Pooled Asset Replacement Forecasting Methodology

Power and Water Corporation

CONTROLLED DOCUMENT

1 Introduction

1.1 Purpose

The purpose of this document is to provide an overview of the approach PWC has adopted in the development of its replacement capital expenditure forecast of its low value assets for 2018/19 and its next regulatory control period, 1 July 2019 to 30 June 2024.

The low value assets are typically referred to as 'volumetric' assets, meaning that individually each asset is low cost but there are high volumes that need to be replaced each year, so overall the program is significant. The assets are typically simple assets and do not generally need specific designs completed for their installation. Their replacement needs have been forecast using the Pooled Asset Model.

Specifically, the asset categories include in the Pooled Asset Model are:

- Overhead Conductors
- Pole Top Structures
- Underground Cables
- Service Lines
- Distribution Transformers
- Distribution Switchgear
- Other – Connectors
- Other - Surge Arrestors
- Other – Pillars

This document should be read in conjunction with the Pooled Asset Replacement Model.

This document does not relate to network operating expenditure forecasts.

1.2 Context

PWC has a relatively small network that is split into four regions of Darwin, Katherine, Alice Springs and Tennant Creek. Table 1 provides an overview of the volume of assets that are part of the Pooled Assets group for the full network.

The assets are classified into the RIN categories for the purpose of forecasting replacement needs for the Pooled Assets.

Table 1: Asset population overview, includes HV and LV assets

ASSET GROUP	As at November 2017
OVERHEAD CONDUCTORS	5,412 km
POLE TOP STRUCTURES[1]	44,254 units
UNDERGROUND CABLES	1,607 km

[1] Based on one pole top structure per pole.

SERVICE LINES	55,074 units
DISTRIBUTION TRANSFORMERS	4,630 units
DISTRIBUTION SWITCHGEAR	6,728 units
OTHER – CONNECTORS	Unknown
OTHER - SURGE ARRESTORS	Unknown
OTHER – PILLARS	7,280 units

The age profile of assets in PWC's network is influenced by Cyclone Tracey (1974) which destroyed a significant portion of the network and as a result there is a large peak in age profiles between 1974 and 1976 as the network was rebuilt. There was also a period of rapid expansion of the network that was driven by development of new suburbs between 1979 and 1985 which has resulted in a large peak in most asset classes installed during those years. The age profile is shown in Figure 1.1, grouped into five year intervals. It clearly shows the peak in asset installation in the period of time between 35 and 45 years ago that reflect the events mentioned above.

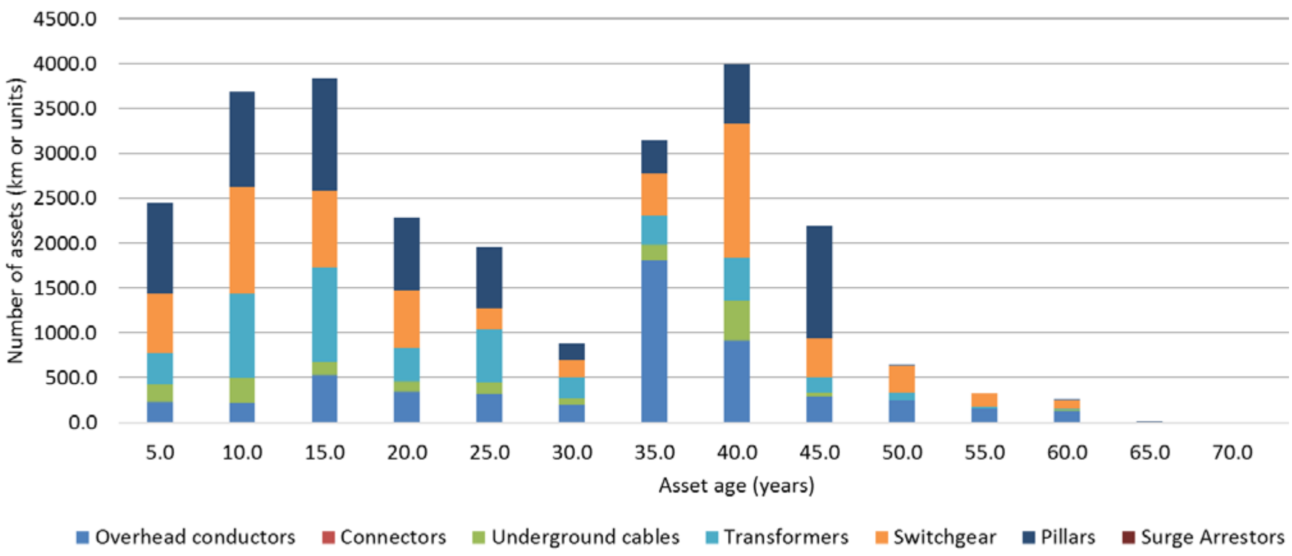

Figure 1.1: Age profile of low value 'volumetric' assets

2 Forecasting method

2.1 Overview

PWC has developed a model to forecast the replacement volumes and expenditure for volumetric assets. As stated in section 1.1, the assets included in the low value asset pool are simple, individually of low value and typically a failure of any one item does not have a high impact. It is impracticable to economically collect condition information for the purpose of trending deterioration rates and assessing optimal replacement timing. It is practicable to conduct visual inspections to find damage, particularly damage not relating to age that might have safety impacts, and where the asset is determined to be unserviceable to schedule replacement before failure. Assets in the low value asset pool whose condition cannot be determined by visual inspection are generally left in service until they run to failure.

In general, PWC has developed its replacement forecasts using three key forecasting approaches:

1. **Trending**. The trend of asset failures in service has been used to forecast future replacement requirements. A flat trend using historical data based on the P50 level or a line of best fit (using linear regression) has been used depending on the asset type.
2. **Probabilistic**. A probabilistic approach has been used to forecast the expenditure required for asset replacement due to condition. This approach forecasts based on the age profile, conditional probability of failure and historical volumes and unit costs.
3. **Discrete analysis**. For example, a specific engineering analysis.

The Low value asset pool uses two of these approaches – trending and probabilistic – as described in this forecasting methodology and shown in Table 2. Discrete analysis is not appropriate to be used given the high volume of assets in the low value pool.

Table 2 provides the guiding principle for the adoption of the most appropriate asset management strategy. Table 3 shows the asset management approach adopted for each asset in the low value asset pool along with the approach taken to forecast replacements needs.

Table 2: Asset management strategies

Asset Management Strategy	Asset risk profile suitability
Run-to-failure Reactive (functional failure)	• Asset has low criticality, low consequence • Asset condition information is difficult to gather
Condition based (Conditional failure)	• Asset is critical and function failure is likely to result in consequences with a likelihood adjusted NPV that is greater than the replacement cost • Asset condition is measurable

Table 3: Asset management approach

Pooled asset	Asset Management Strategy	Forecast approach
Overhead Conductors	Condition based	Probabilistic
Pole Top Structures	Condition based	Trend
Underground Cables	Run to fail	Probabilistic
Service Lines	Condition based	Trend
Distribution Transformers	Majority run to fail, condition based for large distribution transformers	Probabilistic
Distribution Switchgear	Run to fail	Probabilistic
Other – Connectors	Run to fail	Trend
Other - Surge Arrestors	Run to fail	Trend
Other – Pillars	Condition based	Probabilistic

The Pooled Asset Model does not identify specific assets for replacement. Instead, it uses asset characteristics to forecast the expected replacement expenditure that will be required during the forecast period.

The specific assets replaced are selected based on condition assessments made by field crews throughout the forecast period. All assets are inspected on a cyclic basis as set out in PWCs testing and inspection procedures. When defects are found, they are prioritised based on risk of failure and are included in the maintenance program. Defects that cannot be found through visual inspection will eventually result in failure of the asset. This ensures that only assets requiring replacement are replaced.

2.2 Trending approach

This trending approach was applied to assets where the age profile is not recorded by PWC due to the low value of the assets or where experience demonstrates that the in-service failures follow a deterministic trend, and trending is the most appropriate replacement forecasting method.

The Low value pool assets that fail in service generally cause an outage to customers and these outages are recorded in the Utilities Commission Standards of Service reporting data. The outage data is audited to ensure it is accurate and appropriate for use and therefore represents the best data source to forecast asset in service failures.

Since PWC's objective is to maintain reliability, the historical trend of asset failures reflects a reasonable basis from which to establish a historical trend, and forecast failures expected in the future.

2.2.1 Model Architecture

The model is an MS Excel Workbook containing data on asset failure rates that is analysed to determine historical trends and project them into the future. The Asset Failure Trend part of the model consists of four worksheets:

- ESAA Outage Dataset 2000-2017: contains the failure data
- Pivot: pivot tables of the failure data and trend calculations
- Vols – Trend: Output sheet
- Exp – Trend: Output sheet

Output worksheets are used to collate data from the trending and probabilistic parts of the workbook.

2.2.2 Calculation methods

The calculation sheets use historic data to calculate the number of assets expected to fail each year. The assets are allocated to the appropriate asset category based on asset type data available in outage reports.

The modelling approach has used either a flat trend (average of historical failures) or linear regression (line of best fit) as appropriate based on:

- asset type
- knowledge of how the asset is managed
- emerging trends in asset failures, and
- sensibility check of the trend output to make sure there is not an unrealistic increase or decrease in forecast asset failures.

Once the volumes are forecast, they are multiplied by a unit rate to calculate the forecast expenditure.

Where applied, the flat trends were tested at P50 and P90 values to assess the sensitivity of the analysis. Calculated trends were checked using engineering judgment and operational experience on the network to ensure the trends were appropriate. Where unrealistic trends were identified, alternative conservative assumptions were made instead, typically the historical average continuing as a flat trend.

2.2.3 Basis of assumptions

Asset replacement forecasts are made using the trending approach when there is insufficient data to enable the probabilistic approach to be applied or where a trending approach is considered most appropriate for the asset type. For example, when the assets are not recorded in Maximo so there is no age profile or where there is not considered to be a strong relationship between asset replacement needs and age (ie, fuses and surge arrestors where replacement is driven by events that are not age related).

Assets that are not recorded in Maximo are:

- pole tops (including cross arms and insulators)
- service lines

Assets where replacement is caused by events that are not related to asset age include:

- surge arrestors (ie, related to lightning strikes)

Data used for modelling these assets was sourced from the 2000-2017 AER and UC Target Standards Dataset (29 Aug 2017), which is audited outage data. Seven years of data has been used to provide a reasonable history of data but ensuring that it still reflects the current opex and repex practices and the types of assets on the network.

2.3 Probabilistic approach

During normal inspection cycles, assets are identified to be in poor condition and scheduled for replacement. This is a pass/fail test and does not provide condition data that can be used to forecast replacement needs based on individual asset condition. To establish remaining life based on current condition is not an economically viable approach for high volume low cost assets. Therefore, PWC has developed a model to forecast the number of replacements required using a probabilistic approach. Some of the assets will fail in service prior to being replaced. These assets will be captured in the Utilities Commission Standards of Service reporting data.

The probabilistic methodology uses the principles from the AER's Repex Model, but is augmented by additional knowledge of the network. Our approach to forecasting replacement volumes captures both in service failure or condition based replacement as drivers of replacement.

To ensure no double counting of assets, the model only applies either a trending or probabilistic approach to forecasting asset replacements for each asset class in the low value asset pool and excludes assets that are forecast for replacement through other programs of work.

The model is expected to provide a more accurate (lower) expenditure requirement than using the AER's Repex Model alone. Comparison to the AER's Repex model output is shown in Section 6.2.

2.3.1 Model architecture

The model is an MS Excel Workbook containing data on asset age. VBA code is used to cycle through the asset categories to produce estimated failures per year. The Probabilistic part of the model consists of six worksheets:

- Age profile: contains the age profile of all relevant asset classes
- Age profile adjust: contains the assets that are covered by other programs of work and need to be removed from the asset age profile for the purpose of this model
- Historical volumes: contains the sum of annual replacement volumes for assets that have failed in service and asset that have been replaced due to condition (prior to failure)
- Replacement Calc: calculates the forecast replacement volumes
- Vols – Prob: output worksheet
- Exp – Prob: output worksheet

Output worksheets are used to collate data from the calculation worksheets of the trending model.

2.3.2 Calculation methods

Key features of the Probabilistic model are:

- The expected life of an asset is used to create a cumulative normal distribution curve to forecast the probability of asset failure in any given year. The cumulative distribution curve is used to calculate the 'survival curve' which is the conditional probability of failure (refer to Attachment 1 for detailed explanation) in each year.
- The standard deviation of the asset has been calculated as the square root of the mean life. This is consistent with the approach taken by the AER's Repex model.
- The age profile of the asset class is adjusted to remove assets that are forecast for replacement through another program of works. The reduction of assets is shown in the tab "Age profile adjust".
- Each year of the age profile is multiplied by the corresponding conditional probability of failure for that year (as calculated by the survival curve) to calculate the expected number of assets that will fail or require replacement with that age. The sum of expected failures or replacement from all age groups is the total number of replacements forecast for the year.
- The age profile is then incremented to simulate aging by one year and the process is repeated until the forecast horizon is reached. In this case, the forecast horizon is 7 years for the period FY18 to FY24.
- The process is repeated for all asset types in the low value asset pool to which a probabilistic forecasting approach is being used.

- Once the volumes are forecast, they are multiplied by a unit rate to calculate the forecast expenditure.

