) - replace critical assets at the end of their design life and non-critical assets at failure with the same model (if spares available) or modern equivalent.
- Proactive replacement (managed) - replace the assets prior to end of life by assessing performance and asset condition.

9.3.3 Asset management plan

The preferred option is **option 2: replace at end of life.** This option ensures the maximum useful life of the asset is achieved and the N-1 design criteria of the network ensure that network security and reliability is maintained.

As part of this option, any in service failures of these assets must be quickly replaced to ensure continual and secure operations of the communications network. This program will guard against random failures for assets that still have an expected design life remaining beyond the end of vendor support, the end of life management program will involve:

- Purchasing a number of spares of specific assets to ensure rapid restoration of the network following an in-service failure.
- Where spares are not available, assets in selected substations will be replaced and the current assets will be recovered and retained as spares for the network.
- Where assets may pose a security threat or there is no redundancy in the network the assets will be replaced at end of vendor support.

9.4 Upgrade DKTL Secondary systems [PRD32117]

Refer to the Business Needs Identification – Secondary systems upgrade of 132kV substations at Manton, Pine Creek and Katherine, document number PRD32117, for details of this project.

9.4.1 Overview

The Darwin to Katherine 132kV Transmission Line (DKTL) runs from Channel Island Power Station to Manton, Pine Creek and Katherine zone substations. It was constructed in 1986 and predominantly contains original equipment.

While piecemeal replacement has been undertaken as required, the interconnected nature of these systems means that this is increasingly difficult. Modern assets interface directly with SCADA systems, rather than via hard wiring. As such, the communications system must be upgraded to accommodate the new asset requirements whilst maintaining an obsolete technology for the older assets.

9.4.2 Issues and options

A holistic review of the entire DKTL secondary systems is necessary to determine the most prudent and efficient method for update/replacement. There are a number of related individual issues that need to be resolved on the DKTL. The major issues addressed by the program include:

- Transformer AVR and tap control asset at Pine Creek, Katherine and Manton 132kV substations

- Auto reclose function at Pine Creek, Katherine and Manton 132kV substations
- Remote Terminal Units (RTU) at Pine Creek and Manton 132kV substations
- Grid Island detection at Pine Creek 132kV substation.

The majority of the secondary systems assets installed at terminals along the Darwin – Katherine Transmission Line (DKTL) are 30+ years old, these assets have not only exceeded their operational life but are obsolete models, no longer supported by the Original Equipment Manufacturer (OEM) and cannot be technically or economically repaired.

Failure to replace these aging, unsupported assets on the essential DKTL will expose Power and Water and its customers to system security risk. As the assets continue to fail, customers will be affected by unplanned outages. The likelihood of extended unplanned outages will be high due to the unavailability of spare parts for the aged assets.

Due to the interconnected nature of the secondary system assets, it is more efficient to replace/update these components under the same project rather than as piecemeal replacement.

9.4.3 Asset management plan

The Darwin secondary systems upgrade program will replace outdated and failing assets with newer supported and easy to maintain assets. This in turn will reduce the asset failure rate of the SCADA asset fleet. The program will also significantly improve the quality and quantity of system information data available.

Table 9.3 Forecast replacement assets and volumes

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
SCADA assets at Pine Creek and Manton 132kV substations			1 RTU 1 SDH multiplexor at each site 1 PDH multiplexor				
Grid Island detection at Pine Creek 132kV substation			4 PDH multiplexors				

Refer to the Business Needs Identification – SCADA secondary systems upgrade PRD32117 for specific details regarding this project.

9.5 Energy Management System (EMS) Replacement Project [PRD33134]

Refer to the Business Needs Identification – Preliminary Business Case EMS Replacement Project, document number PRD33134, for details of this project.

9.5.1 Overview

The EMS project comprises a [redacted] and hardware to 'in support' versions.

9.5.2 Issues and options

The following key issues have been identified for EMS SCADA assets:

- Hard drive and power supply asset failures. Servers, routers, switches, workstations and other ancillary service equipment have shown to be reliable; however, asset failures will likely increase as digital assets age beyond their expected life.
- Hardware obsolescence; servers, workstations, and other network infrastructure will lose vender support over the coming regulatory period.
- Operating systems, GE software, and 3rd party software applications will reach end of extended support in 2020.
- A cybersecurity audit identified vulnerabilities in Power and Water's current system.
- A lack of OT/IT integration and data access.

The options considered are:

- Option 1 – do nothing
- Option 2 – [redacted]
- Option 3 – [redacted]

9.5.3 Asset management plan

An analysis of the non-cost attributes for each option has been completed using a multi-criteria analysis method. The attributes are selected considering major risks and priorities to achieve the project objectives.

The preferred option is [redacted] This option best fulfils the project objectives of asset renewal. This option will also cater for and support the reporting needs of the AER to be met.

The following items represent the key scope inclusions:

- Replacement of EMS hardware (servers, workstations, networking equipment, security appliances, data backup hardware and distribution training system) to address the limited life of the current hardware.
- Migration to a new operating system (addressing the obsolescence of the current operating system).
- Migration of EMS software and applications [redacted] to ensure the EMS is 'in support'.
- Installation of a current suite of SCADA/EMS applications, as required, to effectively manage the Electrical Network and meet the compliance obligations of Power and Water.
- Training for operators and technical staff.
- De-commissioning of the existing EMS system and migration of assets, users and data.

Table 9.4: Forecast replacement assets and volumes

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
EMS upgrade			0	1				1

Refer to the Business Needs Identification – Preliminary Business Case EMS Replacement Project, document number PRD331347 for specific details regarding this project.

9.6 Other projects with secondary systems asset replacement components

Refer to the Business Needs Identification or Preliminary Business Case for each of the individual zone substation replacement or augmentation projects for further details.

9.6.1 Overview

Asset renewal is a key component of zone substation replacement and upgrade programs. When Power and Water replaces key assets or entire zone substations the adjoining SCADA asset fleet associated with the replacement is upgraded to ensure congruency in technology. This process also minimises energy loss and system downtime.

There are several projects which will have a significant impact on the SCADA asset fleet:

- Berrimah ZSS replacement
- Humpty Doo ZSS
- Centre Yard ZSS
- Cosmo Howley transformer replacement

9.6.2 Issues and options

The renewal of zone substations and transformers without an upgrade to SCADA systems could result in conflicting technology between assets. When a substation requires augmentation or replacement (in full or in part) the options analysis includes an assessment of the most prudent and efficient manner in which to manage SCADA assets.

The most efficient approach to manage the SCADA assets will depend on the extent of the substation project, the age and type of the existing assets and the long-term strategy for the zone substation.

9.6.3 Asset management plan

These programs set out in Table 9.5 are to be completed in over the next regulatory control period.

Table 9.5: Asset replacement programs that are part of ZSS and key asset upgrades– regulated networks

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Berrimah ZSS transformer replacement			2 RTUs 2 batteries 2 SDH multiplexors 4 PDH multiplexors				
Humpty Doo ZSS				2 RTUs 2 batteries 1 SDH multiplexor 2 PDH multiplexors 1 microwave link			
Centre Yard ZSS					2 RTU 1 microwave link 1 PDH multiplexors		
Cosmo Howley transformer replacement				1 RTU 1 microwave link			
Weddell transformer			2 RTUs				

Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24
replacement							

9.7 Long-term (8-12 years) 2024-29 regulatory period

Current projections predict the progressive replacement of:

- SDH multiplexors no longer manufactured or supported and as failure rates are expected to increase reducing the adequacy of available spares
- DWDM equipment no longer manufactured or supported and as failure rates are expected to increase reducing the adequacy of available spares
- Some selected microwave systems to provide additional working spares
- Battery systems as their condition requires
- Equipment shelters as their condition dictates
- Telemetry systems as their condition dictates
- Test equipment as their condition dictates and
- Process coolers and UPS's as their condition dictates.

CNMS and EMS software and hardware replacements will also be required during this period.

Power and Water will continue to monitor SCADA assets and will react to any type issues that emerge as we have done in the past.

10 Investment program

The investment program is developed based on the:

- Continuation of the established lifecycle asset management approaches – discussed in Section 13
- Specific requirements related to growth in the asset class – outlined in Section 4.4
- Specific requirements related to renewal and maintenance of the asset class – outlined in Section 9.

10.1 Capital expenditure (capex)

10.1.1 Augmentation expenditure (augex)

Augmentation (growth) related investment in the SCADA asset class has been identified for the short and medium term where possible.

The Optus fibre cable shared asset installation will cost [redacted] (real FY18) per year from FY20 to FY24 for a total augex of $[redacted]. The SCADA specific augex expenditure components of the Wishart new ZSS is estimated to be $1 million, with a negligible estimated cost as part of the Archer 3rd transformer works as it only requires a reconfiguration of existing assets.

10.1.2 Renewal expenditure (repex)

Replacement related investment in the SCADA asset class has been identified for the short and medium terms, as shown in Table 10.1.

Table 10.1: Replacement expenditure forecast – regulated networks ($m, real FY18)

Program	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total FY20-24
Safety and compliance program			0	0	0.390	0.115	0.225	0.73
Battery system replacement program			0.06	0.61	0.06	0.11	0.18	1.02
SCADA and communication asset replacement program			0.96	0.54	0.78	0.75	0.44	3.47
DKTL - Secondary systems upgrade		0.3	0.2	0.2				0.4
Energy Management System				[redacted]	[redacted]	[redacted]		[redacted]
Berrimah ZSS replacement		0.7	0.3	0.3				0.6
Humpty Doo ZSS					0.5	0.2		0.7
Centre Yard ZSS					0.15			0.15
Cosmo Howley transformer replacement				0.1				0.1
Weddell transformer replacement				0.08				0.08
Total	0	1.00	1.52	2.43	7.78	1.975	0.845	14.55

10.2 Operational expenditure (opex)

The operating expenditure forecast for cables for the next regulatory period is provided in Table 10.2.

Table 10.2: Operating expenditure forecast

Asset type	Expenditure category	FY14 (H)	FY15 (H)	FY16 (H)	FY17 (H)	FY18 (H)	FY19 (F)	FY20 (F)	FY21 (F)	FY22 (F)	FY23 (F)	FY24 (F)
SCADA	Routine	$0.25	$0.09	$0.05	$0.07	$0.10	$0.09	$0.08	$0.08	$0.08	$0.08	$0.08
	Non-routine	$1.14	$1.19	$1.25	$1.01	$1.13	$1.02	$0.90	$0.90	$0.90	$0.90	$0.90
	Fault and emergency	$0.01	$0.03	$0.00	$0.04	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Total		**$2.60**	**$1.56**	**$1.09**	**$1.17**	**$1.47**	**$1.34**	**$1.22**	**$1.22**	**$1.22**	**$1.22**	**$1.22**
Communications	Routine	$1.77	$0.39	$0.35	$0.10	$0.54	$0.50	$0.46	$0.46	$0.46	$0.46	$0.46
	Non-routine	$0.77	$1.04	$0.72	$0.65	$0.78	$0.70	$0.62	$0.62	$0.62	$0.62	$0.62
	Fault and emergency	$0.07	$0.12	$0.02	$0.43	$0.15	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14
Total		**$1.40**	**$1.31**	**$1.30**	**$1.12**	**$1.24**	**$1.12**	**$1.00**	**$1.00**	**$1.00**	**$1.00**	**$1.00**
Total	Routine	$2.02	$0.49	$0.40	$0.17	$0.63	$0.59	$0.54	$0.54	$0.54	$0.54	$0.54
	Non-routine	$1.90	$2.23	$1.96	$1.66	$1.91	$1.72	$1.53	$1.53	$1.53	$1.53	$1.53
	Fault and emergency	$0.08	$0.15	$0.03	$0.47	$0.17	$0.16	$0.16	$0.16	$0.16	$0.16	$0.16
Total		**$4.00**	**$2.87**	**$2.38**	**$2.30**	**$2.71**	**$2.47**	**$2.22**	**$2.22**	**$2.22**	**$2.22**	**$2.22**

11 Asset class outcomes

The performance of SCADA assets against the specific objectives and measures identified in section 2.3 are provided here. The performance indicators represent the forecasted performance of the asset class based on the program of works planned from FY18 through to FY24. It is expected that benefits from investments proposed in the next regulatory period will manifest as benefits in these key objectives.

