Program Business Need Identification

Power and Water Corporation

CONTROLLED DOCUMENT

PRD33394

Transmission Line Pole Top Replacement Program

Proposed:	Approved:
Stuart Eassie Manager Asset Strategic Engineering Power Networks Date: 7/2/2018	Michael Thomson Chief Executive Power and Water Corporation Date: / /20

	Refer to email D2018/57840	Refer to email D2018/59242
Djuna Pollard Executive General Manager Power Networks Date: 7/2/2018	Finance Review Date: 06/02/2018	PMO QA Date: 17/01/2018

1 Program Summary

Program Name:	Transmission Line Pole Top Replacement Program		
Program No:	PRD33394	**SAP Ref:**	
Financial Year Commencement:	2019/20		
Business Unit:	Power Networks		
Program Owner (GM):	Djuna Pollard	**Phone No:**	08 8985 8431
Contact Officer:	Stuart Eassie	**Phone No:**	08 8924 5214
Date of Submission:		**File Ref No:**	D2017/366501
Submission Number:		**Priority Score:**	
Primary Driver:	Compliance	**Secondary Driver:**	Safety
Program Classification:	Capital Program of Works		

2 Recommendation

MAJOR PROJECT >$1M OR PROGRAM

It is recommended that the Chief Executive note the proposed five year transmission pole top replacement program for an estimated budget of $1.9 million, and approve the inclusion of this program into the SCI for this amount, with a corresponding completion year of June 2024.

The forecast for this program of work extends beyond the current SCI period. The first two years of this program aligns with the last two years of the 2017-18 SCI. This program will be included in the 2019-24 Regulatory Proposal to the Australian Energy Regulator (AER).

Note that individual projects within the program will be documented in Business Case Category Cs to be approved by the Executive General Manager Power Networks.

3 Description of Issues

The scope of this program covers the pole tops of transmission lines in the Darwin region, specifically the 132kV Channel Island to Hudson Creek lines A and B (132 CI-HC A/B), and the 66kV Weddell to Strangways line (66 WD-SY). Inspections have determined that sections of the 132 CI-HC A/B have corroded insulators and the 66 WD-SY has corroded crossarms both of which are explained in more detail below. These lines are both generator connection points for the two largest power stations in the Northern Territory, providing all generation capacity for the Darwin region. Figure 1 below shows the location of these lines with PWC's transmission network.

