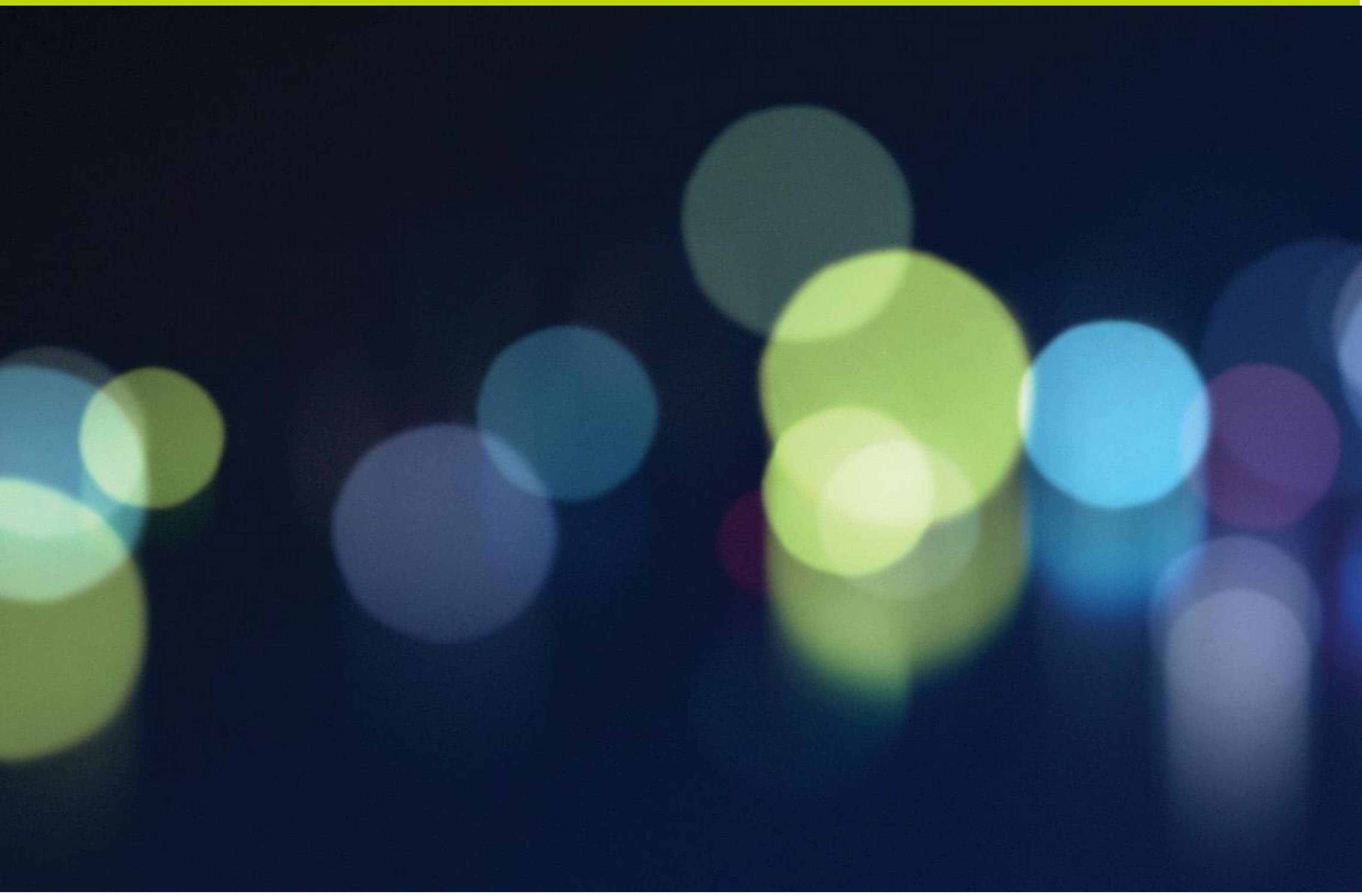
Underground Cables Asset Class Plan

Mains Assets

November 2022



Endeavour Energy

Version control

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1. Executive Summary

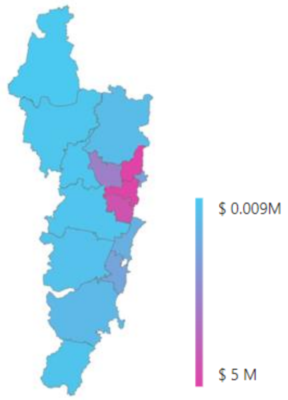
A 10-year strategy for underground cables has been defined, driven by the risk associated with the aging population of the asset class. The forecasted risk, strategy cost breakdown, and performance metrics are outlined below including oil filled 132kV cables and all other underground cables, excluding underground services.

Risk Forecast

The failure of underground cables may lead to Reliability, Financial, or Environmental consequences.

These consequences are quantified in $'s and coupled with statistical modelling to determine the risk associated with the fleet of in-service underground cables.

As these assets age, the risk associated with their failure also increases and this is geographically represented.

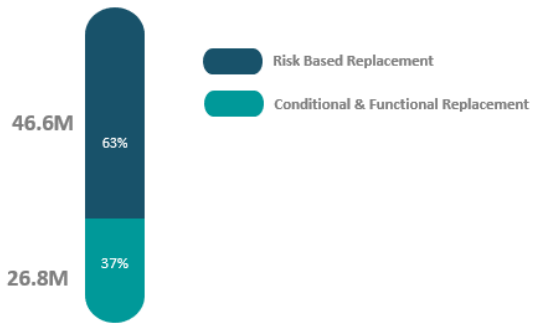


Strategy and Cost

The selected intervention options to address the risk associated with underground cables includes a mix of conditional and run to failure replacement and risk-based replacement.

Continued maintenance is also to be applied.

The total cost of this strategy for the 2023-2032 period is $73.8M and is categorised based on intervention type.



Key Performance Indicators

Underground cable performance is defined based on the following performance categories and objectives.

For all asset types, the targets for these objectives are either already met, or cannot currently be measured. In these cases, monitoring systems are to be setup to allow for appropriate data collection to determine if objectives are being achieved.

All objectives are forecasted to improve or remain stable based on the 10-year strategy proposed in this asset class plan.

Performance Category	Objective	Status
Asset Utilisation	TBC	-
Safety	-	N/A
Reliability	Reduce the number of unplanned outages associated with functional failures	●
Resilience	TBC	-
Financial	Reduce the number of maintenance events	●
Bushfire	-	N/A

2. Overview

2.1 Purpose

The purpose of this document is to outline previous, current and proposed asset management practices for underground cable assets and define a 10-year strategic plan for the asset class based on the asset's risk and cost.

The 10-year plan seeks to use all current knowledge of the asset in context with the whole network to establish Key Performance Indicators (KPI) to assist in understanding and monitoring the ongoing performance of the asset. The adopted levels of service for underground cable assets are based on risk / benefit trade-offs versus cost options, legislative requirements, customer expectations, and strategic goals set by Endeavour Energy.

This document is intended to function as part of the "Performance Monitoring and Review Process" as established in the Asset Management System (AMS) outlined in Section 9 of this report. The document plays a key role in ensuring:

- A continuous feedback loop is established between the performance of the individual assets and the performance of the more macro level Asset Class
- Monitoring of the performance of the asset class against Key Performance Indicator (KPI's) set
- Changes in the performance or risk (positive or negative) are identified as early as possible
- Communicating the historic, current and proposed balance of risk and cost (as shown via the number of asset replacements caused by functional failures, condition-based replacements and risk based replacements).

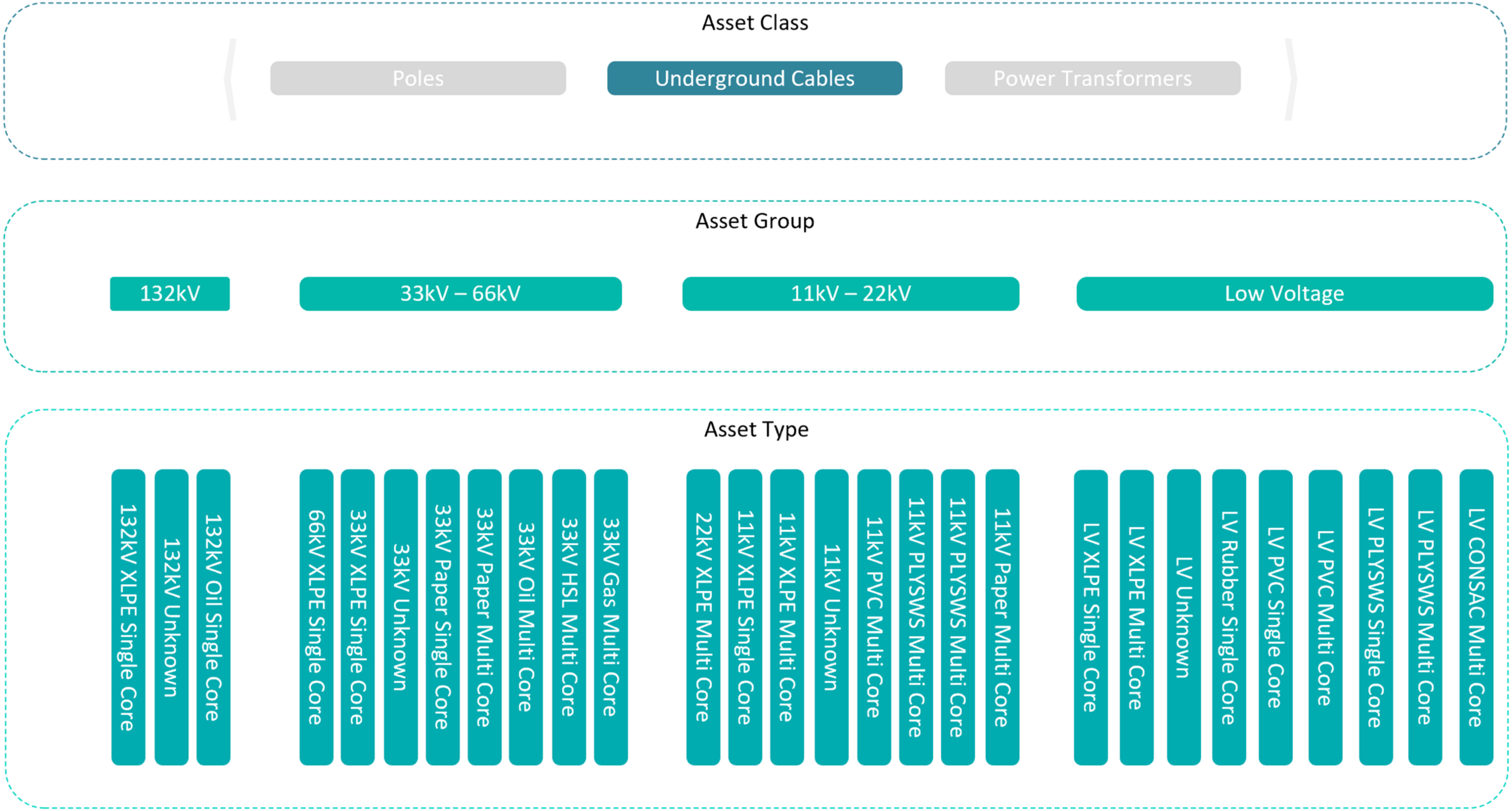
The document will highlight and discuss historical trends and future forecasts for three primary asset management strategies:

- Risk Based asset replacements (e.g. those proposed to be completed on a risk / cost justification basis)
- Condition Based asset replacements (e.g. asset triggered for replacement due to inspection and/or maintenance program)
- Functional asset failures (e.g. assets replaced post an asset failure whilst in service)

The forecasted "outcome" risk projections (for safety, reliability, resilience, bushfire etc) throughout this document are based on the optimal investment profiles proposed in the Case for Investments (CFI's) as well as the continuation of the existing maintenance strategies. The "baseline" risks outlined throughout this document represent the natural increase in risk without an asset replacement program.

2.2 Scope

This report covers all Endeavour Energy owned underground cables (excluding underground services) which includes the following highlighted assets:



3. Asset Portfolio

3.1 Asset Function

Underground cables currently perform one primary function which is to convey electrical power. Underground cables are a vital component of the network and provide a physical medium to distribute electricity from one place to another. For Endeavour Energy's network, the distribution of electricity is typically between TransGrid bulk supply points and residential, commercial and industrial customers. Underground cables also function to carry load and fault current and maintain continuity under both normal and fault conditions.

Currently, within Endeavour Energy's network there are 28 different types of underground cables in-service which vary in voltage, construction and insulation material. The current role and minimum performance measures for underground cables within each part of Endeavour Energy's network is underpinned by Company Policy 9.2.5 Network Asset Design. This policy states that underground cables should be designed for their intended function as a part of the below network sub populations.

1. **Low Voltage (LV) network -** The collection of assets (lines, cables and associated equipment) the purpose of which is to distribute electricity from distribution substations to individual customers. The LV network in the company's area operates at nominal voltages of 400V (phase to phase) three phase and 230V (phase to earth) single phase.
2. **High Voltage (HV) distribution -** A voltage nominally greater than 1,000V. In particular, the 11kV and 22kV networks are the standards adopted by Endeavour Energy for HV distribution.
3. **Sub-Transmission network -** The collection of assets (sub transmission lines, cables, zone substations and associated equipment) purpose of which is to distribute power in bulk from transmission substations to zone substations which feed the distribution network or a particular customer. The sub-transmission voltage of the company's network is ranges between 132kV and 33kV.