11.1Operational Performance

Table 11.1 Operational performance objectives

Description	Targets	Actual
SCADA's annual NT SAIDI (five-year average)	under development	0.457
SCADA's annual NT SAIFI (five-year average)		0.011
SCADA's annual contribution to total NT SAIDI (five-year average)		0.261%
SCADA's annual contribution to total NT SAIFI (five-year average)		0.600%
Annual in-service asset failures		2
Availability of core SCADA services		N/A
Availability of Communications Backbone		N/A
Number of obsolete or no longer supported assets without strategic spares		17

11.2Health and Safety

Table 11.2 Health and Safety performance objectives

Description	Target	Actual	Gap
Number of safety incidents (near misses, injuries, fatalities).	0	0	0

12 Performance monitoring and improvement

Ongoing condition and performance monitoring is a key part of Power and Water's performance evaluation and improvement strategy. Study of the condition and performance data captured over time assists in developing valuable insights on SCADA defect modes and trends. These insights provide for informed decision making on whether to repair or replace assets. It assists in the continuous development of the asset management strategy for SCADA.

12.1Monitoring and improvement

This Asset Management Plan will be reviewed at least every two years or when there is a significant driver from the network or other events that requires revision.

Improving data resources, undertaking data analysis and deriving insights will be undertaken as business as usual activities. Any improvements in analysis of the SCADA asset fleet will be included in this AMP when it is updated.

13 Appendix A – Lifecycle asset management

Power and Water make great efforts to be a customer oriented organisation that provides a safe, reliable and efficient electricity supply in the Northern Territory. This is demonstrated in the approach Power and Water take in managing its assets. The life cycle asset management approach applied by Power and Water is aimed at making prudent asset management decisions such that its assets do not cause harm to any person, have minimal environmental impact, and meet agreed service performance outcomes, consistent with current and future needs.

The approach includes:

- Maximising the utilisation of its assets throughout its life cycle
- Optimising life cycle asset management costs
- Reducing asset risks as low as reasonably practical
- Continually improving its knowledge in respect of its assets

The following asset management activities details Power and Water's life cycle management of its SCADA assets.

13.1 Planning (augmentation)

The asset planning stage defines the need for an asset to exist. It also establishes the functional requirements of the assets and ultimately the number of assets, design, function, criticality, configuration, level of redundancy, capability, and capacity.

Key criteria to ensure optimal line route selection, establishing prudent, cost efficient, intrinsically safe, and sustainable corridors for the life cycle management of the SCADA assets include consideration of:

- Optimised utilisation of existing SCADA assets
- Schedule and cost impacts from existing adjacent infrastructure
- Transport and logistics
- Project cost implications
- Safety and reliability risks
- Environmental and approvals risk
- Stakeholder and community requirements
- Design and execution requirements
- Operation and maintenance requirements.

An example of the planning approach is the proposed replacement of the SCADA asset replacement program, where the replacement of assets is part run-to-fail and part targeted replacement (based on obsolescence and deficient functionality). This program utilises a combination of new and existing assets to optimise cost-efficiency whilst minimising risk. Various options are considered during the planning stage, with the optimal option being implemented.

13.2 Design

The design phase is where decisions around the physical characteristics and functioning of the asset are made. This life cycle stage defines the quality and reliability of the asset, and the whole of life cycle costs that can be realised. It influences the total cost and the level of service that the assets can deliver to customers and shareholders.

The standardisation of SCADA asset designs considers whole of life cycle management in a prudent and efficient manner. Standardisation is defined as the process of developing and agreeing on uniform technical design criteria, specifications and processes and is a key aspect of Power and Water's asset management process.

Along with continuity, leverage and scalability, standardisation enables consistent application of best industry practise and continuous performance improvement. It establishes technical commonality that allows for an off-the-shelf, best practice, and fit-for-purpose approach to engineering solutions. It also allows for interchangeability that provides operations and asset management benefits.

Power and Water's SCADA asset design standardisation offers the following specific benefits to the business:

- Helps with the ranking and prioritisation of investment projects
- Gives confidence in the safe and reliable functioning of the assets
- Provides assurance that the assets will do the job they were intended for
- Boosts production and productivity
- Encourages higher quality of engineering leveraging specialist knowledge and optimum solutions
- Allows for the uniform execution of projects
- Enables standardisation of construction equipment and processes.

Examples of continuous improvement in this design approach are demonstrated in the ongoing development of a Communications Design Manual. The design manual has been used to assist in the design of communications panels as part of recent Zone Substation replacements. The benefits from this design include:

- Reduced design and reviews times
- Standardisation of equipment used, including miscellaneous items such as wire types and sizes and MCB's
- Reduced costs and stores requirements as a result of less varied components used in the communications panels.

13.3 Operation

Asset operations include activities associated with the monitoring, operation and control of the asset to adapt to changing requirements of the network. This includes:

- Planned switching of the network for scheduled works (e.g. maintenance)
- Emergency switching of the network in response to incidents (e.g. fault events)
- Real time switching to operate the asset within its design parameters (e.g. loading)
- Monitoring of the condition of the asset (e.g. alarms)
- Adjusting tap changer settings to regulate voltage levels.

13.4 Maintenance (opex)

Inspection and testing is undertaken in accordance with SCADA's maintenance policy which sets out the type and frequency of inspection and testing to be undertaken. The testing schedule is modified, where possible, to align with major asset inspections or works.

If an asset is found to fail testing a report is raised to the SCADA engineers to determine the most appropriate action to be taken on a case-by-case basis.

Currently a number of different contractors undertake routine maintenance activities at communications sites, such as vegetation management, air-conditioner servicing and tower inspections by external contractors and visual inspections via internal staff. Leveraging the capability of the external contractors to undertake visual inspections should reduce the costs of visual inspections. Additionally, better utilisation of remote monitoring systems at sites can also reduce the need to attend sites. Some additional monitoring equipment may need to be installed to improve monitoring of some systems such as battery banks, environmental conditions internal to the shelter and possibly the status of antenna systems.

13.4.1 Condition assessment

The deterioration will be evidenced through condition assessments carried out by maintenance engineers.

In addition to the routine maintenance activities listed above Power and Water field crews will begin undertaking condition assessments on batteries and non-electronic assets such as cables and shelters over the coming regulatory period. Power and Water engineers are further assessing the viability and potential value of developing conditional assessments for electronic assets; if prudent Power and Water will begin to collect this data.

This process will improve network reliability, minimise risk and reduce asset management costs.

13.4.2 Inspection and maintenance

Power and Water's SCADA engineers have specific inspection and maintenance requirements for SCADA assets. These requirements are based on location, function, criticality, health, asset type and many other factors.

The following documents outline the frequency and methodology of Power and Water's inspection and maintenance policies for SCADA assets.

13.5 Renewal (repex)

Asset renewal is the establishment of a new asset in response to an existing asset's condition. The need for the renewal of existing assets is identified in the asset maintenance stage and 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.

If a SCADA asset is replaced as part of a zone substation renewal and has not reached the end of its expected life and if the asset is still operating efficiently then the asset should be kept as a spare, and be used in the case production during the lifecycle of the asset ceases. This allows for quick like-for-like replacement as well as the modular replacement of certain assets in which

Power and Water has the personnel with the skills to repair the asset to as-good-as new replacement level.

Power and Water has asset replacement programmes in place to renew assets of poor condition prior to the asset failing.

13.6 Disposal

The decision to reuse or dispose of an asset is made with consideration of the potential to:

- Reuse the asset
- Utilise the asset as an emergency spare
- Salvage asset components as strategic spare parts.

The remaining asset is disposed of in an environmentally responsible manner.

14 Appendix B – Asset data

14.1 Asset type data breakdown

Table 14.1: Summary of asset types

Asset category	Asset description	Quantity	Average Age (years)	Average nominal Lifespan (years)	Percentage exceeding lifespan
Field devices	RTU	111	9.47	15	20.72%
Communications network assets	Management systems	8	3.50	6	0%
	Microwave links	54	4.96	15	0%
	DWDM systems	5	5.60	15	0%
	SDH multiplexors	63	6.33	15	0%
	PDH multiplexors	149	7.78	15	0.67%
	UHF system	61	12.20	14.08	36.07%
	Telemetry systems	65	5.83	15	0%
	Teleprotection systems	74	9.00	16	5.41%
Master station assets	EMS	7	3.00	6	0%
	Server/equipment room	13	6.92	15	0%
Communications site infrastructure	Power supply	78	5.67	15	0%
	Battery systems	107	5.92	12.08	0%
	Solar system	22	6.95	20.45	0%
	Shelters	28	20.46	39.64	0%
	Structures	18	20.28	50	0%
Communications linear assets	Fibre cable	291,282(km)	11.50	40	0%
	Pilot cable	84,779(km)	26.16	50	0%
Other	Substation LAN	11	2.36	15	0%

14.1.1 Field devices

RTUs	Number of assets
C2025	13
C50	10
SCD5200	88

Total	**111**

14.1.2 Communications network assets

Management systems	Number of assets
CNMS hardware	1
CNMS cybersecurity devices hardware	1
CNMS software	1
CNMS cybersecurity devices software	1
SOEM hardware	1
SOEM cybersecurity devices hardware	1
SOEM software	1
SOEM cybersecurity devices software	1
Total	**8**

Microwave links	Number of assets
Microwave systems	54

DWDM system assets	Number of assets
DWDM system	1
Mitchell centre	1
HCCC	1
Chan	1
BHWS (DR)	1
Total	**5**

SDH multiplexors types	Number of assets
1412	10
846	11
OMS1240	39
GPS clock for SDH multiplexors	3
Total	**63**

PDH Systems	Number of assets
PDH	**149**

UHF systems	Number of assets
Fixed	1
Handheld (50 units)	1
Mobile (310 mobiles)	1
DMR Core (hardware, software, cybersecurity)	3
DMR repeater (access routers, cybersecurity, software)	3
UHF Radio System (Alice Springs, Darwin/Jabiru, Katherine, Tennant Creek)	10
UHF systems	42
Total	**61**

Telemetry	Number of assets
WestGap (2 Base, 6 Outstations)	8
PAWT (1 Base, 3 Outstations)	4
OSSS (1 Base, 6 Outstations)	7
MMRS (1 Base, 10 Outstations)	11
MBCS (1 Base, 4 Outstations)	5
Kath 12ML (1 Base, 1 Outstation)	2
HCRS (1 Base , 6 Outstations)	7
DRDCS (1 Base, 2 Outstations)	3
DKLB (1 Base, 3 Outstations)	4
CIRS (1 Base, 2 Outstations)	3
CAWT (2 Base, 6 Outstations)	8
ARWT (1 Base, 1 Outstation)	2
3G/4G Modems	1
Total	**65**

