PowerWater

Asset Management Plan – Conductors

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 its network of assets are overhead conductors made up of transmission and distribution conductors. These overhead conductors perform a critical function in maintaining the business objectives of delivering a safe and reliable supply of electricity to Power and Water's customers.

Assets contribute a modest proportion to the total asset base *– age compared to expected life is of increasing relevance.*

Conductors make up 13% of the total replacement value of the asset base and contributes to around 5% of the total operating expenditure. The asset fleet has an average age of circa 30 years which is midway through the potential lifespan of this asset class. An increasing number of distribution conductors, i.e. high voltage and low voltage conductors, will soon reach end of life based on a standard average lifespan of 60 years.

Assets operate across a diverse environment *– temperature, humidity, rainfall, adverse weather 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 2 key challenges that require management *– low spans, mechanical fatigue due to deterioration*

Key asset challenges include conductors in breach of statutory safe ground clearance standards, and conductors in poor condition. Recent investigations identified a range of defects associated with the Lake Bennett 22kV distribution feeder including, failure to meet safe ground clearance, burnt conductor damage, single and multiple broken strands, and conductor corrosion. The conductor assets in the Darwin region are also subject to high corrosion and annealing, leading to mechanical fatigue, conductor strand breakage, and ultimate asset failure.

A further challenge is the "poly-pipe" corrosion issue. Widespread damage to overhead conductors has been identified where "poly-pipe" style bat protection has been used. This style of protection is used widely in the Katherine region and sporadically in Darwin's rural area. The risk associated with this damage is conductor failure and wires dropping onto the ground.

Maturing condition data associated with conductor assets is a key asset management challenge. With few condition-based functional failures observed in the network to date, conductor condition issues have generally been managed as corrective maintenance. With asset failures starting to increase, an increased focus on the collection of ground clearance, corrosion and condition data and analysis are being put into effect to better support asset management decision making. Focused routine inspections and targeted methodical inspections prioritising

high corrosion areas are some of the proposed undertakings aimed at improving data collection and analysis during business as usual activities.

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

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

- Lake Bennett Feeder conductor clearance rectification program. A replacement program targeting the installation of approximately 227 midspan poles across the length of the feeder, the replacement of 241 existing poletops, and the installation of around 40km (route length) of overhead conductor (noting that 5km has been previously replaced but without addressing the clearance issues). Expenditure associated with the replacement of the poles and poletops are included in this program.
- Pooled conductor asset replacement program. The pooled program captures those conductor assets that fail in service. A total of 10.7 km of conductor replacements is forecast over the 5 year regulatory period and includes for 1.5 km of transmission conductor and 9.2 km of distribution conductor replacements.

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 conductor investment programs focusing on the highest risk assets as a priority.

The investment program is summarised as follows:

Year	2019-20 ($ million)	2020-21 ($ million)	2021-22 ($ million)	2022-23 ($ million)	2023-24 ($ million)	Total ($ million)
Renewal plans	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Pooled program replacements	$0.29	$0.37	$0.47	$0.58	$0.73	$2.44
Maintenance Plans	$0.94	$0.94	$0.94	$0.94	$0.94	$4.70
Total	**$3.70**	**$3.10**	**$2.08**	**$1.66**	**$1.71**	**$12.25**

The forecast investment over the regulatory period has been compared to the AER's repex model output. As shown in Figure 1, Power and Water's forecast investment in conductors is not well aligned with the repex model projections. The reason for this is that Power and Water's investment is targeted towards specific assets that are in poor condition with an allocation to replace conductors that fail in service. The repex model is projecting an upward expenditure profile consistent with the age of the fleet of conductors; however, Power and Water is not proposing an age based replacement strategy.

The higher levels of expenditure in the early years of the regulatory period are for the works required on the Lake Bennett feeder and include conductor, pole and pole-top replacements.

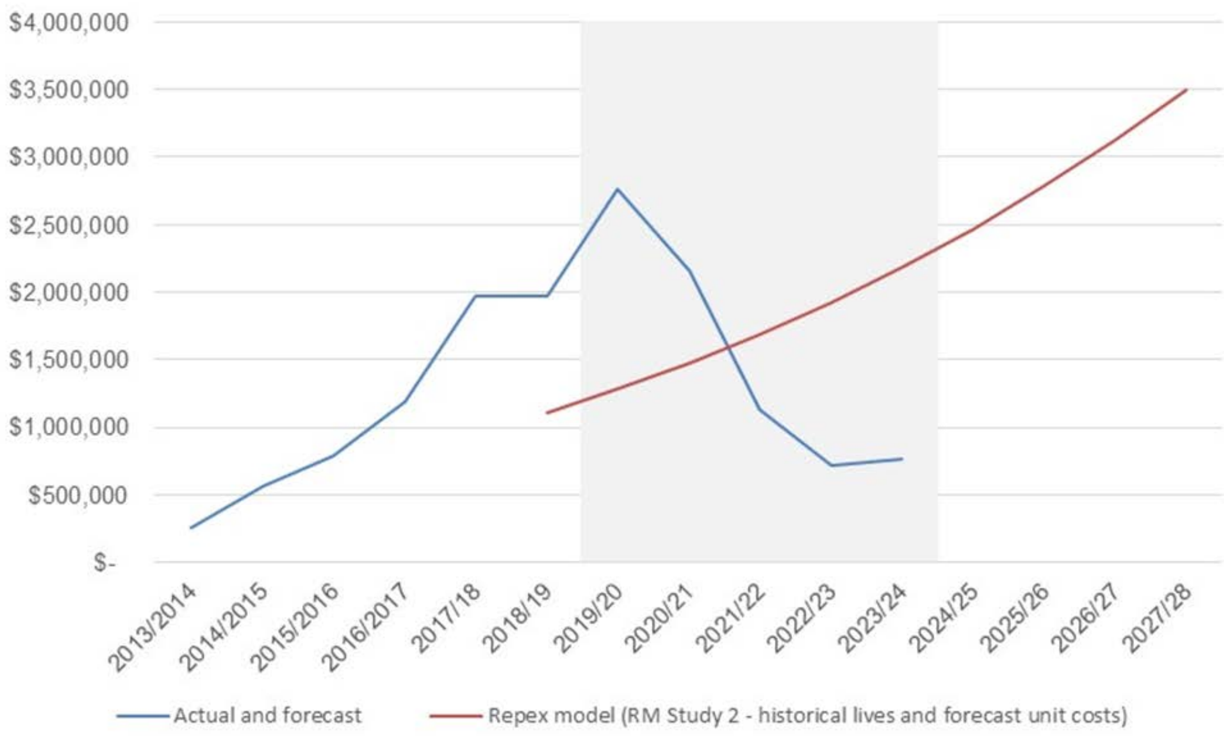


Figure 1: Investment in conductors over the regulatory period

<u>Benefits from the investment program</u> *– reliability improvement*

The proposed investment in the overhead conductor renewal is expected to impact on the contribution to system SAIDI/SAIFI performance, reducing the SAIDI contribution by up to 0.56%, and the SAIFI contribution with up to 0.47% over the next regulatory period.

The investment programs target the highest risk assets and are expected to affect the risk profile of the conductor asset class.

Transmission conductors

With only in-service failure investment over the next 5 year regulatory period the health and criticality profile for transmission conductors is expected to change to that shown in the second table below. The mitigated risk is demonstrated in the number of assets that transfer from the H3 health category. For the transmission assets a reduced risk is reflected in a 3% reduction in the number of poor health assets in the H3 category.

Transmission conductor health-criticality matrix (qty) by 2023/24, with no investment

	H1	H2	H3
C1	187 km	343 km	41.7 km
C2	11 km	58 km	7.4 km
C3	31 km	57 km	0.05 km

Transmission conductor health-criticality matrix (qty) by 2023/24, with investment

	H1	H2	H3
C1	188 km	343 km	40.5 km
C2	11 km	58 km	7.2 km
C3	31 km	57 km	

Distribution conductors

With investment and including for growth over the next 5 year regulatory period the health and criticality profile for distribution conductors is expected to change to that shown in the second table below. The mitigated risk is demonstrated in the number of assets that transfer from the H3 health category. For the distribution conductor assets a reduced risk is reflected in a 3.6% reduction in the number of poor health assets in the C2 and C3 criticality zones.

Distribution conductors health-criticality matrix (qty) by 2023/24, with no investment

	H1	H2	H3
C1	549 km	177.1 km	34 km
C2	341 km	252 km	507 km
C3	1,910 km	895 km	711 km

Distribution conductors health-criticality matrix (qty) by 2023/24, with investment

	H1	H2	H3
C1	549 km	177 km	34 km
C2	343 km	252 km	505 km
C3	1,952 km	895 km	669 km

The movement in risk demonstrated by the movement of assets predominantly from the poor health and applicable criticality zones substantiates Power and Water's investment strategy that targets the highest risk assets.

The risk profile snapshot has been based on the current understanding of the conductor asset 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.

1 Purpose

The purpose of this asset management plan (AMP) is to define Power and Water's approach to managing the life-cycle activities for conductors. It defines the rationale and direction that underpins the management of these assets into the future:

- Short Term (0-2 years): Detailed maintenance and capital work plans for the upcoming financial year based on current asset condition.
- Medium Term (2-5 years) 2019-24 Regulatory Period: Strategies and plans based on trends in performance and health indicators.
- Long Term (5-10 years) 2024-29 Regulatory Period: Qualitative articulation of the expected long-term outcomes.

The conductor 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 in Figure 2.

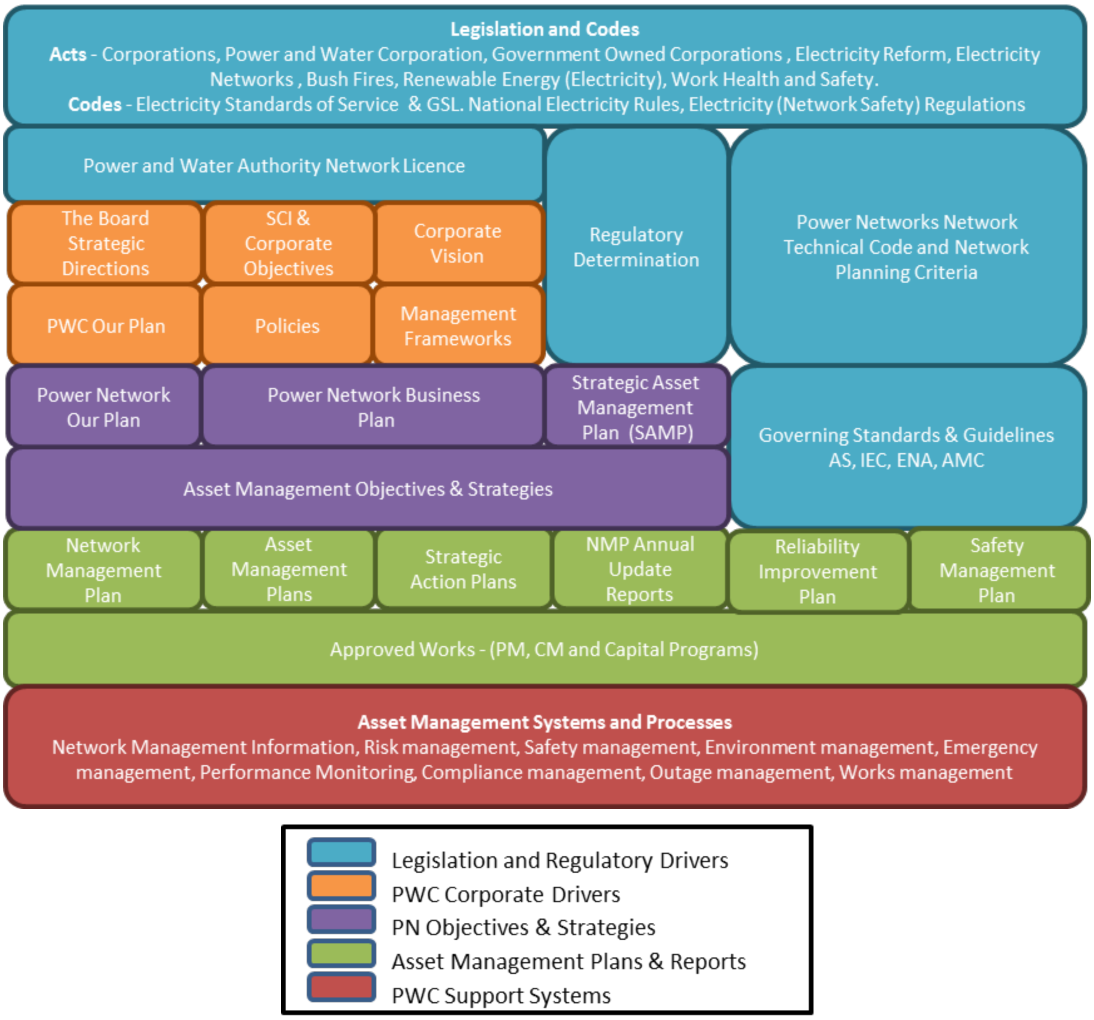


Figure 2: Asset management system

2 Scope and objectives

2.1 Asset class overview

In-scope assets include Power and Water's transmission conductors and distribution conductors. Table 1 provides an overview of the asset class. The scope does not include other overhead network assets such as poletops and distribution switchgear.

Table 1: Overview of in-scope assets

Asset type	Quantity	Voltage	Average Age	Nominal Lifespan	% exceeding lifespan in reg. period	Key points
Transmission	736km	132kV 66kV	32.8	60	2.8%	• Located in Darwin, Katherine and Alice Springs. • Dating from the 1963s. • Most conductor assets mid-life.
High Voltage	3,361km	22kV 11kV SWER	28.8	60	0.0%	• Located in Darwin, Katherine, Tennant Creek, and Alice Springs. • Dating from the 1950s • Some renewable and replacement proposed in the forecast regulatory period.
Low Voltage	1,788km	415V	29.4	60	2.0%	• Located in Darwin, Katherine, Tennant Creek, and Alice Springs. • Dating from the 1950s • Conductor assets seems to have high average age.
Total	**5,885km**	**132kV to 415V**	**30.3**	**60**	**2.0%**	

Note: Streetlight conductor not included in analysis

The conductor asset class make up a significance proportion of Power and Water's assets and activities. This is because much of the network is supplied using overhead assets. Currently, the conductor asset class comprises:

- 13% of the network by replacement value;
- 5% of operational expenditure (opex);
- 6% of capital expenditure (capex), including:
  - 2% of replacement expenditure (repex); and
  - 14% of augmentation expenditure (augex).

Power and Water's conductor assets are distributed throughout its network footprint which covers the Northern Territory (NT).

2.2 Asset class function

Conductors, suspended by towers and poles, form part of the structure used in the transmission of electricity over long distances. Most of the insulation for overhead conductors is provided naturally by air, therefore overhead power lines are generally the lowest-cost method of power transmission for large quantities of electricity.

The function of conductors within Power and Water's electricity network is illustrated by Figure 3.