Technology advancements may impact the maintenance and operations associated with this asset class as parts of the network transition to XLPE cables. The function of this asset class is however unlikely to change.

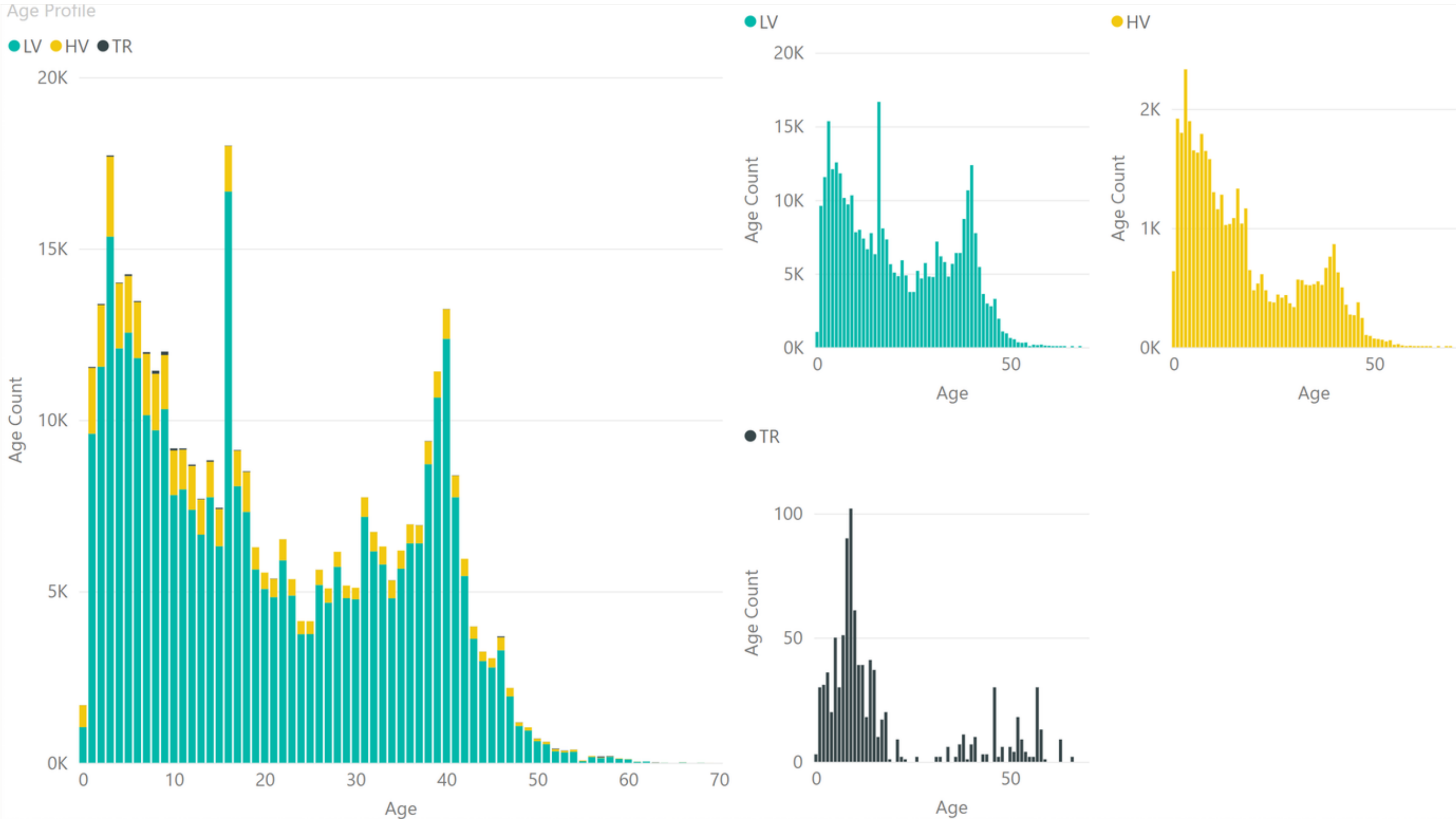
The breakdown of risks that are attributed to this asset class are shown in section 4 to illustrate performance measures and key drivers.

3.2 Asset Population

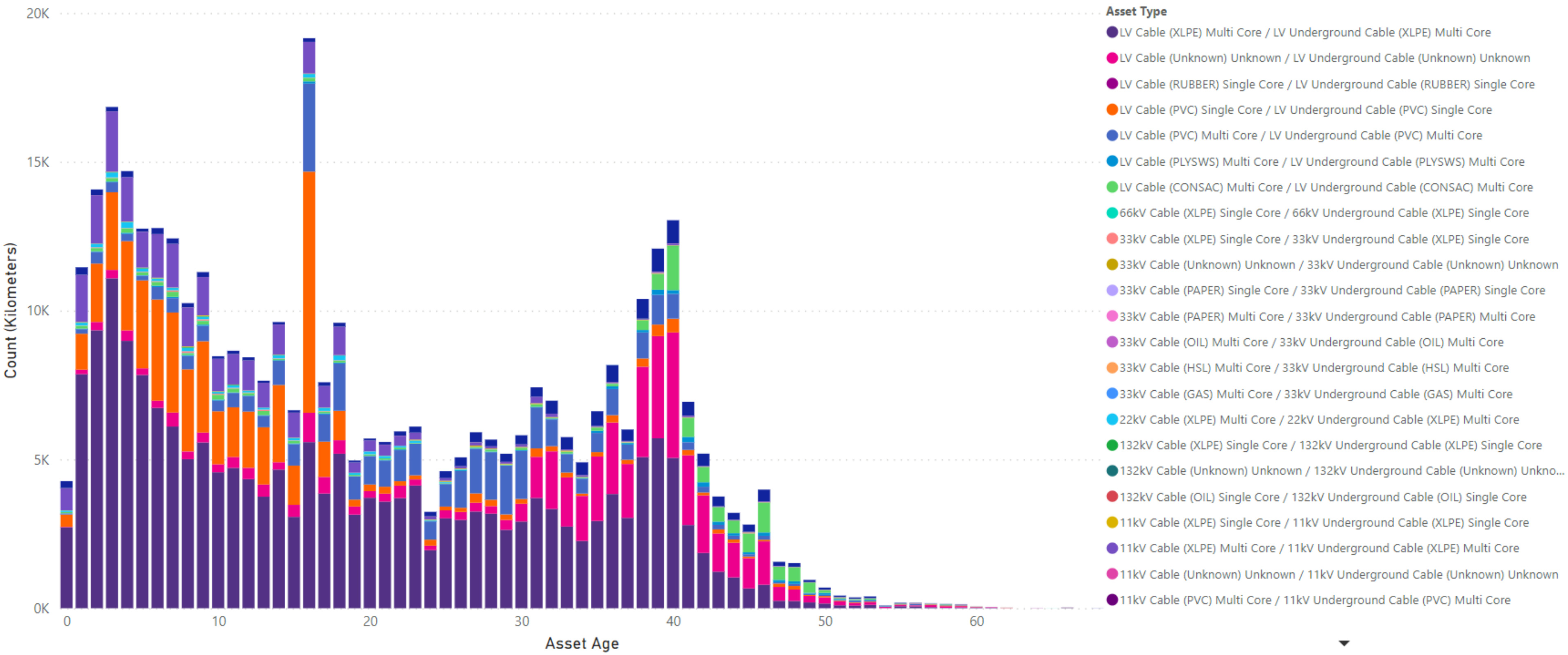
Endeavour Energy owns 20,564 kilometres of underground cables in-service represented by 395,097 unique underground cable linear assets. Each underground cable linear asset represents a unique segment of cable of varying length.

The total number of assets in the network has increased significantly over the previous 10 years as most network extensions are in the underground network. Undergrounding of the existing overhead network has also contributed to the overall increase in underground cable population. The number of assets in this class is expected to increase over the next 10 years following this trend. This is in line with Endeavour Energy's ambition to increase their overall proportion of underground network to suit customer expectations and mitigate risks associated with the overhead network.

The age profile of LV, HV and sub-transmission underground cables is summarised in the below figure.



- The above age profile indicates that most existing underground cables are less than 60 (sixty) years old. Over the next 10 years the oldest proportion of existing assets will approach or exceed their nominal design life of 60 years. This is expected to contribute to a forecast increase in conditional and functional failures over the FY22-32 period.
- The age profile of underground cables and distribution of cable types is shown in the below figure. The figure illustrates that a significant proportion of existing assets approaching their nominal design life (60 years) are oil filled sub-transmission cables.



4. Asset Performance

This section quantifies the risks and asset performance measures associated with Underground Cables. The weighting for different risk categories illustrates the areas of focus for managing the maintenance, life cycle and intervention options for this asset class. These are further broken down into performance measures that enable clear relationships to be drawn between risk and asset performance.

The level of risk (by risk category) is determined for each individual asset, based on its location in the network and probability of failure (as per the risk based replacement review). The following table summarises the risk categories and provides an overview of the average risk contribution made by each risk category (e.g. safety, reliability bushfire etc), illustrating the primary risk drivers for the asset class.

It should be noted that the risk proportions for Oil filled 132kV cables and other underground cables have been quantified separately in their respective CFI's. The risk proportions in the below tables are therefore represented separately for Oil filled 132kV cables and other underground cables.

The largest risk for this asset class is associated with reliability.

Oil Filled 132kV Underground Cables		
Risk Category	Consequence	Risk Contribution
Safety	No significant safety consequences are anticipated for failures of these cables.	0%
Reliability	Camellia Transmission Substation, East Parramatta Switching Substation and Granville Zone Substation are supplied via these cables. Reliability risk for feeder 22W and 228 is increasing over time due to a future loss of redundancy from forecasted load growth in the Greater Parramatta. This poses a significant reliability risk should feeder 22W or 228 fail beyond 2027.	86.3%
Bushfire	There are nil significant bushfire risks associated with failure of oil filled cables.	0%
Environmental	These cables contain free flowing oil inside their lead sheath and a failure either of the sheath or an electrical failure will lead to the leakage of oil into the surrounding area. As these cables are predominantly directly buried in the ground, the oil will pool into the surrounding soil. Given the location of these cable routes, if escaped oil reaches a water table there is potential for it to pollute the nearby Duck Creek which flows into the Parramatta River. This poses a potential risk to the environment, wildlife and members of the public in the case of a failure which results in a significant oil leak.	0.2%
Financial	Not replacing the asset before a failure may lead to capital expenditure related to reactive replacement. Not replacing the asset before a failure may also lead to additional reactive maintenance costs pertaining to the upkeep of oil levels within these cables resulting from oil leaks.	13.4%

Note: The risk proportions shown in the above table represent the combination of BAU (business as usual) condition-based risk and EUE (expected unserved energy) risk. For the purposes of this ACP, the EUE risk is treated as a contributor to the total reliability risk.

Other Underground Cables		
Risk Category	Consequence	Risk Contribution
Safety	No significant safety consequences are anticipated for failures of these cables.	0%
Reliability	Loss of supply to customers supplied by the associated feeders.	78%
Bushfire	No significant bushfire consequences have been experienced or are anticipated and are therefore not considered a risk to be managed.	0%
Environmental	No significant environmental consequences have been experienced or are anticipated and are therefore not considered a risk to be managed.	0%
Financial	The cost of repair procedures can incur large financial costs.	22%

The table below summarises the asset performance service level and objectives across the fleet of underground cables.

Performance	Objective	Performance Measure	Asset	Current	Performance Target	Status	Trend
Asset Utilisation	TBC	Availability of sections lengths / impact to network	LV	-	To be determined	■	■
			HV	-		■	■
			TR	-		■	■
			All	-		■	■
Safety	-	-	LV	-	-	-	-
			HV	-		-	-
			TR	-		-	-
			All	-		-	-
Reliability	Reduce the number of unplanned outages associated with functional failures	5-year rolling average of unplanned outages	LV	97.6	Reduce in line with forecasts	●	▼
			HV	49.2		●	▲
			TR	0.8		●	▼
			All	147.6		●	▲
Resilience	TBC	Not currently measured	LV	-	To be determined	■	■
			HV	-		■	■
			TR	-		■	■
			All	-		■	■
Financial	Reduce the number of maintenance events	5-year rolling average of maintenance events	LV	28.5	Reduce in line with forecasts	●	▼
			HV	27.3		●	▲
			TR	20		●	▼
			All	75.8		●	▼
Bushfire	-	-	LV	-	-	-	-
			HV	-		-	-
			TR	-		-	-
			All	-		-	-

4.1 Asset Utilisation - TBC

4.1.1. Objective

4.1.2. Performance

4.1.3. Gap

4.1.4. Response

4.2 Safety

4.2.1. Objective

Reduce safety risk in line with the performance targets identified.

4.2.2. Performance

No significant safety consequences are anticipated for failures associated with underground cables.