2.3.3 Calibration

The model is calibrated so that the volume of replacements in the first year of the forecast is aligned to the average volume of replacements during the preceding five years of historical data. This approach is based on these assets having long lives and network conditions not changing significantly from one year to the next, so replacement requirements of the near future are expected to be similar to those experienced in the recent past. Calibration was implemented using the following approach:

- Where there are historical replacement volumes, the expected life of the asset is adjusted so that the volumes forecast for replacement in the first year of the forecast is equal to the historical average of the past five years.
- Where there is no historical failure data available, the Peer Calibrated Life[2] is applied without further calibration.

2.3.4 Verifying outputs

The outputs of the model were checked for reasonableness compared to the historical requirements of the network, while considering new programs that have started and old programs that will end prior to the next regulatory period. Sensitivity and scenario analysis was undertaken to assess the model outputs and care was taken to avoid double counting asset replacements.

This has been done by:

- Undertaking sensitivity and scenario analysis through the selection of various combinations of unit rate and mean life including: Peer DNSP data for Calibrated and Uncalibrated Lives, Benchmark Unit Rates, Historical Unit Rates, and PWC estimates.
- Removing assets from the age profile that are the subject of other projects or programs of work (for example the Northern Suburbs Cable replacement program)
- Calibrating to historical replacements with the data obtained from the most reliable and accurate sources. The data set excludes specific historical programs of work that will not continue, assets with type issues that will be removed from the network by the start of the next regulatory period and assets, or subcategories of asset classes, that were part of the low value asset pool in the current period but will be covered by specific programs in the forthcoming regulatory period.
- Verification on a like for like basis to historical data at a total level for the assets modelled
- A manual verification by PWC's subject matter experts to ensure the forecast is reflective of expected future network needs and emerging issues.

2 The Peer Calibrated Life is the average calibrated life published by the AER for the rural and urban based distribution businesses in the NEM. This is a conservative approach as asset lives are typically found to be shorter in PWCs network, particularly the Darwin region, due to the climatic conditions.

2.3.5 Basis of assumptions

Key assumptions implemented in the model include:

- Two categories of distribution transformer are not calibrated as the calibration process resulted in unrealistic mean ages (either very low or negative). As a result, the expected life age was applied without calibration.
- There is no overlap between failures and condition based replacement data as the expenditure and asset volumes are recorded under different codes in Maximo.
- The average of the calibrated peer expected lives was used to ensure a conservative forecast for the cases where no historical data is available.
- PWC unit rates, calculated from historical costs, were applied to best reflect PWCs actual costs as incurred in their network region (refer to Attachment 2)

3 Key inputs

3.1 Unit rates

3.1.1 Overview

Key inputs to the model include the unit rates and expected asset lives. These inputs are impacted by PWC's network location. The harsh environment includes climatic conditions, fauna and demand profiles that put pressure on distribution assets. The cumulative impact of the operating conditions is an increased rate of asset deterioration that impacts on expected asset lives.

Comparisons with other DNSPs typically show that below ground assets have similar expected lives for similar assets but are larger in size to compensate for higher ambient ground temperatures. This impacts on unit costs for similar types of assets. Above ground assets also have larger sizes to compensate for higher ambient temperatures and have higher rates of deterioration, and hence reduced expected lives in the order of 15 to 20%.[3]

PWC has good information on historical unit costs, but little information to support its expected asset lives. Hence, the primary source of data is from PWCs RINs that will be submitted to the AER as part of the regulatory submission. However, to enable testing of the model and assessment of the forecast developed by the Pooled Asset Model, additional data was sourced from peer DNSPs that operate predominately urban and rural networks. The most recent RIN for each of the peer DNSPs were used to calculate a Peer average for the unit rates and expected lives of assets. The peer data was used for scenario testing of the model as described in section 6.

The peer DNSPs included in the data set are the predominantly urban and rural DNSPs that most closely reflect the types of assets owned by PWC. The DNSPs are:

- ActewAGL

[3] For example, Distribution transformers installed by other DNSPs are often assigned an expected life of 50 or 55 years, compared to 45 years for PWC.

- Endeavour
- Ergon
- Essential
- Powercor
- SAPN
- TasNetworks.

3.1.2 Historical rates

The historical unit rates were calculated from the capex backcasting model used to populate PWCs Category Analysis (CA) RIN templates. This model contains repex costs and quantities by year for the FY14 to FY17 period. Data prior to FY14 is considered low quality, due to changes in asset management systems and capitalisation policy that occurred in prior years, so it was excluded from the unit rate analysis.

Other projects were excluded from the unit rate analysis, as they were deemed to be not representative of works to be completed under the pooled asset replacement program:

- Specific projects which were deemed to be cost outliers – e.g. insulator replacement on marine towers
- Projects where assets were issued at no cost – this is a correction for a legacy issue where old stock in the store had no value attached. Where relevant to ensure a reasonable sample size, the non-asset costs on these projects were used to inform the unit rates calculation.
- Projects which were part of a specific program to be completed prior to the next regulatory period – e.g. Oil RMU replacements
- Major projects, since the unit costs for distribution equipment replaced at large scale under major projects are not expected to be representative of the replacement of small quantities under the pooled asset replacement program.

The unit rates were then calculated as the historical total cost divided by the total replacement volumes in the 2013/14 to 2016/17 period.

The rates and assumptions for each asset type are set out in a table in Attachment 2.

3.1.3 Forecasting approach

The Pooled Asset model uses the average historical unit rates for forecasting the future expenditure requirements.

3.2 Expected life

3.2.1 Mean expected life

The mean expected life represents that age at which an asset is expected to require replacement due to deterioration of its condition to a point such that it is no longer safe or sufficiently reliable to remain in service on the network.

PWC does not have sufficient historical asset data regarding the age of assets when they were replaced. Therefore, PW has used alternative information sources to estimate that age. The three sources of information used in the model to calculate the future replacement needs and to undertake analysis of the forecast are:

- PWC economic life: the asset life used by PWC for network planning and financial depreciation purposes. This age was based on a study that investigated the expected age of assets from electricity networks throughout Australia and internationally[4].
- Peer DNSP base age: the average asset age of peer DNSPs prior to the calibration applied by the AERs repex model
- Peer DNSP calibrated age: the average asset age of peer DNSPs post the calibration applied by the AERs repex model

3.2.2 Standard deviation

The standard deviation could not be calculated due to insufficient data regarding the asset age at time of failure or replacement (due to condition). As a result, the approach used by the AER in the Repex Model was adopted. This approach is to use the square root of the mean age as an approximation for the standard deviation.

3.2.3 Forecasting approach

The Pooled Asset model uses the selected expected life to calculate the standard deviation, then applies these inputs to forecast the future replacement needs.

Due to the calibration process applied to the model, the expected life input into the model only provides a starting point for all assets with historical replacement volume data available.

For assets where there is no historical replacement data available, the expected life applied is based on the economic life of the asset and is not able to be calibrated. As a result, the asset life input to the model determines the forecast for those assets. By using the average Peer DNSP calibrated age, which was generally larger than the PWC economic life, PWC took a conservative approach to forecasting further replacement needs for these assets.

The model was further investigated through scenario analysis and comparison to other modelling approach, as discussed in section 6.1.

3.3 Establishing the historical repex

The replacement of assets in the low value asset pool is a subset of the total replacement expenditure (repex) forecast. Historically these assets have been replaced under the volumetric pooled asset replacement program including the cost of projects that targeted specific regions or asset types that were demonstrating specific failure modes.

To ensure accurate comparisons, it is necessary to remove the programs of work or types of assets that will not be continued in the next regulatory period. The following expenditure items were removed from the historical expenditure for the purpose of providing the historical expenditure on the same basis as the forecast:

4 SKM Asset Verification & Valuation Report - Power Networks Regulated Electricity Network (September 2013)

- Asset replacements that were previously undertaken as part of the Pooled Asset programme but have been separated out into their own programmes for the forthcoming regulatory period, for example, the Northern Suburbs Cable Replacements.
- Assets with type issue are expected to be fully removed from the network prior to the start of the next regulatory period.
- Assets which do not have failure modes that are suitable for modelling using the Pooled Asset modelling approach were not included in the model and the historical costs were removed, for example, poles and cross arms.

Table 4 below sets out the historical total repex, the historical low value asset pool and the required adjustment.

Table 4: Historical expenditure

$M (real, June 2018)	FY14 Actual	FY15 Actual	FY16 Actual	FY17 Actual	FY18 Budget
Total repex	$47.8	$46.9	$47.8	$30.1	$24.1
Low value asset related repex	$7.1	$11.6	$11.4	$11.1	$11.1
Low value asset related repex (% of total repex)	15%	25%	24%	37%	46%
Adjustments (removal of specific replacement programs or type issues)	$2.43	$6.67	$5.29	$5.20	$5.78
Adjusted low value asset related repex	$4.66	$4.88	$6.06	$5.88	$5.32
Adjusted low value asset pool (% of total repex)	10%	10%	13%	20%	22%

Figure 3.1 shows the comparison of historical, budgeted and forecast expenditure. It demonstrates that the forecast expenditure is in line with the historical expenditure for the failure modes being modelled. Each of the series have the following definitions:

- Historical – total: this is the total historical expenditure including any asset replacements that will form part of separate programs in the next regulatory period and any assets with type issues that are expected to be removed from the network prior to the start of the next period.
- Historical – adjusted: the historical expenditure excluding any asset replacements that will form part of separate programs in the next regulatory period and any assets with type issues that are expected to be removed from the network prior to the start of the next period.
- Budgeted – total: this is the budget for these asset classes that are in the annual SCI and were approved in the previous determination.
- Budgeted – forecast: the forecast expenditure required in FY18 and FY19 based on the outputs of the Pooled Asset model when calibrated to the 'Historical – adjusted' replacement volumes.
- Forecast: the forecast expenditure required in FY20 to FY24 based on the outputs of the Pooled Asset model when calibrated to the 'Historical – adjusted' replacement volumes.

This chart shows that, although there is a slight upwards trend during the forecast period, it is roughly in line with the adjusted historical expenditure. PWC has taken a conservative approach, as although all currently known assets with type issues are expected to be addressed and removed from the network, there may be new asset types that develop issues during the next period which have not be explicitly allowed for in this model. PWC took this approach as the probability, magnitude and urgency of any new type issues cannot be adequately forecast above any replacements required on a probabilistic modelling basis.

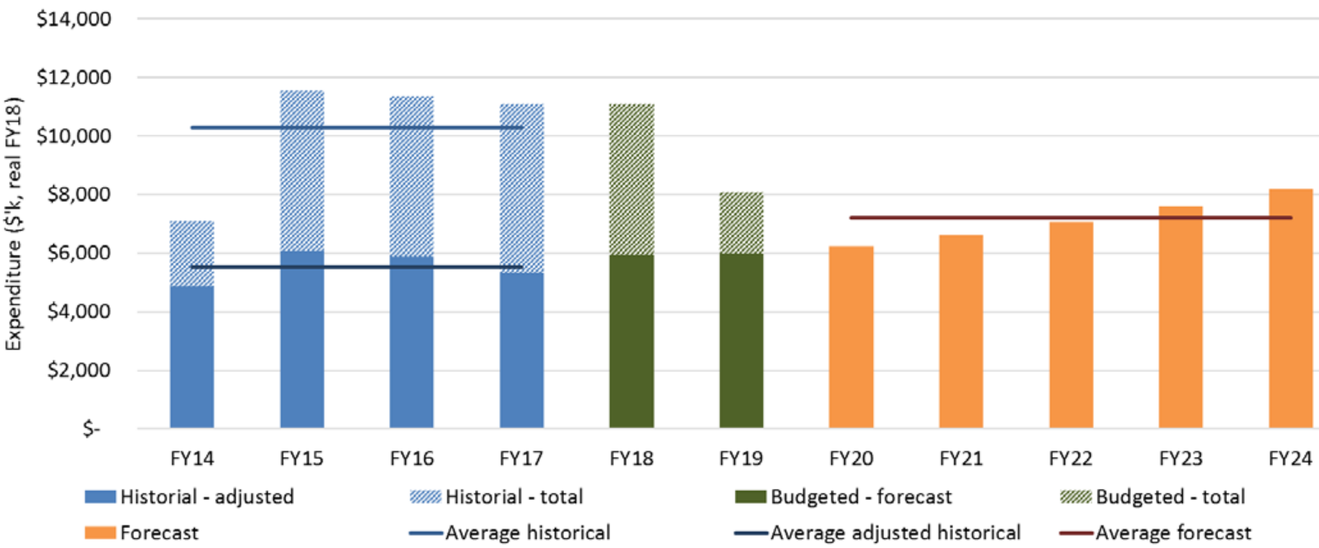

Figure 3.1 Comparison of historical, budgeted and forecast expenditure

4 Asset data and assumptions

4.1 Overview

PWCs network covers four distinct regions (the Darwin, Katherine, Tennant Creek and Alice Springs), however, approximately 75% of the network is located in the Darwin region and is subject to tropical monsoonal climatic conditions. In 1974, Cyclone Tracy destroyed a significant portion of the network, then in the early 1980's there was a rapid expansion of Darwin through increasing residential and commercial development in the Northern Territory.

As a result, there is a significant proportion of the network that was constructed between 1975 and 1985. Figure 4.1 below clearly shows the impact of the cyclone and subsequent construction boom. These assets will be between 35 and 43 years old at the start of the next regulatory period and 40 and 48 years old by the end of the period. Additionally, being located predominantly in the Darwin region, they are subject to harsh conditions and therefore are expected to be approaching the end of their lives which will result in an increasing rate of asset failure or assets identified as requiring replacement during inspections.