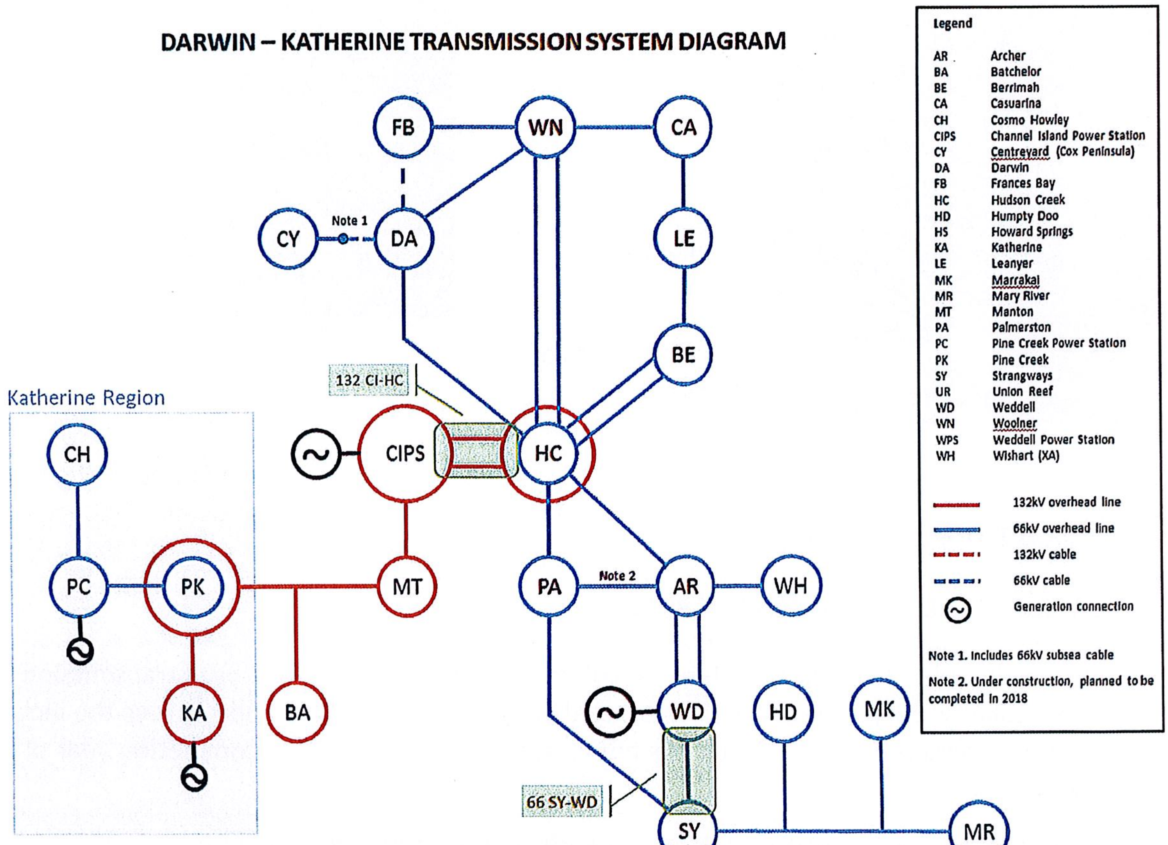


Figure 1 Simplified Transmission System Diagram with Affected Transmission Lines Identified

3.1 CI-HC Lines A and B

Line inspections undertaken in 2017 identified advanced corrosion of insulators on the 132kV feeders between Channel Island Power Station and Hudson Creek Terminal Station (CI-HC Line A and B). In particular, the sections of line between Channel Island and the Elizabeth River involving approximately 70 towers that traverse inter-tidal mangrove areas.

Corrosion of porcelain insulators in suspension configuration is known in the industry as a common failure mode of insulators[1]. Corrosion generally occurs at the live or "hot" end where they connect to the conductor due to leakage current through the insulator, particularly when wet. In the Darwin region, a concerted condition based replacement program was undertaken over the last five years, targeting transmission line insulators where advanced corrosion or damage from lightning was identified. An increased awareness of corrosion issues has also led to more insulators being identified for replacement during tower inspections. The program replaced around 5.5%, or 142 transmission insulator installations. Despite this active replacement effort, recent inspections confirmed an ongoing need for investment in upholding the health of the transmission network insulator population.

Figure 2 - Example Corrosion and section loss after cleaning on 132kV Insulator Disc from Tower 9A

The failure mode associated with corroded insulators is a mechanical failure of the insulator string, either due to the loss of steel section, or the corrosion affecting the grout which bonds the pin to the insulator. Specific risks associated with crossarm and insulator failure include:

- Risk to personnel regularly climbing towers and poles to perform detailed inspections, conduct maintenance or emergency repairs. This includes the risk from both the mechanical energy associated with a failure, and electrical hazards associated with a failure during live line work.
- Public safety risk also exists with tower and pole top structure failures resulting in damage to property, injury or death to the public. The 132HC-CI line traverses many access points to busy industrial sites and runs parallel to corridors for earth moving equipment between quarries and industrial sites.
- System security risks associated with loss of either 132 CI-HC Line A and B lines which are critical assets within the PWC network and are the only connection between Channel Island power stations and Darwin network. The loss of either line due to asset failure has a direct impact on system security. The risk is exacerbated by the potential for cascading failures given the advanced level of corrosion observed at towers inspected to date.

3.2 WD-SY Line

[1] D2017/490948 NGK – Pin Corrosion Discussion Paper and D2017/488027 NGK - Porcelain Suspension Insulator Pin corrosion assessment guide

The basic function of cross-arms is to support overhead electrical conductors and other cross arm mounted assets, providing safe clearance and isolation from ground and between phases and other adjacent objects, complying with safety regulations. The consequence of a cross-arm failure can be catastrophic, with the possibility of damage to property, injury or death.