4.3 Reliability

4.3.1. Objective

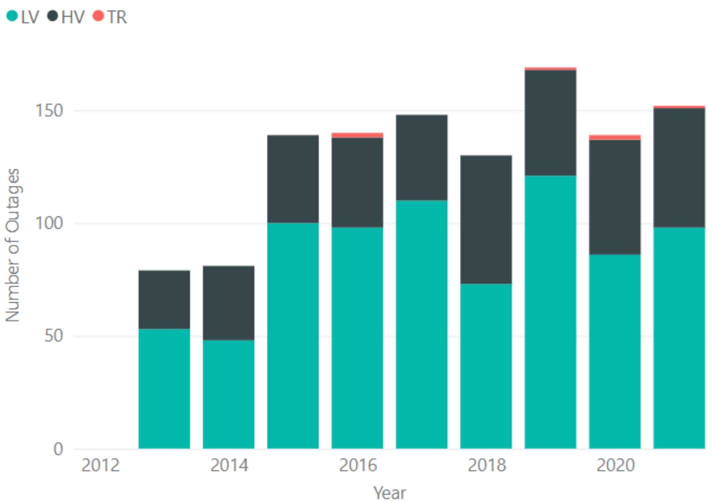
Reduce the level of network reliability risk and number of outages caused by unassisted asset failures associated with underground cables.

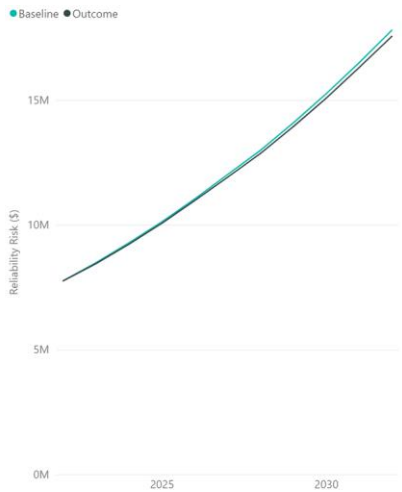
4.3.2. Performance

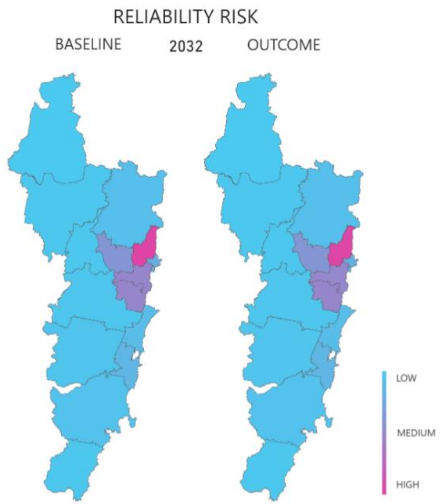
Undergrounds cables have historically performed in a reliable manner and the majority of failure modes have occurred at locations of cable joints or terminations where the highest electrical stress existing. From FY17 onwards Endeavour Energy has experienced on average 146 unassisted functional failures of underground cables per year. As this asset class continues to age and asset population continues to grow it is expected that with no intervention this level of failure will continue to increase over time.

Camellia Transmission Substation, East Parramatta Switching Substation and Granville Zone Substation are supplied via oil filled 132kV cables on feeders 228, 22W and 233. There is currently network supply redundancy available across these feeders and as such a reliability impact would require concurrent failures to occur. However, reliability risk for feeder 22W and 228 is increasing over time due to a future loss of redundancy from forecasted load growth in the Greater Parramatta. This poses a significant reliability risk should feeder 22W or 228 fail beyond 2027.

The normalised geographic risk concentration across the network is not currently uniform, however is expected to improve over the coming regulatory period. It should be noted that data associated with oil filled cables has not been included in the below charts.







4.3.3. Gap

The baseline annual reliability risk (no intervention) associated with this asset class (excluding oil filled cables), is projected to more than double to $19 million if no action is taken. The outcome risk based on the proposed intervention profile is projected to have minimal influence on projected risk over the following 10 years. This is attributed to a majority of investment being directed towards reactive replacement programs ($26.8M) and relatively minor investment in proactive replacement programs ($0.4M). This is reflected in Section 1.5 UG Cables CFI.

4.3.4. Response

The preferred risk treatment option is the proactive replacement of 7 underground cables with a modern equivalent cable. These 7 cables are selected for proactive replacement based on achieving their maximum NPV within the FY22-FY32 period. The residual reliability risk remains significant ($340.7M) as noted in Section 5.4 UG Cables CFI.

Reliability risk associated with oil filled cables includes both the functional failure impacts and the expected future unserved energy. The preferred intervention program reduces the residual reliability risk value to $460K. This is noted in Section 5.5 Guildford to Camellia 132kV Cables CFI.

It is recommended that time based maintenance activities are maintained in accordance with Section 5.3 of this ACP to mitigate the residual reliability risk and optimise the productive application of the $26.8 million allowance for reactive replacement of underground cables.

Whilst a significant increase is risk is forecast (as the asset base continues to deteriorate in condition and new asset are installed) the high cost of risk based / proactive intervention associated with underground cables results in a reactive program being the best outcome for customers in the current forecast period for the vast majority of this asset class.

4.4 Network Resilience - TBC

4.4.1. Objective

4.4.2. Performance

4.4.3. Gap

4.4.4. Response

4.5 Bushfire

4.5.1. Objective

To reduce the number of functional failures and therefore the likelihood component of bushfire risk associated with underground cables.

4.5.2. Performance

No significant bushfire consequences are anticipated for failures associated with underground cables.

4.6 Financial

4.6.1. Objective

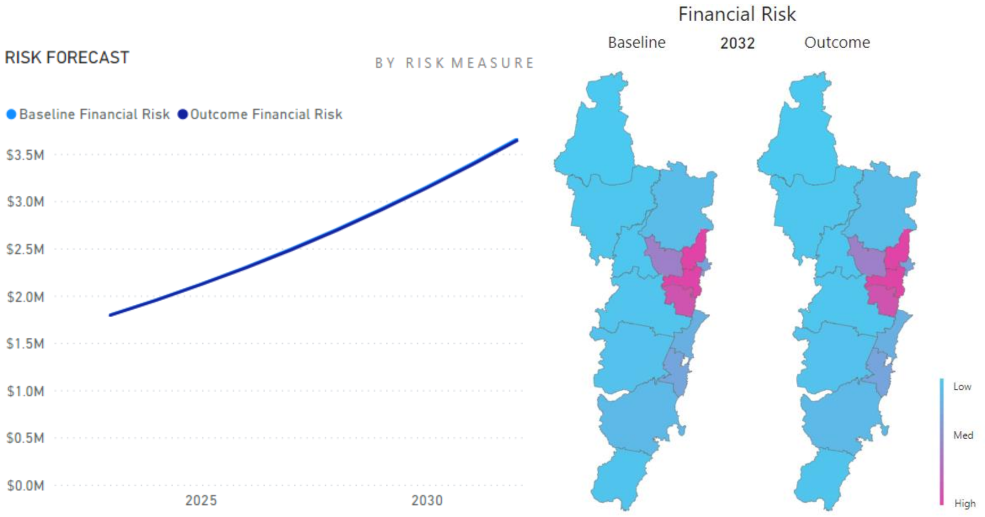
To optimise the productivity of asset lifecycle management activities relative to their respective contributions to cost.

4.6.2. Performance

Cable faults typically lead to financial impacts due to the cost of repair. Financial risk for underground cables is therefore estimated based on the forecast repair cost for all underground cable assets in the network. Low voltage and distribution cable fault repair costs are based on design estimates from the mains design team and subject matter expert feedback on previous repair costs. Sub-Transmission cable fault repair costs are based on past actuals from Ellipse workorders. Oil filled cable fault repair costs are based on previous contractor quotations.

Undergrounds cables have historically performed in a reliable manner and the majority of failure modes have occurred at locations of cable joints or terminations where the electrical stresses on cables are the highest. From FY17 onwards Endeavour Energy has experienced on average 146 unassisted functional failures of underground cables per year, 74 of these failures are attributed to XLPE cables (however a portion of these are expected to be associated with other cables types). As this asset class continues to age and asset population continues to grow it is expected that with no intervention this level of failure will continue to increase over time.

It should be noted that data associated with oil filled cables has not been included in the below charts.



4.6.3. Gap

The baseline annual financial risk (no intervention) associated with this asset class is projected to more than double to $3.6 million if no action is taken. The outcome risk based on the proposed intervention profile is projected to have minimal influence on projected risk over the following 10 years. This is attributed to a majority of investment being directed towards reactive replacement programs ($26.8M) and relatively minor investment in proactive replacement programs ($0.4M excluding planned investment in oil filled cabes). This is reflected in Section 1.5 UG Cables CFI.

4.6.4. Response

The preferred risk treatment option is the proactive replacement of 7 underground cables with a modern equivalent cable. These 7 cables are selected for proactive replacement based on achieving their maximum NPV within the FY22-FY32 period. The residual financial risk remains significant at $3.6M.

Financial risk associated with oil filled cables includes the cost of restoration works to return a failed 132kV oil filled cable to service. The proposed intervention program for these assets reduces the residual financial risk value to zero.

It is recommended that project spend on maintenance activities be continually monitored against budgets to ensure maximum productivity is achieved relative to cost.

4.7 Environmental

4.7.1. Objective

To reduce the number of functional failures causing leakage of oil into the surrounding environment and therefore reducing the likelihood component of environmental risk associated with underground cables.

4.7.2. Performance

Concerns with the condition of the 132kV oil filled cables were initially raised in 2011 after the discovery of a major oil leak on feeder 233. Along the routes of feeders 228, 22W, 22U and 9J8, there are twelve known sections of cable out of a total of nineteen sections where oil leaks are present. The presence of existing oil leaks indicates that there is an elevated risk of a major oil leak developing which will require interventive restoration works.

The environmental risk cost of consequence has been determined based on the land use sensitivity around each cable. Values of consequence are then assigned based on clean-up and compensation cost estimates. All 132kV oil filled cable locations considered in this ACP reside in urbanised areas which have been classified as low sensitivity.

4.7.3. Gap

The total value of BAU environmental risk is estimated at $300,000. This is applicable to 132kV oil filled cables only as noted in Section 4.2.2 Guildford to Camellia 132kV Cables CFI FY23, Table 3.

4.7.4. Response

The preferred risk treatment option is the proactive replacement of oil filled cables on feeders 228, 22W and 233. The residual forecast risk value considering these interventions is reduced to $0.

It is recommended that regular monitoring of oil pumping and oil leaks continue for cables not currently identified for proactive replacement.

It is also recommended that practical cost-effective methods for identifying oil filled cable leak locations be further investigated to mitigate future environmental risk.

5. Asset Lifecycle

This section discusses underground cable assets throughout the asset lifecycle and brings to light key factors that currently (or may) impact the asset class performance.

5.1 Acquisition

Currently, within Endeavour Energy's network there are 28 different types of underground cables in-service.

Medium and long-term forecasts for the Endeavour Energy supply area continue to indicate stable growth in energy consumption and peak demand. Growth is largely driven by greenfield development (where limited network currently exists) and organic growth due to infill and old-area redevelopment. New redeveloped residential, commercial, industrial and town centre developments are required to be reticulated via underground distribution cables. Existing areas of the overhead network also continue to be progressively undergrounded as areas are further developed.

Acquisition of underground cable assets is also driven by asset renewal planning and reactive replacement. Historically, programs for the management of underground cables have been primarily reactive in identification of assets which require intervention. In recent years programs such as DS006 – LV CONSAC cable replacement (2003 - 2022), DS014 – LV cable network renewal (2016 - 2018), and DS415 – LV mains replacement (2014 - 2015) have been carried out to manage the risk posed by underground cables on the network. These programs all targeted specific asset types of underground cables which were experiencing poor performance.

The current technical criteria for this asset class are defined in Equipment Technical Specifications (ETS) as listed in Section 9.1. These standards define the technical parameters for the acquisition of new or renewed underground cable assets. Selection for underground cable type is driven primarily by their required continuous current rating. This is defined in MDI 0046 Transmission underground cables – continuous current ratings and MDI 0011 Underground distribution cables – continuous current rating.

Asset types have largely been defined based on the technology type, failure mode and replacement cost. The current asset types will continue to be further subdivided as appropriate based on continued performance data monitoring.

5.2 Operations

The function of underground cable assets is to convey electrical power. Required operational interactions by Endeavour Energy staff is therefore minimal. Optimising the operational utilisation of underground cable assets is however a key factor in demonstrating whole of asset lifecycle returns for investment in underground cable assets.

Operational restrictions for underground cables are dictated primarily by the continuous current rating (CCR) for the respective cable types. The continuous current rating is defined as the maximum current that can be allowed to flow indefinitely without causing damage to the cable material such as screenin and insulation, or accelerate the ageing of such materials. Continuous current rating for transmission and distribution underground cables are defined in MDI 0046 Transmission underground cables – continuous current ratings and MDI 0011 Underground distribution cables – continuous current rating respectively. It should be noted that CCR will vary depending on rating factors unique to the location and arrangement of underground cables in the network.

Optimisation of the operating load relative to the CCR of underground cables should be a consideration in operational decision-making for the network.