Figure 4.1 also shows that since approximately 2004 there has been an increase in new assets installed on the network. This is a combination of augmentation due to increased residential and commercial drivers during the mining boom and also the need to replace assets that have reached end of life or have failed in service.

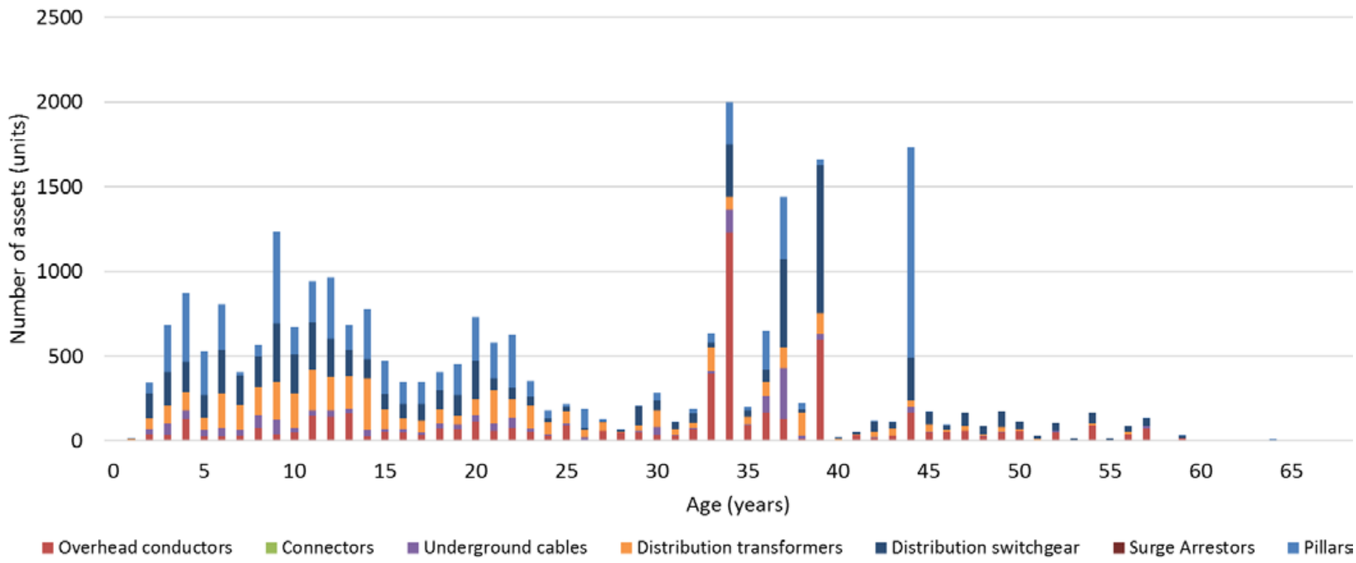

Figure 4.1 Asset age profile

Note: The age is not known for pole top structures, service lines or connectors.

Table 5 shows the number of assets that are over 50 years old now and how the number will increase over time (assuming no replacement or failures for simplicity). The age of 50 years has been selected for the comparison as it is the simple average of the expected life of all assets and is useful to demonstrate the aging network. Table 5 demonstrates that between FY18 and the end of the next regulatory period in FY24, there is expected to be an average three-fold increase in assets older than 50 years.

Table 5: Volume of assets exceeding 50 years old

ASSET GROUP	FY18	FY20	FY24
OVERHEAD CONDUCTORS (km)	286	396	753
UNDERGROUND CABLES (km)	22	23	64
SERVICE LINES (unit)	2,193	2,783	6,671
TRANSFORMERS (unit)	35	71	196
SWITCHGEAR (unit)	245	390	874
OTHER – PILLARS (unit)	16	16	1,260

Although this does not translate directly into an equivalent need for replacement, it does indicate a growing risk in the network and that it is reasonable to expect the volume of replacements needed is likely to increase.

Using a probabilistic approach to forecasting asset replacements means that the increased probability of failure of old assets and the volume of the old assets is explicitly considered in the model and will therefore result in a forecast for increasing volumes requiring replacement. This is a logical outcome as assets have a finite life and are expected to fail at some point in time. Maintenance can delay the need for replacement of some assets but not all assets can be maintained.

The model includes assets from all three electricity networks operated by PWC. The asset classes, by RIN category, are listed in Attachment 2.

The following sections discuss the historical data, adjustments and assumption made to it for the purpose of modelling future replacements needs. The forecast is discussed in section 5.

4.2 Overhead conductors

4.2.1 Overview

Overhead conductor replacement volumes have been forecast using a probabilistic approach. Five conductor categories are modelled, to align with the RIN categories as shown in Table 6.

Table 6: Overhead conductor categories

Asset code	RIN code
OH1	< = 1 kV
OH2	> 1 kV & < = 11 kV
OH3	> 11 kV & < = 22 kV ; Multiple-Phase
OH4	> 22 kV & < = 66 kV
OH5	> 66 kV & < = 132 kV

4.2.2 Historical volumes

Historical replacement volumes are shown in Figure 4.2. Failures recorded in the outage data were assumed to require the replacement of 10 metres of conductor to rectify the fault by replacing the damaged section. The length of overhead conductor replaced based on condition was extracted from records in Maximo. The historical HV conductor shows a flat trend while LV conductor has a decreasing trend.

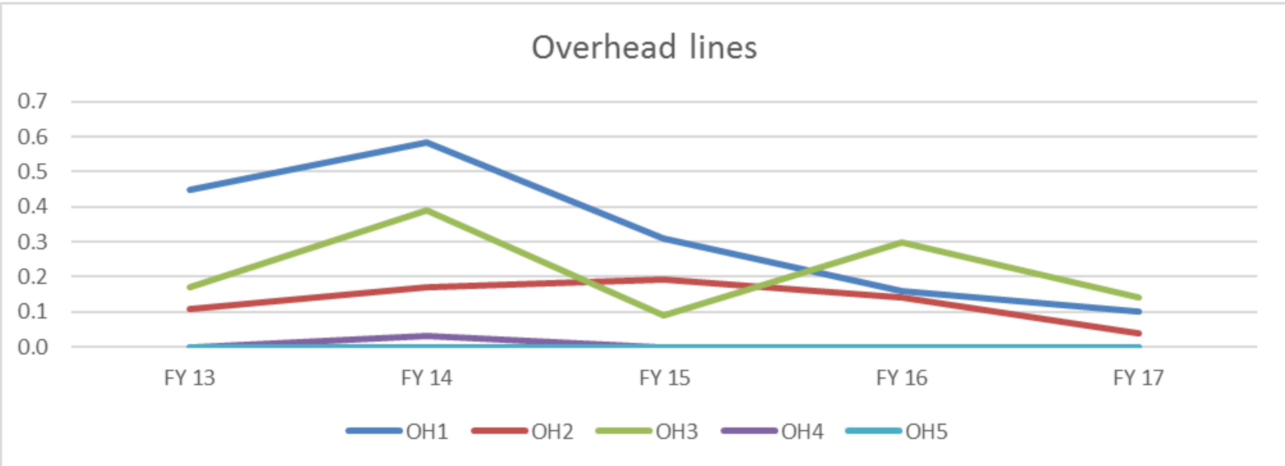

Figure 4.2 Historical replacement volumes – Overhead lines

4.2.3 Basis of adjustments to asset profile

41.1 km of overhead conductor were removed from the age profile form 1975 to reflected the program to remediate issues with the Lake Bennett Feeder.

4.3 Pole top structures

4.3.1 Overview

Pole top structure replacement volumes have been forecast using a trending approach. Five categories are modelled, to align with the RIN categories as shown in Table 7.

Table 7: Pole top categories

Asset code	RIN code
PT1	Insulator LV
PT2	Insulator 22kV
PT3	Insulator 66kV
PT4	Crossarm 22kV
PT5	Crossarm LV

4.3.2 Historical volumes

Historical replacement volumes are shown in Figure 4.3. Historically there has not been a dedicated pole top replacement program and any replacements have been carried out in an ad-hoc manner as the need is identified. Since all cross arms are steel construction, there are very few failures.

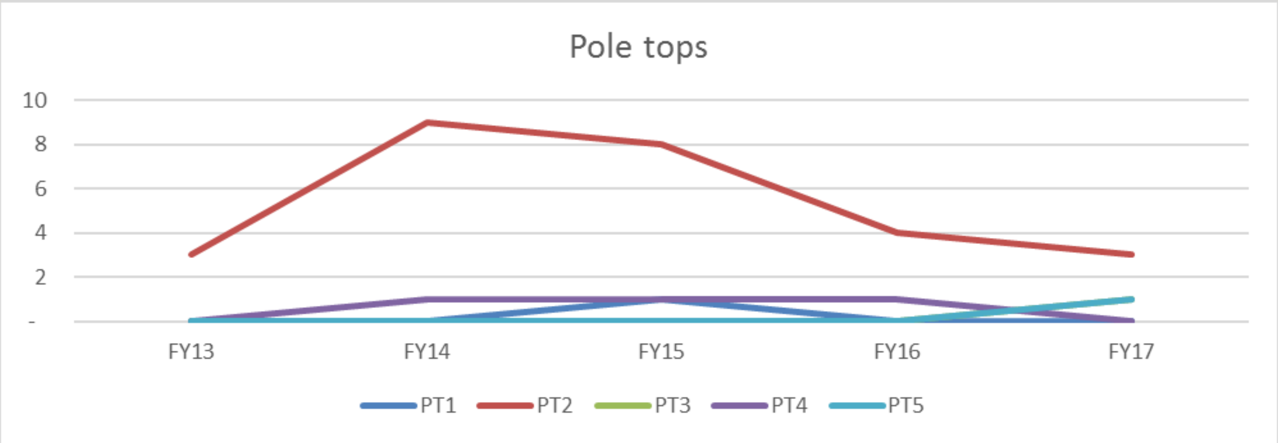

Figure 4.3 Historical replacement volumes – Pole tops

4.3.3 Basis of adjustments to asset profile

No adjustments were made. This asset was forecast using the trending approach so the age profile was not relevant.

4.4 Underground cables

4.4.1 Overview

Underground cable replacement volumes have been forecast using a probabilistic approach. Four categories are modelled, to align with the RIN categories as shown in Table 8.

Table 8: Underground cable categories

Asset code	RIN code
UG1	< = 1 kV

UG2	> 1 kV & < = 11 kV
UG3	> 11 kV & < = 22 kV
UG4	> 33 kV & < = 66 kV

4.4.2 Historical volumes

Historical replacement volumes are shown in Figure 4.4. Failures recorded in the outage data were assumed to require the replacement of 10 metres of cable to rectify the fault by replacing the damaged section with an allowance for joints. The length of underground cable replaced based on condition was extracted from records in Maximo. Cables of all voltage levels have been exhibiting an increasing replacement trend since FY15. This is consistent with the condition of cables found in the northern suburbs and general deterioration due to moisture and fauna throughout the network.

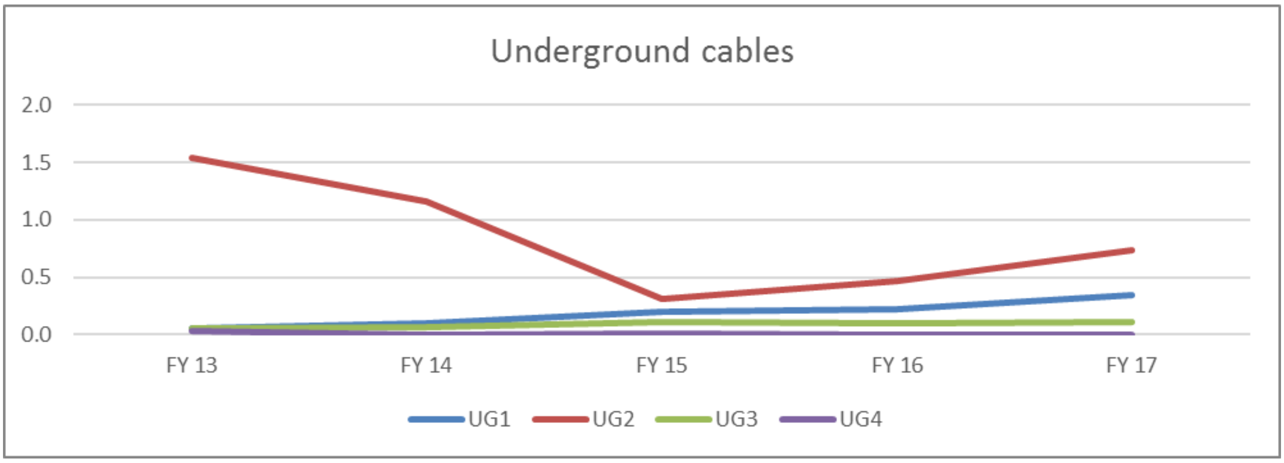

Figure 4.4 Historical replacement volumes – Underground cables

4.4.3 Basis of adjustments to asset profile

Adjustments to the age profile was made to remove underground cables that are planned to be replaced under specific projects. Table 9 shows the forecast replacement volumes by year.

Table 9: Other repex projects – Underground cables

Project	Code	FY20	FY21	FY22	FY23	FY24
High Voltage Cable Replacement – Darwin Northern Suburbs (km)	UG1	10.70	11.10	11.70	6.30	6.50
Cullen Bay and Bayview LV cable Replacement (km)	UG2	1.80	1.60	1.40	1.20	1.00

The adjustments are made in the 'Age profile adjust' worksheet. The cable was removed on a pro-rata basis from each of the years when this type of cable was installed: between 1960 and 1985 for the HV cables; and, between 1989 and 2003 for the LV cables.