Feeder inspections completed in 2016/17 identified areas of advanced crossarm corrosion particularly on the aged assets. The 66kV Weddell Power Station to Strangways Zone Substation (66 WD-SY) transmission line was noted as having particularly advanced levels of corrosion. The feeder was constructed in 1987 and consists of 154 transmission poles of which 6 were replaced in 2008. A further 6 have been replaced in 2017. Photos of the units replaced in 2017 are shown in Figure 2.

The crossarm construction is unique in that hollow box section steel was used and not galvanised. This is thought to be creating a "micro-environment" inside the sections due to the humid conditions allowing corrosion to advance at a higher rate than observed on "Angle" or "Channel" section steel generally used elsewhere on the network.

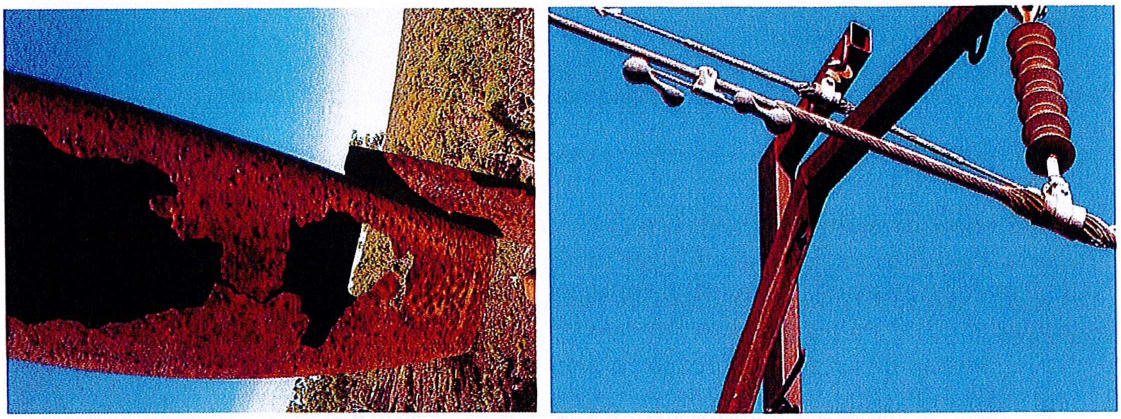


Figure 3 - Example Corrosion on 66 SY-WD Crossarm

The failure mode associated with corroded crossarms is a mechanical failure due to the loss of steel section. Specific risks associated with and insulator failures are similar to those detailed for the insulator corrosion.

3.3 Project Needs

a. Safety
Advanced deterioration in pole top structures (insulators and crossarms) poses a safety risk to the public as well as PWC employees involved in undertaking works on and being in the proximity of the asset. Replacement of corroded insulators and crossarms effectively addresses the public and worker safety risk.
b. Compliance

A fundamental business driver for PWC is compliance with the Network Technical Code and Network Planning Criteria objective of providing safe, secure, reliable, high quality power supply at a minimal cost.

Targeted replacement of deteriorated insulators and crossarms will maintain the effective functioning of the transmission pole top structures and reduce risk associated with employee and public safety, and system security related to asset failure, compliant with the business objective.

c. Security (if not compliance obligation)

The transmission network contributes to the security of the power system. The advanced deteriorated condition of sections of the network's pole top structures impacts on the ability to effectively maintain network security. The 132 CI-HC and 66 WD-SY lines are both generator connection points for the two largest powerstations in the Northern Territory.

Replacement of corroded insulators and crossarms will ensure continued maintenance of system security and achievement of PWC's system security obligations.

4 Potential Solution

Options to maintain the safe and reliable operation of the network have been considered. These include:

Option 1 - Run to failure

Run to failure is not an industry approach that is applied to transmission crossarms and insulators. The public and worker safety risk and adverse system performance impacts makes this an unsuitable approach to managing transmission tower and pole top insulator and crossarm assets.