Teleprotection	Number of assets
DM1200	44
Power line carrier line plant (Line traps / UAP)	12

Teleprotection	Number of assets
Power line carrier terminals	8
RFL / TPD-15	4
TPS64	6
Total	**74**

14.1.3 Master station assets

EMS assets	Number of assets
Network Applications	1
Servers, core networks, GPS Clocks	1
Other support applications/hardware	1
Hardware	1
Cybersecurity devices/software	1
Core SCADA Software and applications	1
Backup Systems (Commvault and hardware)	1
Total	**7**

Server / equipment room assets	Number of assets
UPS	7
Process coolers	6
Total	**13**

14.1.4 Communications site infrastructure

Power Supply	Number of assets
Power Supplies	78

Battery systems	Number of assets
7OPzV600	12
8OPzv960	3
A600/720	2
SBS580	14
SBS320	11
A406/165	2

UXF-150-12	6
PS1207	2
G85	43
SBS330	10
A212/9.5	2
Total	**107**

Solar systems	Number of assets
IMARK 5000	2
IMARK MPPT SDS48-100	7
IMARK MPPT SRX80	5
Sunpower SPR-E20-327	1
Solar Panels	7
Total	**22**

Shelters	Number of assets
Shelters / compounds / access	**28**

Structures	Number of assets
Towers & Masts	**18**

14.1.5 Communications linear assets

Fibre cable types	Length of cable (km)
Optus network underground	123,047
OPGW (optical ground wire)	137,740
CBD SMOF (single mode optical fibre)	5414
CBD MMOF (multiple mode optical fibre)	5414
Other underground fibre cables	19,667
Total	**291,282**

Pilot cable types	Length of cable
Pilot Cable	**84,779**

14.1.6 Other (substation LANs)

Substation LAN	Number of assets
Fixed LANs	8
NOMAD LANs	2
Mobile switch room LAN	1
Total	**11**

14.2 Asset challenges by asset type

14.2.1 Field devices

Remote Terminal Units (RTU) - includes Human Machine Interface (HMI) & GPS clocks:

Several field devices require replacement due to equipment obsolescence and end of vendor support, these include:

- RTU - SCD5200, no longer have vendor support, however they are backwards compatible with the newer SCD6000 model, some software reconfiguration is required in the process.
- GPS clocks
- HMIs

14.2.2 Communications network assets

Management systems – CNMS, SO-EM

Communications Network Management Systems (CNMS)

The CNMS is a manager of management system. The CNMS (software), operating systems (OS) and the hardware they operate on are out of vendor support.

A number of equipment managers, referred to as Element Managers are also out of vender support, these include:

- Ericcson's Service On Element Manager (SO-EM)
- Nokia Q1 Element Manager.

Cyber security for the CNMS requires regular review and update to maintain a high level of protection against cyber threats. Measures to meet these requirements include:

- Cyber security audits
- Implementation of major audit findings

An improved focus on cyber security as a result of the last cyber security audit is expected to implement:

- Regular vendor approved patching and software releases
- Hardware refreshes; and
- Implement a suitable system monitoring regime.

However, since the system is no longer supported by the vendor, these updates are no longer available and will result in the system becoming vulnerable from a cyber security perspective and risky from an asset condition perspective.

A project to update the core hardware and networking elements of the CNMS is planned. Once this is completed, an upgrade of the CNMS and other obsolete Element Managers is planned.

Microwave links – includes antennas and feeders

Antennas and associated coaxial feeders are key components of microwave and UHF radio systems. Ongoing system performance monitoring and the review of the existing system alarms are planned for these components to ensure the ongoing correct operation of the associated system.

Some microwave radio links are beyond their expected life and vendor support is no longer available. Where possible, additional spares have been sought or spares have been generated by replacing some installations on the network. The following installations are scheduled to be replaced:

- Lake Bennet Communications Site to Batchelor Water Tank
- Weddell Power Station – Strangways Communications Site
- Weddell Power Station – Channel Island Communications Sites
- Pine Creek Mesa Communications Site – Pine Creek Substation
- Parap Communications Site – Channel Island Communications Site.

Additional analysis and condition assessment is required to determine the remaining life of the retained installations.

Dense Wavelength Division Multiplex (DWDM) systems

The current DWDM equipment is at end of life; however, there are spares available to support the system should one of the DWDM fail. A replacement program is planned for the next regulatory period.

Synchronous Digital Hierarchy (SDH) multiplexors – includes GPS clocks

SDH/PDH systems continue to be the primary communications technology in the OTN. Currently no plans exist to move to an alternate technology.

Some utilities are implementing MPLS technology to enable the better management of IP services. However, MPLS is significantly more complex that the traditional SDH/PDH systems and Power and Water does not consider that any benefits merit the cost to consumers. Additionally, the implementation of MPLS could require a complete revision of the support and maintenance staff capabilities to manage a MPLS system.

Currently the OMS846 and OMS1240s are in a phase of life extension by strategic replacement of some sites with OMS1410s and the OMS1240s retained for spares.

Plesiochronous Digital Hierarchy (PDH) multiplexors

PDH is still widely used and available from a number of vendors. Currently no plans exist to move to alternative technologies.

Currently the Nokai PDH is in a phase of life extension with the Avara equipment being a direct like for like replacement.

UHF system - includes core sites and repeater sites

A Ultra High Frequency (UHF) Digital Mobile Radio (DMR) system is to be commissioned by June 2018. This is a new system which is expected to present few operational issues. It replaces the existing UHF analogue mobile radio network. Changes by the Australian Communications and Media Authority (ACMA) to the UHF frequency band plan dictated the requirements to replace the analogue system.

The system vendor, Tait is required to manage and support the DMR system during the first 12 months (Defect Liability Period) after Practical Completion. No additional management and support services beyond the initial 12 months of Defect Liability have been contracted and this will need to be resolved during the Defects Liability Period. The options available include:

- Utilise the SCADA resources; or
- Seek pricing from external maintenance suppliers.

Telemetry systems

After allowing for the DMR UHF radio system to be bedded in, it is planned to trial the provision of telemetry using the DMR via the Tait product, GridLink. This trial is planned to occur during the current regulatory period with any future rollout to be justified for inclusion in the next regulatory submission.

The existing Telemetry equipment is due for replacement in the 2025-2029 regulatory period. Currently various telemetry products are used which are inefficient to manage and maintain. Utilising Gridlink is expected to maximise the benefits of the DMR, allow standardisation of product delivery and reduce costs for management of telemetry systems.

Teleprotection systems

A number of teleprotection systems are obsolete and will be managed through the following projects:

- Legacy RFL equipment will be replaced as part of planned major projects replacing existing substations.
- The legacy TPD-15 equipment will be replaced as part of the major project DKTL Secondary System Upgrade.
- Nokia TPS 64 equipment will be replaced by the DM1200 and this is included in the major project DKTL Secondary System Upgrade.

14.2.3 Master station assets

Energy Management System (EMS)

To maintain the level of power system visibility, ensure the required SCADA and EMS availability targets are met, to maximise the protection against cyber security risks and to meet business needs, the core SCADA, EMS and operating systems (OS) software and server and IT network hardware require regular updating and periodic replacement. SCADA, EMS and OS software upgrades are planned based upon the current and planned release of vendor software.

As the existing server hardware, EMS software (GE) and IT networking hardware will all be out of support by 2022, a major capital project exists (PRD33134) to refresh the EMS system starting in FY2019-2020.

In addition, the following is planned as part of the ongoing management of the EMS:

- Annual cyber security audits
- Implementation of vendor approved patching and software releases for Operating Systems and EMS applications;
- Appropriate levels of vendor support contracts for hardware and software; and
- Implement a suitable system monitoring regime.

Server/equipment room – Uninterruptible Power Supplies (UPS) and process coolers

Age based replacement of these assets is planned until a better understanding of the asset condition can be obtained. As solid state computer equipment, there is limited condition assessment or repair that can be undertaken by Power and Water.

14.2.4 Communications site infrastructure

Battery systems

Battery systems provide critical functions and need to be duplicated. Previous design standards allowed for a single battery charger with dual charging outputs which no longer meets the current design standards. A program to upgrade battery systems to the current standards will be undertaken (see section 9.2).

Currently the basis for battery replacement is purely age based until a better understanding of the capacity and performance of the banks can be determined.

Depending on the manufacturers design criteria, batteries have varying design lives ranging from 5–20 years when operated in ideal conditions, some of the batteries used with the OTN operate in less than ideal conditions. Some of the standalone telecommunications sites have no 240VAC supply and rely entirely on solar power, these sites also have poor ‘wet season’ access making it difficult to service the site during the wet season. As well as the solar sites, some 240VZC sites require suitably sized and operating battery systems to support prolonged periods of monsoonal activity as well as a prolonged loss of 240VAC power which could be experienced as a result of storms and cyclonic events. Battery system upgrades and replacements have been reactionary in the past and a more robust and routine monitoring regime for these critical assets is required. Investigations into the air-conditioning of battery rooms should be undertaken to determine if the additional cost of air-conditioning and its maintenance is offset by the expected longer life of the battery systems (and other digital assets).

A number of new battery banks have been installed as part of the DMR project. Where possible, the battery banks removed from service have been redeployed to minimise the number of banks needing replacement. The exact status of the relocated banks is unknown and further analysis of these banks will be required.

Solar systems - includes frames

Large solar panels arrays are used at:

[redacted]

Due to water ingress of the solar panels, the arrays at [redacted] solar panels were upgraded in 2011. On-going monitoring of array capacity at all sites is required to ensure battery banks can be fully restored to design capacity in appropriate time frames. Due to the amount of cloud cover that can occur during the wet season, solar arrays need to be oversized to ensure that the batteries can be charged in low sun condition. This increases the cost (capex) of the solar arrays.

Performance of solar systems will continue to be monitored.

Shelters – Stand-alone communication sites

The condition of shelters varies considerably and the overall integrity along with their capacity to withstand a cyclonic event needs review. This review may result in upgrades or replacement programs for some shelters. Many shelters are also reaching a physical size limit and some sites have required the addition of a shipping container to house the required capacity of batteries. The shipping containers used are not considered ideal due to the poor thermal protection they offer the batteries, hence leading to reduced battery life.

Structures (towers and masts)

As the microwave radio systems require improved availability and increased capacity to service the traffic needs of the OTN, the microwave radio links will need larger solid parabolic antennas. The load capacity of the guyed towers is limited and in some cases across the network they will be reaching their maximum load capacity.

Any future upgrades of these guyed towers will require careful assessment to determine the best option for future loading requirements. It is possible that this will require moving to free standing towers which can support significantly larger wind loadings as strengthening of the existing guyed tower will not be sufficient.

Routine inspections of the integrity of both guyed and free standing towers is required to maintain these assets to a safe level. An assessment of each tower has been undertaken to determine its criticality and desired inspection period based on its construction type, use and location.

14.2.5 Communications linear assets

Fibre cable – Underground and Optical Pilot Ground Wire (OPGW)

Some of the sites connected via the OTN do not have the physical diversity required by the Technical Code. Sites requiring improved diversity are:

- Casuarina ZSS
- Berrimah ZSS

In addition to the lack of diversity for some sites, the Hudson Creek - Channel Island OPGW (fibre) bearer was installed circa 1988-1989 and increased monitoring will be required to assess the condition of this fibre link as it approaches end of life.