4.5 Service lines

4.5.1 Overview

Service line replacement volumes have been forecast using a trending approach. Two categories are modelled, to align with the RIN categories as shown in Table 10Table 6.

Table 10: Service line categories

Asset code	RIN code
SL1	< = 11 kV ; RESIDENTIAL ; SIMPLE TYPE
SL2	< = 11 kV ; COMMERCIAL & INDUSTRIAL ; SIMPLE TYPE

4.5.2 Historical volumes

Historical replacement volumes are shown in Figure 4.5. The historical data shows a significant increase in the number of replacements. This is due to two reasons: firstly, improved recording of replacements; and secondly, a targeted replacement program run in Alice Springs to resolve a type issue. The forecast is to return to historical levels of replacement.

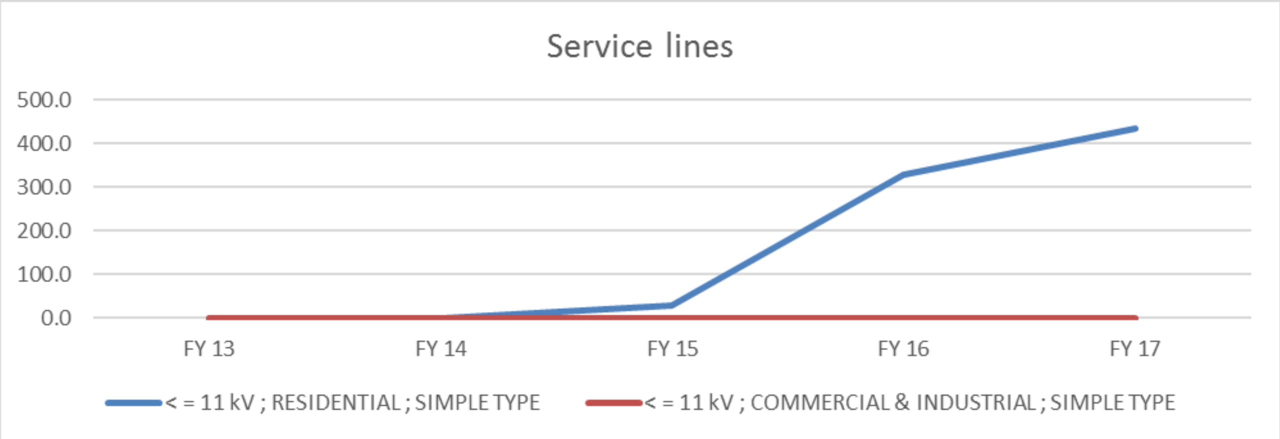

Figure 4.5 Historical replacement volumes – Service lines

4.5.3 Basis of adjustments to asset profile

No adjustments were made. This asset was forecast using the trending approach so the age profile was not relevant.

4.6 Transformers

4.6.1 Overview

Transformer replacement volumes have been forecast using a probabilistic approach. Twelve categories are modelled, to align with the RIN categories as shown in Table 11.

Table 11: Transformer categories

Asset code	RIN code
TF1	Pole Mounted ; < = 22kV ; < = 60 kVA ; Single Phase
TF2	Pole Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Single Phase
TF3	Pole Mounted ; < = 22kV ; < = 60 kVA ; Multiple Phase
TF4	Pole Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Multiple Phase
TF5	Pole Mounted ; < = 22kV ; > 600 kVA ; Multiple Phase
TF6	Kiosk Mounted ; < = 22kV ; < = 60 kVA ; Single Phase
TF7	Kiosk Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Single Phase
TF8	Kiosk Mounted ; < = 22kV ; < = 60 kVA ; Multiple Phase

TF9	Kiosk Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Multiple Phase
TF10	Kiosk Mounted ; < = 22kV ; > 600 kVA ; Multiple Phase
TF11	Ground outdoor/Indoor chamber mounted; < 22 kV ; > 60 kVA AND < = 600 kVA ; Multiple Phase
TF12	Ground outdoor/Indoor chamber mounted; < 22 kV ; > 600 kVA ; Multiple Phase

4.6.2 Historical volumes

Historical replacement volumes are shown in Figure 4.6. The replacement volumes have been consistent, with a slight increasing trend.

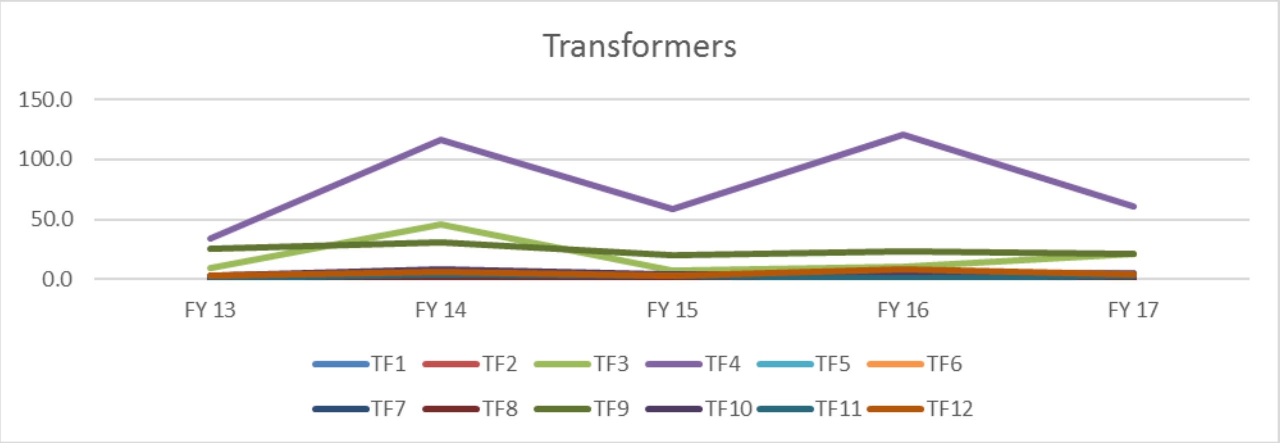

Figure 4.6 Historical replacement volumes - Transformers

4.6.3 Basis of adjustments to asset profile

No adjustments were made to 10 of the 12 transformer categories.

Two categories were adjusted to allow for type issues being addressed through the dedicated replacement program for distribution substations. There were 86 of the '60kVA to 600kV multiphase' and 154 of the 'less than 60kVA single phase' transformers removed from the age profile between 1975 and 1985 on a pro-rata basis.

Two categories of distribution transformer (TF2 and TF7) are not calibrated as the calibration process resulted in unrealistic mean ages (either very low or negative). Hence the expected life (using the Peer Calibrated Age) was applied without calibration. Calibration is the process of increasing the expected life of a transformer until the first year of the forecast replacement volumes is equal to the average of the recent historical replacement data (five years in this model).

4.7 Switchgear

4.7.1 Overview

Switchgear replacement volumes have been forecast using a probabilistic approach. Four categories are modelled, to align with the RIN categories as shown in Table 12.

Table 12: Switchgear categories

Asset code	RIN code
SG1	< = 11 kV ; Switch

SG2	< = 11 kV ; Circuit Breaker
SG3	> 11 kV & < = 22 kV ; Switch
SG4	> 11 kV & < = 22 kV ; Circuit Breaker

4.7.2 Historical volumes

Historical replacement volumes are shown in Figure 4.7. The trends are showing there was a decrease in replacements between FY14 and FY16, but the replacement volumes have become steady during the past two years. This is expected to increase slightly based on the aging asset fleet.

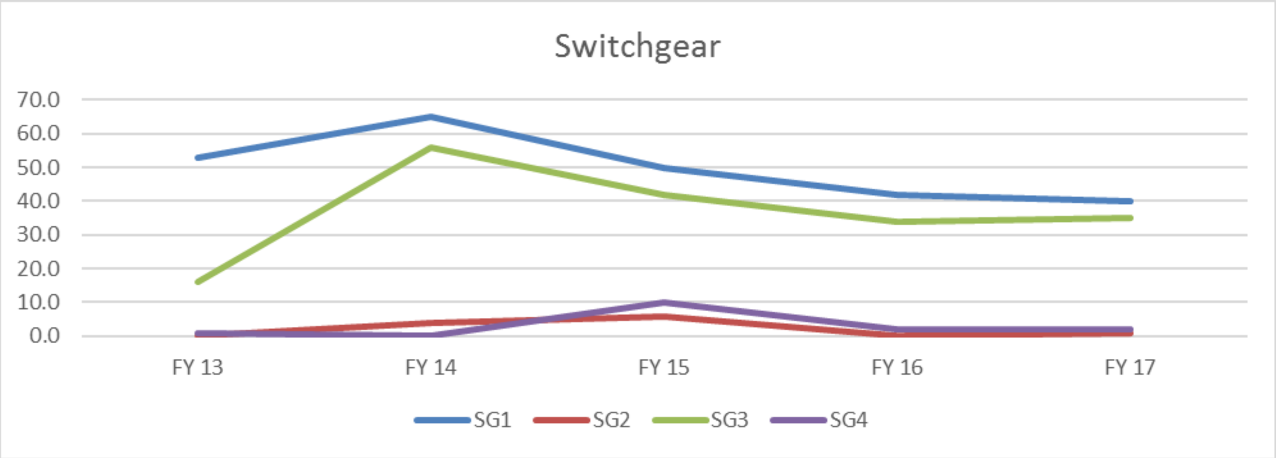

Figure 4.7 Historical replacement volumes - Switchgear

4.7.3 Basis of adjustments to asset profile

Two categories were adjusted to allow for type issues being addressed through the dedicated replacement program for distribution substations. There were 86 of the 11kV switches and 154 of the 22kV switches removed from the age profile between 1975 and 1985 on a pro-rata basis.

4.8 Other - connectors

4.8.1 Overview

Connector replacement volumes have been forecast using a trending approach. Two categories are modelled, to align with the RIN categories as shown in Table 13.

Table 13: Connector categories

Asset code	RIN code
OH6	> 11 kV & < = 22 kV
OH7	< = 1 kV

4.8.2 Historical volumes

Historical replacement volumes are shown in Figure 4.8. The connectors are showing a slightly increasing trend with a large increase in FY17 that may be an outlier.

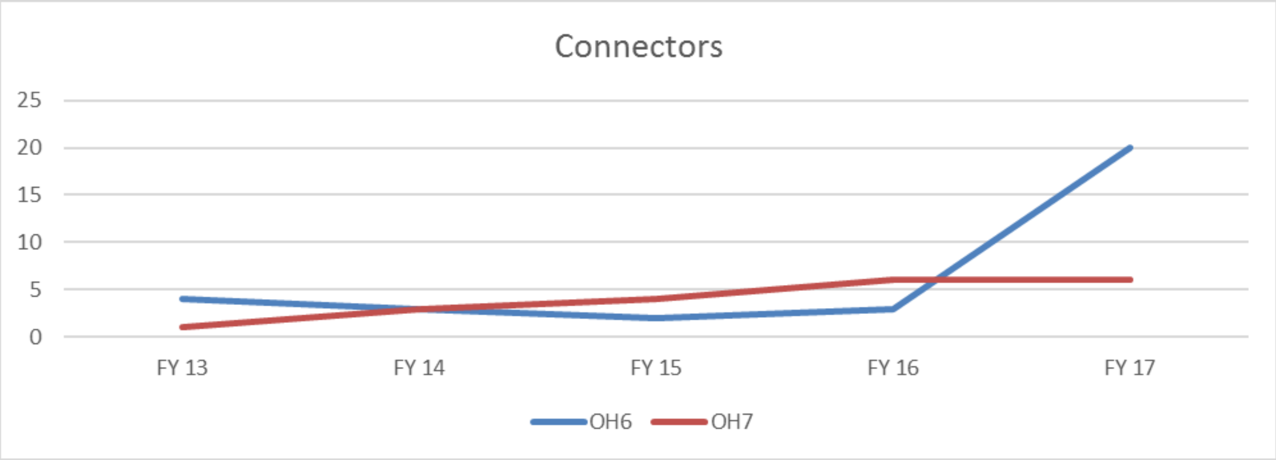

Figure 4.8 Historical replacement volumes - Connectors

4.8.3 Basis of adjustments to asset profile

No adjustments were made. This asset was forecast using the trending approach so the age profile was not relevant.

4.9 Other – surge arrestors

4.9.1 Overview

Surge arrestor replacement volumes have been forecast using a trending approach. One category is modelled, to align with the RIN category as shown in Table 14.

Table 14: Surge arrestor categories

Asset code	RIN code
SA	Surge Arrestors

4.9.2 Historical volumes

Historical replacement volumes are shown in Figure 4.9. The chart shows was an increase in FY16 that appears to be returning to the longer term average.