5.3 Maintenance

An overview of the current maintenance activities being performed on underground cable assets are summarised below. These maintenance activities result in the current asset performance (e.g., risk and number of unassisted / conditional asset failures). The continued reactive replacement strategy for this asset class plan is expected to maintain the underlying risk profile associated with the following maintenance strategy.

5.3.1. Inspections & Preventative Maintenance

The following table summarises the frequency of different inspection programmes and preventative maintenance applicable to underground cables.

<table>
<tr><th></th><th colspan="2">Programme Name</th><th>Interval (Years)</th><th>Reference</th></tr>
<tr><td rowspan="20">Inspections</td><td rowspan="5">Routine Patrols</td><td>132kV cables</td><td>Weekly</td><td rowspan="5">MMI 0006</td></tr>
<tr><td>66kV/33kV oil and gas filled cables</td><td>Every four (4) weeks</td></tr>
<tr><td>Critical 66kV/33kV cables</td><td>Every four (4) weeks</td></tr>
<tr><td>Major pilot cables (on-road)</td><td>Weekly</td></tr>
<tr><td>Major pilot cables (off-road)</td><td>Every four (4) weeks</td></tr>
<tr><td rowspan="2">Insulation Resistance Test</td><td>Paper</td><td rowspan="15">- As required by commissioning
- Recommissioning after cable repairs
- When cable condition is suspect</td><td rowspan="15">MMI 0025</td></tr>
<tr><td>XLPE</td></tr>
<tr><td rowspan="4">Cable serving insulation resistance test</td><td>Gas</td></tr>
<tr><td>Fluid Filled</td></tr>
<tr><td>33kV and above XLPE</td></tr>
<tr><td>22kV and above XLPE</td></tr>
<tr><td rowspan="4">Cable serving DC withstand test</td><td>Gas</td></tr>
<tr><td>Fluid Filled</td></tr>
<tr><td>33kV and above XLPE</td></tr>
<tr><td>22kV and above XLPE</td></tr>
<tr><td>AC withstand test</td><td>XLPE</td></tr>
<tr><td>24hr soak test</td><td>XLPE</td></tr>
<tr><td rowspan="3">DC voltage withstand test</td><td>Paper</td></tr>
<tr><td>Gas</td></tr>
<tr><td>Fluid Filled</td></tr>
</table>

Programme Name		Interval (Years)	Reference
Partial discharge (PD) test	XLPE		
	Paper		
	Gas		
	Fluid Filled		
Pilot cable insulation resistance test	Pilot cable (with PE insulation)		
	Pilot cable (with PVC insulation)		
Oil and gas pressure readings	Oil-filled, with single-level alarms	Every (2) weeks	MMI 0006
	Oil-filled, with three-level alarms	Every (4) weeks	
	Gas-filled, with single-level alarms	Every (2) weeks	
	Gas-filled, with three-level alarms	Every (4) weeks	
Cable Route Labelling	All UG Cables	1	MMI 0006
Oil pressure alarms system check	Oil filled cables	0.5	MMI 0006
Gas pressure alarms system check	Gas filled cables	1	MMI 0006
Zero and positive sequence impedance test	All UG Cables (excluding transmission)	- As required by commissioning - Recommissioning after cable repairs - When cable condition is suspect	MMI 0025
Sheath bonding test	All UG Cables		
Cable cover protection unit (CCPU) tests	CCPUs		

Resource availability for the above maintenance activities was a significant constraint at the time of drafting this ACP. The above table may therefore not be representative of the actual maintenance activities currently undertaken by Endeavour Energy. Accelerated underground cable deterioration may result where maintenance activities are not completed in accordance with the relevant Endeavour Energy Standards. It is recommended that Endeavour undertake an audit of current maintenance activates against the requirements of the above table to identify any critical resourcing gaps.

It should be noted that the above table does not include testing requirements for commissioning and recommissioning of cables.

5.3.2. Essential Spares

The requirement for an essential spares strategy is governed by the criticality of the equipment's function in the network and is dependent on the lead time for acquisition.

Given the availability of various suppliers, the ease of procuring items and the level of inventory maintained for underground cables there is no existing essential spares strategy for underground cables.

Endeavour Energy’s procurement and logistics section is responsible for the on-going sourcing strategy of underground cables including its supply chain security. It is recommended that Endeavour Energy’s procurement and logistics section undertake a review of essential spares strategies to investigate appropriate adaptations in response to covid supply chain disruption.

5.4 Disposal

Disposal of underground cable assets should be completed in accordance with the Endeavour Energy Waste Management Standard EMS 0007. Redundant underground cable assets, cable drums or their components (oil from oil filled cables) should be reused where possible by Endeavour Energy or by the equipment supplier. Where re-use or recycling of the asset is not possible, the components should be disposed of in accordance with the following Endeavour Energy procedures.

- GSU 0006 – Disposal of Surplus Good and Equipment
- GSU 0012 – Selection and Approval of a Disposal method
- GSU 0009 – Disposal of Scrap Metal
- WNV 1016 – Preparation and Disposal of Surplus Oil Filled Distribution Equipment

6. Intervention Options

A range of options have been considered as possible options to address the risk presented by underground cables. These options are initially considered at an asset type / class level to determine if they are technically feasible and/or practical. Intervention options deemed to be a viable option are then considered at an asset level to determine the most appropriate option for each individual asset.

Intervention Type	Option	Assessment of effectiveness	Credibility
Non-Network Based	-	There are no credible non-network solutions capable of replacing underground cable functionality under the assumption that the feeder in which they service is still required. Upon functional or conditional failure of an underground cable, the future requirement of the feeder should be considered on a site-specific basis prior to undertaking replacement of the linear asset.	Not A Feasible Solution
Condition Based	Additional maintenance to extend the life of the existing asset	Maintenance procedures are unable to further extend the life of an underground cable. The ongoing management and maintenance of underground cables typically involves routine inspections for defects.	Not A Feasible Solution
	Reactive repair and/or replacement of underground cables after conditional or functional failure	This approach forms part of the business-as-usual practice but does not entirely mitigate the impact of failures. The historical observed quantities of unassisted functional failures are inclusive of Endeavour Energy's existing BAU practice. Unidentified conditional failures which lead to functional failures are not avoided under a purely reactive repair approach. Furthermore, repairs where a small section of cable is replaced post failure, the overall condition of the entire section of cable and future probability of failure remain relatively unchanged (as-good-as-old).	Technically feasible solution but does not always effectively mitigate risk of future failures
	Gradually replace sections of oil cable after failure **(oil filled 132kV cables on feeders 228, 22W and 233)**	Gradual replacement of minor sections of the oil filled cables after failure does not mitigate the risk posed by the cables and does not address forecast load capacity constraints beyond 2031.	Not A Feasible Solution
Risk Based	Reduce the load on the asset through network reconfiguration, network automation or demand management **(oil filled 132kV cables on feeders 228, 22W and 233)**	The risk of failure is largely independent of load. Notwithstanding this, forecast load growth in the area will use up all available capacity for offloading the cables by 2031. Furthermore, these sub-transmission cables are integral to the supply of energy to their substations which are required to carry load for the foreseeable future. Further, there are no practicable non-network solutions for replacing the function a cable provides to supply a zone or transmission substation.	Not A Feasible Solution
	Reduce the load on the asset through network reconfiguration, network automation, demand management or other non-network options	The risk of an unassisted failure occurring is generally independent of load. A minor reduction in the consequences of failure could be achieved by transferring load from any of the feeders in which underground cables are installed however, these options are very limited within the low voltage and high voltage distribution network. Underground cables provide a physical medium to distribute electricity from one place to another on the distribution and sub-transmission networks, there are no practicable non-network solutions for replacing the function they provide.	Not A Feasible Solution
	Replacement to reduce the consumer's long-term service cost	Replacement options for these cables exist and can be carried out in a proactive and planned manner. Replacement of the cables with like for like XLPE cables to manage the failure risk.	Technically feasible but lower benefits as it does not address future

	(oil filled 132kV cables on feeders 228, 22W and 233)		network capacity constraints
	Staged replacement to maintain option value and reduce the consumer's long-term service cost	On replacement, risk associated with underground cables will be reduced to the risk associated with the replacement option.	Feasible Option
	Replacement to reduce the consumer's long-term service cost **(oil filled 132kV cables on feeders 228, 22W and 233)**	Replacement options for these cables exist and can be carried out in a proactive and planned manner. Replacement of the cables with higher capacity XLPE cables to manage the failure risk and provide for the expected unserved energy due to the forecast load growth.	

6.1 Non-Network Based Interventions

There are no credible non-network solutions capable of replacing their functionality under the assumption that the feeder in which they service is still required. Upon functional or conditional failure of an underground cable, the future requirement of the feeder should be considered on a site-specific basis prior to undertaking replacement of the linear asset. Therefore, network options should be considered which include intervention to address the identified need.

The estimated project costs of oil filled cable replacement ($46.2 million) exceeds the threshold for application of the Regulatory Investment Test for Distribution (RIT-D) (currently $6.0 million). The RIT-D is therefore applicable to this project in accordance with clause 5.16.3 of the National Electricity Rules. It is recommended that the RIT-D process be commenced to test for feasibility of non-network solutions to address the risks presented by the oil filled cables in feeders 228, 22W and 233.

6.2 Condition Based Interventions

The inspections and preventative maintenance programs outlined in 5.3 Maintenance results in the following condition-based repairs, replacements and defects on underground cables. The objective of the condition-based maintenance is to identify functional asset failures prior to them occurring, however as close as possible to the assets technical / economic end of life.

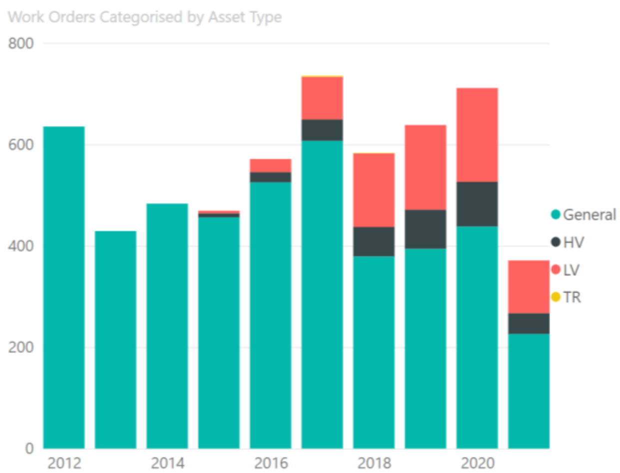
Defects are directly linked to an asset's failure mode(s) with the aim to proactively identify issues which may result in functional failure of the asset. Defects are currently prioritised based on a qualitative probability assessment of a resulting functional failure.

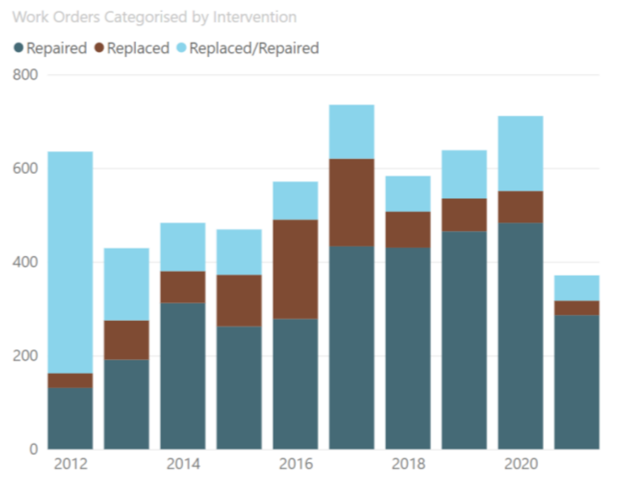
Endeavour Energy determines what constitutes a defect based on Failure Modes Effects and Criticality Analysis (FMECA). FMECA is an analytical process that is derived from an assessment of an asset's ability to sustain technical function and purpose and relies on information relating to failure modes, their probability and consequences of failure. FMECA establishes a condition-based approach to asset maintenance that enables a risk-based determination of the maintenance requirements for assets.

MMI 0025, and MMI 0006 provide further detail on what is to be recorded as a defect, the required actions, and the corresponding priority for each failure mode, the table below provides an overview of applicable defects associated with underground cables.

Asset Type	Defects	Repair / Replacement	Standard job description
All Underground Cables	1CABTE	Repair/Replace	Repair or replace terminations on UG cables on UGOH poles or switchgear.
	1CAGRD	Replace	Replace damaged or missing cable guards on UGOH poles.
	1HVCAB	Repair	Repair HV cable fault
	1LVCAB	Repair	Repair LV cable fault
	1MD4CA	Repair	Repair MD4 Cable Termination.
	1TRCAB	Repair	Repair transmission cable fault
	1UGCAB	Repair	Repair defective UG cable.
	1SLCAB	Repair	Repair streetlight cable fault

From FY17 onwards Endeavour Energy has experienced on average 146 unassisted functional failures of underground cables per year. As this asset class continues to age it is expected that with no intervention this level of failure will continue to increase over time. At present underground cable and street light cable repairs are creating the majority defects in the underground cable asset class. This indicated that the majority of interventions from the maintenance inspection programs are asset repairs and not asset replacements. This is evident in the chart below which is populated based on the repair/replacement categorisations in the above table. It is also noted that most work orders are categorised under "general" as this refers to standard jobs such as repair or replace terminations on UG cables and repair defective UG cables.