Option 2 - Inspection and repair/replace

This approach involves the detailed inspection of every transmission pole top structure and insulator to determine the discreet condition of each repair item followed by an evaluation to determine if the condition warrants remedial action. To date, detailed inspections have been undertaken at selected towers to identify the above failure modes, however, in the case of the insulators failures it is only after they have been removed from site that the true extent of the corrosion can be measured. In the case of cross-arms the determination of loss of section is not obvious from the ground. Determining loss of section for every pole crossarm would involve capturing the loss section measurements during a planned outage using sophisticated measuring devices. After obtaining the data a Finite Element Analysis FEA computer modelling would be required to determine the minimum section requirements in order to maintain the cross arm function.

In summary the measurement of discreet assets to determine the replacement event is considered to be expensive and impractical in that for the inspection the access is difficult and requires a higher number of safety barriers and may risk system security.

Option 3 - Targeted proactive replacement

The targeted proactive replacement of ageing transmission insulators and crossarms is a concerted approach directed at maintaining system safety and reliability in a prudent and cost efficient manner. It relies on a risk based prioritisation of transmission pole top structures taking into consideration asset health and criticality to inform a replacement program.

4.2 Comparative Cost Analysis

A comparative cost analysis of the three options has been undertaken. The net present cost of each option including Opex and Capex over a 40 year period is detailed in the table below.

Option	Capital cost ($M)	Net Present Cost ($M)	Comments
1 – Run to failure	1.9	2.8	Assumes replacement of 5% of proposed volumes each year during asset age span of 40-60 year.
2 – Inspection and repair/replace	1.9	3.4	Assumes that 20% of proposed volumes require replacement after inspection, remainder replaced during asset age span of 40-60 year. Includes opex allowance for engineering assessments of inspection results.
3 – Targeted proactive replacement	1.9	3.5	Assumes replacement of all proposed volumes during 2020-2025

As outlined above, option 1 has the lowest net present cost of the three options. Option 2 and Option 3 have very similar net present costs.

4.3 Non-cost attributes

An analysis of the non-cost attributes for each option has been completed using the multi-criteria analysis method. The attributes are selected considering major risks and priorities to achieve Project Objectives. A weighting is allocated to each, totalling 100%. Each attribute is given a score out of 5 (from 1 – Fails to satisfy, to 5 – exceeds requirements); the score is then multiplied by the relevant weighting to give the weighted score that is summarised in the table below.

Table 1 Non-cost Attributes Assessment

	Technical & System Risk		Stakeholder Risk	Commercial	
Criteria	Reliability	System Security	Safety	NPC	Weighted Scores
Weighting (%)	10	20	30	40	100
Option 1	0.2	0.4	0.3	2.0	**2.9**
Option 2	0.3	0.6	0.9	1.2	**3.0**
Option 3	0.4	0.8	1.2	1.2	**3.6**

4.4 Preferred Option

Option 3 is the preferred option. Despite Option 1 having the lowest net present cost, this solution does not adequately address the non-financial safety and system security risks resulting from asset failure.

A risk based approach has been used to establish a targeted replacement program. The program will replace 220 x 132kV insulators and 90 x 66kV crossarms in the next regulatory period, 2019/20 to 2023/24. The approach focuses on defined feeder sections taking into consideration mobilisation costs and system performance impacts.

This strategy will result in the replacement of all the known high risk 132kV insulators and 66kV crossarms during the regulatory period. Allowances have also been made for expected emerging replacement requirements given an increased awareness and focus on corrosion issues.

The program considers asset criticality, health, and probability of failure to prioritise the transmission pole top structures that poses the higher risk. Criticality has been determined based on specific identified and known high risks issues related to the 132 CI-HC Line A and B and 66 WD-SY lines, and inspection findings and the criticality of the assets within the power system. These transmission feeders are critical assets for maintaining security of supply within the network. The severity of corrosion identified to date combined with structure age provided an indication of asset health. Probability of failure has been based on the findings of recent pole top inspections taking into consideration the replacements undertaken over the last five years.

Year	2019-20 Qty	2020-21 Qty	2021-22 Qty	2022-23 Qty	2023-24 Qty	Total Qty
Crossarm Replacement Volumes	18	18	18	18	18	90
Insulator Replacement Volumes (towers/poles)	44	44	44	44	44	220
Total	**62**	**62**	**62**	**62**	**62**	**310**

4.5 Non Network alternatives

No viable non-network alternatives were identified that would mitigate the need for the replacement of the transmission insulators and crossarms.