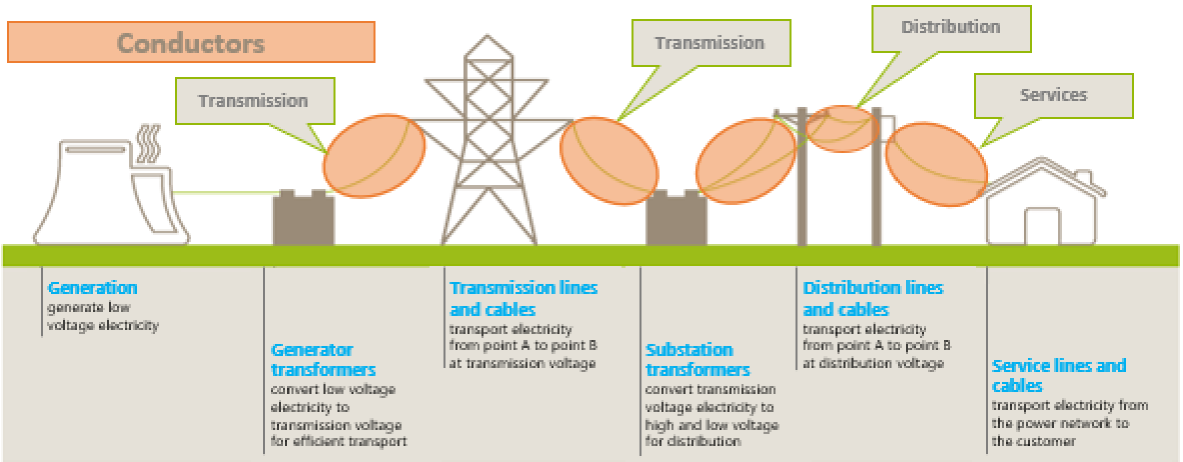


Figure 3: Diagram of in-scope assets

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 4.

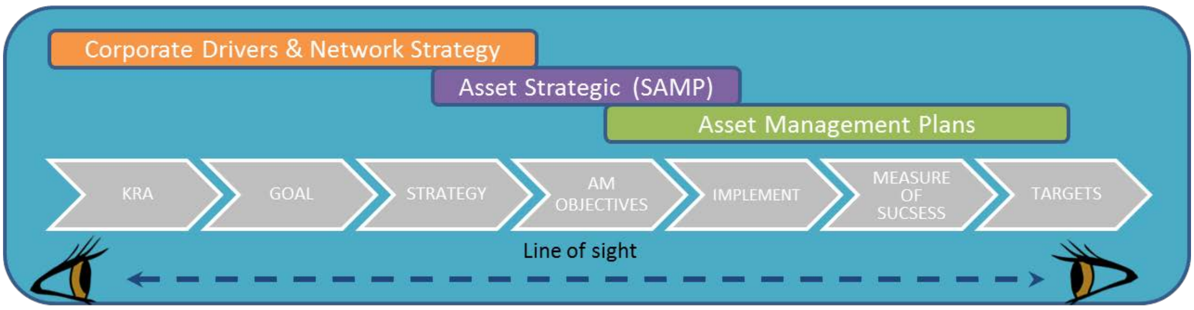


Figure 4 Asset Management Line of sight from Corporate and Network strategies through the Asset Management objective to the targets in the asset management plan

Table 2 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 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 • Ensure the safety of its employees and the public.	• Total asset class specific safety incidents Cable Dig-ins • Known conductor clearance breaches (from ground) • Vegetation clearance breaches between cutting cycles • Electric Shock due to neutral connection faults	• Total asset class specific safety incidents not exceeding 8 per annum
• All environmental risks have been defined, mitigation controls implemented and responsibility for risk ownership has been assigned to appropriate leaders • Develop Environmental Improvement Plans for significant risks to reduce risk exposures and tracked through a governance framework • Develop performance indicators for intended environmental outcomes.	• Total asset class specific environmental incidents associated. • Fires starts caused by asset failure	• Total asset class specific environmental incidents associated not exceeding TBA
• Ensure that the systems and processes provide sufficient and appropriate data and information to drive optimal asset and operating solutions. • Reduce network system damage and supply interruptions, particularly during storms.	• Asset class contribution to system SAIDI • Asset class contribution to system SAIFI • GSL contribution per year Guaranteed Service Levels	• SAIDI for this asset class TBA. • SAIFI for this asset class TBA. • GSL contribution per year TBA
• Proactively and systematically measure the network power quality	• Asset class related number of poor power quality incidents.	• 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 regulatory and stakeholder expectations. • Define and communicate the level of risk associated with the investment program	• Critical spares analysis completed for asset class • Operator/Maintainer risk assessment completed for asset class and risk register updated	• Achieved
• 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.	• Achieved

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 speaking:

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

3.2 RACI

The Responsibility, Accountability, Consulted, Informed (RACI) matrix for the conductor asset class is provided in Table 4. This defines the roles and accountabilities for each task by allocating to specific roles/personnel in Power and Water.

Table 3 RACI matrix for Conductors

Process	Exec GM Power Networks	Group Manager Network Assets	Chief Engineer	Network Planning Manager	Major Project Delivery Manager	Southern Delivery Manager	Group Manager Service Delivery	Field Services Manager	Works Management Manager	Strategic Asset Engineering	Asset Quality & Systems
Establish condition limits		A	C	C		I	I	C/I	I	R	I
Performance and condition data analysis	I	A	I	I		I	I	I	I	R	I
Plan capital works (Options, costs, BNIs, BCs, etc.)	I	R	A		C/I	R	R	R	R	R	I
Execute maintenance plans	I	I	I			A	A	R	R	C/I	I
Deliver identified major projects and programs of work	I	C	A	C	R	R	R	C/I	C/I		
Manage asset data (data entry, verify data)		A	I	I						C/I	R
Monitor delivery of capital plans and maintenance	I	A	I	I	I	R	R	R	R	R	R

- *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

Power and Water owns and maintains a portfolio of 5,885 km of conductors distributed across the four regions of Alice Springs, Darwin, Katherine, and Tennant Creek, with the largest population in the Darwin Region.

The conductors function across the different network voltage levels including transmission voltage (66kV and 132kV), HV (6.6kV, 11kV, 22kV), and LV (240V, 415V).

4.2 Asset types

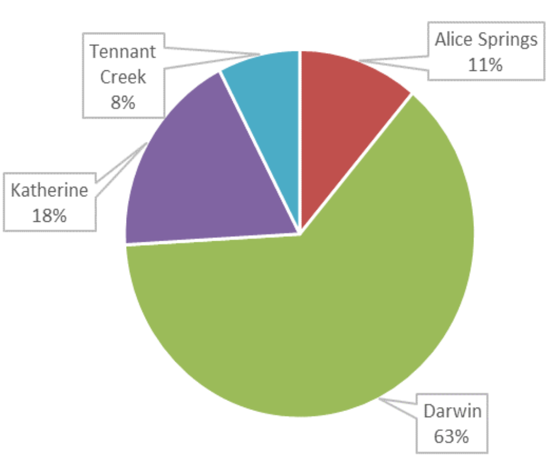
An overview of the different conductor voltage groups per region is provided in Table 7.

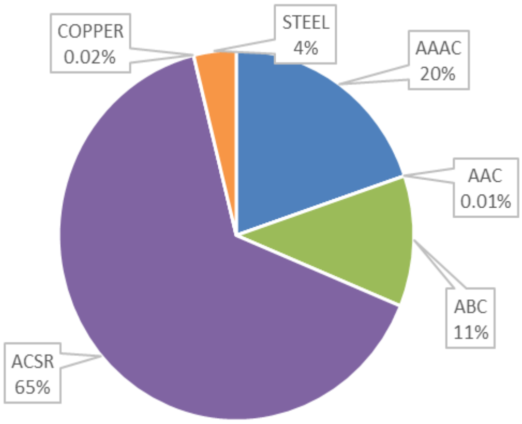
Table 4: Asset types comprising the conductor voltage groups by region

Region	Network Category	Period of installation	Voltage levels	Quantity (km)	Expenditure / risk implications
Alice Springs	*Transmission*	*2011 – present*	66kV	32	
	Distribution	*1962 - present*	415V 11kV 22kV	143 70 345	• Some assets have reached the end of their expected functional life • Increased asset failure rates for short rural lines • Increased asset failure rates for short rural lines
Darwin	*Transmission*	*1965 – present*	132kV 66kV	300 349	
	Distribution	*1960 - present*	415V 11kV 22kV	959 276 1503	• Some assets have reached the end of their expected functional life • Increased asset failure rates for short rural lines • Increased asset failure rates for short rural lines
Katherine	*Transmission*	*1985 –present*	132kV 66kV	50 4	
	Distribution	*1950 - present*	415V	146	• Some assets have reached the end of their expected functional life
			11kV 22kV	40 757	• Increased asset failure rates for short rural lines • Increased asset failure rates for short rural lines
Tenant Creek	*Distribution*	*1962 - present*	415V	57	• Some assets have reached the end of their expected functional life
			11kV	4	• Increased asset failure rates for short rural lines
			22kV	367	• Increased asset failure rates for short rural lines

4.3 Asset population analysis

A detailed breakdown of the conductor assets by region and conductor type is provided in Figure 4. The Darwin region makes up the largest region in terms of overall conductor quantity at 63%.





*Note that the total conductor population per Category only contain those conductors for which information is confirmed, over 30% of the total conductor population is not included in this representation.

Figure 5: All conductors by region and asset type

A further detailed breakdown of the specific conductor types is provided in Figure 5. Please note that Figure 5 only includes the conductors for which information was confirmed to be accurate. Ongoing efforts are made to update asset information as part of the maintenance strategies.

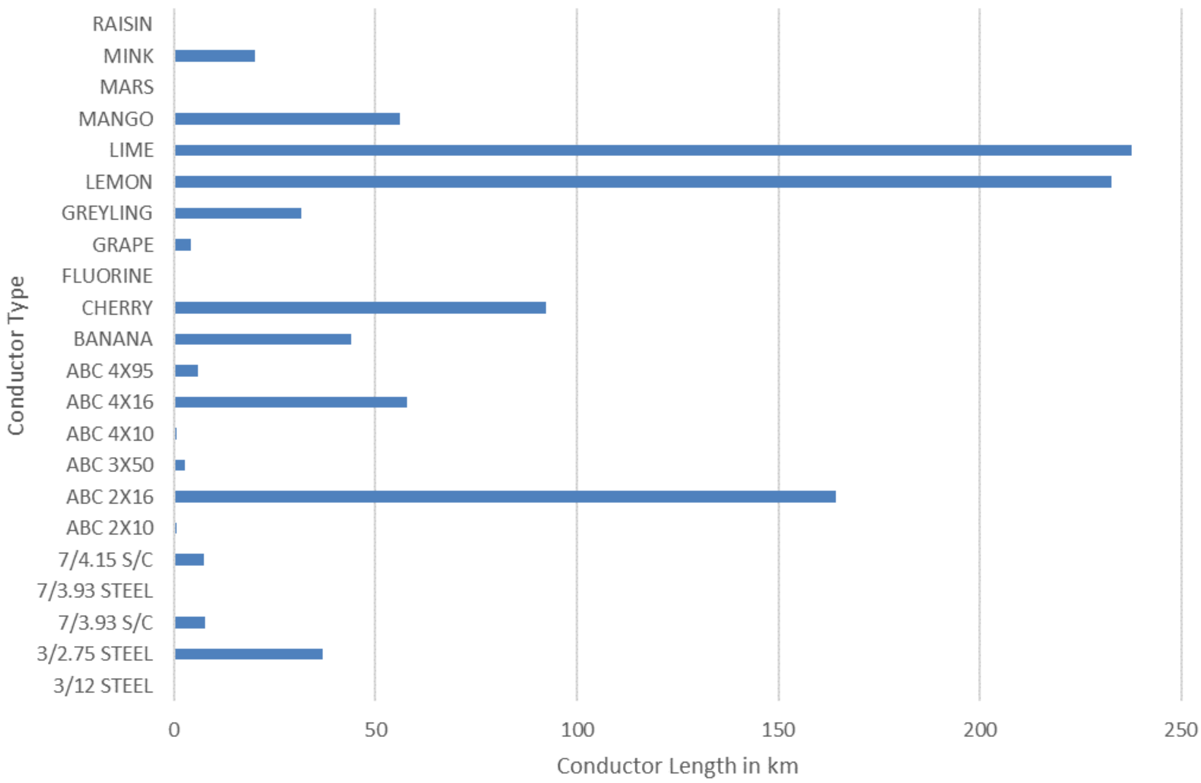


Figure 6: Conductors by asset type

4.4 Growth profiles

4.4.1 Transmission conductors

As can be seen from Figure 6, the largest portion of transmission conductor was installed during the 1985-86 financial year with the establishment of the Darwin-Katherine 132kV transmission system. With these conductors having a lifespan of 60 years it is clear that majority of the transmission conductors is still well within the expected lifespan.

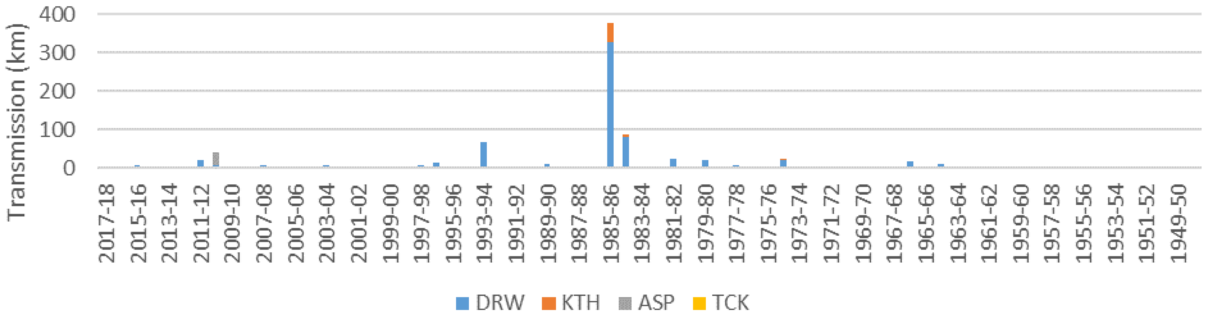


Figure 7: Transmission conductors by age and region

4.4.2 Distribution conductors

Figure 7 and Figure 8 provide insight into the installation periods of high and low voltage distribution conductors. In both instances a large quantity of conductor were installed during the mid-seventies. This was as result of two main factors; namely a strong growth period in the region and the impact from Cyclone Tracy that took place in December 1974. Large portions of the network had to be rebuilt due to this cyclone under the auspices of the Darwin Reconstruction Commission.