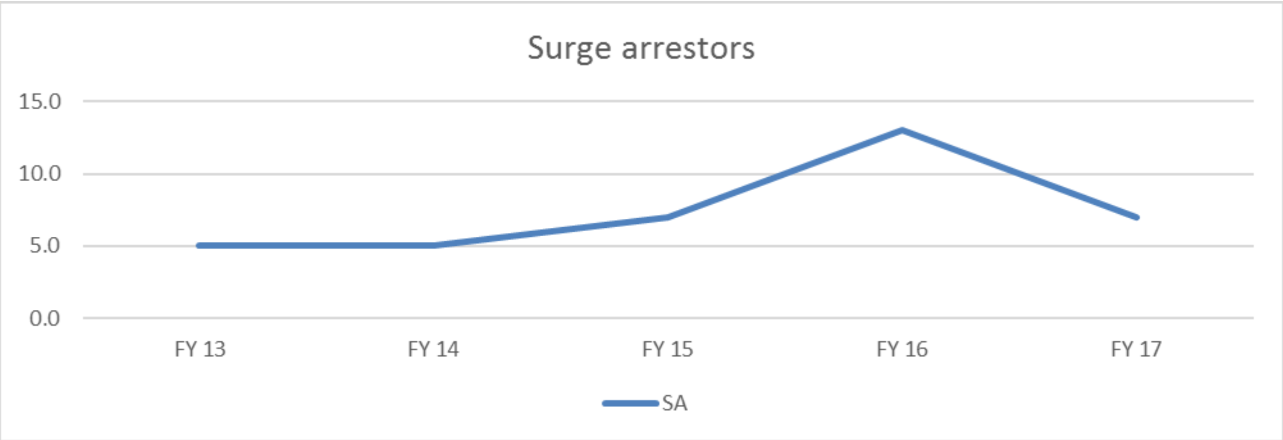

Figure 4.9 Historical replacement volumes – Surge arrestors

4.9.3 Basis of adjustments to asset profile

No adjustments were made. This asset was forecast using the trending approach so the age profile was not relevant.

4.10 Other – pillars

4.10.1 Overview

Pillar replacement volumes have been forecast using a probabilistic approach. One category is modelled, to align with the RIN category as shown in Table 15.

Table 15: Pillar categories

Asset code	RIN code
UG5	Pillars

4.10.2 Historical volumes

Historical replacement volumes are shown in Figure 4.10. Pillars are showing a strong increasing trend. This is consistent with their age profile that shows a large number were installed following Cyclone Tracey which occurred 40 years ago which is just beyond their expected life of 35 years.

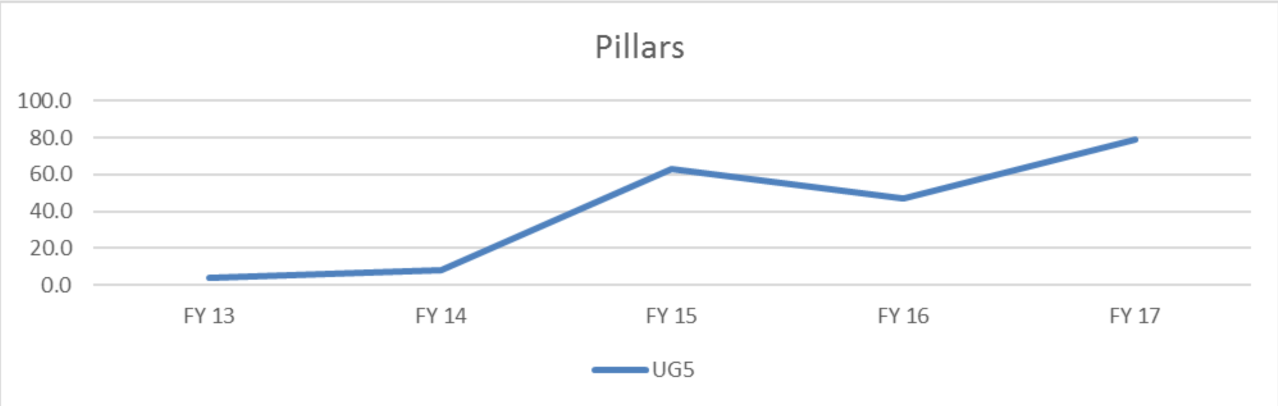

Figure 4.10 Historical replacement volumes - Pillars

4.10.3 Basis of adjustments to asset profile

No adjustments were made.

5 Forecast expenditure

5.1 Summary

The historic and forecast expenditures are shown by RIN category in Figure 5.1. Section 3.3 describes the adjustments made to historical data so that it reflects the scope of assets included in the Pooled Asset Model.

Overall, the figure shows that forecast expenditures follow the uplifting trend of historical expenditures, consistent with the increasing failure rates associated with aged assets and the increased volume of assets entering the wear out phase as shown in Table 5.

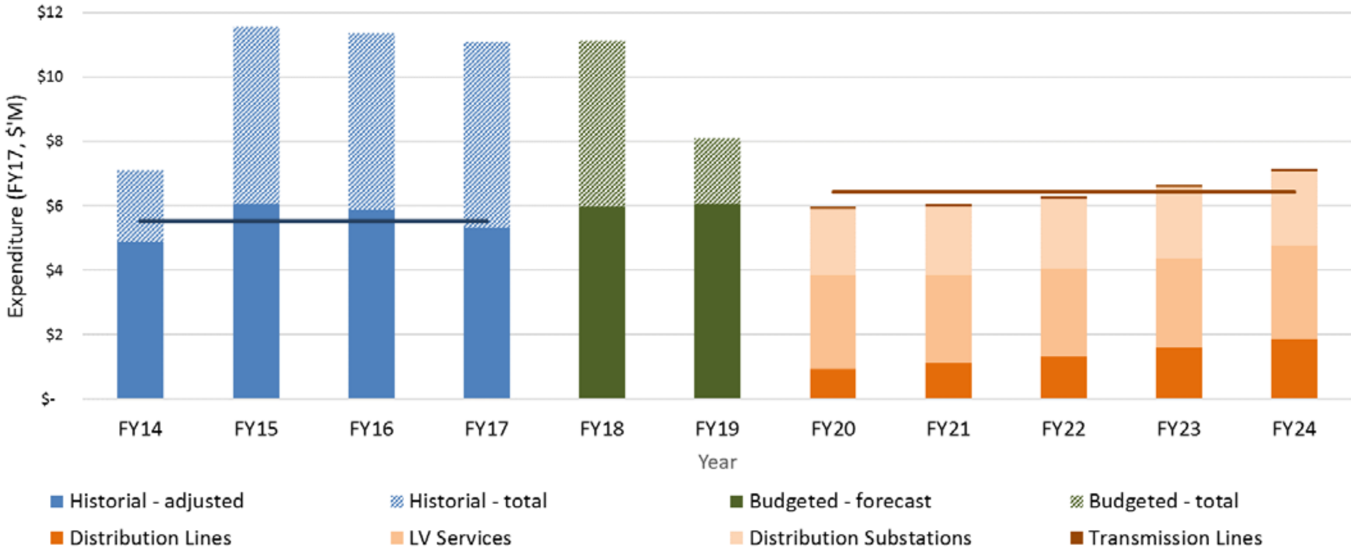

Figure 5.1 Historical and forecast expenditure by RIN category ($m, 2017)

The outputs of the model, in terms of expenditure, are shown in summary in Table 16 and Table 17, while the expenditure by asset type is detailed in the following sections.

Each individual category is not forecast to increase by an immaterial amount but in aggregate there is an increase of $1.9 million from FY20 to FY24. This is consistent with the increasing number of assets approaching the end of their serviceable lives as discussed in section 4.1 and Table 5.

The forecast is driven by the assets modelled using the probabilistic approach. This is largely due to more information being captured for more valuable assets which enables more advanced modelling approaches to be applied.

The transformer and switchgear asset categories account for 72% of the total replacement expenditure forecast by the Pooled Asset model for the next regulatory period, and will result in an increase of $700k (14%) in FY24 compared to FY20. This does not appear to be an unreasonable increase considering the asset age profile and recent experience of emerging type issues with existing assets and replacement trends in the historical replacement volumes.

The underground cables are the next largest contributor to the increasing trend. They are forecast to increase from $582k in FY20 to $1,169k in FY24. Given that the number of cable assets expected to be entering their wear out phase during the next regulatory period will increase from 22km to 64km (refer to Table 5), the forecast is considered to be conservative.

Table 16: Summary of capital expenditure by forecasting method ($'000, 2017)

$M (real 2017/18)	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
Trend	$127	$128	$128	$127	$128	$637
Probabilistic	$6,178	$6,560	$7,035	$7,581	$8,191	$35,545
Total	$6,305	$6,688	$7,163	$7,709	$8,319	$36,182

Table 17: Summary capital expenditure by asset type ($'000, 2017)

Asset	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
Overhead Conductors	$286	$367	$469	$596	$752	$2,471
Pole Top Structures	$24	$24	$24	$24	$24	$120
Underground cable	$582	$689	$818	$976	$1,169	$4,235
Service lines	$76	$76	$76	$76	$76	$380
Transformers	$2,711	$2,778	$2,888	$3,015	$3,142	$14,533
Switchgear	$2,162	$2,225	$2,293	$2,363	$2,433	$11,476
Other - Connectors	$16	$17	$18	$18	$19	$88
Other - Surge arrestors	$11	$11	$11	$9	$9	$49
Other - Pillars	$437	$501	$566	$632	$695	$2,830
Total Expenditure	**$6,305**	**$6,688**	**$7,163**	**$7,709**	**$8,319**	$36,182

5.2 Overhead conductors

The volume of LV and 22kV overhead conductors forecast to be replaced rises over the regulatory period as more conductors enter the wear out phase. Other types of conductor show a modest rise. Table 18 shows the forecast expenditure by asset code and Figure 5.2 shows the overall expenditure profile.

Although the forecast expenditure appears to be increasing significantly, it is important to note that the annual expenditure is under $1 million each year with a total of under $2.5 million for the next regulatory period, and therefore is not an unreasonable expenditure. The increasing volumes reflect the age profile for this asset category which has significant populations that were installed between 1975 and 1985 which are expected to start reaching the end of their serviceable lives and result in an increased volume of replacements.

Table 18: Forecast expenditure - Overhead conductor ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
OH1	< = 1 kV	$132	$163	$199	$241	$291	$1,025
OH2	> 1 kV & < = 11 kV	$22	$29	$38	$49	$62	$200
OH3	> 11 kV & < = 22 kV ; Multiple-Phase	$80	$103	$131	$166	$209	$691
OH4	> 22 kV & < = 66 kV	$18	$24	$32	$42	$54	$171
OH5	> 66 kV & < = 132 kV	$33	$48	$69	$98	$137	$384
Total		$286	$367	$469	$596	$752	$2,471

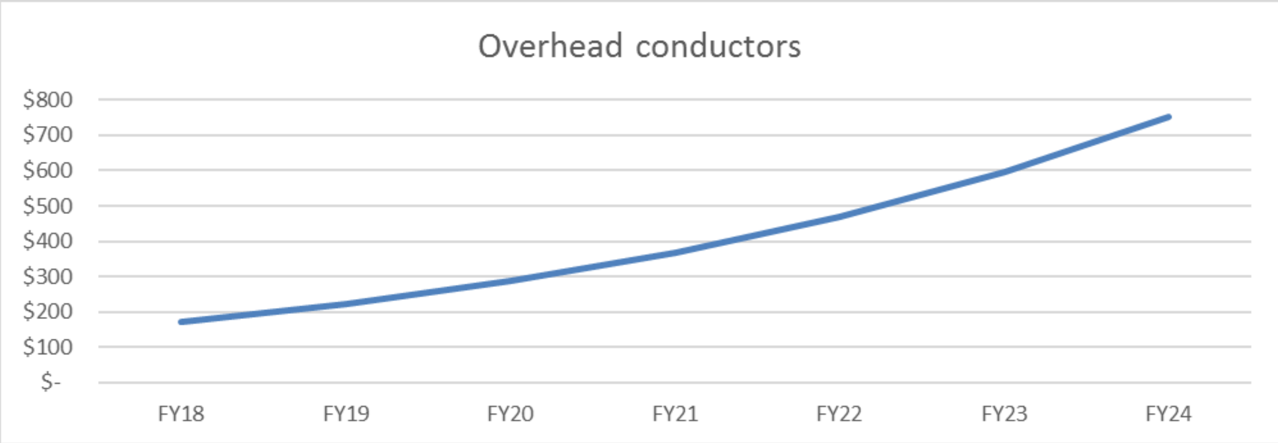

Figure 5.2 Forecast expenditure - Overhead conductor ($'000, 2017)

5.3 Pole top structures

Pole top structures are forecast to remain at current replacement levels. Table 19 shows the forecast expenditure by asset code and Figure 5.3 shows the overall expenditure profile.

Table 19: Forecast expenditure – Pole top structures ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
PT1	Insulator 22kV	$-	$-	$-	$-	$-	$-
PT2	Insulator 66kV	$14	$14	$14	$14	$14	$72
PT3	Insulator LV	$-	$-	$-	$-	$-	$-
PT4	Crossarm 22kV	$14	$14	$14	$14	$14	$72
PT5	Crossarm LV	$8	$8	$8	$8	$8	$39
Total		$24	$24	$24	$24	$24	$120

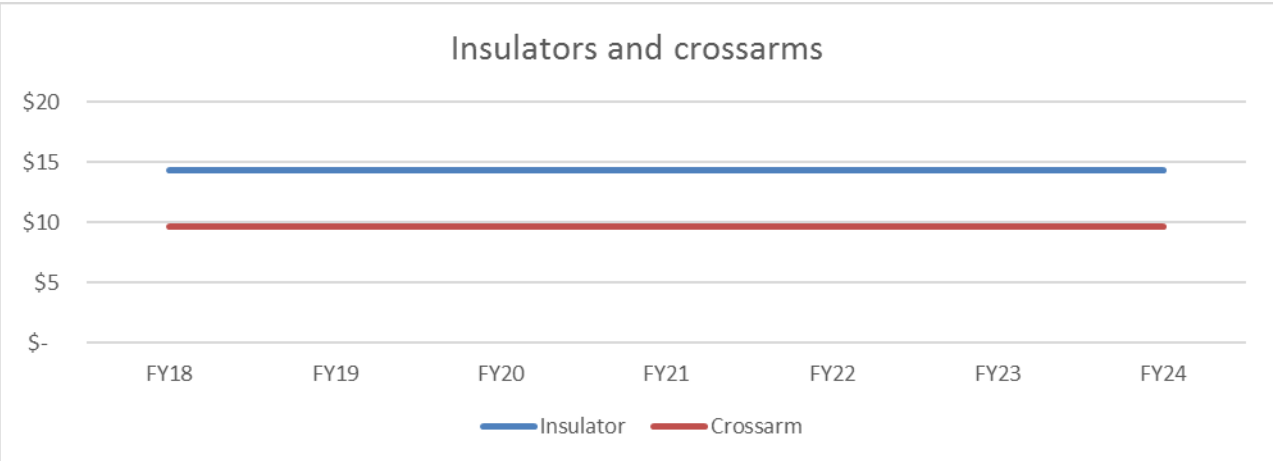

Figure 5.3 Forecast expenditure – Pole top structures ($'000, 2017)

5.4 Underground cables

Table 20 shows the forecast expenditure by asset code and Figure 5.5 shows the overall expenditure profile.