6.3 Risk Based Interventions

Risked based intervention options considered as feasible intervention options have been further considered to address the risk presented by underground cables at the asset level. The customer benefit achieved by the proposed intervention options is compared with the cost of the proposed intervention(s) to determine if the option is financially viable and in the customer's interest. This approach generates a cost to benefit ratio / NPV for every asset and intervention option being considered.

The following risk based interventions (as specified in the CFI's) are proposed as part of this strategy:

- **Guildford to Camellia 132kV Cables CFI**: Proactive replacement of oil filled cables on feeders 228, 22W and 233 with higher capacity XLPE cables to mitigate forecast network capacity exceedance. expected unserved energy (EUE).
- **Underground Cables CFI:** Proactive replacement of 7 underground cables with a modern equivalent cable.

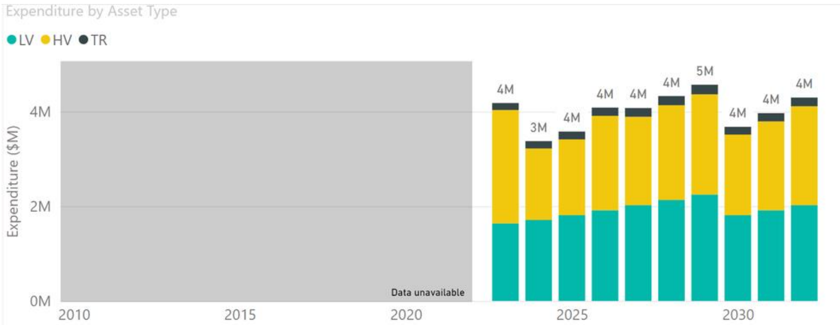
8. Forecasts

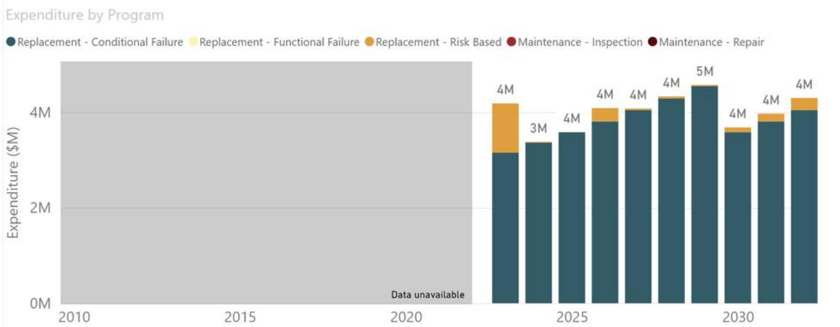
8.1 Cost

The risk-based replacement program has identified assets within this asset class that are currently justified for a risk-based asset intervention over the upcoming regulatory period. Assets that reach their NPV maximum point are illustrated in the images below. A number of other assets will have reached the point of being NPV positive (e.g. risk are higher than intervention costs), however these will be considered as part of the portfolio optimisation process.

The proposed investment profile is relatively flat over the forecast period. The forecast investment peak in FY29 is likely to be flattened over the fire year period once additional constraints (project timing, access, leadtimes etc) are considered.

Over the next 10 years, inspection and maintenance spend is expected to remain stable. It should be noted that data associated with oil filled cables has not been included in the below charts.





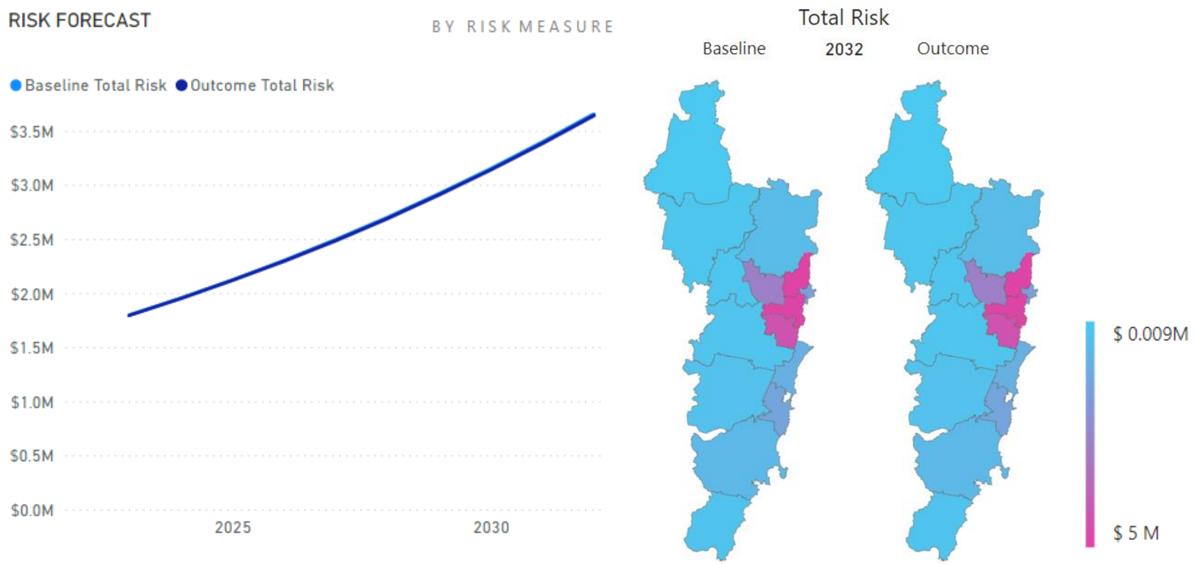
8.2 Risk

Network risk associated with underground cables has been calculated as per the current value framework. The total risk proportion for this asset class is split between 132kV oil filled cables and other underground cables. The respective total risk proportions for this asset class are summarised below.

- **Oil filled 132kV Cables**: Reliability (86.3%), Financial (13.4%) and Environmental (0.2%)
- **Underground Cables:** Reliability (78%) and Financial (22%)

The baseline annual risk (no intervention) associated with this asset class is projected to more than double to $3.5 million if no action is taken. The outcome risk based on the proposed intervention profile is projected to have minimal influence on projected risk over the following 10 years. This is attributed to a majority of investment being directed towards reactive replacement programs ($26.8M) and relatively minor investment in proactive replacement programs ($0.4M). This is reflected in Section 1.5 UG Cables CFI.

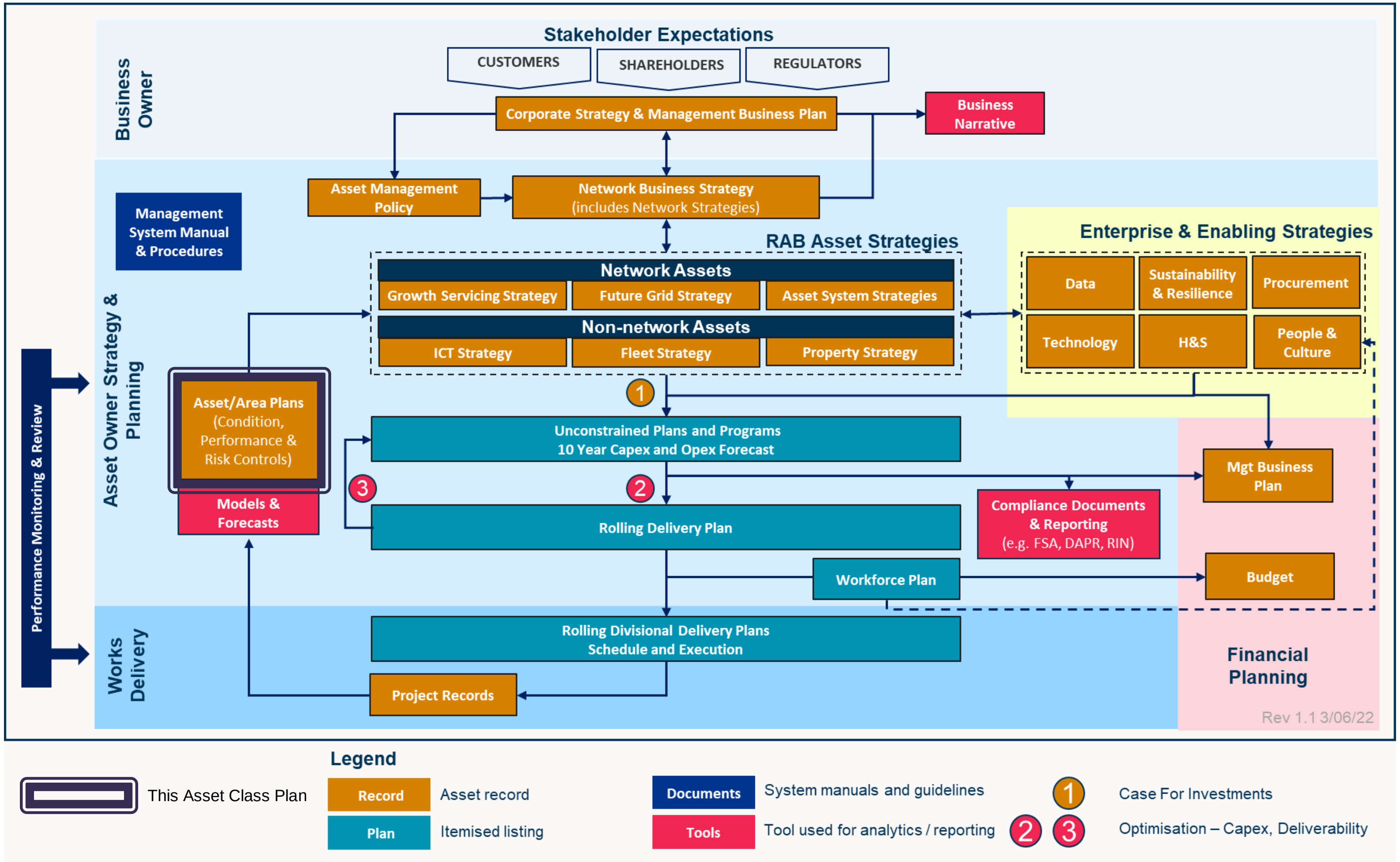
The outcome risk associated with oil cables is significantly mitigated by the intervention profile over the following 10 years. The BAU total risk value of $139.1M is reduced to a residual risk value of $460K based on the proactive replacement program. This is reflected in Section 5.5 Guildford to Camellia 132kV Cables CFI. It should be noted that data associated with oil filled cables has not been included in the below charts.



9. Asset Management Systems

This section identifies the strategies, practices and guidelines supporting the management of this asset class. A detailed description of Endeavour Energy's asset management system and its constituent parts is available in the Asset Management System Manual and the Asset Management System Guidelines.

The relationship between this document and the other artefacts within Endeavour Energy's asset management system is illustrated below:



9.1 Standards, Guidelines & Policies

Endeavour Energy's asset management practises are governed and guided by numerous legislative requirements, guidelines, and industry best practises throughout Australia and Internationally. Endeavour Energy's manuals, procedures and workplace policies are all underpinned by these key documents as documented in 'GQY 1190 Policy and Procedure Framework' and demonstrated in the adjacent figure. Legislation, regulations, and high-level Australian Standards applicable to HV network operations are detailed in the Endeavour Energy Asset Management System.

Endeavour Energy has developed the following documentation to specifically guide the life-cycle management of underground cable assets:

Company Policies

9.1.6	Approved Materials List
9.1.7	Commissioning network Electrical Assets
9.1.9	Network Technical Compliance
9.2.1	Network Planning
9.2.2	Network Protection
9.2.5	Network Asset Design
9.7.1	Network Asset Construction
9.8.3	Network Operations
9.9.1	Network Asset Maintenance
9.9.2	Essential Spares

Approved Materials Lists & Specifications

ETS 0111	132kV polymeric insulated underground cables
ETS 0112	66kV polymeric insulated underground cables
ETS 0113	33kV polymeric insulated underground cables
ETS 0043	Underground fibre optic cable specification

Design Instructions

MDI 0011	Underground distribution cables – continuous current rating
MDI 0028	Underground distribution network design
MDI 0046	Transmission underground cables-continuous current ratings
MDI 0051	Underground transmission mains design

Construction & Commissioning Standards

SDI 120	Testing and Commissioning for Distribution Systems

Maintenance & Operations Standards

MMI 0013	Vegetation Clearance Management
MMI 0034	Pre-summer Bushfire Inspections
MMI 0006	Underground transmission cables routine maintenance
MMI 0025	Tests for transmission/sub-transmission underground cables

9.2 Asset Management Tools

Endeavour Energy use numerous integrated data-base and geographical information system related tools to aid in the management of underground cable assets.