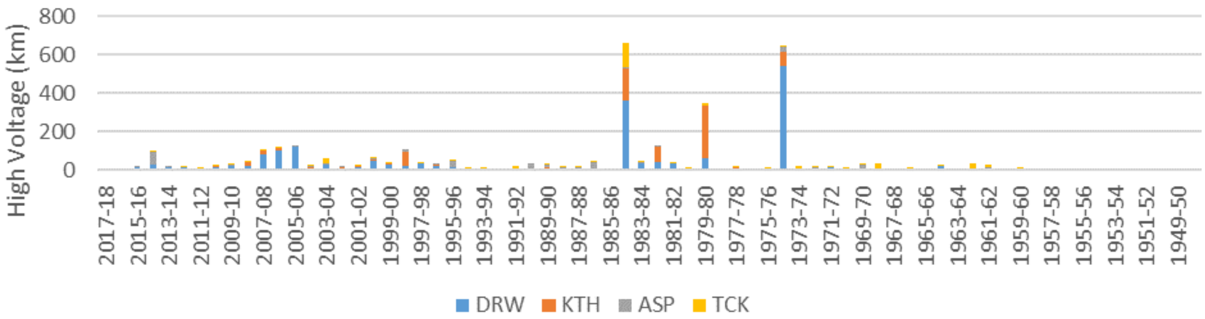


Figure 8: High Voltage Distribution conductors by age and region

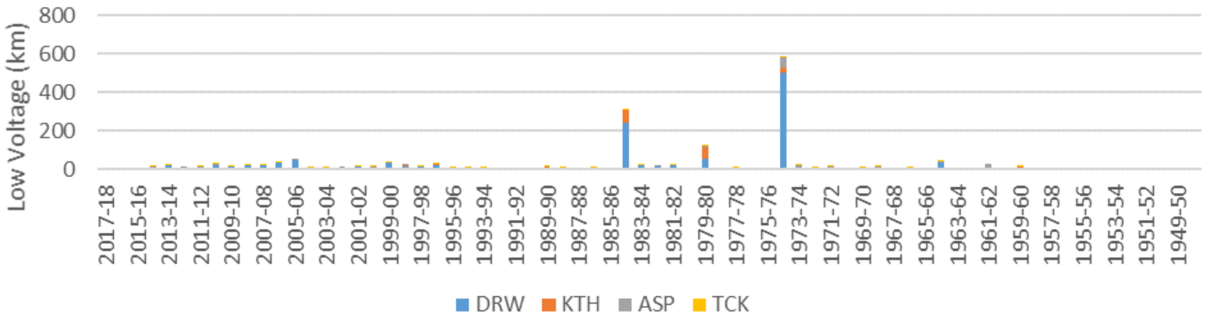


Figure 9: Low Voltage Distribution conductors by age and region

4.4.3 Standard Asset Life

The asset life is the period of time that an asset can be expected to reliably and efficiently provide the service capability for which it was designed. Understanding the asset life is important to the establishment of a suitable maintenance regime including a planning and recording system together with its impact on capital and operational expenditure forecasts.

The situation and environment in which an individual asset operates can have a significant impact on both the required level of reliability and the rate of asset deterioration. The asset life is typically determent by factors such as:

- the cost of maintenance versus the cost of replacing the asset;
- the maintainability of the asset, particularly if replacement components are no longer available;
- the risk associated with the failure of the asset, particularly if the consequence of failure increase to unacceptable level.

It is therefore important to note that the asset life represents an average expected life of the asset. Some individual assets will last much longer than the expected asset life and others will fail prematurely.

The asset lives applied by Power and Water as a standard have been based on in-house engineering experience and judgement, supplemented by general industry experience across the National Electricity Market (NEM). The asset life is also referred to in the AMP as the replacement life or the economic life referring to the expected life at which the asset is typically replaced or renewed.

A standard replacement life of 60 years was applied to the conductor assets. It corresponds with the economic replacement life of conductors applied by Power and Water in asset valuations. The asset life compares with transmission and distribution asset lives observed across the NEM as demonstrated in Figure 9.

The comparatively high asset life is reflective of a low failure rate averaging 0.013% of the conductor population per annum[1]. Increasing failures are being observed in high corrosion areas of the network and as the conductor assets continues to age and deteriorate the failure rates are expected to increase. It is expected that that the standard asset life may need to be reassessed in near future as more asset performance and condition data becomes available.

[1] Pooled asset replacement program forecast model

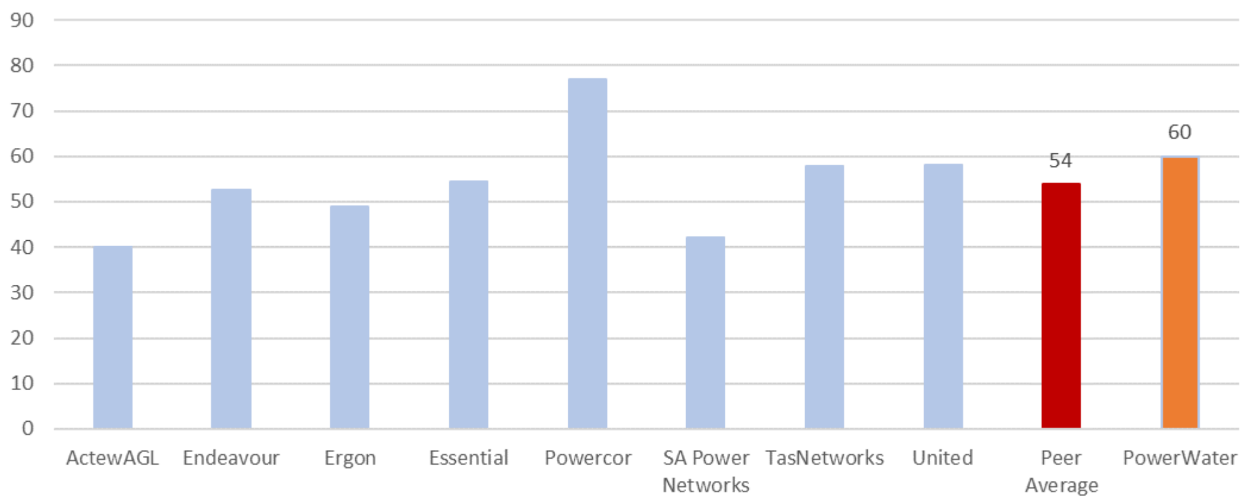


Figure 10: Transmission and Distribution Conductor replacement life

4.4.4 Age profiles

The age profiles provide an early indication of expected asset condition and potential life extension or renewal investment requirements. The typical asset replacement life for transmission and distribution conductors as observed across the NEM is 60 years.

The transmission conductors are relatively young at an average age of around 28.8years. Some of the earlier installations in the Darwin region will start to reach end of life by the end of the 2nd regulatory period. General deterioration issues are expected to start emerging towards the end of the next regulatory period.

Table 8, Table 9 and Table 10 provide a summary of the asset base remaining life against the industry standard asset lives. The tables include an illustration of the expected increase in assets that will be exceeding the asset life over the next two regulatory periods.

The transmission conductors are relatively young at an average age of around 28.8years. Some of the earlier installations in the Darwin region will start to reach end of life by the end of the 2nd regulatory period. General deterioration issues are expected to start emerging towards the end of the next regulatory period.

Table 5: Transmission conductors average age and remaining life

Region	Weighted Average Age	Weighted Average Remaining Life	% of asset population	% exceeding replacement life in 2017	% approaching replacement life by 2024	% approaching replacement life by 2029
Alice Springs	6.0	54.0	4.4%	0.0%	0.0%	0.0%
Darwin	29.7	30.3	88.2%	0.0%	0.0%	4.2%
Katherine	31.1	28.9	7.4%	0.0%	0.0%	0.0%
Tennant Creek	-	-	-	-	-	-
Total	28.8	31.2	100.0%	0.0%	0.0%	3.7%

The high voltage distribution conductor age profile shows assets at mid-life with very few expected upcoming investment requirements. Pocketed areas of concern do exist where particular deterioration issues have been observed and these are being addressed as explained later in this AMP. Tennant Creek is expected to require investment in upcoming regulatory periods given the age of the installations. The need for investments will be guided by ongoing condition assessments.

Table 6: Distribution high voltage average age and remaining life

Region	Weighted Average Age	Weighted Average Remaining Life	% of asset population	% exceeding replacement life in 2017	% approaching replacement life by 2024	% approaching replacement life by 2029
Alice Springs	26.4	33.6	12.3%	0.0%	2.7%	4.0%
Darwin	28.0	32.0	52.9%	0.0%	0.2%	1.5%
Katherine	31.1	28.9	23.7%	0.3%	0.4%	0.6%
Tennant Creek	35.7	24.3	11.0%	0.0%	12.9%	17.5%
Total	29.4	30.6	100.0%	0.1%	2.0%	3.3%

Table 10 provides insight into the age profile of the low voltage distribution network and indicate that, given an expected lifespan of 60 years the asset age is starting to age with up to 6% exceeding the nominal replacement life within the next two regulatory periods. Even so, with condition based monitoring, the efficiency at which these conductors will be replaced in future will be optimised.

Table 7: Distribution low voltage average age and remaining life

Region	Weighted Average Age	Weighted Average Remaining Life	% of asset population	% exceeding replacement life in 2017	% approaching replacement life by 2024	% approaching replacement life by 2029
Alice Springs	38.9	21.1	11.5%	0.0%	13.0%	20.9%
Darwin	31.5	28.5	71.4%	0.0%	0.7%	3.5%
Katherine	34.1	25.9	12.9%	2.0%	5.6%	5.8%
Tennant Creek	34.0	26.0	4.2%	0.0%	1.3%	8.0%
Total	32.8	27.2	100.0%	0.3%	2.8%	6.0%