4.6 Capex/Opex substitution

The proposed transmission insulator and crossarm replacement program addresses an asset degradation issue that cannot be solved through operations and maintenance activities.

4.7 Contingent Project

The expenditure does not meet the criteria for a contingent project - National Electricity Rules, section 6.6A.1(b)(2).

5 Strategic Alignment

This program aligns with the Asset Objectives defined in the Strategic Asset Management Plan (SAMP) and Asset (Class) Management Plans (AMP). The capital investment into transmission infrastructure outlined in this program will contribute to the Corporation achieving the goals defined in the boards Strategic Directions and SCI Key Result Areas of Health and Safety and Operational Performance.

6 Timing Constraints

It is essential that this program commence as proposed to manage the continued safe and reliable operation of the network.

Insulators in the inter-tidal mangrove area between Channel Island and the Elizabeth River need to be proactively replaced to mitigate the risk of failure due to compromised strength. If not replaced a failure is likely with significant impact to system security. The worst case scenario is the potential of injury or death to PWC workers and/or the public. Extreme weather is a catalyst for potential failures increasing the risk of failure dramatically during severe weather events.

Transmission line pole top replacement during the build-up and wet season will be avoided. Pole top replacements require towers to be climbed and manual handling of insulators and crossarms. These activities require a high metabolic work rate. The efficiency of performing work outside of the cooler dry season months is greatly compromised and places personnel at risk of heat related illness[2]. Where work is required to be done in hotter months it is characterised by significantly shorter working hours per person through regular breaks and cycling of crew members to manage heat stress.

7 Expected Benefits

Driver	Benefit	Measure
Renewal / Replacement	Network safety	Health and Safety Index
Compliance	System Security	Comply with Power Networks Technical Code and Planning Criteria
Service Improvement	Network reliability maintained	Performance against SAIDI and SAIFI targets
Social / Environmental	Reputation	Avoid negative publicity due to a failure of critical infrastructure.

8 Milestones (mm/yyyy)

Investment Planning	Project Development	Project Commitment	Project Delivery	Review
01/2018	NA	01/2019	06/2024	09/2024

9 Key Stakeholders

Stakeholder	Responsibility
Internal governance stakeholders	Executive General Manager Power Networks
	Group Manager Service Delivery
	Chief Engineer

[2] D2017/493408 Thermal Performance Heat Impact on Productivity - Analysis of Darwin and other regions

Stakeholder	Responsibility
Internal design stakeholders	Senior Manager Network Development and Planning
	Senior Manager Contracts and Projects
	Senior Manager Asset Management
	General Manager System Control
External – Unions and public	Local Residents
	ETU
	Ministers
External regulators	Utilities Commission
	Australian Energy Regulator

10 Resource Requirements

Not applicable. Resourcing requirements for this program are considered Business as Usual and will be incorporated into the development of Category C Business Case's for each period of work.

11 Delivery Risk

Capacity of the internal workforce during the peak dry season period can be augmented by contract labour to mitigate delivery risks. Expenditure forecast has been based on recent similar investments and reflects similar costs achieved through outsourcing. The expenditure forecast is considered reasonable for a combination of internal and external resourcing.

12 Financial Impacts

12.1 Expenditure Forecasting Method

The expenditure forecast has been based on a program approach. The forecast volumes have been determined using a risk based prioritisation of assets focusing on the replacement of the highest risk installations.

The transmission insulators on the 132 CI-HC Line A and B lines will be completed in stages, prioritised by the rates of corrosion measured. Replacement of 66kV crossarms on the 66 SY-WD line will also be completed in phases and when efficient to do so, included as part of other work programs, minimising mobilisation costs.

The asset replacement investment program is internally driven and no customer contributions are expected.

12.2Historical and Forecast Expenditure

Insulator replacements have historically been performed on an ad hoc basis as non-routine (Corrective) maintenance when identified as being corroded or lightning damaged through inspections. The volume of replacements has increased significantly over the last 5 years, mainly as result of an increased awareness that has led to more effective identification of corrosion issues during pole top structure inspections. Historical maintenance and capital expenditure has been identified through analysis of work order data and is shown in Figure 2 below. The budget for FY18 and FY 19 is based on current defective insulators identified. While there is a significant increase in the upcoming period it is driven by the specific corrosion issues that are the subject of this BNI.