End of life for fibre cable is not fully understood due to its relatively recent use of this technology. Monitoring of deterioration of the fibre will allow determination as to when it should be replaced. The Weddell - Strangways OPGW bearer has also required more maintenance than other OPGW's recently and has suffered several core failures.

All fibre bearers should be monitored and assessed at regular intervals. More frequent analysis of the Hudson Creek – Channel Island OPGW and the Weddell – Strangways OPGW should occur.

Additional data collection and analysis is required before appropriate management strategies for this asset can be developed.

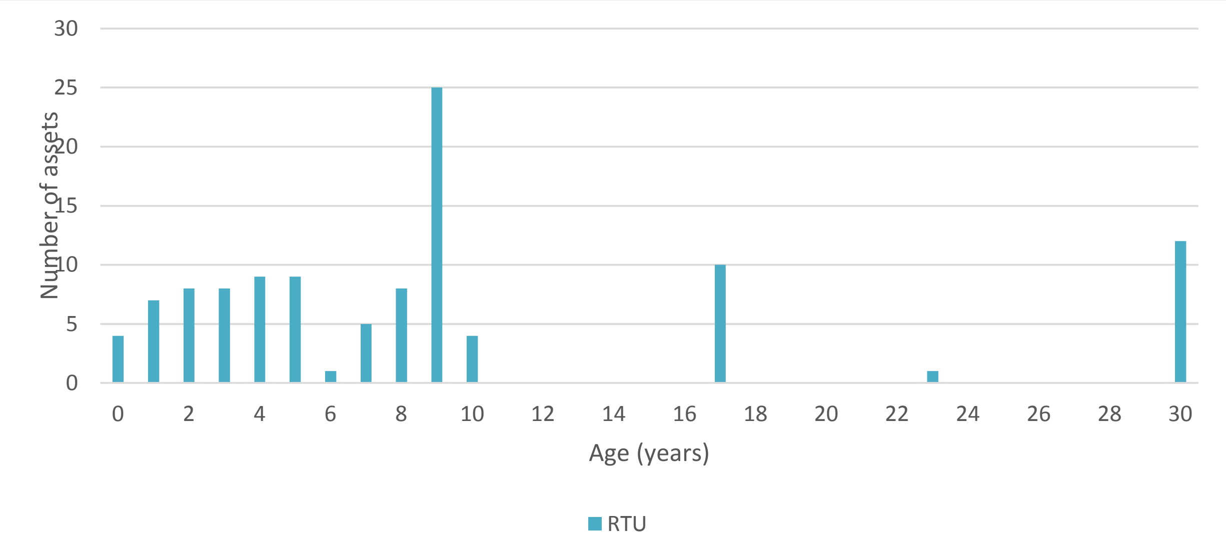
Pilot cable

Pilot cable is an ageing asset. The reliance on Pilot Cables has been reduced at the 66kV level with the use of digital protection schemes now being implemented. 11kV protection schemes continue to use pilot cables. This is primarily in the Darwin CBD. New pilot cables have been installed as part of zone substation replacements and switching station refurbishments.