4.4.5 Transmission conductors – Age profiles by region

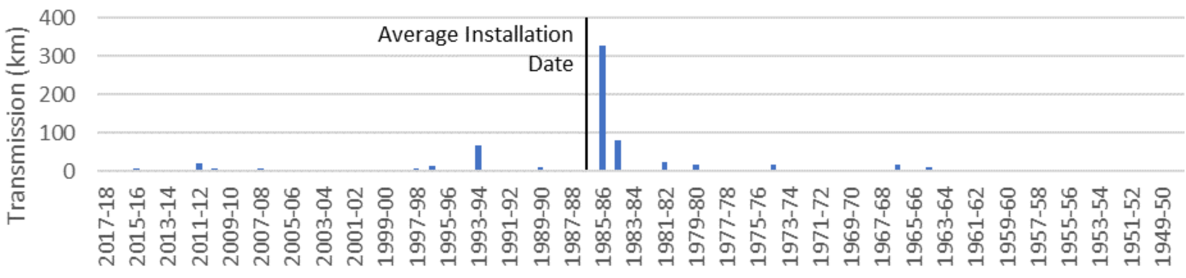


Figure 11: Darwin – Transmission conductor age profile

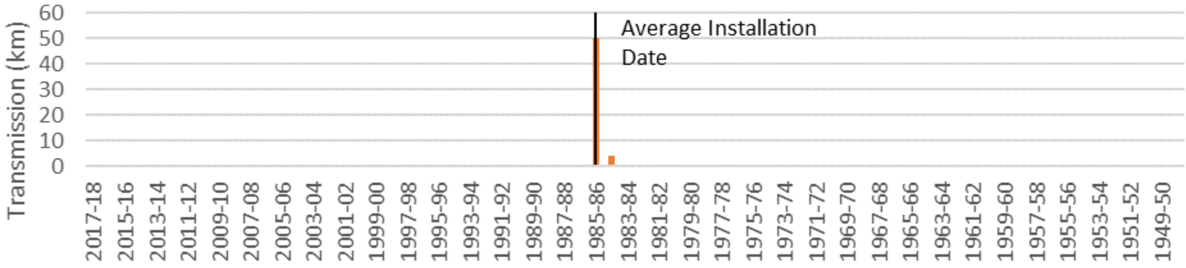


Figure 12: Katherine - Transmission conductor age profile

Figure 13: Alice Springs - Transmission conductor age profile

4.4.6 High Voltage Distribution Conductors – Age profiles by region

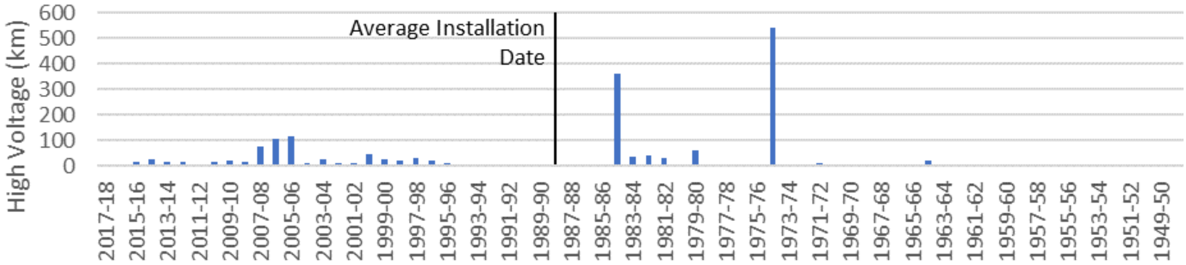


Figure 14: Darwin – High voltage distribution conductor age profile

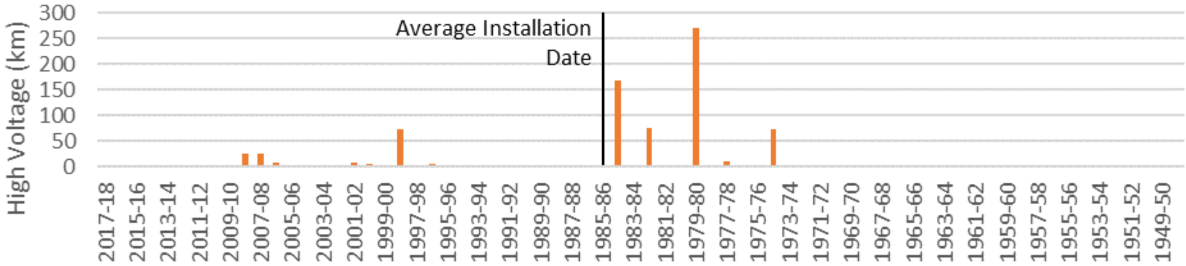


Figure 15: Katherine – High voltage distribution conductor age profile

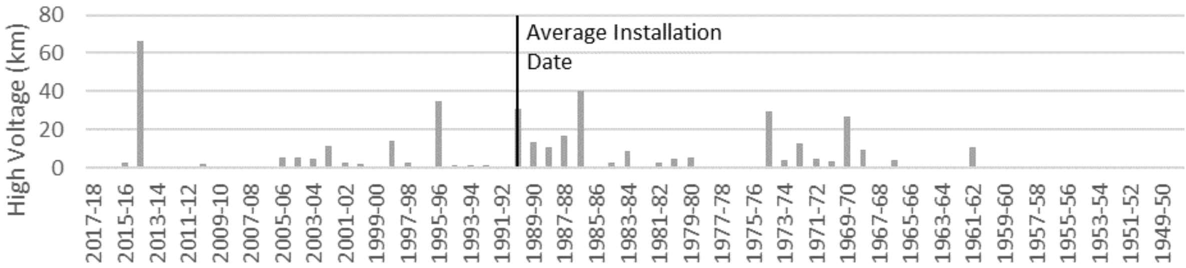


Figure 16: Alice Springs – High voltage distribution conductor age profile

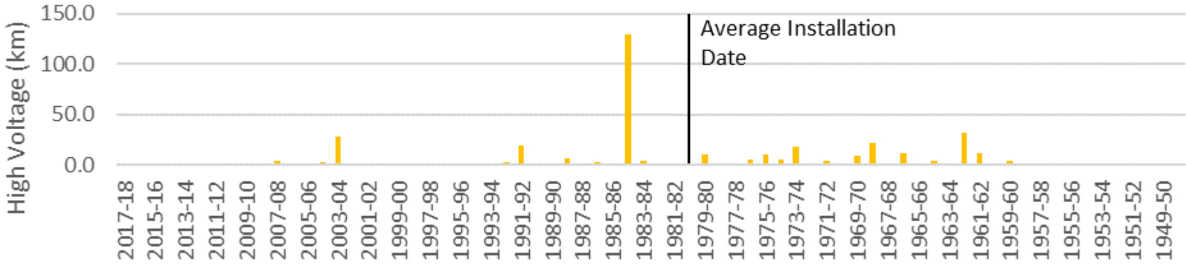


Figure 17: Tennant Creek – High voltage distribution conductor age profile

4.4.7 Low Voltage Distribution Conductors – Age profiles by region

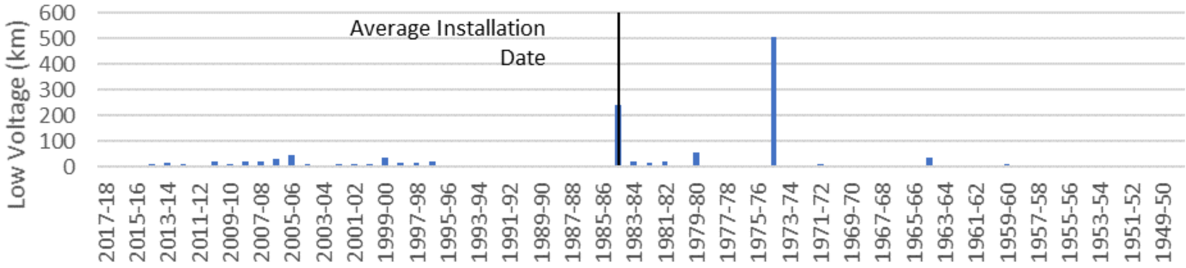


Figure 18: Darwin – Low voltage distribution conductor age profile

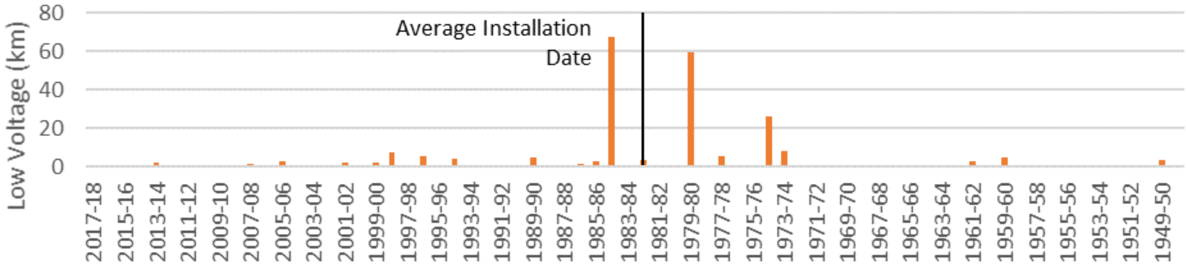


Figure19: Katherine – Low voltage distribution conductor age profile

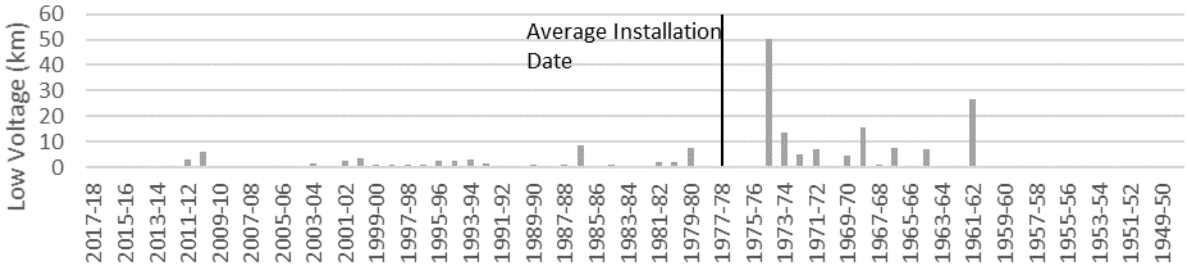


Figure20: Alice Springs – Low voltage distribution conductor age profile

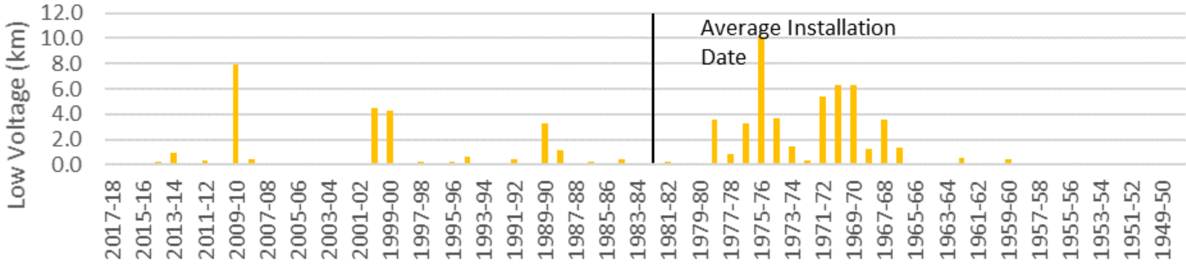


Figure21: Tennant Creek – Low voltage distribution conductor age profile

5 Health and criticality profiles

5.1 Asset indices

Risk is that uncertain event or condition associated with an asset failure that, if it occurs, will affect Power and Water's ability to successful execute its strategies to achieve its organisational objectives of operating a safe and reliable power network at the lowest cost to the customer. The health and criticality framework[2] provide the basis for calculating the risk associated with the conductor assets. It combines failure data and recent condition data (routine visual inspection, targeted methodical inspection, and testing results) to modify the assessment of expected remaining life and the associated likelihood of failure across the fleet of conductor assets.

The health and criticality indices developed for conductor assets establishes the context of the risk associated with these assets and defines the parameters that influences how the risk is managed. Asset health is a key driver in the likelihood of asset failure, and the asset criticality is a key determinant in quantifying the risk associated with the failure.

It should be noted that the health and criticality indices rely heavily on available asset data and evolves as the quality of data regarding asset age, condition and operating environment improves. It will continue to evolve over time as the asset composition changes with age, investments, and network development. These changes are captured during routine inspections and targeted methodical inspections aimed at recording and updating asset data related to age, condition, and operating environment. These processes and practices are continuously being improved within Power and Water.

The probability of asset failures and the associated risks are therefore continually refined as routine data, and targeted data is collected across the asset base.

The risk associated with the functional failure of conductors is physical and electrical harm to the public and to Power and Water employees that traverse the power network daily. Conductors also contribute to the reliability of the electrical network. The reliability risk associated with the functional failure of conductors is system outages impacting varying numbers of customers.

5.1.1 Asset health

The underlying failure mode for conductors is mechanical fatigue resulting from annealing, or corrosion leading to a deterioration in the asset health, and ultimately the functional failure, or

[2] 'Asset Heath and Criticality Method' decision making process discussion paper

collapse of the asset. The deterioration in asset health is accelerated by factors such as design defects, third-party impacts, vegetation impacts, and damage during severe weather events. The main failure modes observed on the conductor assets are summarised in Table 11.

Table 8: Conductor failure modes

Failure mode	Description
Corrosion	Conductor degradation and mechanical fatigue as result of corrosion ultimately leading to conductor failures
Annealing	Conductor degradation and loss of strength as result of annealing brought about by overheating
Structural damage	Degradation and mechanical fatigue as result of the forceful impact from vehicles colliding with a pole or tower, debris strikes, vegetation, and wind force during severe storm events ultimately leading to conductor failures
Conductor vandalism	Conductors being shot at in remote areas which causes conductor damage/ failures and conductor drops onto ground
Conductor connector failures	Conductor connectors like PG clamps failures due to ageing, high resistance connections and fault currents leading to open circuits and some instances to conductor failures. Also conductor end connections like deadends/wraps fail due to lightning surge currents and cause conductor failures

Power and Water assesses and records asset condition during routine inspections, as part of other works in the vicinity, and through targeted methodical inspections and testing.

- Routine inspections done by Power and Water on conductor assets in the Darwin region are finding an increase in the number of advanced corrosion issues. Inspection criteria are currently being adapted to more accurately capture conductor condition data to allow for trending analysis.
- The *AS/NZS 2312 - Guide to the Protection of Structural Steel Against Atmospheric Corrosion by the Use of Protective Coatings*, and a study on corrosion rates developed by Wattyl Industrial Coatings in 2004 (*GUIDE TO AS/NZS 2312:2002*) provided guidance on the disparate corrosion related issues observed by Power and Water in the power network. The coastal area of Darwin is identified as an area subject to higher corrosion rates, whereas the inland areas of the power network are subject to relatively lower expected corrosion rates.

The outcomes of the inspections and studies mentioned above have been used to inform the conductor asset health segregation. For both transmission and distribution conductors the asset **health** segregation has therefore been based on corrosion zones and asset age. Conductors in higher corrosion, tropical coastal areas, and older age were assigned a lower health whereas assets in lower corrosion, desert type areas, and younger age were allocated a higher health. The segregation was done using the standard asset life of 60 years and adopting the three-point health index scale used to categorise assets in terms of their expected remaining life where conditional factors were not evident to suggest a different segregation. The approach is described in the Asset Health and Criticality Method discussion paper.

Conductor assets in the Darwin region have been assessed based on a shorter asset life. Recent inspections indicated that majority of conductors in need of investment were aged around 40 years and older. Assuming a normal distributed failure rate and allowing for one standard deviation an asset life of 50 years was applied. This asset life would be commensurate with emerging conductor failures being observed now.

Assets outside the Darwin region have been assessed using the standard asset life of 60 years and adopting the same three-point health index scale described in the Asset Health and Criticality Method discussion paper.

The criteria applied to allocate a health score are provided in Table 11. Assets with unknown remaining lives were assigned a good health score, H1.

Table 9: Health indices criteria

Health score	Description	Criteria
H1	Good	Outside Darwin region: 60 years asset life and more than 15 years remaining life In Darwin region: 50 years asset life and more than 15 years remaining life
H2	Average	Outside Darwin region: 60 years asset life and between 5 and 15 years remaining life In Darwin region: 50 years asset life and between 5 and 15 years remaining life
H3	Poor	Outside Darwin region: 60 years asset life and less than 5 years remaining life In Darwin region: 50 years asset life and less than 5 years remaining life

5.1.2 Asset criticality

The conductor assets contribute to both the reliability and safety risk of the power network. Risk quantification undertaken in the industry across asset classes has found reliability risk to routinely be the more prominent risk associated with asset failures. Reliability risk is that risk related to the duration and frequency of outages resulting from asset failures, and is linked to the number of customers impacted by an outage.

The criticality of the conductor assets within the network has in the first instance been based on the expected contribution to the system reliability risk resulting from asset failure. Where appropriate and based on specific inspection and test data, the criticality level for particular assets may have been adjusted to reflect the higher level of understanding and or contributions to public and worker safety risk. Any adjustments that may have been included are discussed in the sections below.

5.2 Transmission conductors

For transmission conductors the asset **health** segregation has been based on the criteria described in section 5.1.1.

Criticality ratings have been assigned at feeder level based on the impact of contingencies on the security of supply and system loading conditions. A workshop involving key Power and Water planning and asset management personnel as well as external expertise were undertaken to assess the relative criticality of transmission feeders. The main criteria included an assessment of contingencies resulting in radialisation of the network, system overload conditions, and system critical supply feeders. Allocations were made as shown in Table 13.

Table 10: Transmission feeder criticality assignment

Feeder ID	Description	System radialisation under single contingency *C1 - No radialisation* *C2 – System radialisation* *C3 - Power station link*	System overload under single contingency *C1 - No overload* *C2 - Exceed normal rating but not contingency rating* *C3 – Exceed emergency rating*	Feeder criticality
132 CI-HC A	Channel Island - Hudson Creek	C3	C1	C3
132 CI-HC B	Channel Island - Hudson Creek	C3	C1	C3
132 CI-MT	Channel Island - Manton	C1	C1	C1
132 MT-BA-PK	Manton-Batchelor-Pine Creek	C1	C1	C1
132 PK-KA	Pine Creek - Katherine	C1	C1	C1
66 AR-WD 1	Archer-Weddell	C1	C1	C1
66 AR-WD 2	Archer-Weddell	C1	C1	C1
66 BE-HC 1	Berrimah-Hudson Creek	C1	C1	C1
66 BE-HC 2	Berrimah-Hudson Creek	C1	C1	C1
66 BE-LE	Berrimah-Leanyer	C2	C1	C2
66 CP-DA	Cox Peninsula-Darwin	C1	C1	C1
66 DA-FB	Darwin-Frances Bay	C1	C1	C1
66 HC-AR	Hudson Creek-Archer	C1	C1	C1
66 HC-PA	Hudson Creek-Palmerston	C1	C1	C1
66 LE-CA	Lenyer-Casuarina	C2	C1	C2
66 MR-SY	Mary River-Strangways	C2	C1	C2
66 PA-SY	Palmerston-Strangways	C2	C1	C2
66 WD-SY	Weddell-Strangways	C2	C1	C2
66 WN-CA	Woolner-Casuarina	C2	C1	C2
66 WN-DA	Woolner-Darwin	C1	C1	C1
66 AR-WS	Archer-Wishart	C1	C1	C1
66 HC-DA	Hudson Creek-Darwin	C1	C1	C1
66 HC-WN 1	Hudson Creek-Woolner	C1	C2	C2
66 HC-WN 2	Hudson Creek-Woolner	C1	C2	C2
66 LG-OS 1	Lovegrove-Owen Springs	C3	C1	C3
66 LG-OS 2	Lovegrove-Owen Springs	C3	C1	C3
66 WN-FB	Woolner-Frances Bay	C1	C1	C1

The transmission conductor asset health and criticality profile is provided in Table 14. It prioritises around 30.05 km of conductor as being of poor health and higher criticality.

Table 11: Transmission conductor health-criticality matrix (qty)

	H1	H2	H3
C1	524 km	17 km	30 km
C2	50 km	26 km	
C3	88 km	0.05 km	

The asset health and criticality is a function of time and is expected to change as the assets continue to age. With no investment over the next 5 year regulatory period and with no growth expected in the number of transmission conductors over this period, the profile is expected to change to that shown in Table 15. The increase in risk is demonstrated in the increase in the number of assets that entered the H3 health category.

For the transmission conductors an increase in risk is reflected in an 64% increase in the number of low health assets.

Table 12: Transmission conductor health-criticality matrix (qty) with no investment

	H1	H2	H3
C1	187 km	343 km	41.7 km
C2	11 km	58 km	7.4 km
C3	31 km	57 km	0.05 km

5.3 Distribution conductors

For distribution conductors the asset **health** segregation has been based on the criteria described in section 5.1.1.

Asset **criticality** across the distribution assets was allocated in the first instance based on the customer density as approximated by the feeder categorisation. Based on good historical performance and a high level of system redundancy CBD feeders were allocated to C1. Relative low historical performance resulted in short rural feeders being allocated to C3. The underlying criteria applied in allocating conductor asset criticality are provided in Table 16.

Table 13: Distribution conductors criticality criteria

Criticality score	Description	Criteria
C1	Low	Long rural & CBD
C2	Medium	Urban
C3	High	Short rural

The distribution conductor asset health and criticality profile is provided in Table 17. It prioritises around 856 km of HV and LV distribution conductor in the orange and red zones as being of low health and higher criticality.

Table 14: HV Distribution conductor health-criticality matrix (qty)

	H1	H2	H3
C1	627 km	89 km	
C2	487 km	568 km	16 km
C3	2,523 km	769 km	70 km

With no investment over the next 5 year regulatory period and excluding growth the profile is expected to change to that shown in Table 18. The increase in risk is demonstrated in the increase in the number of assets that entered the H3 health category. The significant step increase is indicative of the rapid deterioration projected for the Darwin assets.

Table 15: HV Distribution conductor health-criticality matrix (qty) with no investment

	H1	H2	H3
C1	504 km	177.1 km	34 km
C2	313 km	252 km	507 km
C3	1,756 km	895 km	711 km

6 Key challenges

6.1 Environmental challenges

The network covers a range of environments and geographies which present different challenges for the conductor asset class. Table 19 provides an overview of environmental challenges in relation to managing Power and Water's conductor assets across its four operating regions.

Approximately 80% of Power and Waters network is coastal tropical environments prone to cyclones, monsoons, high ambient temperatures and humidity, and high annual rainfall. The remainder of the network is desert environments subject to high ambient temperatures, occasional flooding, droughts, dust storms, and aggressive soil conditions.