The replacement of underground cables is forecast to rise, driven by more 11kV cables entering the wear out phase due to assets installed between 1975 and 1985 after Cyclone Tracy and during the general network expansion period. Other cable types show a moderate rise. The forecast trend is consistent with the increasing trends shown in the historical replacement volumes in Figure 4.4.

Table 20: Forecast expenditure – Underground cables ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
UG1	< = 1 kV	$140	$162	$188	$220	$259	$969
UG2	> 1 kV & < = 11 kV	$369	$439	$524	$630	$760	$2,721
UG3	> 11 kV & < = 22 kV	$54	$63	$74	$86	$100	$378
UG4	> 33 kV & < = 66 kV	$19	$25	$32	$40	$50	$167
Total		$582	$689	$818	$976	$1,169	$4,235

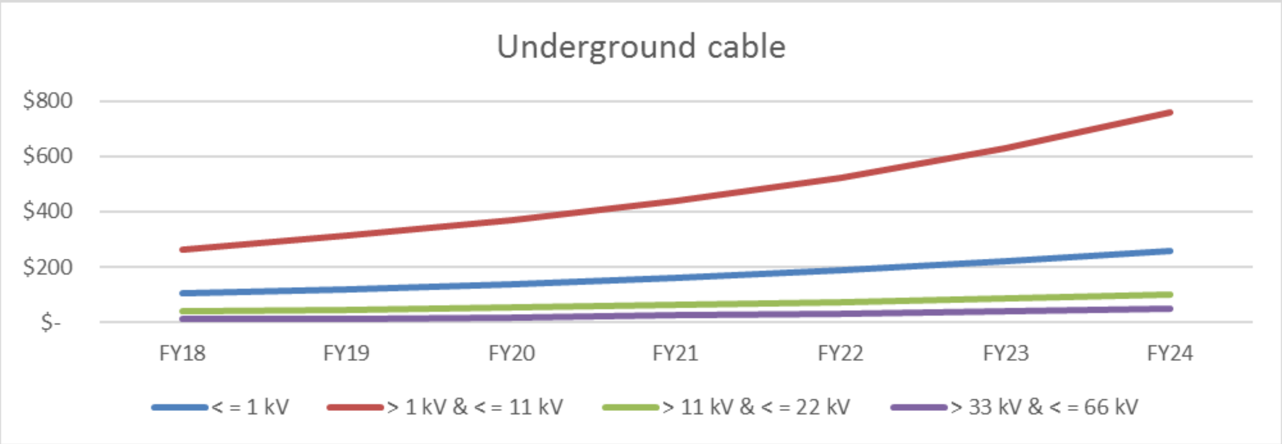

Figure 5.4 Forecast expenditure – Underground cables by cable category ($'000, 2017)

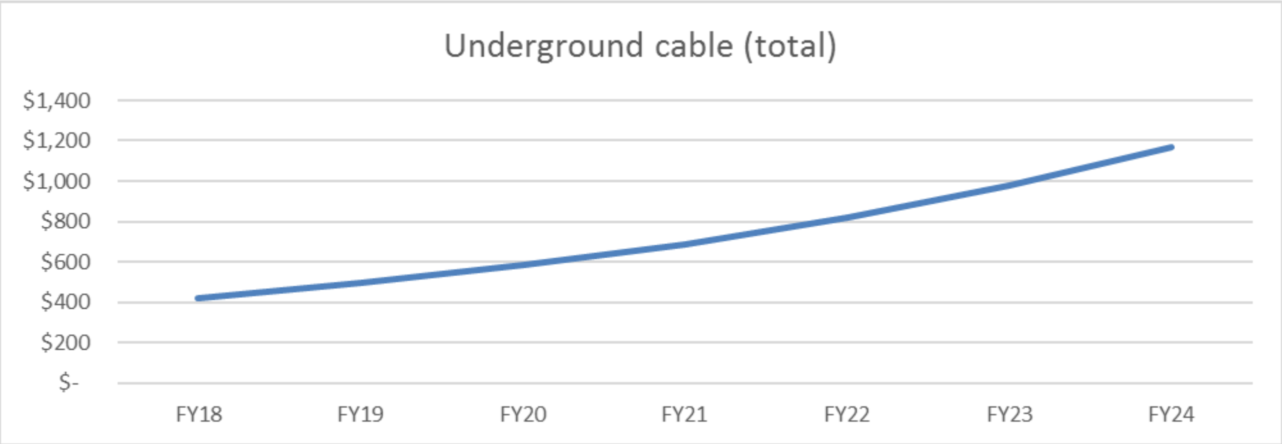

Figure 5.5 Forecast expenditure – Underground cables total ($'000, 2017)

5.5 Service lines

Service lines are forecast to remain at current replacement levels. Table 21 shows the forecast expenditure by asset code and Figure 5.6 shows the overall expenditure profile.

Table 21: Forecast expenditure – Service lines ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
SL1	< = 11 kV ; RESIDENTIAL ; SIMPLE TYPE	$75	$75	$75	$75	$75	$375
SL2	< = 11 kV ; COMMERCIAL & INDUSTRIAL ; SIMPLE TYPE	$1	$1	$1	$1	$1	$5
Total		$76	$76	$76	$76	$76	$380

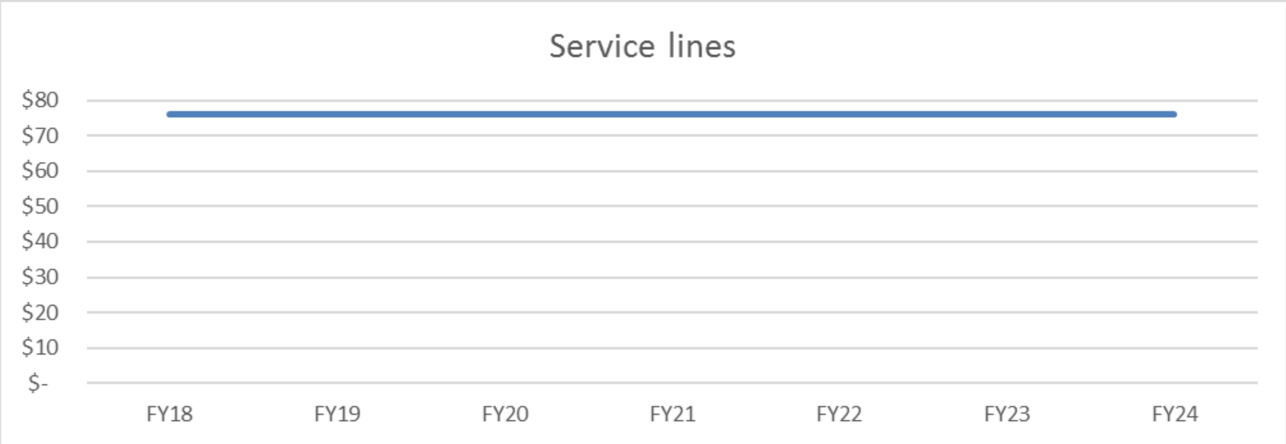

Figure 5.6 Forecast expenditure – Service lines ($'000, 2017)

5.6 Transformers

Transformers are forecast to remain approximately consistent with current replacement volumes. Table 22 shows the forecast expenditure by asset code and Figure 5.7 shows the overall expenditure profile.

The forecast shows a small decrease in replacements during the first couple years of the regulatory period, followed by an increasing trend to return to historical levels.

Table 22: Forecast expenditure - Transformers ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
TF1	Pole Mounted ; < = 22kV ; < = 60 kVA ; Single Phase	$11	$12	$13	$14	$15	$65
TF2	Pole Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Single Phase	$0	$0	$0	$0	$0	$0
TF3	Pole Mounted ; < = 22kV ; < = 60 kVA ; Multiple Phase	$86	$79	$76	$75	$75	$390
TF4	Pole Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Multiple Phase	$783	$708	$684	$688	$710	$3,573
TF5	Pole Mounted ; < = 22kV ; > 600 kVA ; Multiple Phase	$0	$0	$0	$0	$0	$0
TF6	Kiosk Mounted ; < = 22kV ; < = 60 kVA ; Single Phase	$200	$229	$256	$280	$300	$1,266
TF7	Kiosk Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Single Phase	$2	$2	$2	$3	$3	$12
TF8	Kiosk Mounted ; < = 22kV ; < = 60 kVA ; Multiple Phase	$2	$3	$3	$3	$4	$15

TF9	Kiosk Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Multiple Phase	$957	$1,039	$1,115	$1,182	$1,239	$5,532
TF10	Kiosk Mounted ; < = 22kV ; > 600 kVA ; Multiple Phase	$198	$195	$193	$193	$193	$972
TF11	Ground outdoor/Indoor chamber mounted; < 22 kV ; > 60 kVA AND < = 600 kVA ; Multiple Phase	$274	$291	$306	$316	$322	$1,509
TF12	Ground outdoor/Indoor chamber mounted; < 22 kV ; > 600 kVA ; Multiple Phase	$198	$219	$240	$260	$280	$1,197
Total		$2,711	$2,778	$2,888	$3,015	$3,142	$14,533

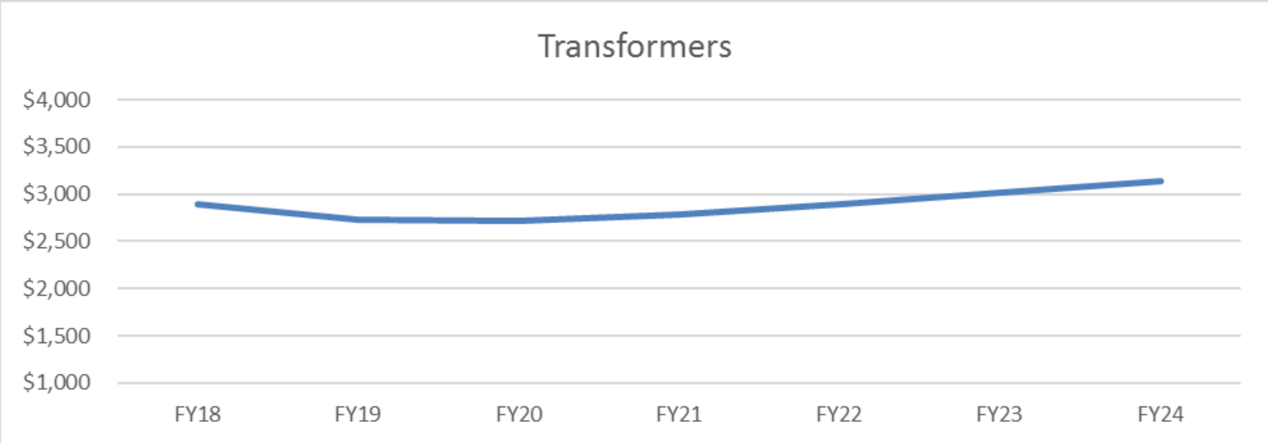

Figure 5.7 Forecast expenditure - Transformers ($'000, 2017)

5.7 Switchgear

The volume of switchgear forecast to be replaced rises over the regulatory period as more HV switchgear reaches end of life. Table 23 shows the forecast expenditure by asset code and Figure 5.8 shows the overall expenditure profile.

The increase in expenditure reflects the asset age profile which shows a significant population was installed between 1979 and 1981. These assets will be approaching the end of their serviceable lives during the next regulatory period and are expected to result in an increase in the volume of replacements required. The total increase over the period is $272k which is not considered to be a material change.