14.3 Age profiles by asset categories and types

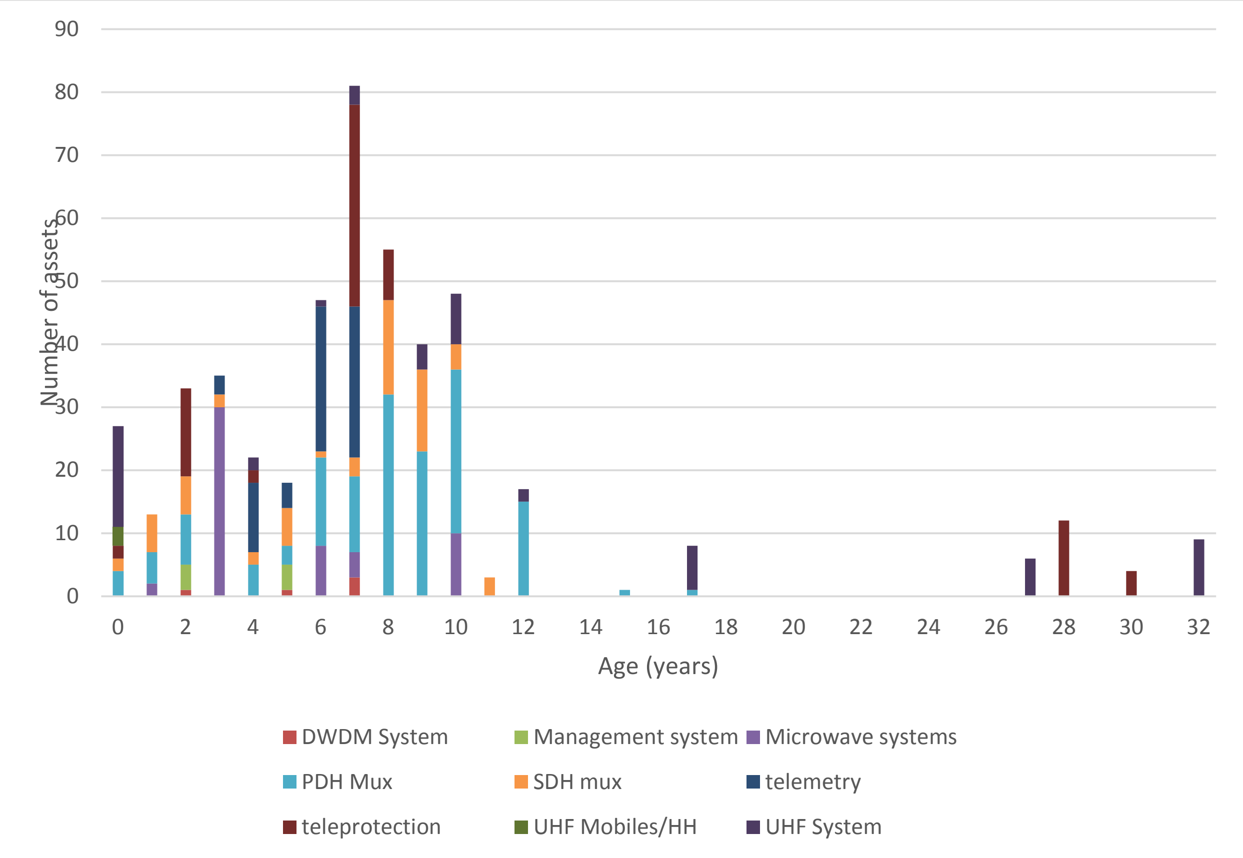
14.3.1 Field devices

Figure 14.1: Field devices age profile



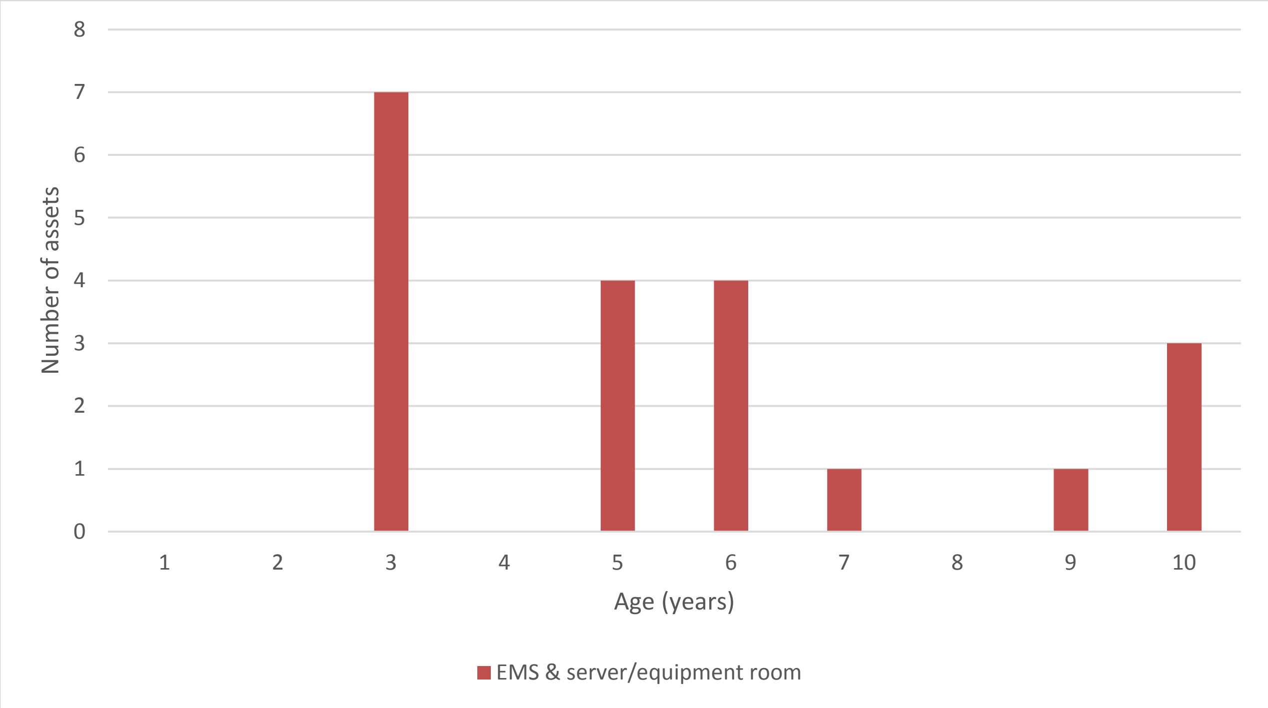
14.3.2 Communications network assets

Figure 14.2: Communication network assets age profile



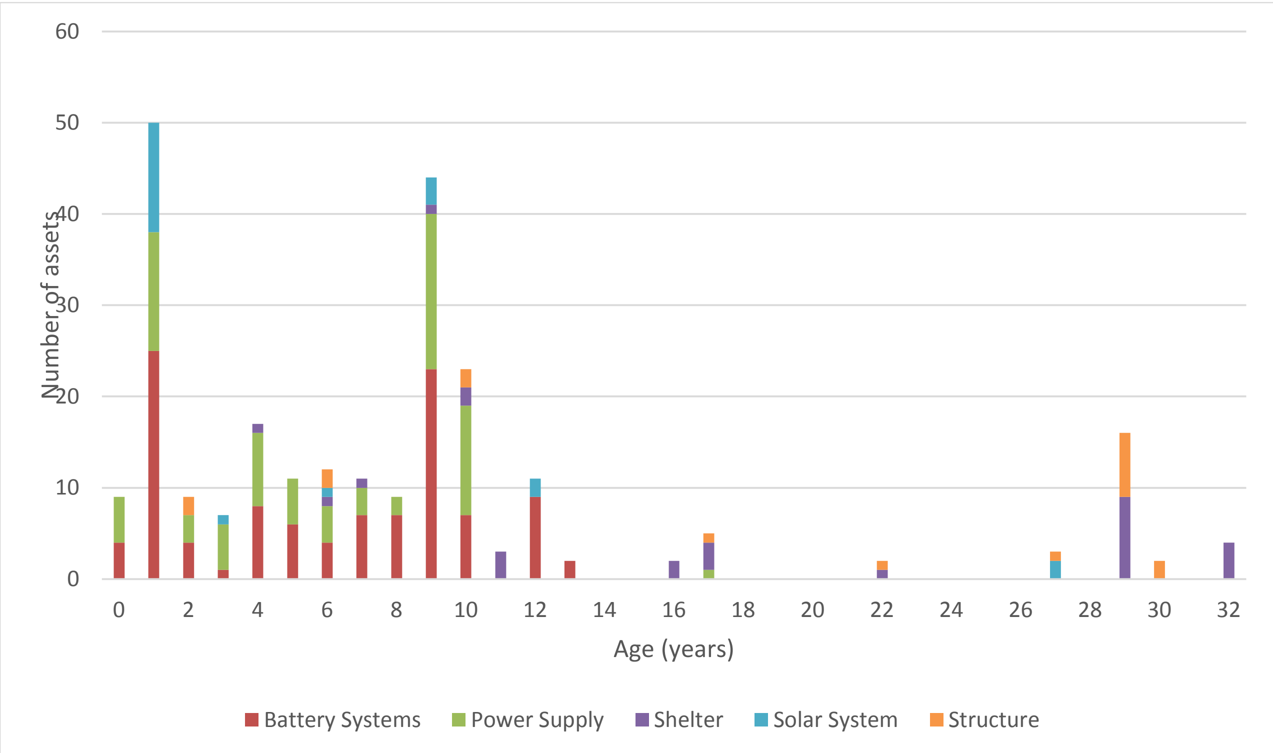
14.3.3 Master station assets

Figure 14.3: Master station assets age profile



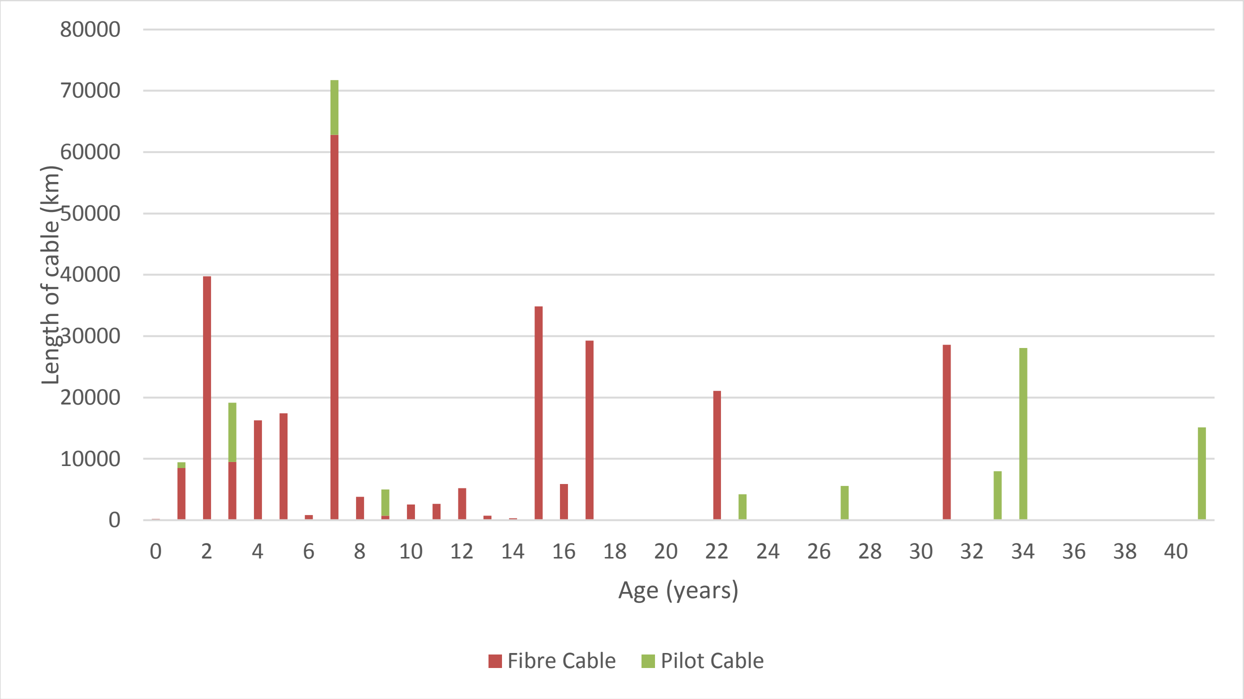
14.3.4 Communications site infrastructure

Figure 14.4: Communications site infrastructure age profile



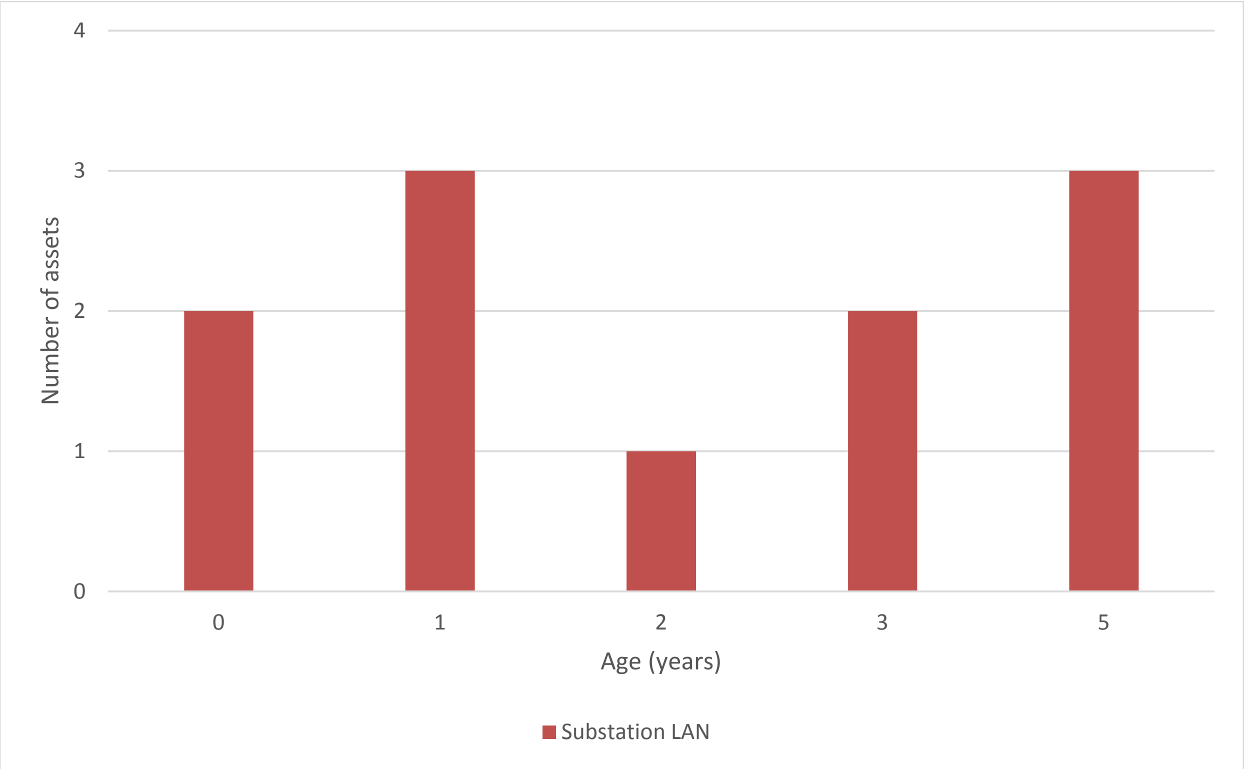
14.3.5 Communications linear assets

Figure 14.5 Communications linear assets age profile



14.3.6 Other (substation LANs)

Figure 14.6: Other assets (Substation LAN) age profile



14.4 Remaining life by asset categories and types

The following charts show the remaining life per asset category by comparing the asset actual age to its expected life.

All SCADA assets

Figure 14.7 shows the expected remaining life of all SCADA assets by asset category. Some key characteristics of Power and Water's SCADA asset fleet are:

- 766 discrete assets or 87.64% have more than 10% of their expected life remaining
- 49 discrete assets or 5.61% are within the last 10% of their expected life
- 59 discrete assets or 6.75% have exceeded their expected life
- All communication linear assets have more than 10% of their expected life remaining.