The unique environment results in a more rapid rate of asset deterioration, and lower worker productivity compared to peer distribution businesses.

Climate change is also expected to further exacerbate the environmental conditions over time, resulting in increased asset damage and failure from increase quantity or/and severity of cyclones, storms, lightning activity, dust storms, and droughts.

These factors impact uniquely on the Power and Water network and assets.

Table 16: Environmental challenges in relation to conductor asset management

Region	Environment	Challenges	Expenditure / risk implications
Alice Springs	Desert	• Dust storms and drought • Occasional flooding after long dry periods.	• Hot desert environment leading to heat related stresses and reduced productivity • Although rare, extreme weather events do occur (eg. flooding) • Aggressive soil types resulting in high corrosion issues (particularly related to steel assets, eg. earthing systems, poles) • Climatic change may result in increased asset damage and failure from increase quantity or/and severity of dust storms and drought • No immediate investment programs planned
Darwin	Coastal / Tropical	• Cyclones • Up to 21,924 lightning strikes per year (Global Position And Tracking Systems (GPATS) - 2007 to 2017 Data) • 6-8 Ground strikes per km^2 per year (Bureau of Meteorology (BOM)) • Tropical storms with winds in excess of 100 kilometres per hour • Long periods of high supply demands	• Hot and humid environment leading to heat related stresses and reduced productivity • Extreme weather events (eg. cyclones, flooding) • Increased asset damage and failure from increased quantity or/and severity of storms and lightning related to climate change • Conductor replacement program

Region	Environment	Challenges	Expenditure / risk implications
		• High corrosion rates	
Katherine	Inland / Tropical	• As above for Darwin	• As above for Darwin
Tenant Creek	Desert	• Dust storms and drought • Occasional flooding after long dry periods.	• Hot desert environment leading to heat related stresses and reduced productivity • Increased asset damage and failure from increase quantity or/and severity of dust storms and drought related to climate change • No immediate investment programs planned

6.2 Operational challenges

1) Asset access

Unpredictable weather conditions and extended and high rainfall periods limit the ability to access assets and effectively schedule and undertake operational and construction activities during the wet season.

2) Asset design

The key operational challenge related to overhead conductors is the geographical spread of the network. Both the transmission and distribution networks include long radial lines and low load density areas.

These network characteristics have influenced line designs to maximise span lengths and conductor sizing, to balance quality of supply and cost efficiency. The Lake Bennett feeder is an example where high tensioned conductor installation using Cockatoo conductor was applied to achieve remarkable span lengths, up to 287 m. The high tensioned conductor installation, however, presents significant operational challenges. It requires specialised equipment and tedious work practices to provide for safe and effective maintenance and repair of the conductor and supporting assets.

This challenge significantly adds to the reliability measures for the assets class. An escalation in asset failure is likely to significantly impact the reliability measures of the asset class, and significantly increase the risk associated with public and worker safety.

3) Operational effectiveness

Power and Water operates in hot and humid environments leading to heat related stresses and reduced productivity resulting in increased time to undertake maintenance and inspection tasks. These environments are not comparable to other networks around Australia and have a significant impact on the productivity of the field crews. To assess and quantify the impact of the climatic conditions, Power and Water undertook a study in selected locations across Australia.

Workability is the term used to describe the productivity impact of climate in both Northern and Southern regions. It is the percentage of time for which work of different physical exertion can be effectively undertaken.

Table 20 describes the work rates used in the study along with a description and examples.

Table 17 Work rate descriptions

Work rate	Description	Work examples
Rest	Rest	Lunch and Crib Breaks
Low	Sitting with light manual hand/arm work. Driving. Standing with light arm work, occasional walking.	Driving, work planning, briefings and toolbox meetings, inspections
Moderate	Sustained moderate hand to arm work, moderate arm and truck work. Light pushing and pulling. Normal walking.	Unpacking tools, spare parts, dismantle/ replace small electronic components, general switching from ground
High	Intense arm and truck work, carrying, shovelling, manual sawing, pushing and pulling heavy loads, walking at a fast pace.	Climbing ladders, working in trenches and cabinets, remove replace larger components
Very High	Very intense activity at fast to maximum pace.	Carrying larger tools and replacement components, lifting, carrying up ladders, digging trenches, hauling cables, moving cable, pillars, poles

The outcome of the study is shown in Table 21 with the impact on Power and Water highlighted in orange. It demonstrates that the climatic conditions, particularly in Darwin where the majority of Power and Water's network is located, result in an average Workability of 65% compared to other major cities in Australia. This would equate to a 35% escalation of labour hours compared with the southern states for similar work and therefore an escalation of opex.

This is supported by feedback received via a heat stress survey which identified that approximately 50% of workers report daily or weekly heat-related impacts on their productivity.

Table 18 Workability for selected Australian locations based upon moderate metabolic rate

Location	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Alice Springs	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Adelaide	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Brisbane	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Darwin	41%	44%	45%	60%	100%	100%	100%	100%	74%	46%	34%	32%
Hobart	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Melbourne	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Perth	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sydney	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

4) Demand profile

The demand profile across the network is flat and consistent across each day, as shown in Figure 21. The daily peak is fairly flat and consistent between 8am and 10pm, and is driven by the use of air conditioners. This shows that all assets are utilised consistently and therefore it is more difficult to remove assets from service for prolonged periods of time.

During the wet season, November to April, the load profile becomes flatter (more consistent) with less difference between the peak and the trough and the demand is about 10% higher.

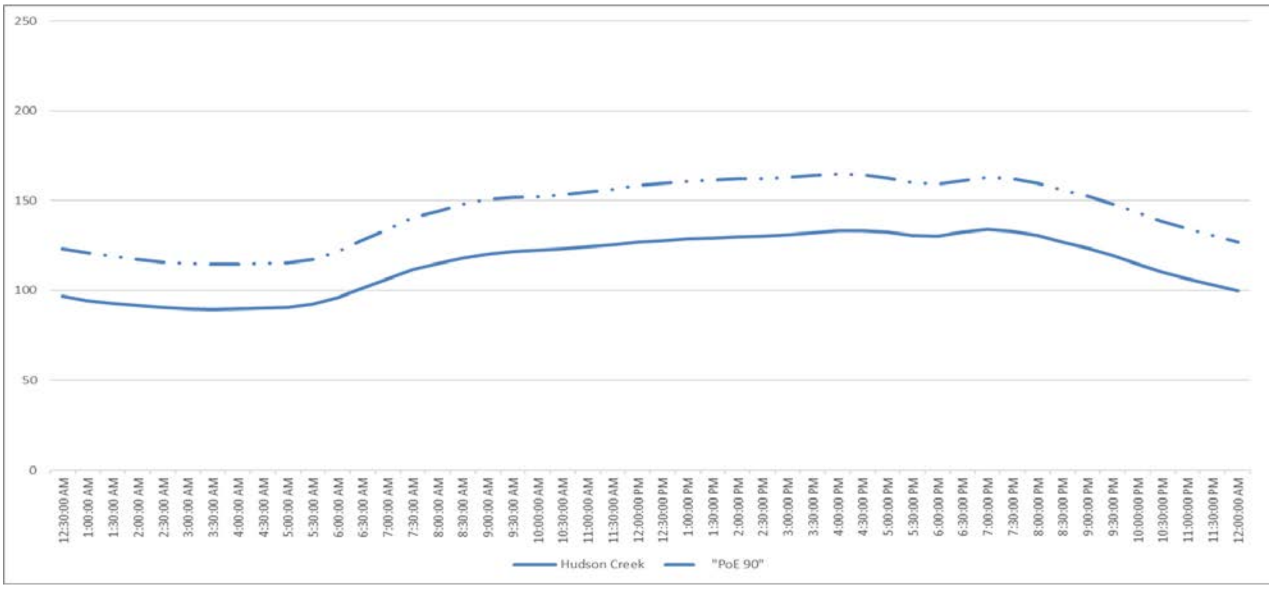


Figure 22 Darwin average daily demand profile (Hudson Creek ZSS) May to October

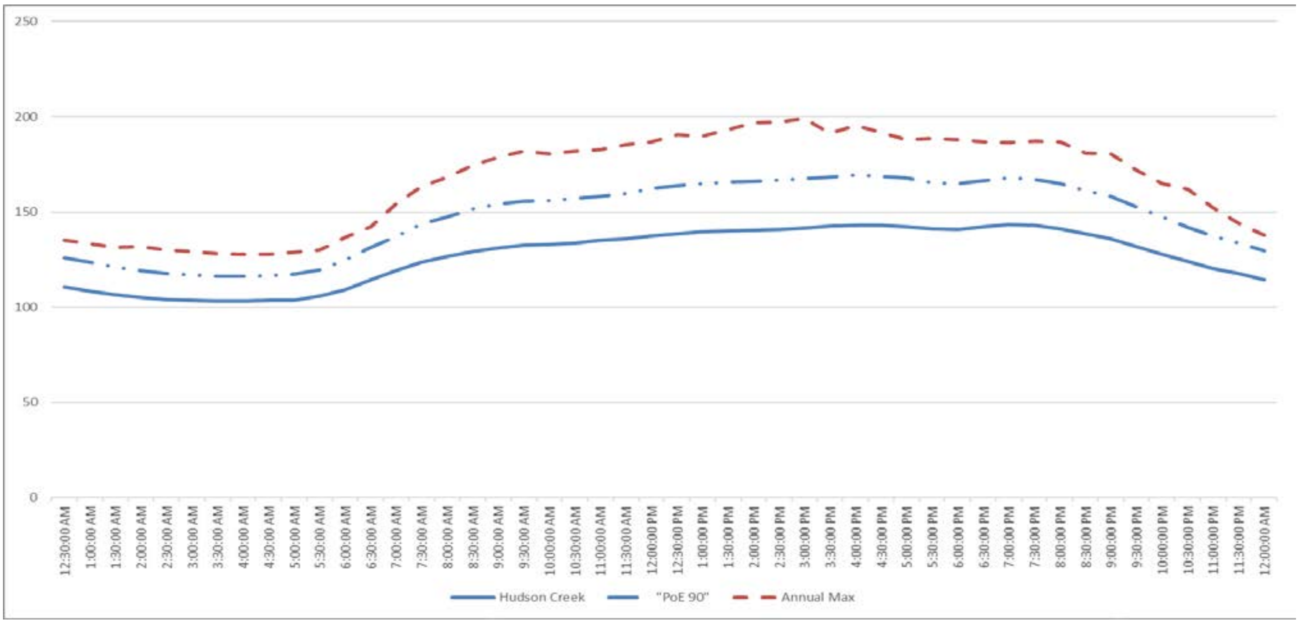


Figure 23 Darwin average daily demand profile (Hudson Creek ZSS) November to April

The annual maximum shows the demand for the highest half hour interval for the year. This shows that although the average peak was approximately 150 MVA, the maximum was 200 MVA, or 33% higher.

5) Seasonal challenges

Darwin has two distinct seasons, the 'wet' and the 'dry'. The wet season runs from November until April, and is characterised by high humidity, monsoonal rains, and storms. Temperatures typically range from a minimum of 20°C to a maximum of 33°C[3] as measured by the Bureau of Meteorology (BOM) over a 77 year period from 1941.

[3] Bureau of Meteorology (BOM), Climate statistics for Australian locations, Darwin

Figure 23 shows the 10 year average monthly maximum temperature measured in Darwin indicating the change in season during the year, in comparison with the corresponding average number of conductor failures. The 'dry' season is characterised by average maximum temperatures dropping to around 31°C and the 'wet' season with average maximum temperatures up around 34°C.

The conductor asset failure profile shows a lagging correlation between conductor failures and the seasonal climate conditions. An increase in asset failures and replacements are observed following the time periods when environmental factors present the most damaging weather conditions.

As climate conditions continue to change a corresponding increase in conductor failures are expected to be observed during these worst periods of the year, and especially impacting the Darwin region at the Top End of the Northern Territory.

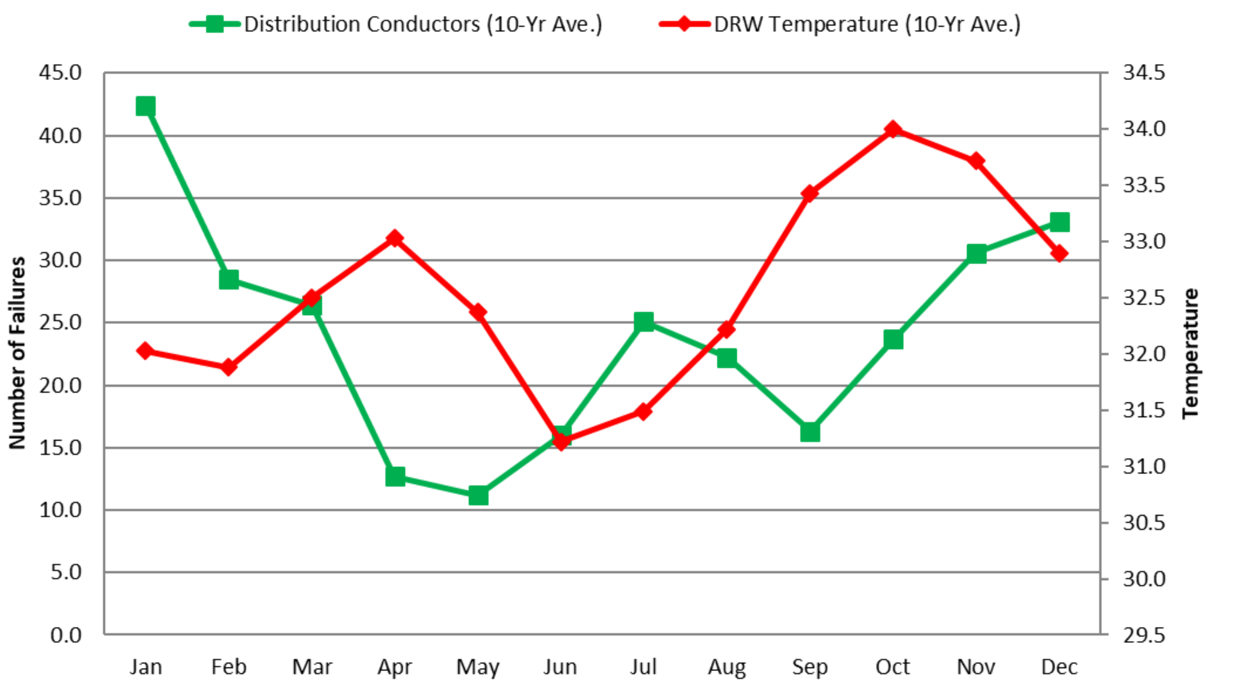


Figure 24: Average annual temperature and conductor asset failure profile

6.3 Asset challenges

The health of conductor assets is uniquely challenged in the Power and Water network. The key underlying issues relates to safe ground clearances and mechanical fatigue. These underlying factor is a key consideration in the following asset challenges identified in the distribution overhead networks.

6.3.1 Safe conductor-ground clearance

Full details on this asset challenge are available in the BNI document:

- NMP5/PRD33435 - Lake Bennett Feeder Conductor Clearance Rectification Program

The Lake Bennett feeder conductors are in breach of statutory safety standards, and in poor condition. The feeder was constructed in the mid-1970's and recent investigations called to attention a range of defects including failure to meet safe ground clearance, burnt conductor damage, single and multiple broken strands, and conductor corrosion.