Key tools used for the management of underground cable assets include:

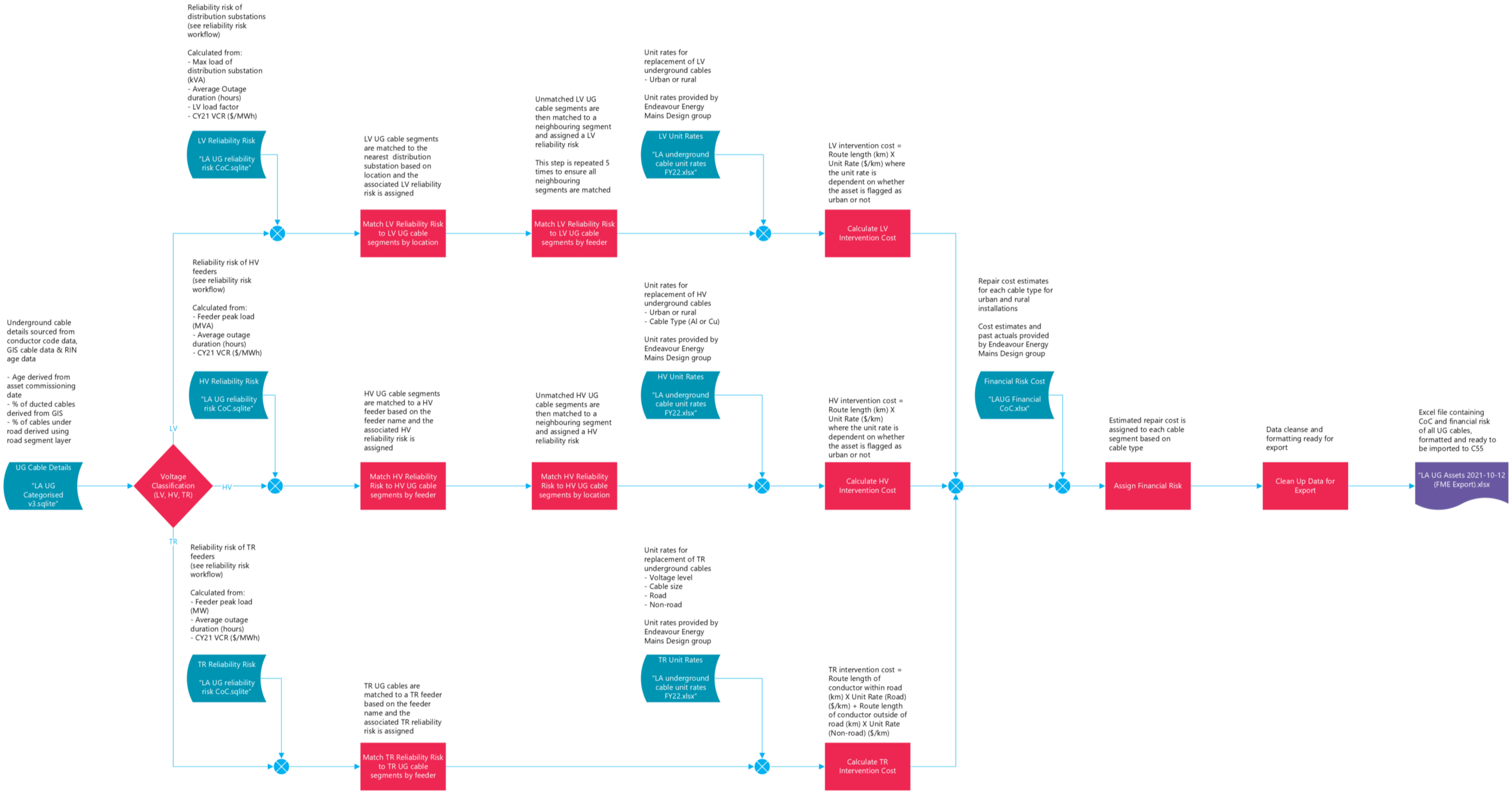
Tools	Current Purpose	Future Purpose
Ellipse Database	Used for historical (2010-2021) asset nameplate details, routine maintenance scheduling, defect workorder recording and management	Superseded by SAP
SAP	Used for recent (2021-Current) asset nameplate details, routine maintenance scheduling, defect workorder recording and management	To be used as the primary data source for: • Asset characteristics • Financials • Safety – safety incidents are to be categorised by asset class, asset type, and severity • Bushfire – bushfire incidents are to be categorised by asset class, asset type, and severity • Environmental – environmental incidents such as SF6 gas leaks are to be captured and categorised by asset class, asset type, and severity
ADMS	Not currently used	To be used as the primary data source for: • Reliability – reliability incidents are to be categorised by asset class, asset type, and include SAIDI and SAIFI contributions. • Resilience – Benefits from network automation to be quantified • Utilisation – switching events are to be categorised by asset class and asset type.
SwitchIt	Used to determined switch utilisation in terms of switching frequency	Superseded by ADMS
OMS	Used for historic (2012-2021) asset related reliability incidents	Superseded by ADMS
MySafe	Used for historic (2012-2021) asset related safety incidents categorised by severity	Superseded by SAP
GIS	Used for spatial mapping of asset information and representing geospatial locations of assets. Also includes detailed asset attributes and meta-data.	To be used as the primary data source for asset location data particularly for linear assets.

Appendix A – Cost of Consequence

Underground linear asset cost of consequence logic and workflow

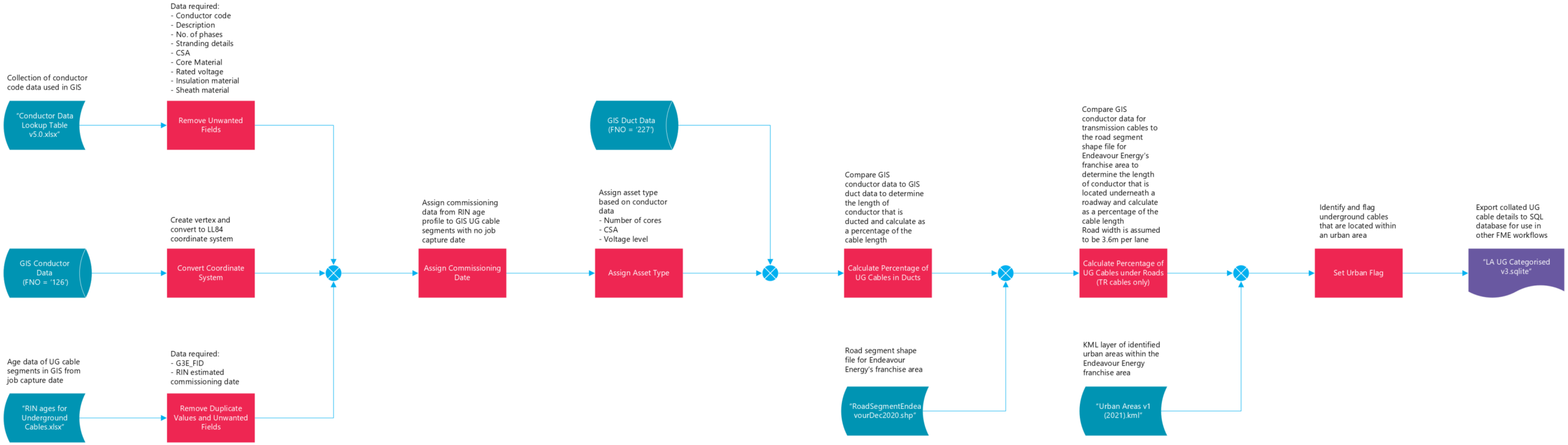
Underground linear asset cost of consequence logic and workflow

(current to 2-12-21, FME workflow *Consolidate data for import to C55.fmw*)

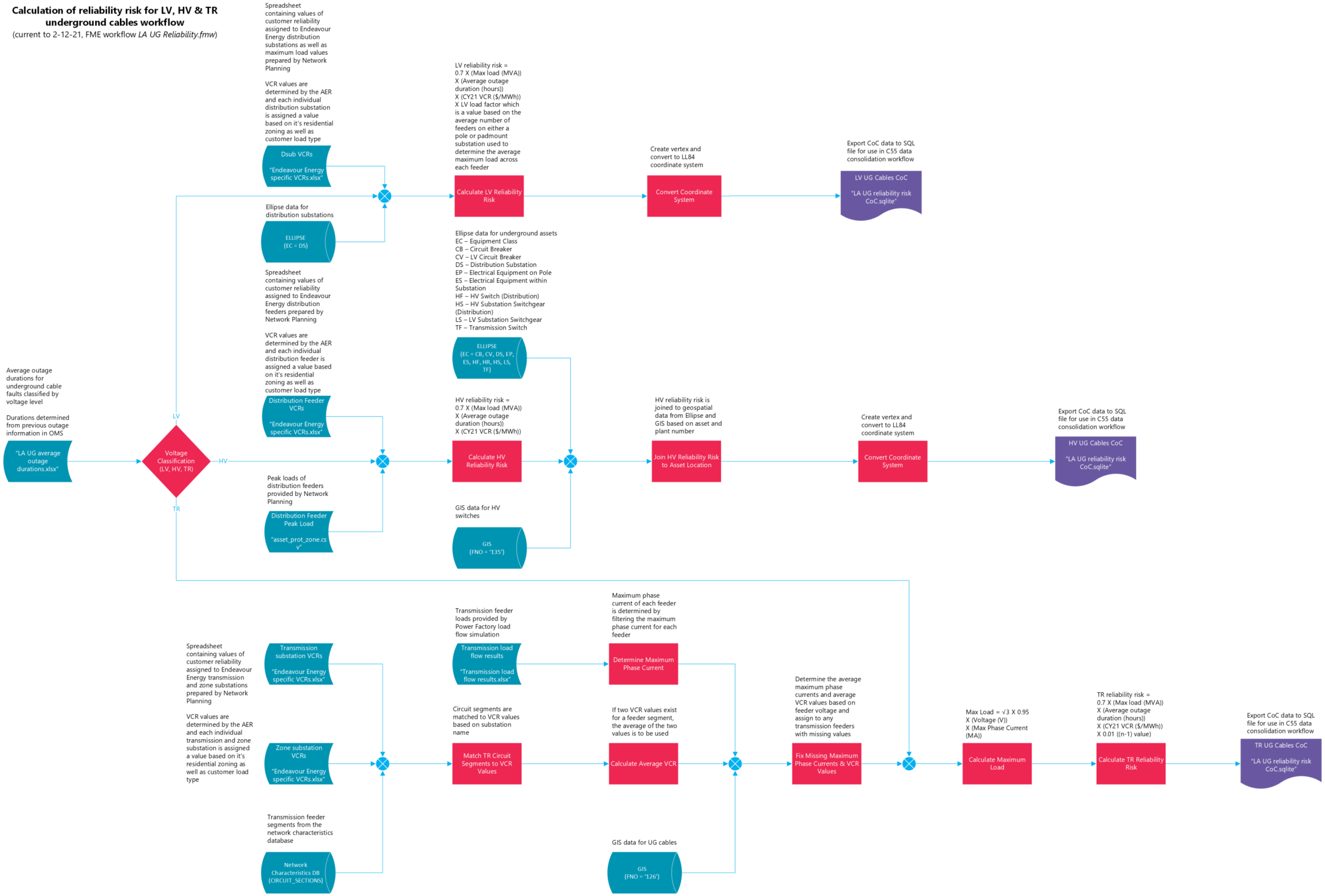


Underground linear asset details workflow

Underground linear asset details workflow
(current to 2-12-21, FME workflow *Underground Cables.fmw*)



Calculation of reliability risk for LV, HV & TR underground cables workflow



132kV oil cable environmental risk inputs

Parameter	Value	Description/justification	Source/assumptions
Environmental - CoF	High sensitivity - $100,000 Medium sensitivity - $25,000 Low sensitivity - $10,000	CoC assigned based on the land use around the cables.	The land use around each cable evaluated rom the ESRI shapefile *LanduseEndeavourDec2020*. Sensitivity assigned based on landuse: “High” – National Parks, state forests, wetlands etc “Medium” – Cropping, high value agriculture “Low” – All others Values of consequence are estimates based on clean-up and compensation costs. All oil filled cable locations reside in urbanised areas and have been assigned a low sensitivity.
Environmental - LoC	100%	Likelihood of the above environmental impact occurring on a cable failure	LoC assumed to be = 1

132kV oil cable reliability risk inputs

Parameter	Value	Description/justification	Source/assumptions
Loss of supply to customers - LoC	1% generally	1% likelihood of loss of load when N-1 supply security is available. Where supply security is lost in future years, PowerFactory modelling provides an estimate of the exceeded capacity. A 30% overload on supporting feeders has been considered acceptable prior to a loss of load been considered.	RisCAT - 1% likelihood the alternate supply path will not be available due to maintenance, or failure. PowerFactory modelling.
Load impacted	Varies based on the substations supplied by the lines the towers support	PowerFactory load flow analysis for feeder loads.	PowerFactory load flow analysis results provided by Network Planning.
Load factor	70%	Load assumed to be lost is 70% of the summer maximum demand value for the supplied substation(s)	Source – studies by Protection Manager.
VCR	Approximately $40,264 per MWhr of unserved energy	Value of customer reliability for an occasional short-term outage.	This value is based on the makeup of customer types supplied by the substations the feeders are supplying and is based on values published by the AER
Duration of interruption	2 hours	2 hours assumed interruption until alternate arrangements are made for supply through switching the network	An average value based on a range of outages of sub-transmission assets. Assumes off-loading to reinstate supply through a combination of SCADA and manual switching.