Figure 14.7: Remaining life for all discrete asset categories

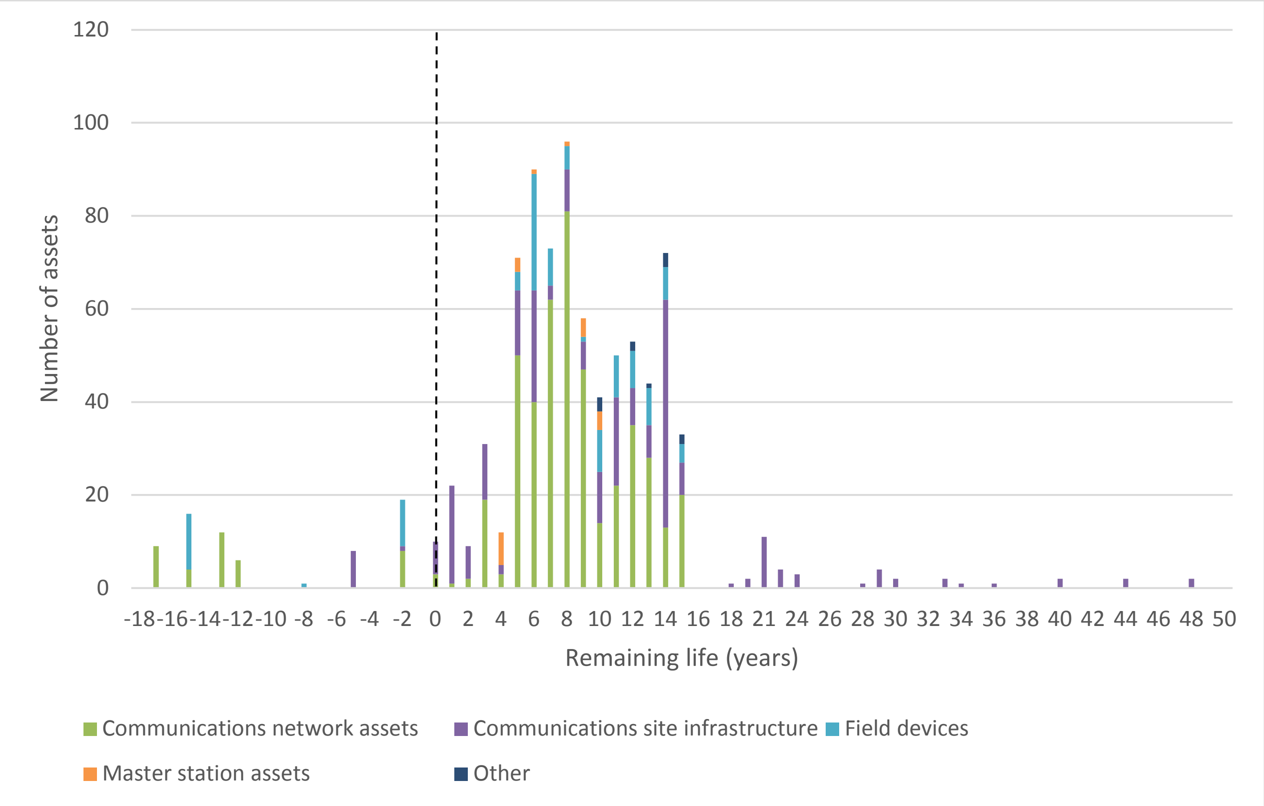
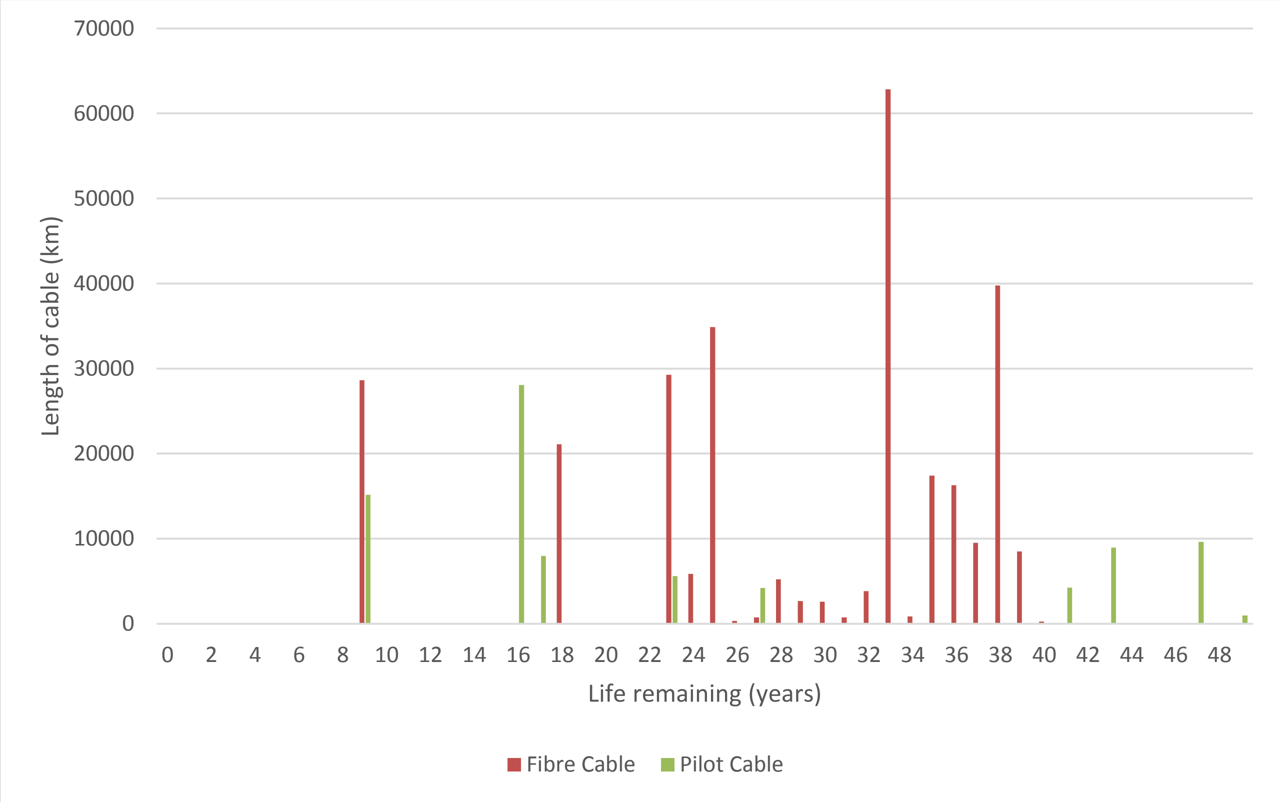


Figure 14.8: Remaining life for communication linear assets (km)

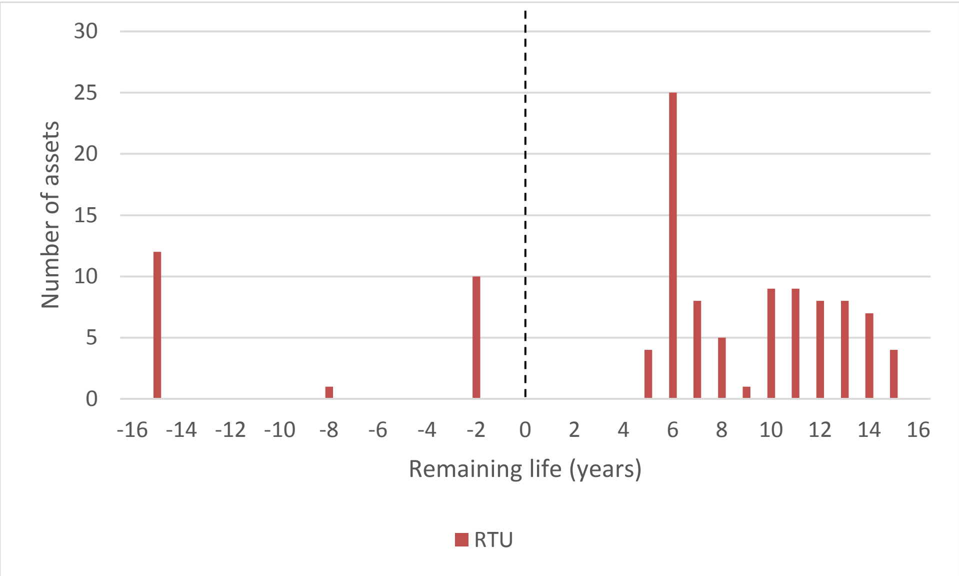


14.4.1 Field devices

Figure 14.9 shows the expected remaining life of Power and Water's field devices. Some key characteristics are;

- 88 RTU's (79.28%) have more than 10% of their expected life remaining
- 23 RTU's (20.72%) have exceeded their expected life

Figure 14.9: Field devices remaining life



14.4.2 Communications network assets

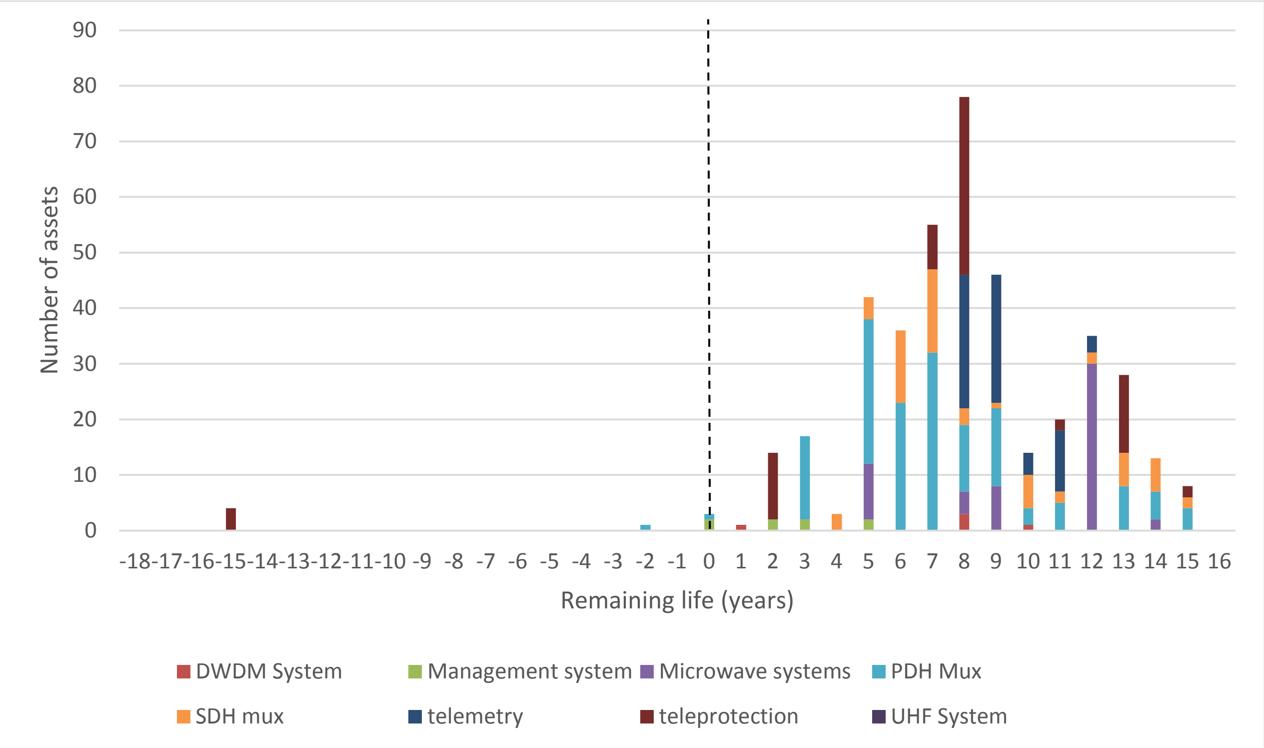
Figure 14.10 shows the expected remaining life of Power and Water's communications network assets. Some general characteristics are;

- 436 assets – 91.02% have more than 10% of their expected life remaining
- 16 assets – 3.34% are within the last 10% of their expected life
- 27 assets – 5.64% have exceeded their expected life

Some key asset type characteristics are;

- All microwave systems, SDH multiplexors, telemetry, and UHF mobiles / handhelds have more than 10% of their expected life remaining
- Assets within the last 10% of their expected life
  - 1 DWDM system – 20%
  - 2 management systems (1 hardware/1 software) – 25%
  - 1 PDH multiplexor – 0.67%
  - 12 teleprotection – 16.22%
- Assets that have exceeded their expected life
  - 1 PDH multiplexor – 0.67%
  - 4 teleprotection – 5.41%
  - 22 UHF systems – 23.53%

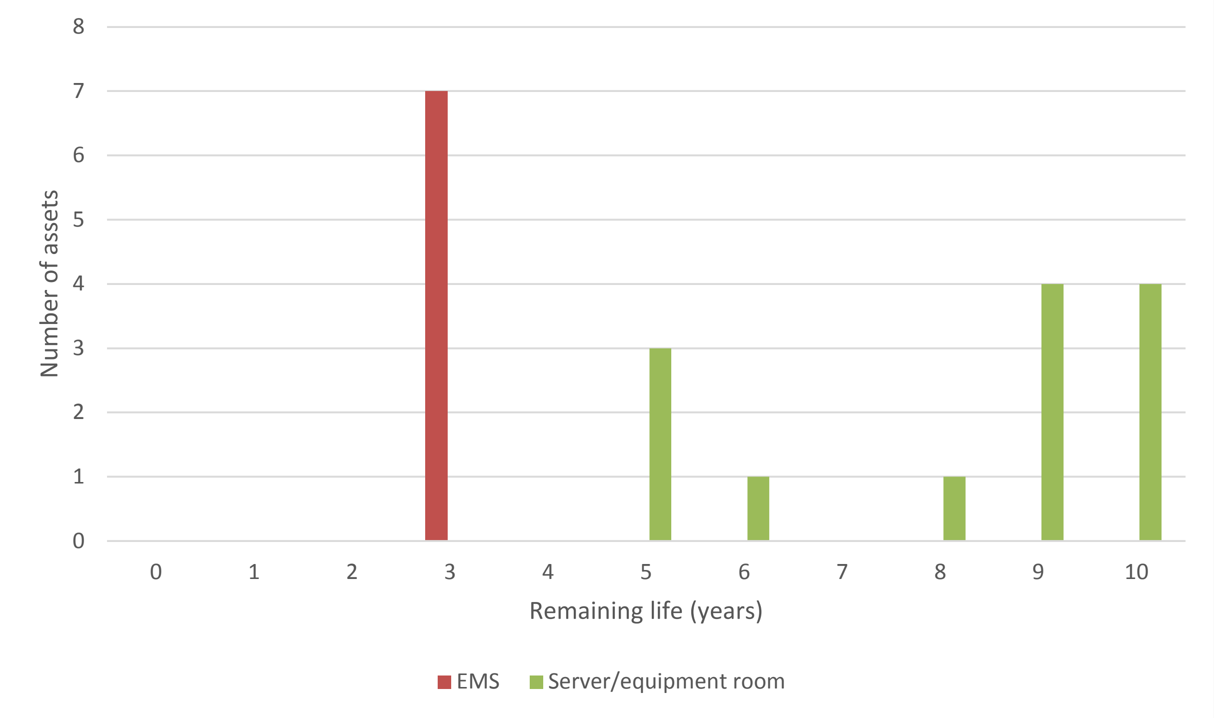
Figure 14.10: Communications network assets remaining life



14.4.3 Master station assets

Figure 14.11 shows the expected remaining life of Power and Water's master station assets. All assets have more than 10% of their expected life remaining.