A conductor clearance investigation was completed in August 2017 involving 21.8 km, or 48.0% of the feeder length. The investigation found 39.6% of the spans inspected in breach of statutory safe ground clearance requirements. On average, the low clearance standard is exceeded by 0.8 m and up to a significant 1.9 m in some instances. The investigation also found that the feeder fails to meet minimum ground clearance with between 2.0 m and 2.3 m at majority of road crossings inspected.

A replacement program targeting the installation of approximately 227 midspan poles across the length of the feeder, the replacement of 241 existing poletops, and the installation of around 40km (route length) of overhead conductor (noting that 5km has been previously replaced but without addressing the clearance issues) is proposed.

6.3.2 Other Conductor challenges

Other challenges associated with conductors that may not be the subject of an investment program for the next regulatory period, includes:

- Mechanical fatigue. The conductor assets in the Darwin region are subject to high corrosion and annealing leading to mechanical fatigue, conductor strand breakage, and ultimate asset failure.
- Conductors in the Power and Water network are affected by the "poly-pipe" corrosion issue. Widespread damage to overhead conductors has been identified where "poly-pipe" style bat protection has been used. This style of protection is used widely in the Katherine region and sporadically in Darwin's rural area. The risk associated with this damage is conductor failure and wires dropping onto the ground.
- Safe ground clearances. Failure to meet safe ground clearances have been identified as a key concern associated with conductor assets. Insufficient data is currently available to make an accurate assessment of this challenge. Investigations are planned to determine the extent of the challenge.
- Conductor corrosion in 3/12 Steel LV conductor: The remaining 3/12 steel LV conductor in the Power and Water network is affected by Corrosion at different levels where the steel conductor gets corroded by moisture and oxygen and also salt water spray especially around Darwin areas near the sea coast. Thus there are existing sections which are to be replaced due to deteriorating condition due to increased corrosion and possibly if in other sections, the 3/12 steel conductor condition deteriorates further, then more 3/12 steel conductor replacement might have to be carried out . The risk associated with this issue is conductor failure and wires dropping onto the ground during faults or fatigue.
- Conductor vandalism: In remote areas there are sporadic cases of conductors being shot and causing conductor damage. The risk is that small conductors (like 3/12 steel) fail and the HV wires drop onto the ground when shot.
- LV ABC insulation degradation issue: There has been instances of deterioration on the LV ABC insulation sheath on the top portions due to UV radiation from the sun and ageing.

Some ABC conductor has been replaced due to deteriorated insulation due to the safety risk of live conductor exposure and risk of conductor failure.

- Conductor connection failures: There has been numerous failures on conductor connectors failing due to ageing, high resistance connections and fault currents. The risk associated with this issue is leading to open circuits and some instances to conductor failures. The risk mitigation would be to upgrade to permanent spliced connections on targeted sections. Also conductor end connections like deadends/wraps fail due to lightning surge currents which cause conductor drops.

6.4 Asset management challenges

Asset management is the application of management, financial, economic, engineering and other practices to infrastructure assets with the objective of providing the required level of service in the most cost-effective manner. It requires the management of the asset condition throughout the asset life cycle, including design, construction, commissioning, operating, maintaining, repairing, modifying, replacing and decommissioning/disposal. A study of condition and performance data captured over time assists in managing the asset to function optimally in a safe and reliable manner throughout its life cycle. The life cycle asset management approach applied by Power Networks is provided in Appendix A.

A key asset management challenge is a lack of comprehensive asset condition assessment data across the network to fully understand and evaluate the health and deterioration of the conductor assets.

Improvement in the processes for and quality of data collection is a key focus and is being prioritised. Significant steps have already been taken through the introduction of mobile devices to capture data in the field at the time of inspection and testing. Feeder inspections including conductor height measurements are also being undertaken to assess the extent of safe ground clearance breaches within the network.

Another important challenge is to ensure that the required relevant/ compatible spares are available for normal and emergency outages for transmission conductor sections with various uncommon unique types and sizes of conductors which have been installed during various times and special conditions, considering the situation that some of the conductor spares are not currently available

7 Performance indicators

The performance of conductor assets against the specific objectives and measures identified in section 2.3 are provided here. The performance shown here represents the historical performance of the asset class to date. It is expected that benefits from investments proposed in the next regulatory period will manifest as benefits in these key objectives. The projected investment outcomes in relation to past performance trends are provided in section 11.

7.1 Operational Performance indicators[4]

[4] NT regulated system performance excluding instantaneous and major event days. Other excluded events include: Planned outages, Generation-related outages, Outages that were internal to customer premises, Outages initiated in the interest of public safety.

The historical performance impact from conductor assets over the last 10 years is provided in the figures below. The Conductor (transmission and distribution) performance over the last 10 years is provided in Figure 24. Conductor outages have shown a downward trend in contributions over the last 10 years, stabilising at an average 37% SAIDI and 30% SAIFI contribution over the last 5 years. There is some year-to-year variation and the SAIDI and SAIFI contribution is forecast to be slowly rising to a 38% SAIDI and 33% SAIFI contribution over the next regulatory period.

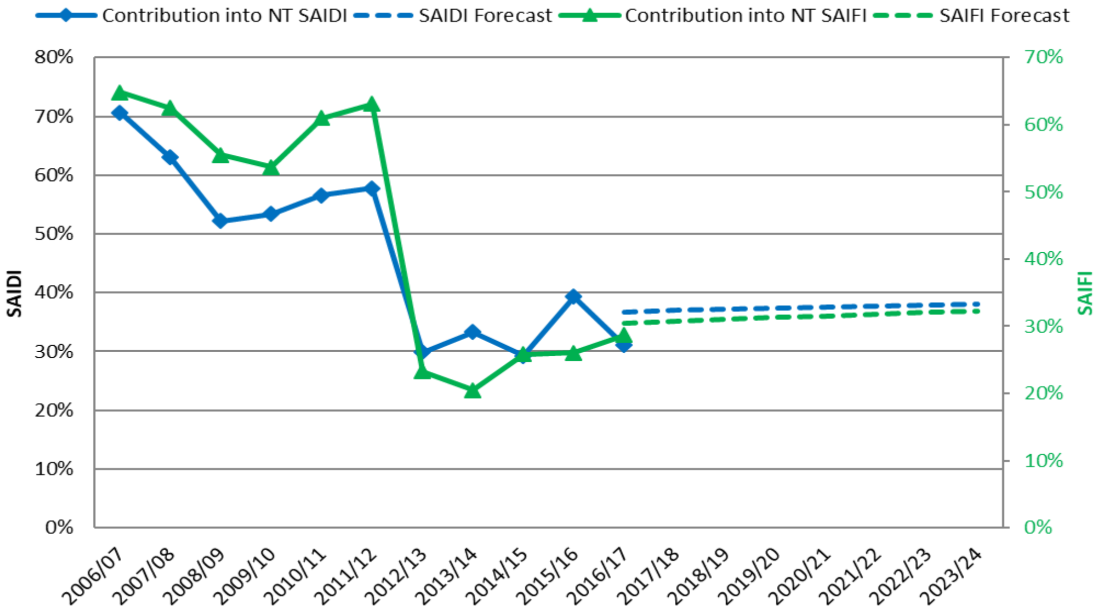


Figure 25: Conductor contribution into SAIDI/SAIFI

7.2 Health and Safety indicators

A key corporate objective is the safe operation of the network. The number of safety related events associated with conductor assets as recorded over the last 10 years is shown in Table 22. Safety-related incidents includes those outages which were caused by vehicle collision with Power and Water assets, public safety-related outages requested by emergency services, and forced outage to allow for safe work on the assets.

Table 19: Number of safety-related incidents associated with conductors

Financial Year	Number of Outages	Comment
2006/07	17	Conductor damaged by vehicle
		Outage in the interest of public safety
		Forced outages to commission electrical assets
		Outage in the interest of public safety-vehicles working near HV conductors
2007/08	51	Conductor damaged during excavations
		Conductor damaged by vehicle
		Forced outage - Power and Water equipment presents unacceptable risk
		Feeder de-energised to allow safe switching operations
		Outage in the interest of public safety (downed conductors)
		Forced outage to repair/replace faulty Power and Water equipment
2008/09	53	Conductor damaged during excavations

Financial Year	Number of Outages	Comment
		Outage in the interest of public safety (electrical assets interfered with during tree trimming)
		Outage in the interest of public safety (vehicle near or in contact with conductors after accident)
		Outage in the interest of public safety (downed conductors)
		Conductor damaged by vehicle
		Feeder de-energised to allow safe switching operations
2009/10	48	Conductor damaged during excavations
		Conductor damaged by vehicle
		Forced Outage - work done near conductors
		Outage in the interest of public safety (vehicle entangled in conductors)
		Outage in the interest of public safety (tree trimming close to conductors)
		Forced outage to remove debris from conductor
2010/11	27	Outage in the interest of public safety (vehicle entangled in conductors)
		Outage in the interest of public safety (safe clearance required for a crane)
		Conductor damaged by vehicle
		Outage in the interest of public safety (tree trimming in the vicinity of conductors)
		Outage in the interest of public safety (downed conductors)
2011/12	25	Conductor damaged by vehicle
		Forced outage - Power and Water equipment presents unacceptable risk
		Outage in the interest of public safety (construction work in the vicinity of conductors)
		Forced outage to repair/replace faulty Power and Water equipment
		Forced outage to facilate zone substation work
2012/13	11	Conductor damaged during excavations
		Conductor damaged by vehicle
		Feeder de-energised to allow safe switching operations
		Forced outage to repair/replace faulty Power and Water equipment
2013/14	7	Conductor damaged by vehicle
		Forced outage to remove trees from conductor
		Forced outage to conduct commissioning work
2014/15	10	Conductor damaged during excavations
		Conductor damaged by vehicle
		Outage in the interest of public safety (downed conductors)
		Feeder de-energised to allow safe switching operations
		Forced outage - Power and Water equipment presents unacceptable risk
2015/16	10	Conductor damaged by vehicle
		Outage in the interest of public safety (downed conductors)
		Forced outage to repair/replace faulty Power and Water equipment
2016/17	11	Forced outage - Power and Water equipment presents unacceptable risk
		Forced outage to remove trees from aerials
		Conductor damaged by vehicle

Financial Year	Number of Outages	Comment
		Outage in the interest of public safety (downed conductors)
		Outage in the interest of public safety (vehicle near or in contact with conductors after an accident)
Grand Total	**270**	

7.3 Financial Performance indicators

Power and Water's long term financial sustainability as underwritten by affordable service and shareholder returns is demonstrated in the efficient and competitiveness of its capital and operating costs.

The capital expenditure forecast for conductor assets has been based on historical unit costs, relying on recent and similarly scoped projects. The approach aligns with industry best practice and rely on data that is continuously validated and updated.

7.3.1 Capital unit costs

The capital unit rates are a significant input towards the capital expenditure forecast and have been calculated and justified to be as efficient and prudent.

The capital unit rates applied in establishing the regulatory capital forecast, have been assessed against similar unit costs observed across the National Electricity Market (NEM). The comparison provided an indicative measure of the reasonableness of Power and Water's costs, and has been based on publicly available data sourced from the Australian Energy Regulator's (AER's) Repex modelling and utility Regulatory Information Notice (RIN) submissions.

There are a number of internal and external operational, asset type, and environmental factors that influence the benchmark costs and provide a challenge in respect of the ability to undertake accurate comparisons. Normalisation for these factors has not been undertaken and the benchmark comparisons provided are an indicative measure of reasonableness only.

In undertaking the comparison, Power Networks was considered comparable with six Australian utilities of largely rural type networks. Subject to the availability of appropriate data these utilities included ActewAGL, Endeavour Energy, Essential Energy, Ergon Energy, TasNetworks, Powercor, and United Energy. Where historical unit costs have been utilised as part of the bottom-up estimates or historical analysis, these have been escalated to 2017/18 dollars by CPI only. The CPI escalation factor was derived from indexes published by the Australian Bureau of Statistics for all consumer groups and applicable to the Darwin area.

In the absence of expenditures recorded by Power and Water for recent similar upgrades, that would take account of the unique long spans and high tension design of the Lake Bennet feeder, the expenditure unit cost has been compared to typical pole and conductor replacement costs encountered by peer utilities nationally. With respect to conductors, shown in Figure 25, the unit cost is lower than the peer average, however this is somewhat expected for a rural line with very limited obstructions along its route.

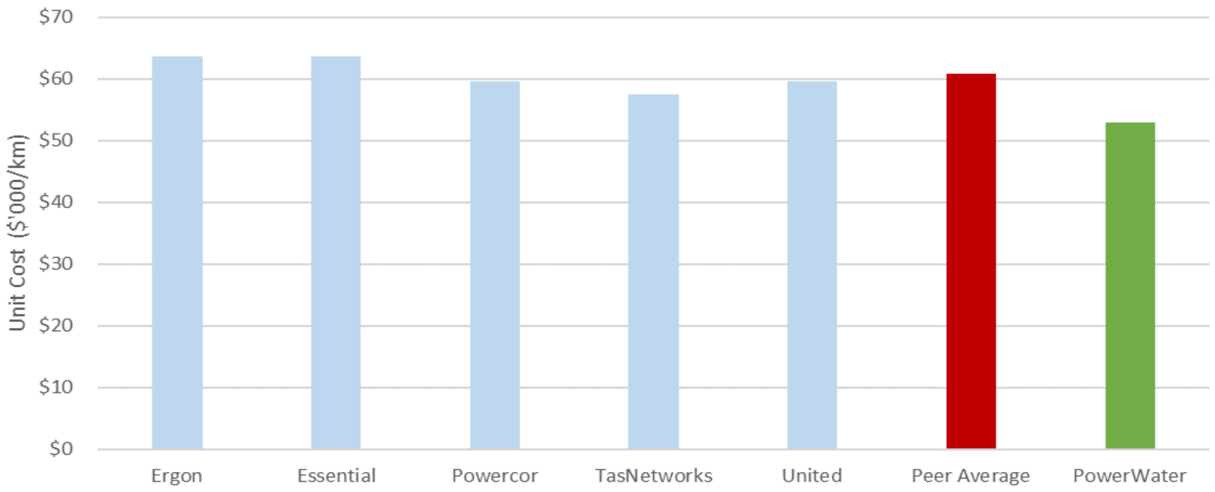


Figure 26 – Conductor replacement unit cost benchmarking

In comparison with peer utilities, Power and Water's pole installation unit cost compares above average. The cost is, however, reflective of the unique welded design of the steel poles that require additional equipment, resourcing, and outage times to allow for the placement and removal of poles. This asset design mitigates many of the unique environment risks, however these challenges are compounded by the remoteness of the network, harsh weather conditions, and a tropical climate that impacts on the productivity of work undertaken in the Northern Territory.

Activity associated with overhead line installation is considered to require a high metabolic work rate, and is therefore heavily affected by the weather conditions in Darwin. Based on analysis conducted by Thermal Hyperformance[5], workability for High metabolic activity reaches approximately 70% during only the coolest months of the year, June. Workability is not affected in any other major Australian population centre except for during the hottest 2-3 months of summer.

Taking into consideration the extenuating asset design and work conditions, the unit cost is considered reasonable.