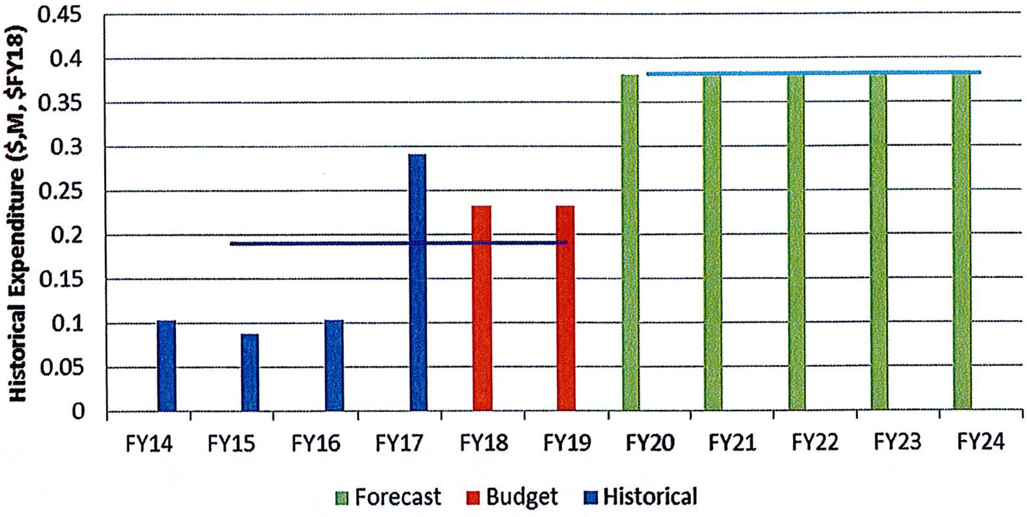


Figure 4 Historical and Forecast Expenditure

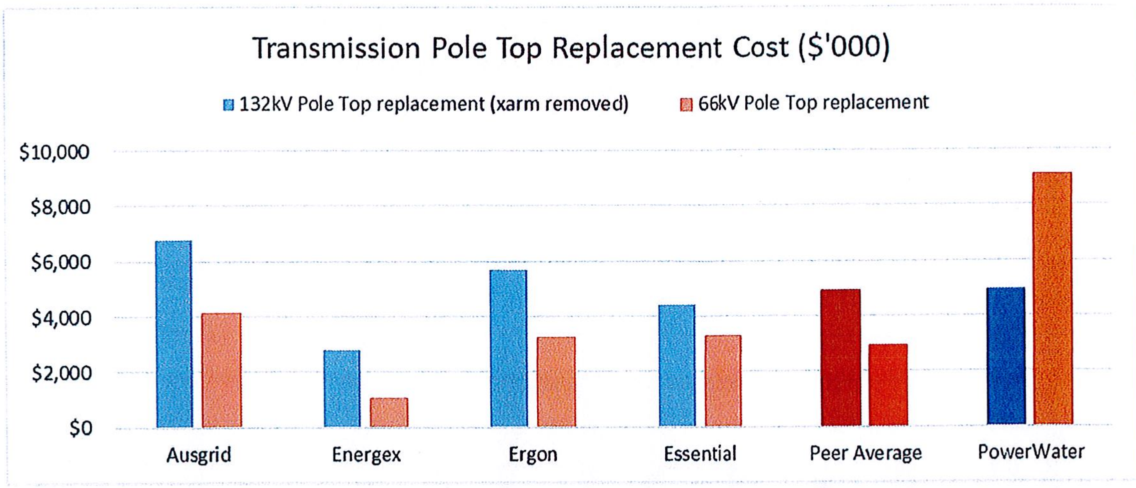
12.3 Validation

The cost estimate has been based on 134 insulator replacements from 2013/14 to 2016/17. It includes both live line and isolated line cases, and reflects the expected forecast work practices.

The crossarm replacement expenditure forecast has been based on a bottom up estimate of labour, material, and services costs.