Figure 14.11: Master station assets remaining life



14.4.4 Communications site infrastructure

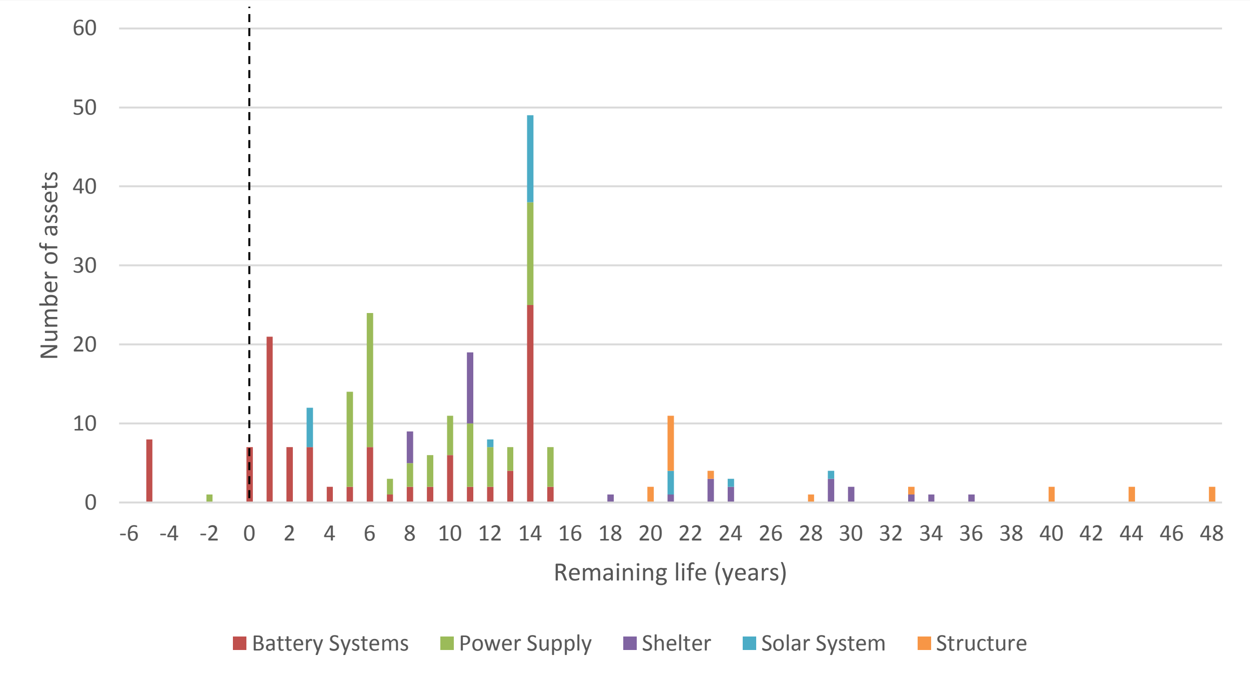
Figure 14.12 shows the expected remaining life of Power and Water's communications site infrastructure. Some general characteristics are:

- 211 assets – 83.40% have more than 10% of their expected life remaining
- 33 assets – 13.04% are within the last 10% of their expected life
- 9 assets – 3.56% have exceeded their expected life.

Some key asset type characteristics are:

- All shelters and structures have more than 10% of their expected life remaining
- Assets within the last 10% of their expected life
  - 30 battery systems– 28.04%
  - 3 solar systems – 13.64%
- Assets that have exceeded their expected life
  - 8 battery systems– 7.48%
  - 1 power supply –1.28%.

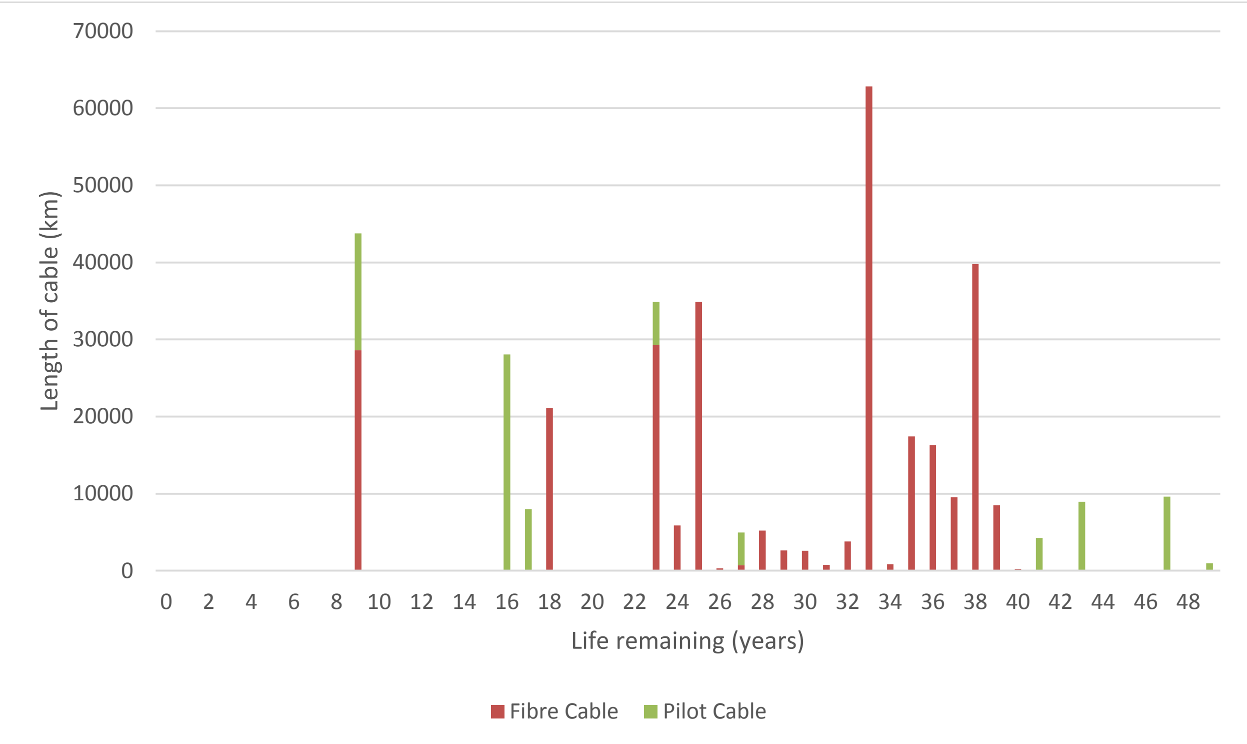
Figure 14.12: Communications site infrastructure remaining life



14.4.5 Communications linear assets

Figure 14.2 shows the expected remaining life of Power and Water's communications linear assets. All assets have more than 10% of their expected life remaining.

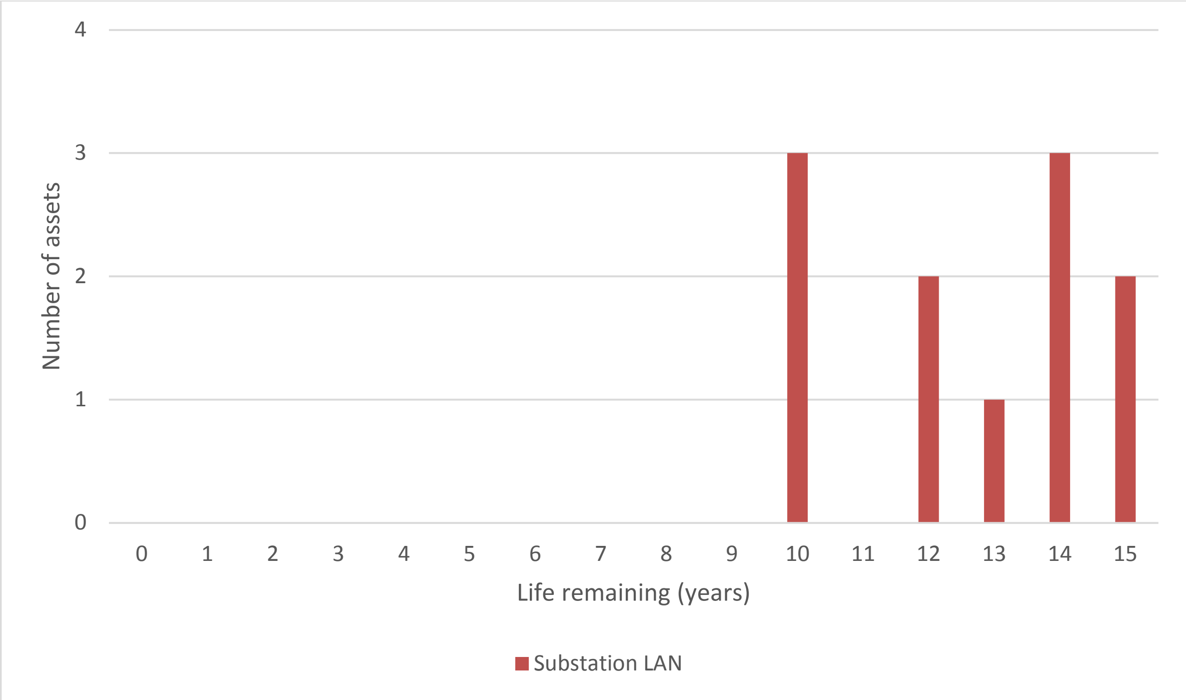
Figure 14.13: Communications linear assets remaining life



14.4.6 Other (substation LANs)

Figure 14.14 shows the expected remaining life of Power and Water's other (Substation LAN) assets. All assets have more than 10% of their expected life remaining.