132kV oil cable financial risk inputs

Parameter	Value	Description/justification	Source/assumptions
Financial – repair costs of oil filled cable – CoC	$601,650	Value of repair costs incurred to locate and repair a damaged oil filled cable	Estimation based on quotation for cable leak detec obtained in 2019 inflated to real FY23 dollars
Financial – repair costs of oil filled cable – LoC	100%	Likelihood of the above Financial – repair cost impact occurring on a cable failure	LoC assumed to be = 1

Other underground cable financial risk inputs

Parameter	Value	Description/justification	Source/assumptions
Financial CoC (repair cost)	- LV Urban - $12,047 - LV Rural - $9,727 - 11kV & 22kV Urban - $19,370 - 11kV & 22kV Rural - $17,047 - 33kV & 66kV Road - $77,861 - 33kV & 66kV Non-Road - $25,343 - 132kV Road - $211,990 - 132kV Non-Road - $43,652 - 132kV Oil Filled Cable - $601,650	Cable fault repair of existing underground cables across urban and rural locations for distribution and within or outside road carriage ways for sub-transmission.	Low voltage and distribution cable fault repair costs provided from mains design team based on design estimates and subject matter expert previous repair costs. Sub-Transmission cable fault repair costs based on past actuals from Ellipse workorders. Oil filled cable fault repair costs based on contractor quotation.

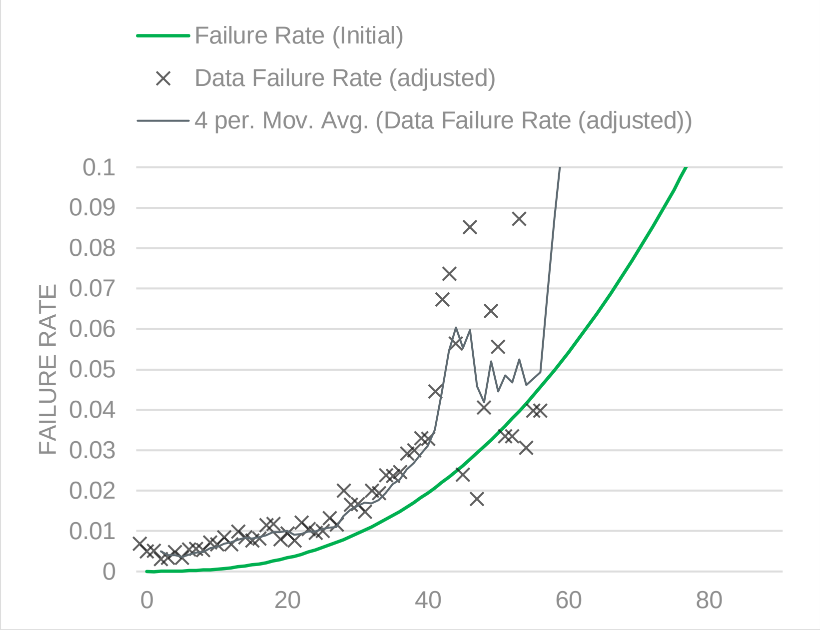
Appendix B – Weibull Parameters

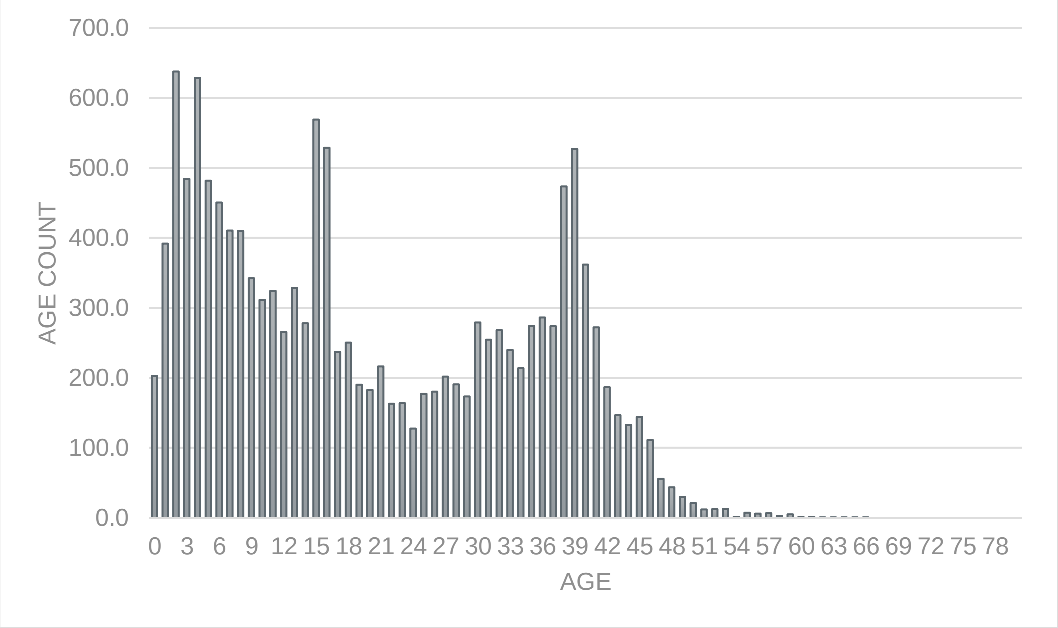
Conditional Weibull Parameters

LV Cable (Generic)

Parameters	Initial	Adjusted
Alpha - (Default = "3.6")	3.6	3.6
Beta	61.6	61.6
Shift - (Default = "0")	0	0

Input Data Statistics	Value
Mean failure age	23
Population size	14179
Avg number of historical annual failures	97.7

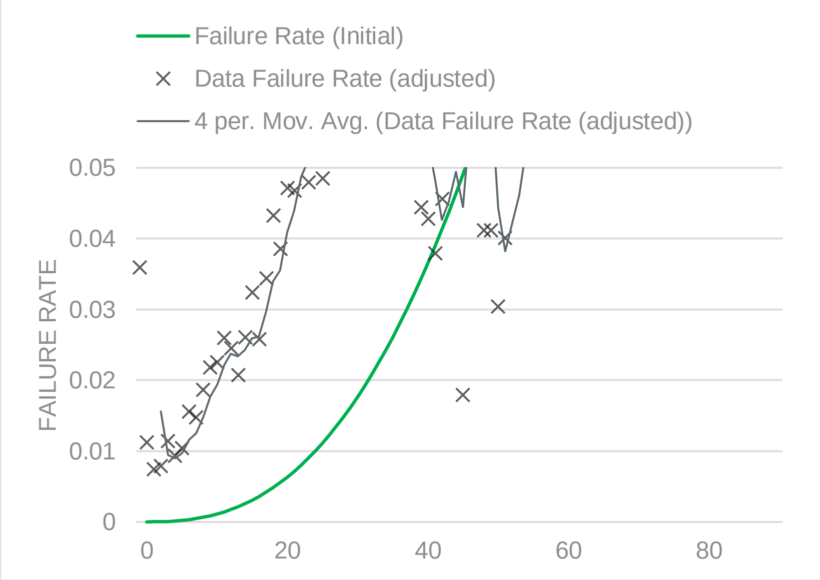


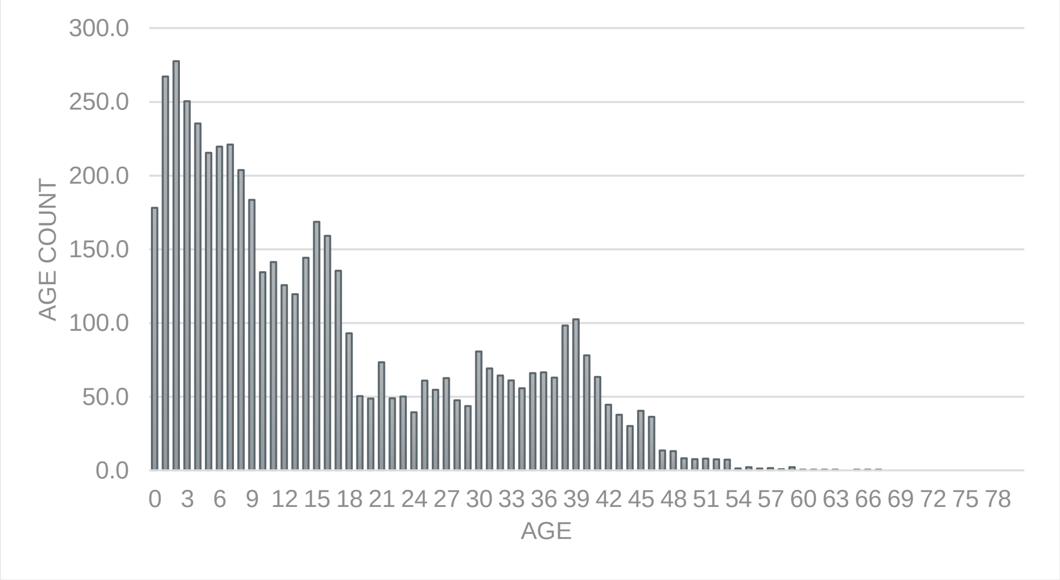


11kV Cable (Generic)

Parameters	Initial	Adjusted
Alpha - (Default = "3.6")	3.6	3.6
Beta	51.6	51.6
Shift - (Default = "0")	0	0

Input Data Statistics	Value
Mean failure age	20
Population size	5184
Avg number of historical annual failures	47.7

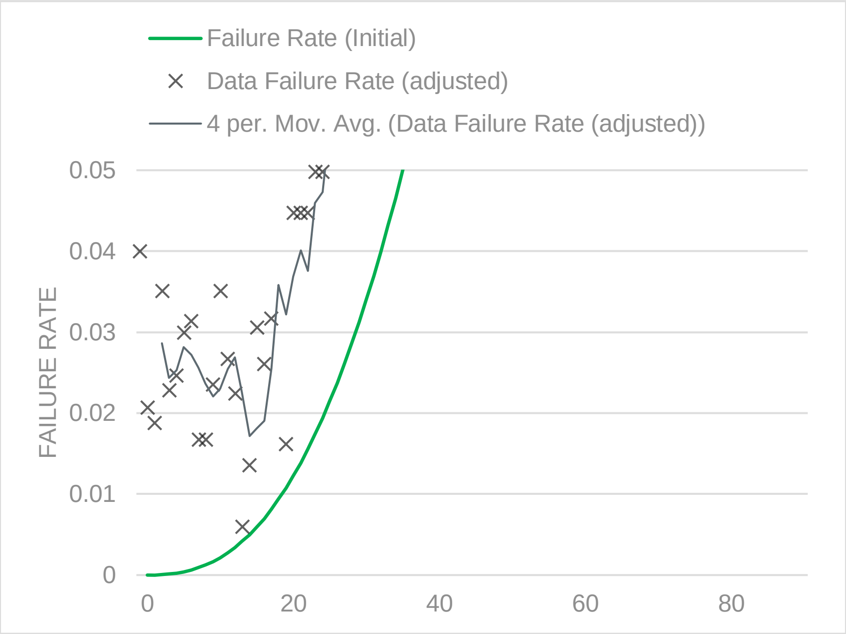


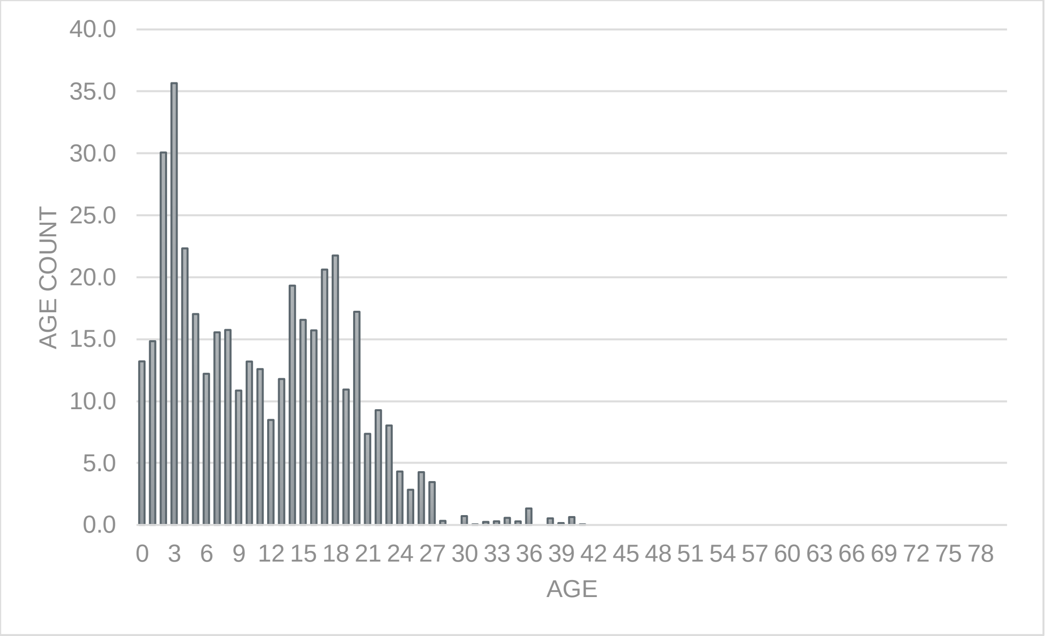


22kV Cable (Generic)