A benchmark of the cost against similar works undertaken by peer utilities indicates that the unit cost for 132kV insulator and 66kV pole top replacements are reasonable. In comparison with peer utilities, PWC's unit cost for 132kV insulator replacements compares with the industry average. The 66kV pole top replacements appears high and is the result of a specific design. The 66 SY-WD crossarms are a wishbone design that is welded to the pole with an earth riser installed on the opposite side of the pole. Replacement of the crossarms requires two cranes, one to hold the conductors and another to lift the new crossarm into place while welded on. This approach adds around 49% to the cost of replacing the 66kV crossarms. An option to design a special bracket that can be installed over the earth riser is being considered. This may alleviate the need for a second crane. The design has not been tested and approved yet, and the unit cost allows for current work practice.

Works undertaken in the Northern Territory are characterised by higher costs than other areas in Australia. This can partly be attributed to the remoteness of the network attracting additional transport and logistic costs, as well as the harsh weather conditions set apart by extended wet periods that impedes the effective execution of works, and a tropical climate that impacts on the productivity that can be achieved during normal work hours.



12.4 Capex Profile

Phase	2019-20 ($'000)	2020-21 ($'000)	2021-22 ($'000)	2022-23 ($'000)	2023-24 ($'000)	Total ($'000)
Investment Planning						
Project Development						
Project Commitment						
Project Delivery	381	381	381	381	381	1,905
Review						
Total	**381**	**381**	**381**	**381**	**381**	**1,905**

12.5 Opex Implications

Insulator replacement expenditure made up on average around 6.3% of the total transmission maintenance expenditure over the last three years. It is expected that the opex associated with the ad hoc replacement of insulators will reduce, however would be offset to some extent by ongoing replacements associated with lightning and flash damage.

Transmission Maintenance Expenditure	2014-15 %	2015-16 %	2016-17 %	Average %
Insulator replacement	11.5%	6.2%	1.2%	6.3%

12.6 Variance

The forecast for this program of work extends beyond the current SCI period. The first two years of this program aligns with the last two year of the 2017-18 SCI.

APPENDIX A

1 Forecast Expenditure by Expenditure Category

The expenditure is to be in today's dollars ($2017/18).

RAB Category	Regulatory Year (A$M, $2017-18, Jul to Jun years)				
	2019-20	2020-21	2021-22	2022-23	2023-24
Total	0.381	0.381	0.381	0.381	0.381
Labour	0.251	0.251	0.251	0.251	0.251
Materials	0.130	0.130	0.130	0.130	0.130
Contractors	0	0	0	0	0
Other	0	0	0	0	0

Definitions

Labour – The cost of direct Labour for the project. No overheads.

Materials – the cost of materials used in the project. No overheads.

Contractors – the cost of work performed by Contractors in the project, whether Labour or Materials. No overheads.

Other – expenditure that is not Labour, Materials or Contractors. No overheads.

2 Forecast Expenditure by RAB Category

The expenditure is to be in today's dollars ($2017/18).

RAB Category	Regulatory Year (A$M, $2017-18, Jul to Jun years)				
	2019-20	2020-21	2021-22	2022-23	2023-24
Total	**0.381**	**0.381**	**0.381**	**0.381**	**0.381**
System Capex					
Substations					
Distribution Lines					
Transmission Lines	0.381	0.381	0.381	0.381	0.381
LV Services					
Distribution Substations					
Distribution Switchgear					
Protection					
SCADA					
Communications					
Non-system Capex					
Land and Easements					
Property					
IT and Communications					
Motor Vehicles					
Plant and Equipment					

3 Forecast Expenditure by CA RIN Category

The expenditure is to be in today's dollars ($2017/18).

RAB Category	Regulatory Year (A$M, $2017-18, Jul to Jun years)				
	2019-20	2020-21	2021-22	2022-23	2023-24
Total	**0.381**	**0.381**	**0.381**	**0.381**	**0.381**
Repex	0.381	0.381	0.381	0.381	0.381
Augex					
Connections					
Non-network: IT					
Non-network: Vehicles					
Non-network: Buildings and property					
Non-network SCADA & network control					
Non-network: Other					