Figure 14.14: Other (Substation LAN) remaining life



14.5 SCADA's NT SAIDI, NT SAIFI and the total number of asset failures

Figure 14.15: NT SAIDI

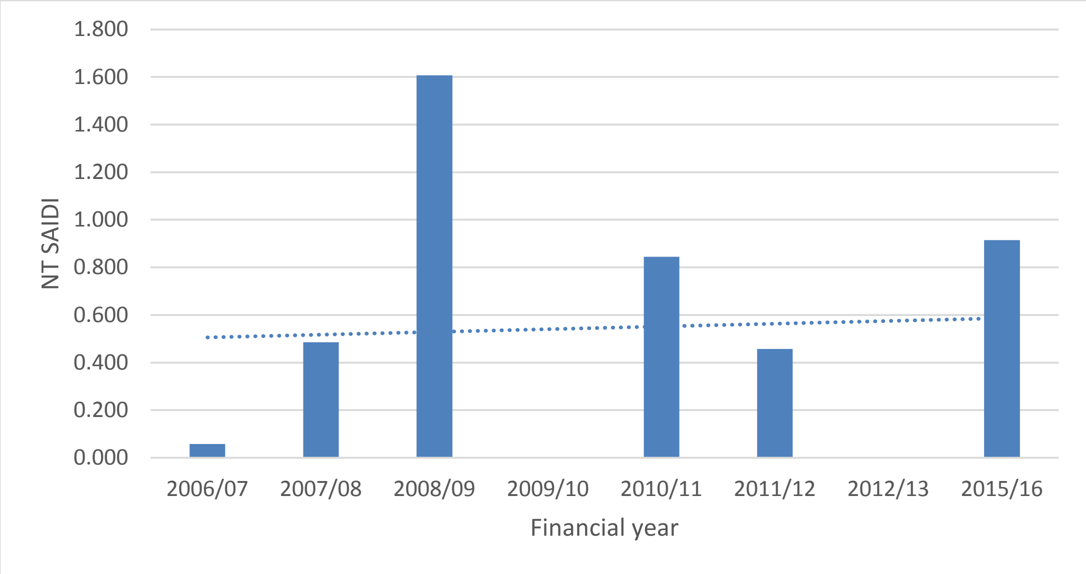


Figure 14.16: NT SAIFI

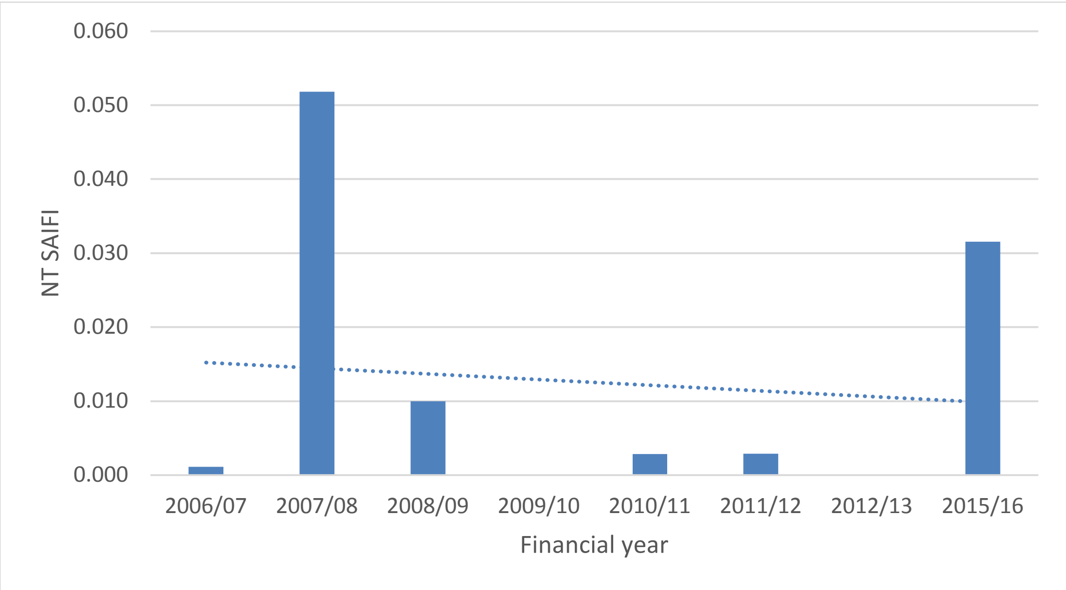
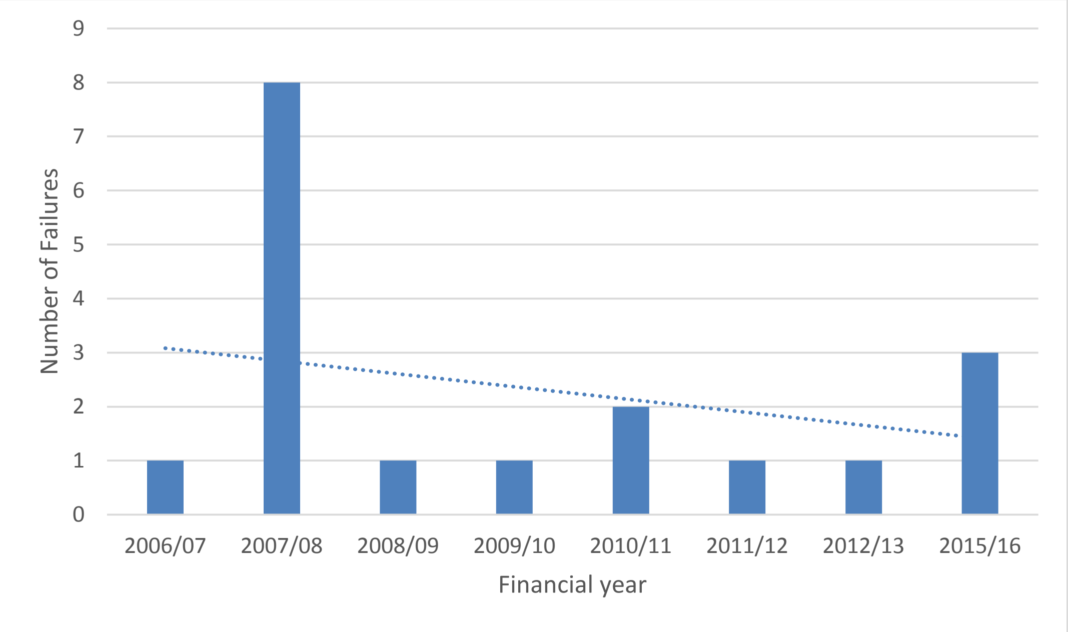


Figure 14.17: Number of SCADA asset failures



14.6 Health score results by asset categories and types

Table 14.2: Field devices (RTU's) health score results

Condition Rank	Condition	Number of assets
H1	Acceptable	88
H2	Caution – monitor	0
H3	Urgent	23

Table 14.3: Communications network assets health score results

Condition Rank	Condition	Number of assets
H1	Acceptable	436
H2	Caution – monitor	16
H3	Urgent	27

Table 14.4: Communications network assets health score results

Asset type	Condition Rank	Condition	Number of assets
DWDM system	H1	Acceptable	4
	H2	Caution – monitor	1
	H3	Urgent	0
Management system	H1	Acceptable	6
	H2	Caution – monitor	2
	H3	Urgent	0
Microwave systems	H1	Acceptable	54
	H2	Caution – monitor	0

Asset type	Condition Rank	Condition	Number of assets
	H3	Urgent	0
PDH multiplexors	H1	Acceptable	147
	H2	Caution – monitor	1
	H3	Urgent	1
SDH multiplexors	H1	Acceptable	63
	H2	Caution – monitor	0
	H3	Urgent	0
telemetry	H1	Acceptable	65
	H2	Caution – monitor	0
	H3	Urgent	0
teleprotection	H1	Acceptable	58
	H2	Caution – monitor	12
	H3	Urgent	4
UHF System	H1	Acceptable	39
	H2	Caution – monitor	0
	H3	Urgent	22

Table 14.5: Master station assets health score results

Condition Rank	Condition	Number of assets
H1	Acceptable	20
H2	Caution – monitor	0
H3	Urgent	0

Table 14.6: Communications site infrastructure asset category health score results

Condition Rank	Condition	Number of assets
H1	Acceptable	211
H2	Caution – monitor	33
H3	Urgent	9

Table 14.7: Communications site infrastructure asset types health score results

Asset type	Condition Rank	Condition	Number of assets
Battery systems	H1	Acceptable	69
	H2	Caution – monitor	30
	H3	Urgent	8
Power supplies	H1	Acceptable	77
	H2	Caution – monitor	0
	H3	Urgent	1
Shelter	H1	Acceptable	28
	H2	Caution – monitor	0

Asset type	Condition Rank	Condition	Number of assets
	H3	Urgent	0
Solar systems	H1	Acceptable	19
	H2	Caution – monitor	3
	H3	Urgent	0
Structures	H1	Acceptable	18
	H2	Caution – monitor	0
	H3	Urgent	0

Table 14.8: Communications linear assets health score results

Condition Rank	Condition	Length of cable (km)
H1	Acceptable	376,061
H2	Caution – monitor	0
H3	Urgent	0

Table 14.9: Other (Substation LAN) health score results

Condition Rank	Condition	Number of assets
H1	Acceptable	11
H2	Caution – monitor	0
H3	Urgent	0

14.7 Criticality by asset categories and asset types

Table 14.10: Criticality of discrete assets

Condition Rank	Number of SCADA assets
C1	836
C2	0
C3	38

Table 14.11: Criticality of communications linear assets

Condition Rank	Length of cable (km)
C1	376,061
C2	0
C3	0

Table 14.12: Criticality by asset category

Asset category	Condition Rank	Number of assets
Field devices	C1	111
	C2	0
	C3	0
Communications network assets	C1	479
	C2	0
	C3	0
Master station assets	C1	0
	C2	0
	C3	20
Communications site infrastructure	C1	235
	C2	0
	C3	18
Communications linear assets	C1	376,061
	C2	0
	C3	0
Other (Substation LAN)	C1	11
	C2	0
	C3	0

Table 14.13: Criticality of communications site infrastructure by asset type

Asset category	Condition Rank	Number of assets
Battery systems	C1	107
	C2	0
	C3	0
Power supply	C1	78
	C2	0
	C3	0
Shelter	C1	28
	C2	0
	C3	0
Solar system	C1	28
	C2	0
	C3	0
Structure	C1	0
	C2	0
	C3	18

14.8 Network risk by asset categories and asset types

Table 14.14: SCADA asset health - criticality matrix for discrete assets

	H1	H2	H3
C1	728	49	59
C2	0	0	0
C3	38	0	0

Risk legend				
Extreme	High	Moderate	Low	Very low

Table 14.15: SCADA asset health - criticality matrix for communications linear assets (km)

	H1	H2	H3
C1	376,061	0	0
C2	0	0	0
C3	0	0	0

Risk legend				
Extreme	High	Moderate	Low	Very low

Table 14.16: SCADA Network risk by asset category

	Asset category	H1	H2	H3
C1	Field devices (RTU's)	88	0	23
C1	Communications network assets	436	16	27
C1	Communications site infrastructure	211	33	9
C1	Communications linear assets	376,061(km)	0	0
C1	Other (Substation LAN)	11	0	0
C2	N/A	0	0	0
C3	Communications site infrastructure	18	0	0
C3	Master station Assets	20	0	0

Table 14.17: Communications network assets network risk by asset type

	Asset type	H1	H2	H3
C1	DWDM System	4	1	0
C1	Management system	6	2	0

	Asset type	H1	H2	H3
	Microwave systems	54	0	0
	PDH Mux	147	1	1
	SDH mux	63	0	0
	telemetry	65	0	0
	teleprotection	58	12	4
	UHF Mobiles/HH	3	0	0
	UHF System	36	0	22
C2	N/A	0	0	0
C3	N/A	0	0	0

Table 14.18: Communications site infrastructure network risk by asset type

	Asset type	H1	H2	H3
C1	Battery Systems	69	30	8
	Power Supply	77	0	1
	Shelter	28	0	0
	Solar systems	19	3	0
C2	N/A	0	0	0
C3	Structures	18	0	0