Table 23: Forecast expenditure - Switchgear ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
SG1	< = 11 kV ; Switch	$1,521	$1,564	$1,608	$1,651	$1,691	$8,035
SG2	< = 11 kV ; Circuit Breaker	$132	$122	$114	$107	$102	$578
SG3	> 11 kV & < = 22 kV ; Switch	$444	$480	$518	$557	$596	$2,595
SG4	> 11 kV & < = 22 kV ; Circuit Breaker	$65	$58	$52	$48	$45	$268
Total		$2,162	$2,225	$2,293	$2,363	$2,433	$11,476

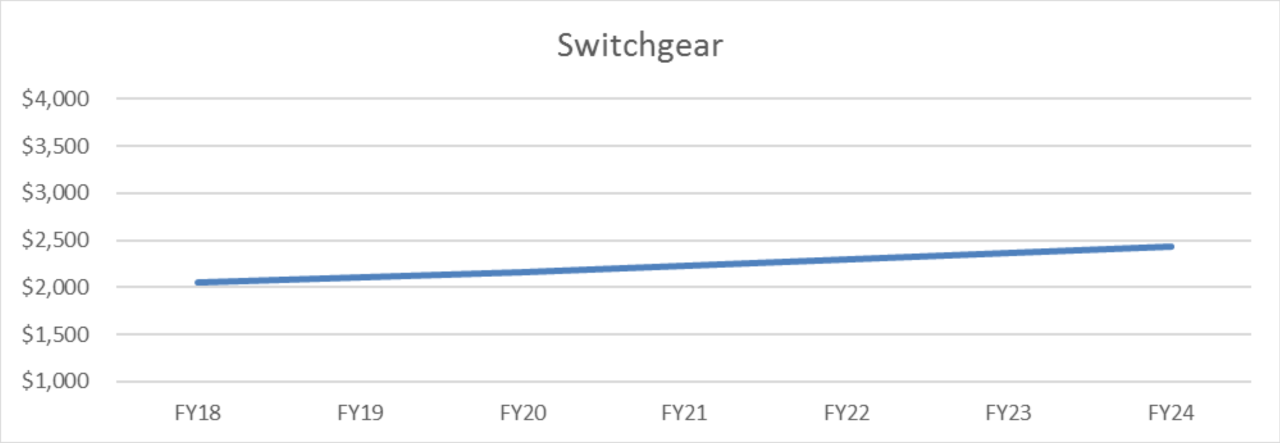

Figure 5.8 Forecast expenditure - Switchgear ($'000, 2017)

5.8 Other – connectors

The volume of connectors forecast to be replaced rises over the regulatory period based on an increasing failure trend. Table 24 shows the forecast expenditure by asset code and Figure 5.9 shows the overall expenditure profile.

Table 24: Forecast expenditure - Connectors ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
OH6	> 11 kV & < = 22 kV	$11	$11	$11	$11	$11	$55
OH7	< = 1 kV	$6	$6	$7	$7	$8	$34
Total		$16	$17	$18	$18	$19	$88

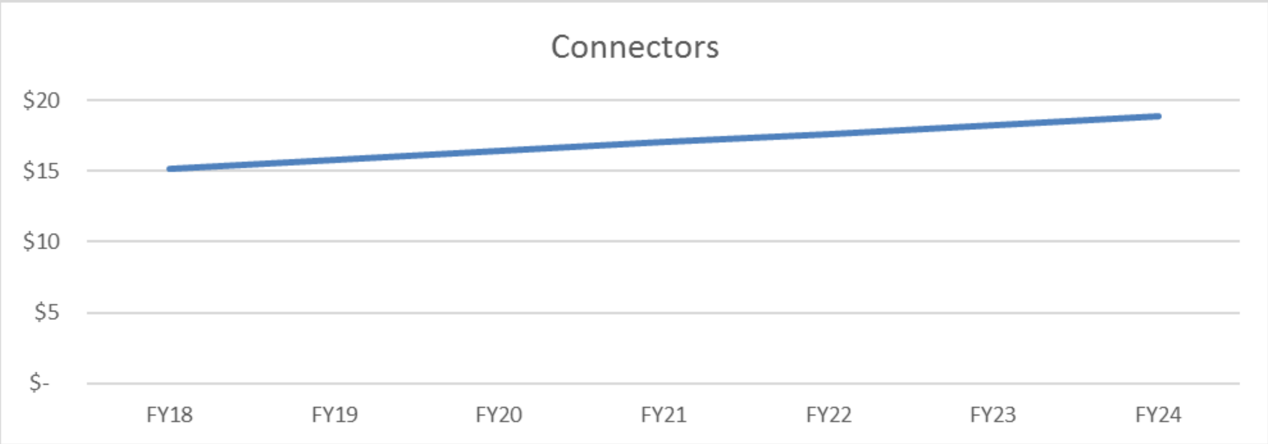

Figure 5.9 Forecast expenditure - Connectors ($'000, 2017)

5.9 Other – surge arrestors

The volume of surge diverters forecast to be replaced drops slightly over the regulatory period based on a decreasing failure trend. Table 25 shows the forecast expenditure by asset code and Figure 5.10 shows the overall expenditure profile.

Table 25: Forecast expenditure – Surge arrestors ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
SA	Surge Arrestors	$11	$11	$11	$9	$9	$49

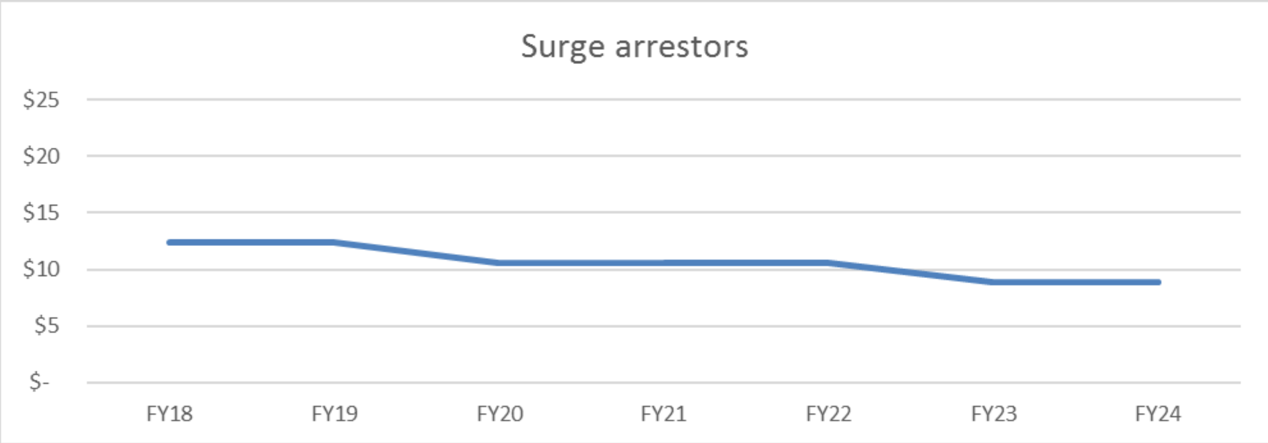

Figure 5.10 Forecast expenditure – Surge arrestors ($'000, 2017)

5.10 Other – pillars

The volume of pillars forecast to be replaced rises over the regulatory period as more pillars reach end of life. Table 26 shows the forecast expenditure by asset code and Figure 5.11 shows the overall expenditure profile. The large volume of pillars installed post Cyclone Tracey (in 1974) is contributing to this increasing trend.

Table 26: Forecast expenditure - Pillars ($'000, 2017)

Code	Description	FY20 Forecast	FY21 Forecast	FY22 Forecast	FY23 Forecast	FY24 Forecast	Total
UG5	Pillars	$437	$501	$566	$632	$695	$437
Total		$437	$501	$566	$632	$695	$437

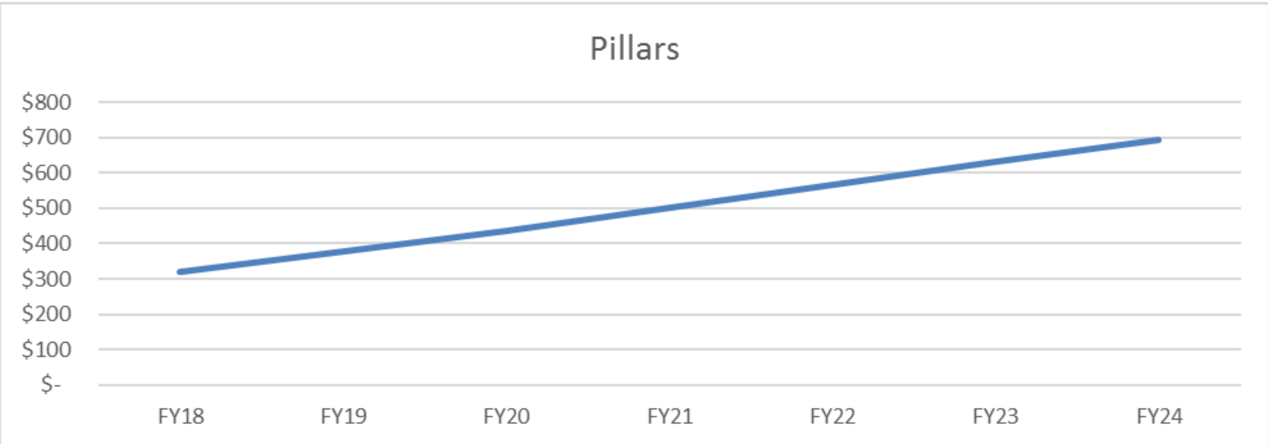

Figure 5.11 Forecast expenditure - Pillars ($'000, 2017)

6 Verification of the forecast approach

The output of the model was verified and tested in several ways to ensure it appropriately reflected the future needs of investment in the network. The following sections set out how the output was verified.

The model output was tested for:

- Scenario analysis of the model by applying a range of input values:
  - the unit costs and expected asset lives based on PWC and peer business data
  - with and without calibration of the model to historical data
  - applying different trend profiles for the trended asset forecasts
- Comparison to historic expenditure
- Comparison against other possible approaches to modelling

6.1 Scenario analysis

Scenario analysis involves changing multiple variables at the same time to alternate values that represent a possible outcome (or scenario) and recording the outcome of the model. This is repeated for multiple scenarios and the outcomes compared and assessed against the criteria of the project. Often the best, worst and most likely scenarios are assessed.

The scenario analysis for the Pooled asset model used all combinations of variables available including the expected lives and unit rates obtained from the AER RIN data, calibrating or not calibrating the forecast and P50 and P90 tending averages. In total, there were 96 scenarios calculated using all combinations of the data available.

The scenario analysis produced a wide range of results between $29m and $223m. This is expected as the model is sensitive to the expected asset age. Applying the calibration process to historical data significantly reduced the variation to between $36m and $89m which provided a more reliable output. The difference between the calibrated scenarios was predominantly determined by the unit cost applied. Applying the PWC unit rates resulted in a range of outputs of between $36m and $47m, which included the two lowest forecasts of calibrated outputs. The scenario adopted by PWC based on the best fit of data is in the lowest 12% of the scenario analysis outcomes.

Based on this analysis, PWC considers that the selection of the parameters used to create the preferred model output are appropriate given the historical replacement requirements of the network, and conservative given the other possible scenarios.

6.2 Comparison to other models

The Pooled Asset model was compared to three other approaches to forecast asset replacement needs:

- Trending historical replacements for all asset types
- Deterministic age based forecast
- The AER's Repex model.

Figure 6.1 shows a comparison of the forecast to alternative models to each other and the historical expenditure. Each of the forecasting approaches are discussed below.

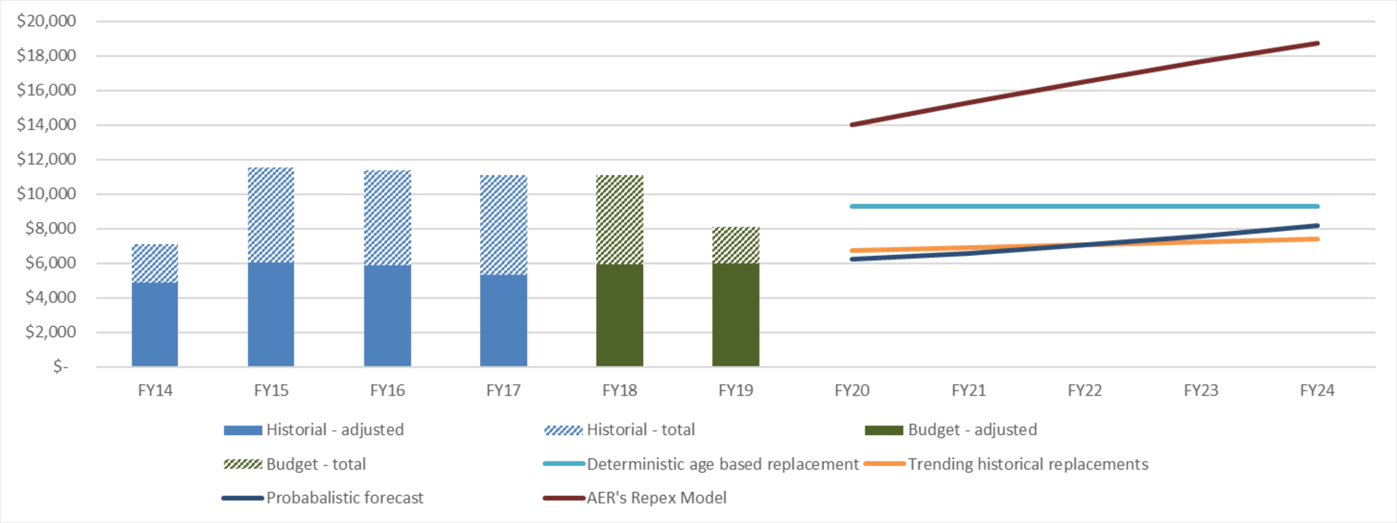

Figure 6.1 Comparison of forecasts using different approaches compare to historical expenditure

6.2.1 Trending historical replacements

A forecast model based on trending past replacement volumes was developed as a comparison to the probabilistic approach. The trending model included historical replacements for both failure and condition based replacement drivers. As shown in Figure 6.1 it resulted in a forecast of $35.4m for the next regulatory period which is similar to, but slightly lower in total, than the probabilistic model forecast. A key difference is that the trending forecast is flatter with a higher forecast in earlier years but lower forecast in the later years.

The trending approach does not account for the changing age profile of the network and how that will impact the need to replace assets as they deteriorate with age and usage.

PWC considers that this alternative approach supports the results from the probabilistic model.