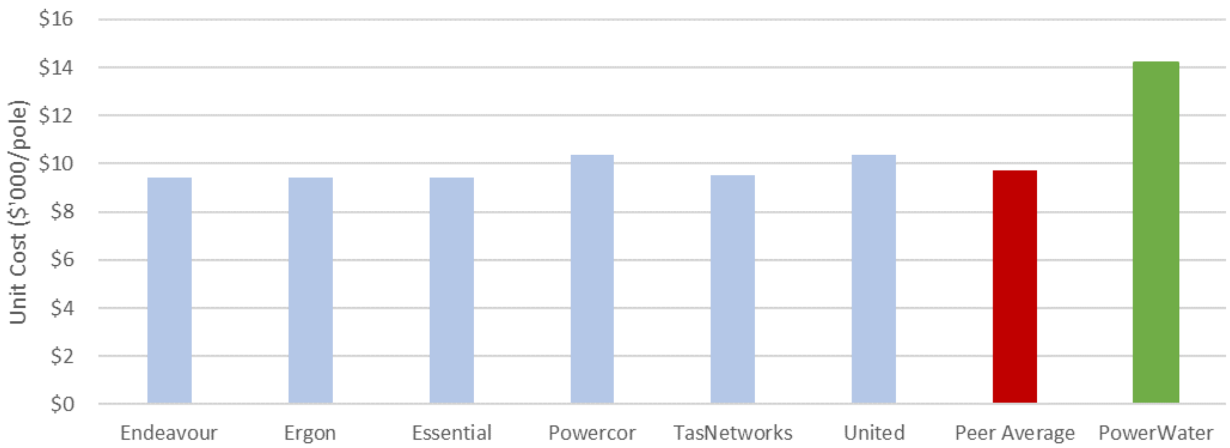


Figure 27: HV Distribution pole replacement Unit cost comparison

[5] Labour Efficiency and Work Management in Hot Humid Climates, Thermal Hyperformance.

7.3.2 Operating unit costs

The operational expenditures include that expenditure incurred in operating and managing the conductor asset fleet, ensuring that the assets continue to provide their pre-determined service capacity and quality of service and achieves its useful life. The operating expenditure therefore includes maintenance and direct overhead expenditure associated with the conductor assets.

Maintenance expenditure includes those costs incurred when:

- an asset is restored to its operational condition, and
- to ensure the asset meets its operational performance, reliability, and
- does not extend the useful life of the asset.

Direct overhead expenditure is expenditure associated with scheduling and planning. These support activities cannot readily be identified as belonging to a particular value adding task/activity and has been allocated on a pro-rata basis.

Similar to the capital cost, a comparison with peer utility expenditures has been applied to provide an indicative measure of the reasonableness of Power and Water's costs and has been based on publicly available data sourced from the utility Regulatory Information Notice (RIN) submissions.

Insufficient peer utility data was available to allow for a comparison of operations and maintenance costs associated with emergency response works at the asset class level. Emergency response operation and maintenance costs have therefore been excluded from the comparison.

There are internal and external operational, asset type, and environmental factors that influence the benchmark costs and provide a challenge in respect of the ability to undertake accurate comparisons. Normalisation for these factors has not been undertaken and the benchmark comparisons provided here are an indicative measure of reasonableness only.

Where historical unit costs have been utilised as part of the analysis, these have been escalated to 2017 dollars by CPI only. The CPI escalation factor was derived from indexes published by the Australian Bureau of Statistics for all consumer groups and applicable to the Darwin area.

A comparison of Power and Water's average annual routine and non-routine maintenance cost in comparison with peer organisations are provided in Figure 27. The Power and Water cost represents the average annual cost recorded over the last 5 years. In the absence of sufficient granularity to separate overhead conductors from poletop assets the unit cost comparison has been based on the maintenance cost per pole. This is commensurate with the location of typical overhead conductor failure modes.

The high level unnormalized comparison indicates that Power and Water's costs compares in the lower range of costs recorded across the NEM. Low historical conductor failure rates resulted in Power and Water managing conductor failure issues as corrective maintenance. A need for planned maintenance has now been identified.

Power and Water's routine and non-routine maintenance costs associated with conductor and poletop assets are considered reasonable.

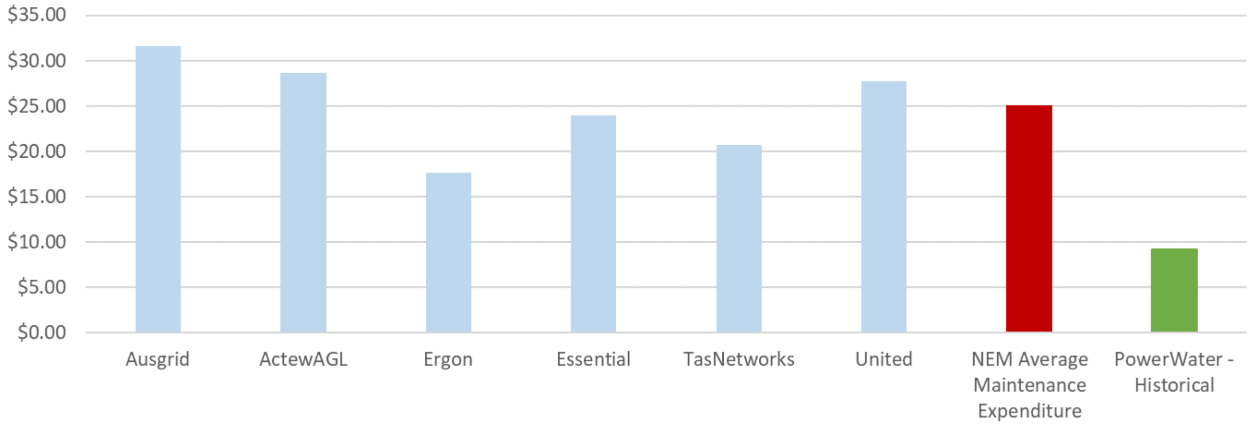


Figure 28: Conductor and Poletop routine and non-routine maintenance cost comparison

8 Growth requirements

The demand for power infrastructure is driven mostly by growth in the number of new network connections. To understand this potential growth Power and Water engaged AEMO in 2017 to undertake a connection forecast for the network regions of Darwin-Katherine, Tennant Creek, and Alice Springs[6]. The study outcome identified relative low customer connection growth across the network with the highest expected average growth in Tennant Creek, 1.0% followed by Darwin, 0.8% and Alice Springs, 0.1%. The outcome of the connection forecast is summarised in Figure 28.

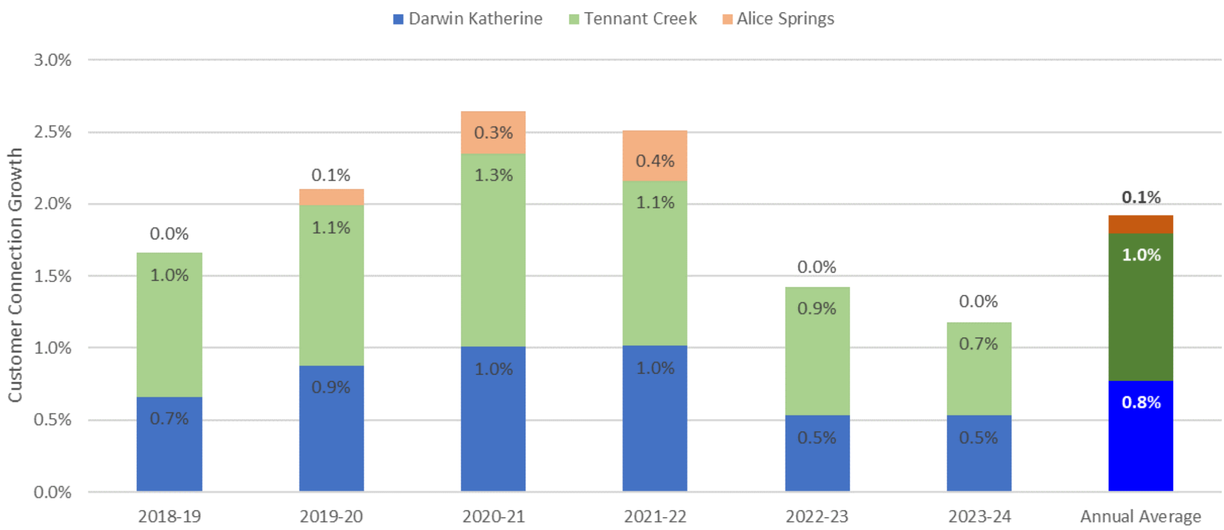


Figure 29: Customer connection growth by region (AEMO 2017 Forecast)

Overhead power lines generally remain the lowest-cost method of power distribution to most new urban and commercial developments in the Power and Water network, making the projected connection growth a very reasonable proxy for the expected increase in overhead infrastructure asset requirements over the same period.

[6] AEMO, Power and Water Maximum Demand, Energy Consumption, and Connections Forecast, September 2017

It is noted that the AEMO connection growth forecast shows a slightly reduced growth rate in comparison with Power and Water's annual average growth in conductor assets over the recent 5 years from 2012/13 to 2015/16. The exception is Tennant Creek and Darwin-Katherine where the connection growth rate is higher than past asset growth rates. This is mainly as result of new developments expected in pocketed areas of Darwin and Tennant Creek. The changing environment with reducing demand growth is expected to impact on the requirement for network growth and the AEMO forecast has been adopted to project the expected growth in conductor assets by the end of the regulatory period, 2023/24.

The projected increase in conductor assets is provided in Table 23. In summary the following approach was taken in doing the asset growth projections:

- No growth in transmission conductor assets is expected/planned.
- The forecast was based on the customer connection forecasts from AEMO's 2017 report: *Power and Water Corporation Maximum Demand, Energy Consumption, and Connections Forecasts.*
- The current asset base (i.e. length of conductor) was increased each year according to percentage change in the forecast number of connections.
- For periods where this percentage change was negative, the asset base remained the same, under the assumption that the existing network size will not reduce as result of short-to-medium term negative customer growth.

Table 20 Conductor forecast growth, qty (FY19 to FY24)

Region	Historical average annual asset growth rate (2012/13 to 2015/16)	AEMO annual connection growth rate	Transmission Conductor increase by 2023/24	Distribution Conductor increase by 2023/24
Darwin-Katherine	0.7%	0.8%	0	192
Alice Springs	2.6%	0.1%	0	5
Tennant Creek	0.1%	1.0%	0	28
Totals	0.9%	0.7%	0	225

The growth in assets will impact on the health and criticality profile of the asset class. The new assets are expected to be of good health with a prorate spread across the asset criticalities

The revised forecast health and criticality profiles for both transmission and distribution conductors by the end of the regulatory period, assuming no investment and including growth are shown in Table 24 and Table 25. The growth numbers are reflected in the increase in the H1 asset quantities. No growth increase is forecast for the transmission conductor assets. An 8.8% increase in H1 distribution conductor assets is projected.

Table 21: Transmission conductor health-criticality matrix (qty) with growth and no investment

	H1	H2	H3
C1	187 km	343 km	42 km
C2	11 km	58 km	7 km
C3	31 km	57 km	0.05 km

Table 22: Distribution (HV & LV) conductor health-criticality matrix (qty) with growth and no investment

	H1	H2	H3
C1	549 km	177.1 km	34 km
C2	341 km	252 km	507 km
C3	1,910 km	895 km	711 km

9 Renewal and maintenance requirements

Power and Water's renewal and maintenance investment plans are aimed at addressing key asset challenges identified within the asset class.

Targeted inspection and testing are undertaken to investigate assets of concern, and a separate assessment applying the asset health and criticality decision making approach[7] and the more detailed understanding of the condition of the specific assets, is used to assess the risk associated with the assets and to identify those assets that bear the greater risk.

Opportunities to maintain the safe and reliable operation of the network are then considered and typically include assessing options of run-to-failure, test and replace, and targeted pro-active renewal. The outcomes of the assessment manifest in a preferred investment option with a high level scope and cost estimate.

Maintenance activities are crucial in the early identification of asset health and condition issues and the prioritisation of assets for further investigation. Inspection findings, field service feedback, and performance measures are the main inputs used to identify those assets that are of particular concern, or may have a type issue. Routine asset inspections are therefore a fundamental aspect of Power and Water's maintenance regime to ensure prudent and effective investments.

The process and outcomes of the renewal and maintenance requirement assessments are documented in the Business Needs Identification (BNI) documents that are prepared for and approved by the Chief Executive.

The following projects and programs have been evaluated and provide the conductor renewal and maintenance requirements proposed for the next regulatory period.

9.1 Transmission Conductors

9.1.1 Transmission Conductor renewal plans

No renewal investment programs have been identified for the immediate future. The assets will be closely monitored to identify any emerging need as network conditions change.

9.1.2 Transmission Conductor asset maintenance plans

The maintenance plan for transmission conductor assets is to continue with the established maintenance regime, which is based on annual patrols, 3 or 5-yearly detailed inspections (depending on line criticality) and repair (or replacement) upon failure. Patrols typically involves

[7] 'Program Replacement Volume Forecast Method' discussion paper

both ground based and aerial assessment of condition. Asset defects are prioritised based on risk of failure and included in the maintenance and defect rectification program.

Defects that cannot be identified through visual inspection eventually result in failure of the asset and are repaired or replaced under the pooled asset replacement program.

9.2 Distribution conductors

9.2.1 Distribution Conductor renewal plans

1) Safe conductor-ground clearance investment

Full details on this asset challenge are available in the BNI document:

- NMP5/PRD33435 - Lake Bennett Feeder Conductor Clearance Rectification Program

Applying the health and criticality criteria laid out in section 5 the assessment of the distribution conductors is provided in Table 26. It prioritises the replacement of those assets in the H3 health category and highest criticality, C3.

Table 23: Distribution conductor health-criticality matrix (qty)

	H1	H2	H3
C1			
C2			
C3			40 km

The projected annual replacement volumes over the regulatory period are provided in Table 27 and will replace 40 km (route length) of the Lake Bennett feeder conductor in the Darwin region.

Table 24: Projected annual Distribution conductor replacement volumes (Qty)

Program	2019-20 Qty	2020-21 Qty	2021-22 Qty	2022-23 Qty	2023-24 Qty	Total Qty
Conductor replacement (km)	18	15	6	1	0	40

9.2.2 Distribution Conductor asset maintenance plans

The maintenance plan for distribution conductor assets is to continue with the established maintenance regime, which is based on 3-yearly inspections and repair (or replacement) upon failure. Inspections typically involve ground based assessment of condition. Asset defects are prioritised based on risk of failure and included in the maintenance and defect rectification program.

Defects that cannot be identified through visual inspection eventually result in failure of the asset and are repaired or replaced under the pooled asset replacement program.

9.3 Pooled conductor asset replacements

Full details of this program evaluation are available in the document:

- 2019-24 Pooled Asset Replacement Forecasting Model Methodology

The pooled program captures those conductor assets that fail in service. These replacements are typically done under emergency conditions and are therefore of limited scope and cost, however impact positively on the overall health of the network moving assets out of the poor health category. These failures are expected to be mostly associated with poor health and low criticality assets, i.e. those assets that are of poor health but not necessarily part a proactive replacement program.

The expected conductor replacements under this program have been projected using a probabilistic approach. The approach forecasts asset failures using a combination of asset age, asset conditional probability of failure, and historical asset failures. A total of 1.5 km transmission conductor and 9.2 km distribution (HV and LV) conductor replacements are forecast over the 5 year regulatory period. The projected annual replacement volumes are provided in Table 28.

Table 25: Projected pooled conductor replacement volumes

Program	2019-20 Qty	2020-21 Qty	2021-22 Qty	2022-23 Qty	2023-24 Qty	Total Qty
Transmission conductor replacements	0.1	0.2	0.3	0.4	0.5	**1.5**
Distribution conductor replacements	1.1	1.4	1.8	2.2	2.7	**9.2**
Total conductor replacements	**1.3**	**1.6**	**2.0**	**2.6**	**3.2**	**10.7**

The health and criticality assessment of the transmission and distribution conductor assets expected to be replaced through the pooled replacement program is shown in Table 29 and Table 30. The pooled replacements are expected to involve those assets of poor health, and varying criticality. A prorate allocation of criticality levels has been made based on the volume of assets in each criticality level.

Table 26: Pooled program transmission conductor health-criticality matrix (qty)

	H1	H2	H3
C1			1.3
C2			0.2
C3			0.0

Table 27: Pooled program distribution conductor health-criticality matrix (qty)

	H1	H2	H3
C1			0.1
C2			1.9
C3			42.5

10 Investment program

The investment program is developed based on the:

- Continuation of the established lifecycle asset management approaches;
- Specific requirements related to growth in the asset class – outlined in Section 8; and
- Specific requirements related to renewal and maintenance of the asset class – outlined in Section 9.

10.1 Augmentation expenditure (augex)

No augmentation related requirements associated with conductor assets have been identified for the next regulatory period.

10.2 Renewal expenditure (repex)

There are two renewal programs proposed for the asset class over the next regulatory period, 2019/20 to 2023/24. The programs are expected to cost $7.55 M over the 5-year period and include investment in both the transmission and distribution assets.

The renewal expenditure forecast based on the mention programs are provided in Table 31.

Table 28: Renewal expenditure forecast

Year	2019-20 ($'000)	2020-21 ($'000)	2021-22 ($'000)	2022-23 ($'000)	2023-24 ($'000)	Total ($'000)
Distribution conductor replacement	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Pooled Transmission conductor replacements	$51	$67	$90	$120	$161	$489
Pooled HV conductor replacements	$109	$139	$176	$222	$278	$925
Pooled LV conductor replacements	$132	$162	$198	$241	$290	$1,024
Total	$2,759	$2,164	$1,136	$723	$768	$7,551

The revised five-year forecast health and criticality profiles for the transmission and distribution conductors following the proposed investments are shown from Table 32 and Table 33. The reduction in risk is demonstrated in the number of assets that move from the low health, H3 category to the high health category, H1 in comparison with the 'current' and 'no investment' risk scenarios provided in section 5.2 and section 5.3.

Table 29: Transmission conductor health-criticality matrix (qty) with investment

	H1	H2	H3
C1	188 km	343 km	40.5 km
C2	11 km	58 km	7.2 km
C3	31 km	57 km	

Table 30: Distribution conductor health-criticality matrix (qty) with investment

	H1	H2	H3
C1	549 km	177 km	34 km
C2	343 km	252 km	505 km
C3	1,952 km	895 km	669 km

10.3 Historic, forecast and future expenditure comparison

Historic expenditure on conductors has been predominantly to address conditional and functional failures discussed in Section 6.3.

As outlined in the preceding sections, the forecast expenditure on conductors is targeted to address specific assets that are in a poor condition and an allowance for replacement of failed conductors.

Future expenditure in the asset class has been forecast using the AER's repex model and shows an increasing requirement for investment. As the AER's repex model is primarily an age-based model, it is expected that Power and Water's future investment requirements can be managed without whole-sale replacement being required. This will involve an approach that continues targeting poor health assets in order to maintain the existing network risk. Future investment in the asset class is expected to be managed at a level below $2 million per annum.

10.4 Operational expenditure (opex)

The operating expenditure for Conductors for the next regulatory period is provided in Table 34.

Table 31: 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)
Transmission conductors	Routine	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Non-routine	$0.00	$0.07	$0.13	$0.02	$0.05	$0.05	$0.04	$0.04	$0.04	$0.04	$0.04
	Fault and emergency	$0.00	$0.00	$0.01	$0.01	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total		**$0.00**	**$0.07**	**$0.13**	**$0.03**	**$0.06**	**$0.05**	**$0.05**	**$0.05**	**$0.05**	**$0.05**	**$0.05**
HV distribution conductors	Routine	$0.00	$0.01	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Non-routine	$0.05	$0.33	$0.10	$0.05	$0.13	$0.12	$0.10	$0.10	$0.10	$0.10	$0.10
	Fault and emergency	$0.20	$0.07	$0.15	$0.16	$0.14	$0.13	$0.13	$0.13	$0.13	$0.13	$0.13
Total		**$0.25**	**$0.41**	**$0.25**	**$0.21**	**$0.27**	**$0.25**	**$0.23**	**$0.23**	**$0.23**	**$0.23**	**$0.23**
LV distribution conductors	Routine	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Non-routine	$0.01	$0.15	$0.06	$0.05	$0.07	$0.06	$0.05	$0.05	$0.05	$0.05	$0.05
	Fault and emergency	$0.40	$0.72	$0.85	$0.80	$0.64	$0.62	$0.60	$0.60	$0.60	$0.60	$0.60
Total		**$0.41**	**$0.88**	**$0.91**	**$0.84**	**$0.70**	**$0.68**	**$0.66**	**$0.66**	**$0.66**	**$0.66**	**$0.66**
All conductors	Routine	$0.00	$0.01	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Non-routine	$0.06	$0.55	$0.29	$0.12	$0.25	$0.23	$0.19	$0.19	$0.19	$0.19	$0.19
	Fault and emergency	$0.60	$0.79	$1.01	$0.97	$0.78	$0.75	$0.73	$0.73	$0.73	$0.73	$0.73
Total		**$0.66**	**$1.36**	**$1.29**	**$1.08**	**$1.03**	**$0.98**	**$0.94**	**$0.94**	**$0.94**	**$0.94**	**$0.94**

Note: 1. The conductor routine maintenance costs appear low as inspection and patrol costs have been allocated to the Poles and Towers asset class.
2. Vegetation maintenance costs are excluded- refer to the Vegetation Management Plan.

11 Asset class outcomes

11.1 Key performance indicators

11.1.1 Operating Performance indicators

No material improvements in system performance are forecast as a result of the proposed investment program. A 0.56% improvement in SAIDI contribution and 0.47% improvement in SAIFI contribution to NT system performance is expected. The conductor investments only affect a small proportion of the assets and most of the historical causes of outages are not related to the condition of the conductor assets (i.e vehicle crashes).

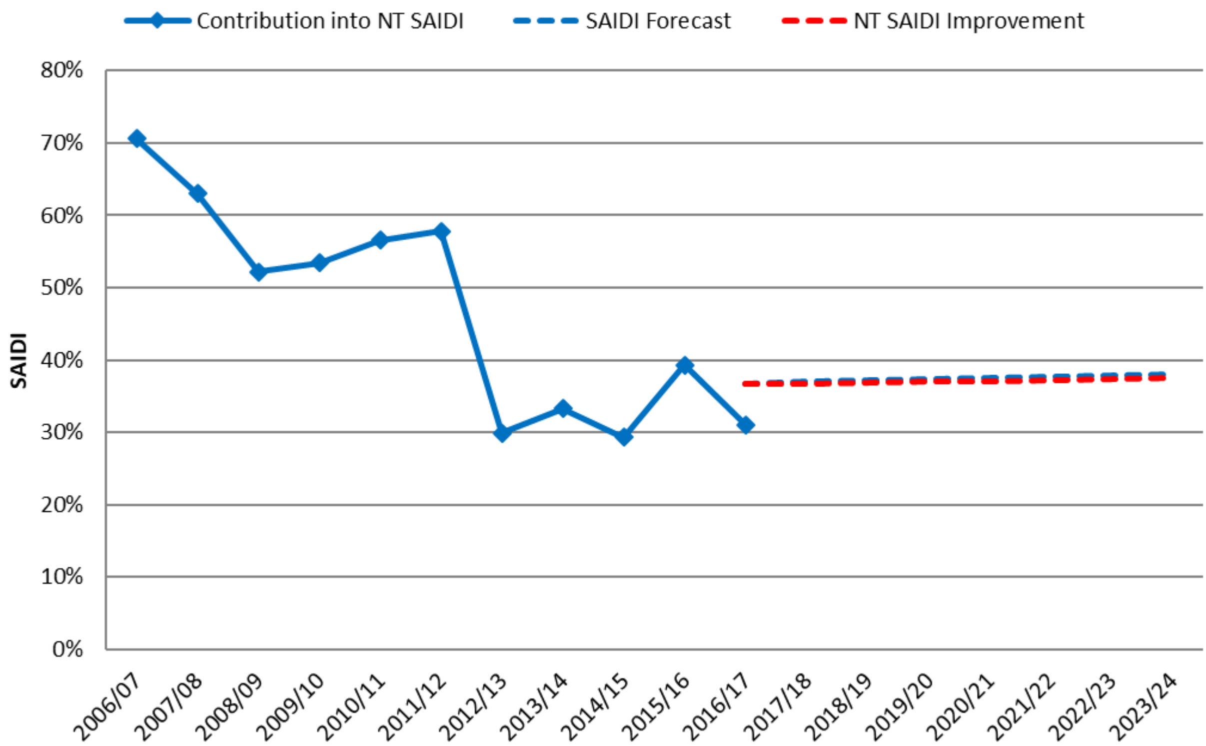


Figure 30: Conductor contribution into system SAIDI following investment

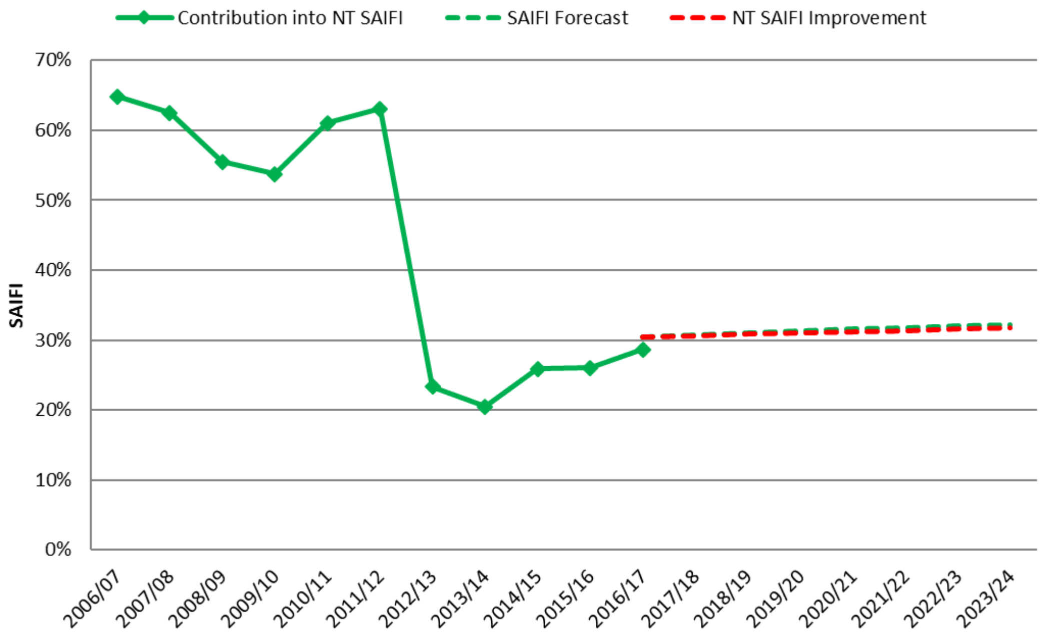


Figure 31: Distribution conductor asset contribution into system SAIFI following investment

11.1.2 Health and Safety indicators

A key corporate objective is the safe operation of the network. Historical safety related incidents predominantly consisted of third party impacts with Power and Water assets, public and worker safety-related operational outages, and forced outages requested by emergency services. The investment program for the next regulatory period replaces low span assets and mechanical fatigued conductor assets. These investments are expected to mitigate against potential safety events which are reasonable common, as demonstrated through the volume of vehicle incidents involving overhead lines.

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 conductor defect modes and trends. These insights provide for informed decision making on whether to repair or replace conductor assets. It assists in the continuous development of the asset management strategy for conductor assets.

This Asset Management Plan will be reviewed at least every two (2) 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 with increased focused. Any improvements in analysis and understanding of the conductor asset fleet will be included in this AMP when it is updated.

The RACI model provided in section 3.2 identifies the roles and responsibilities important in the management of the conductor assets. These responsibilities include ongoing performance monitoring and strategy revisions.

13 Appendix A – Lifecycle asset management

Power and Water exerts great efforts to ensure being a customer oriented organisation that provides a safe, reliable and efficient electricity supply in the Northern Territory. This is demonstrated in the approach it take in managing its assets. The life cycle asset management approach applied 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 conductor 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 conductor assets include consideration of:

- Optimised utilisation of existing conductors
- 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 22kV Lake Bennett feeder where the replacement of the feeder involves using of a combination of new and existing assets to optimise the cost efficient replacement of the feeder. It involves the replacement of conductors as the existing conductors are deteriorated to a point where it is no longer practical and safe to utilise these assets.

13.2 Design

The design phase is where decisions around the physical characteristics and functioning of the asset is 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.

Power and Water's approach to the whole of life cycle prudent and efficient design of assets include the standardisation of conductors and associated equipment. 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 conductor design standardisation offers the following specific benefits to the business. It:

- 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
- Boost 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

During the design of the conductor assets a key input to the decision making is the current and future planned utilisation. The utilisation is informed from the demand forecast typically with contingency conditions as guided by the Network Planning Criteria.

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 (eg. maintenance)
- Emergency switching of the network in response to incidents (eg. fault events)
- Real time switching to operate the asset within its design parameters (eg. loading)
- Monitoring of the condition of the asset (eg. alarms)

Power and Water recognises the need to outline and communicate a single, coherent operating model with clear responsibilities across the full asset lifecycle of the conductor assets. To this end, key competencies required to operate the asset is always identified and adequate training provided. Power and Water works diligently to ensure that different business units of the organisation have clear roles and responsibilities for each asset category.

13.4 Maintenance (opex)

Asset maintenance involves the upkeep of assets to ensure they will function to their required capability in a safe and reliable manner from their commissioning to their disposal. This is achieved though the following maintenance objectives:

- maintain the functional performance of the assets
- identify potential problems before the condition of assets is compromised
- minimise damage to assets during faults
- avoid or limit the duration of customer supply interruptions
- enable a planned and structured approach to repair or replacement of assets
- reduce risk to personnel and public
- mitigate public liability risk

Maintenance requirements evolve as the condition and performance requirements of the assets change through its life. It monitors and provides feedback on asset condition, it incorporates upkeep and repair activities to maintain the condition of the asset, and it also includes the monitoring and management of the deterioration of an asset over time. Three main types of maintenance activities are defined: preventative, corrective, and unplanned maintenance.

- Preventative maintenance involves the controlled care and repair activities carried out to reduce the probability of failure or degradation of asset performance. It includes routine inspection and monitoring, upkeep and repair, testing and component replacements. Preventative maintenance expenditure increases over time as assets age.
- Corrective maintenance involves activities to repair asset defects identified as result of condition assessments or failures. Corrective maintenance expenditure increases over time as assets age and deteriorate.
- Unplanned maintenance involves activities to immediately restore supply or make a site safe in response to unplanned failures. Unplanned maintenance expenditure increases over time as asset age and deteriorate.

Power and Water employs a 3 yearly ground based visual inspection and an annual visual/aerial inspection cycle to assess the health of conductors. Included in this inspection is an assessment of the above ground and accessible components of the asset and associated assets. The inspection involves a judgement of condition and risk of failure based on a visual assessment and in conjunction with system performance tracking provides a pointer to potential asset integrity issues. High risk assets are prioritised for further investigation and testing.

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.

Power and Water has asset replacement programs in place to renew assets of poor condition as close as possible yet 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

Power and Water ensures that all assets identified for disposal are disposed of in an environmentally responsible manner.