6.2.2 Deterministic age based forecast

A deterministic age based model was built as an alternative approach to forecasting. The deterministic model assumes that assets are replaced as soon as they reach their expected life. Calibration of the lives was undertaken in the same manner as for the probabilistic model.

This model resulted in a forecast of $46.4m for the period which is higher than both the trending and probabilistic approaches. Due to the current age profile, age based forecasting results in a very volatile expenditure profile from year to year which is reflective of the age profile. This is not consistent with actual experience on the network and how programs of work are managed. To present a more realistic expenditure profile, the forecast is shown as the average annual expenditure for the period.

6.2.3 AER's Repex model

The repex model uses the same approach as the Pooled Asset model, however, it has been applied to the whole fleet, not only the volumetric assets. To create a like for like comparison, the following adjustments have been made:

- Only the volumetric asset categories were extracted from the AERs Repex Model output
- Specific programs of work proposed by PWC that are related to volumetric assets have been added to the output of the Pooled asset model.

These are compared in Figure 6.2 below.

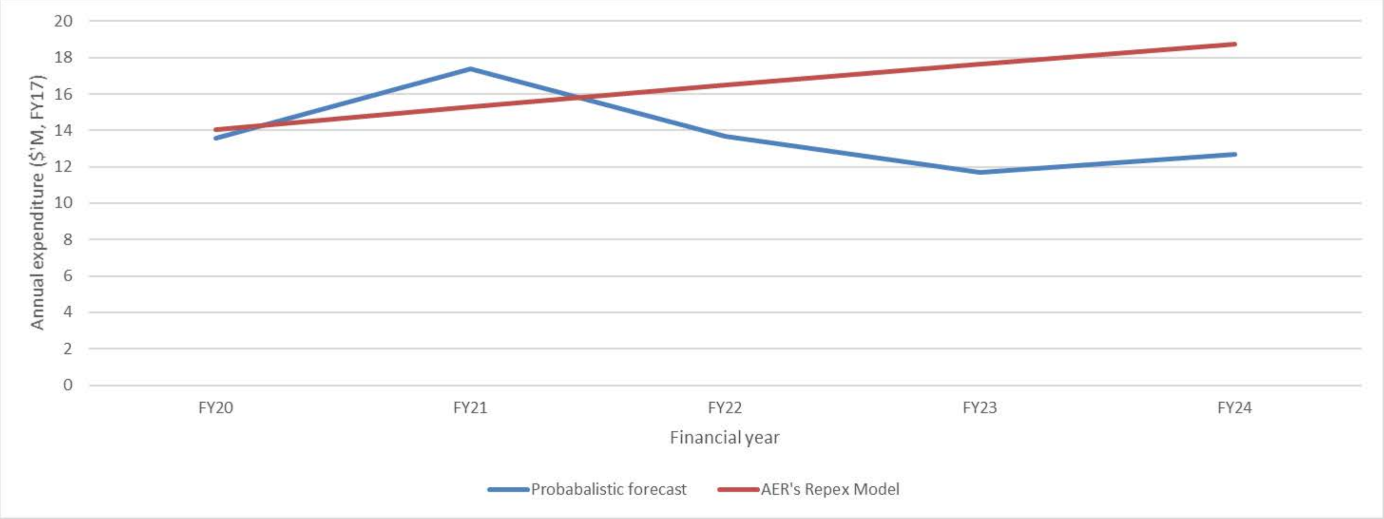

Figure 6.2 Comparison of Repex model and volumetric repex

Despite the limitations of the comparison, it demonstrates that the forecast developed by PWC using the Pooled Asset model (and other forecast programs) is significantly lower than the equivalent forecast created by the AERs Repex model. In total PWC forecasts $69m for these assets for the next regulatory period, which is 16% lower than the forecast of $82m using the AERs Repex model.

This comparison supports the forecast developed by PWC using their Pooled Asset model, and the broader total forecast for volumetric type assets proposed.

6.2.4 Conclusion

The forecasts produced by alternative forecasting methods support the combined trending and probabilistic forecast approach implemented by PWC.

7 Appropriateness of the methodology

As described in this document, PWC has used the most appropriate and best data available to develop the forecast expenditure for the pooled asset replacement program. The methodology used is based on industry accepted principles and the principles applied in the AERs repex model.

The forecast allows for changes in the asset base and management of these assets, including:

- Asset replacements that were previously undertaken as part of the Pooled Asset programme but have been separated out into their own programmes for the forthcoming regulatory period, for example, the Northern Suburbs Cable Replacements.
- Assets with type issue are expected to be fully removed from the network prior to the start of the next regulatory period.

Additionally, a number of sensitivity tests, comparison to alternative modelling approaches, and review by PWC's asset management SMEs have been undertaken to ensure the forecast expenditure is appropriate for meeting the needs of PWC in the next regulatory period.

PWC considers this the best forecast they can produce for these asset classes with the current asset data available.

Attachment 1

Conditional probability of failure

The conditional probability of an asset failure is defined as the probability of an asset failing in year Y +1 (denoted B) given that it has survived until year Y (denoted A). Mathematically conditional probability is written as:

$$P(B|A) = \frac{P(A \text{ and } B)}{P(A)}$$

In the context of asset failure P(A and B) is the same as P(B) that is, the probability of an asset surviving in period Y and Y+1 is the same as the probability of the asset surviving until Y+1. Therefore, the equation is simplified to:

$$P(B|A) = \frac{P(B)}{P(A)}$$

The difference in the curves is shown below:

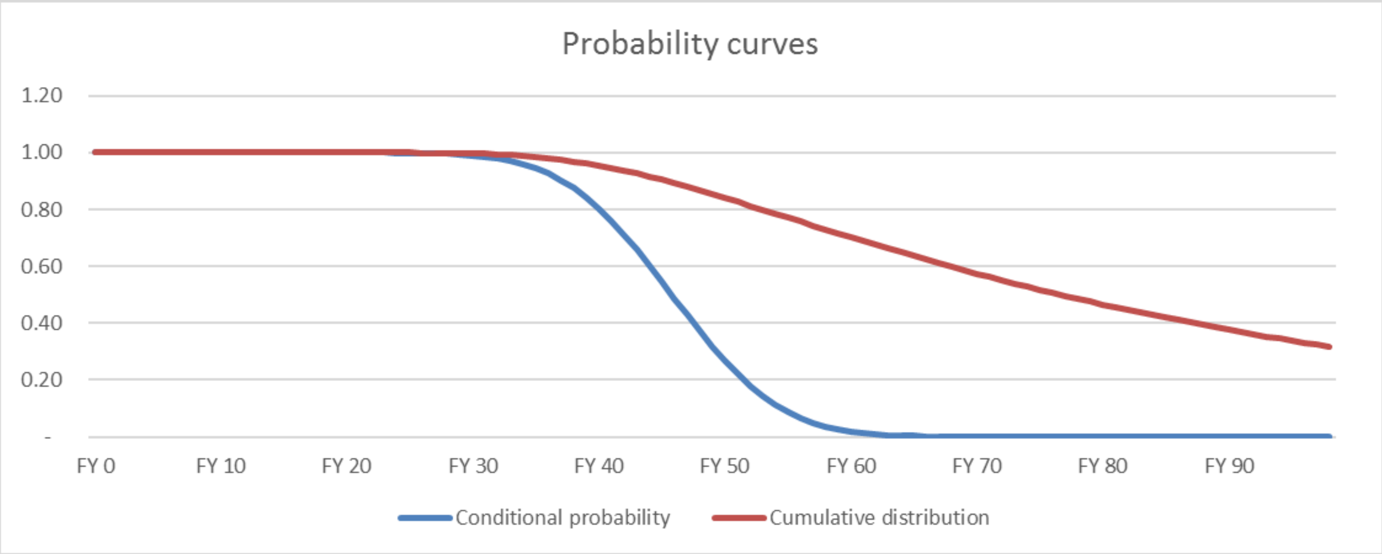

Figure 7.1 Cumulative probability curve compared to conditional probability curve

Attachment 2

Asset Code	Asset Category	Description	Assumptions	Rate ($ FY18 per unit)
OH1	OVERHEAD CONDUCTORS	< = 1 kV	Based on 13/14 to 15/16 projects since 16/17 data was not finalised at time of writing	200
OH2	OVERHEAD CONDUCTORS	> 1 kV & < = 11 kV	Only a single project was completed in the 13/14 to 16/17 period so not enough data to compute a unit rate. The <= 1 kV rate was used but increased by 10% to account for higher material costs.	220
OH3	OVERHEAD CONDUCTORS	> 11 kV & < = 22 kV ; Multiple-Phase	No representative projects were completed in the 13/14 to 16/17, so the 11kV rate was used.	220
OH4	OVERHEAD CONDUCTORS	> 22 kV & < = 66 kV	Used the 13/14 to 16/17 project costs	330
OH5	OVERHEAD CONDUCTORS	> 66 kV & < = 132 kV	Used the 13/14 to 16/17 project costs	264
OH6	Connectors	> 11 kV & < = 22 kV	Used the 13/14 to 16/17 project costs	1,360
OH7	Connectors	< = 1 kV	Used the 13/14 to 16/17 project costs	610
UG1	UNDERGROUND CABLES	< = 1 kV	Based on 13/14 to 15/16 projects since 16/17 data was not finalised at time of writing	240
UG2	UNDERGROUND CABLES	> 1 kV & < = 11 kV	Based on 13/14 to 15/16 projects since 16/17 data was not finalised	450

			at time of writing. Replacements which were completed as part of one-off projects such as cast iron pothead replacements were excluded, as these significantly exaggerate the replacement cost and would not be representative of future replacement costs.	
UG3	UNDERGROUND CABLES	> 11 kV & < = 22 kV	Used the on the 11kV cable rate since there was insufficient project data in the 13/14 to 16/17 period.	450
UG4	UNDERGROUND CABLES	> 33 kV & < = 66 kV	Based on 13/14 to 16/17 projects.	540
SL1	SERVICE LINES	< = 11 kV ; RESIDENTIAL ; SIMPLE TYPE	Based on 13/14 to 16/17 projects.	1,000
SL2	SERVICE LINES	< = 11 kV ; COMMERCIAL & INDUSTRIAL ; SIMPLE TYPE	No projects identified so residential value used	1,000
TF1	TRANSFORMERS	Pole Mounted ; < = 22kV ; < = 60 kVA ; Single Phase	Insufficient data to calculate unit rates so used the multiple phase value	6,000
TF2	TRANSFORMERS	Pole Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Single Phase	Insufficient data to calculate unit rates so used the multiple phase value	16,000
TF3	TRANSFORMERS	Pole Mounted ; < = 22kV ; < = 60 kVA ; Multiple Phase	The actual costs include several replacements done under maintenance which don't appear to include the asset costs. Estimated the materials costs from the projects ($5k), and the non-material costs from the work orders ($1k).	6,000
TF4	TRANSFORMERS	Pole Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Multiple Phase	The actual costs include several replacements done under maintenance which don't appear to include the asset costs. Estimated the materials costs from the projects ($10k), and the non-material costs from the work orders ($6k).	16,000

TF5	TRANSFORMERS	Pole Mounted ; < = 22kV ; > 600 kVA ; Multiple Phase	N/A, none in PWC network	16,000
TF6	TRANSFORMERS	Kiosk Mounted ; < = 22kV ; < = 60 kVA ; Single Phase	Used the > 60 kVA unit rate since replacements would most likely use the larger 75kVA units.	36,000
TF7	TRANSFORMERS	Kiosk Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Single Phase	The actual costs include several replacements done under maintenance which don't appear to include the asset costs. Used the average of the projects only.	36,000
TF8	TRANSFORMERS	Kiosk Mounted ; < = 22kV ; < = 60 kVA ; Multiple Phase	N/A, none in PWC network	36,000
TF9	TRANSFORMERS	Kiosk Mounted ; < = 22kV ; > 60 kVA and < = 600 kVA ; Multiple Phase	The actual costs include several replacements done under maintenance which don't appear to include the asset costs. Used the average of the projects only. Excluded one project where asset costs where not captured.	75,000
TF10	TRANSFORMERS	Kiosk Mounted ; < = 22kV ; > 600 kVA ; Multiple Phase	The actual costs include several replacements done under maintenance which don't appear to include the asset costs. Estimated the materials costs from the projects ($72k), and the non-material costs from the work orders ($21k).	93,000
TF11	TRANSFORMERS	GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 60 kVA AND < = 600 kVA ; MULTIPLE PHASE	Used the 13/14 to 16/17 project costs but excluded a single project which used a refurbished asset at no cost.	80,000
TF12	TRANSFORMERS	GROUND OUTDOOR / INDOOR CHAMBER MOUNTED ; < 22 kV ; > 600 kVA ; MULTIPLE PHASE	Used the 13/14 to 16/17 project costs	115,000

SG1	SWITCHGEAR	< = 11 kV ; Switch	Used the 13/14 to 16/17 project costs	28,000
SG2	SWITCHGEAR	< = 11 kV ; Circuit Breaker	Only recloser projects were included in the analysis since zone substation circuit breakers are not included in the pooled asset forecast. Used the average of 11kV and 22kV category since it gives a larger sample size and expect costs to be similar.	21,000
SG3	SWITCHGEAR	> 11 kV & < = 22 kV ; Switch	Used the 13/14 to 16/17 project costs	12,000
SG4	SWITCHGEAR	> 11 kV & < = 22 kV ; Circuit Breaker	As per < = 11 kV ; Circuit Breaker	21,000
UG5	OTHER	Pillars	Used the 13/14 to 16/17 project costs	8,000
SA	Surge Arrestors	Surge Arrestors	Used the 13/14 to 16/17 project costs	1,760