Parameters	Initial	Adjusted
Alpha - (Default = "3.6")	3.6	3.6
Beta	42.9	42.9
Shift - (Default = "0")	0	0

Input Data Statistics	Value
Mean failure age	8
Population size	400
Avg number of historical annual failures	2.2

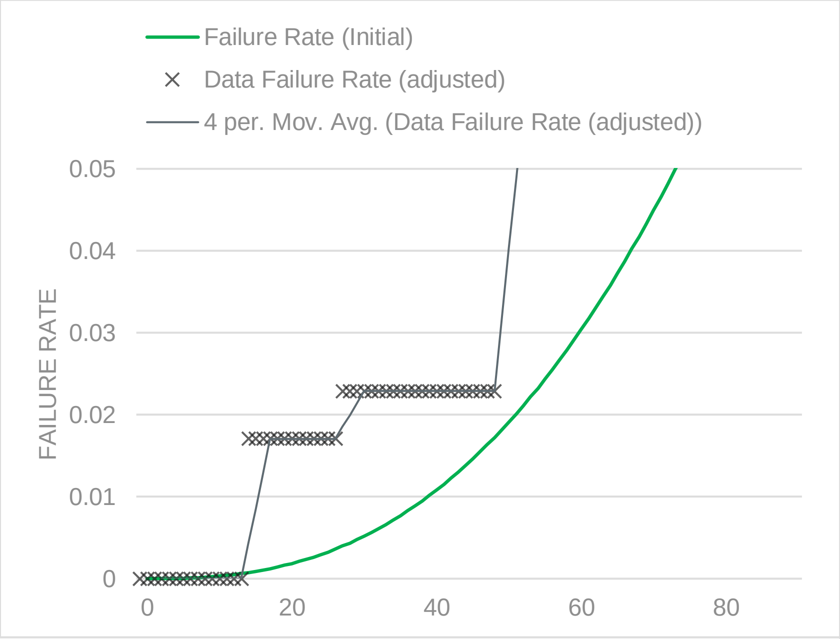


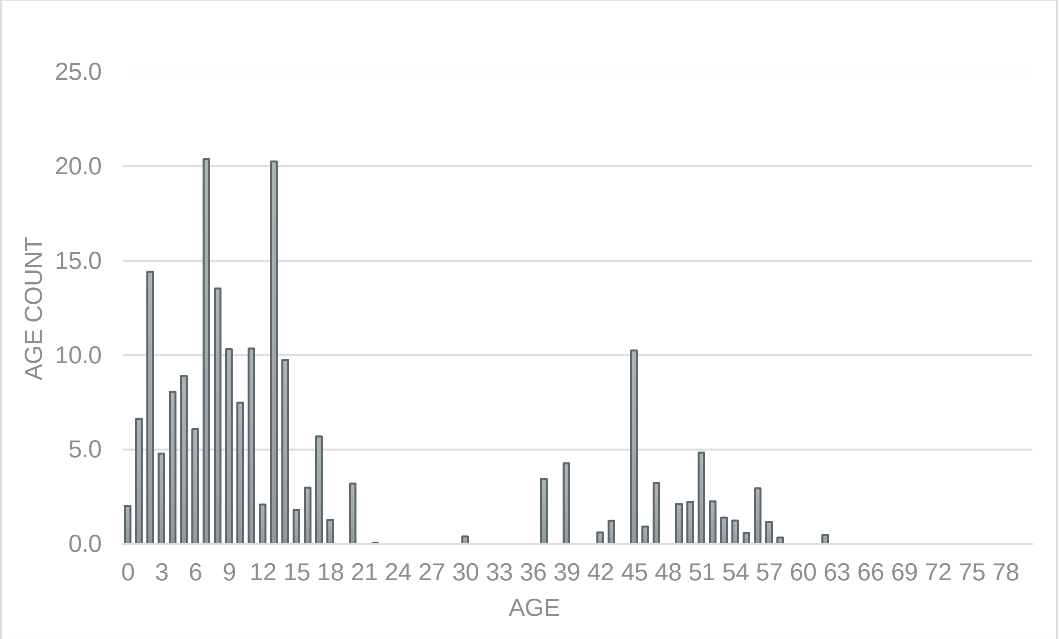


33kV Cable (Generic)

Parameters	Initial	Adjusted
Alpha - (Default = "3.6")	3.6	3.6
Beta	72.6	72.6
Shift - (Default = "0")	0	0

Input Data Statistics	Value
Mean failure age	31
Population size	204
Avg number of historical annual failures	0.8

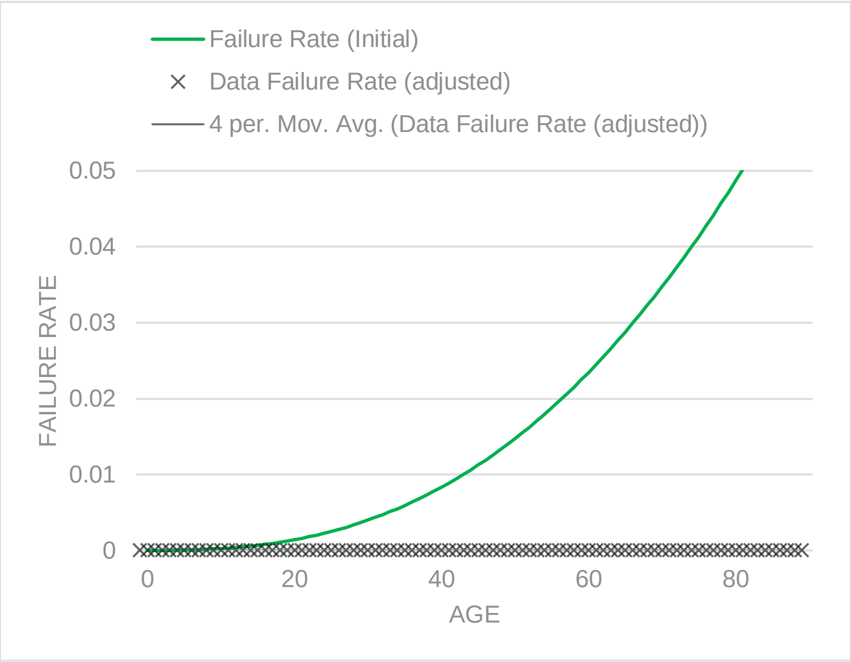


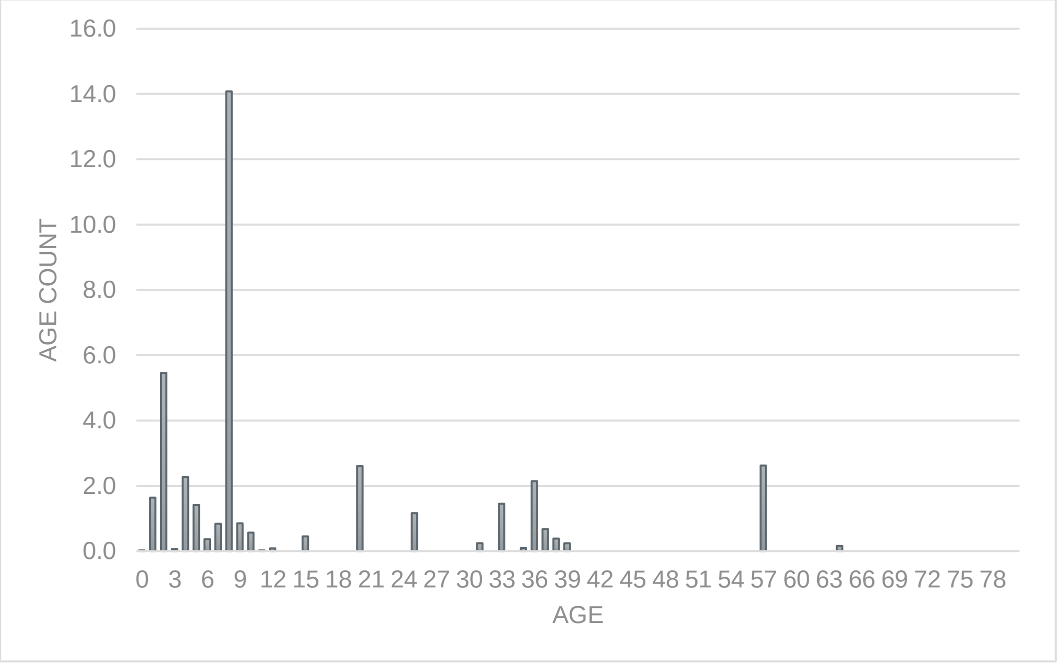


66kV Cable (Generic)

Parameters	Initial	Adjusted
Alpha - (Default = "3.6")	3.6	3.6
Beta	78.1	78.1
Shift - (Default = "0")	0	0

Input Data Statistics	Value
Mean failure age	#DIV/0!
Population size	40
Avg number of historical annual failures	0.1

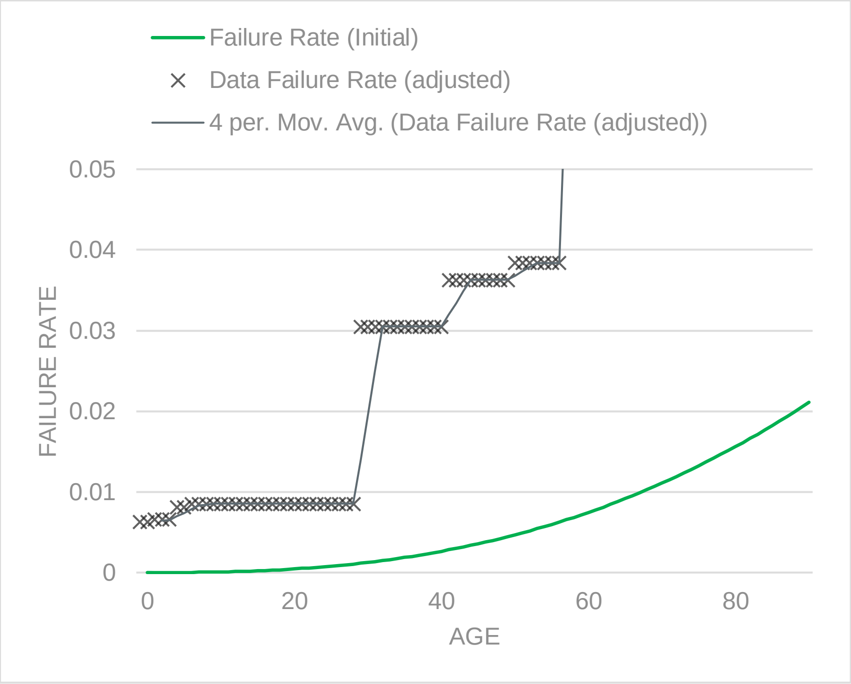


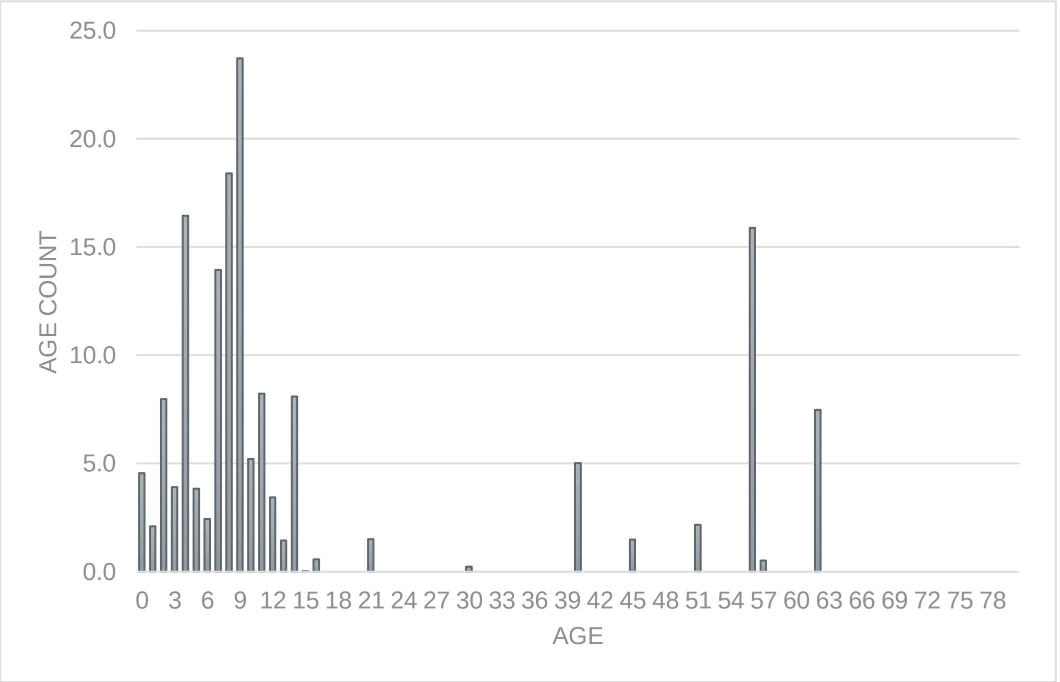


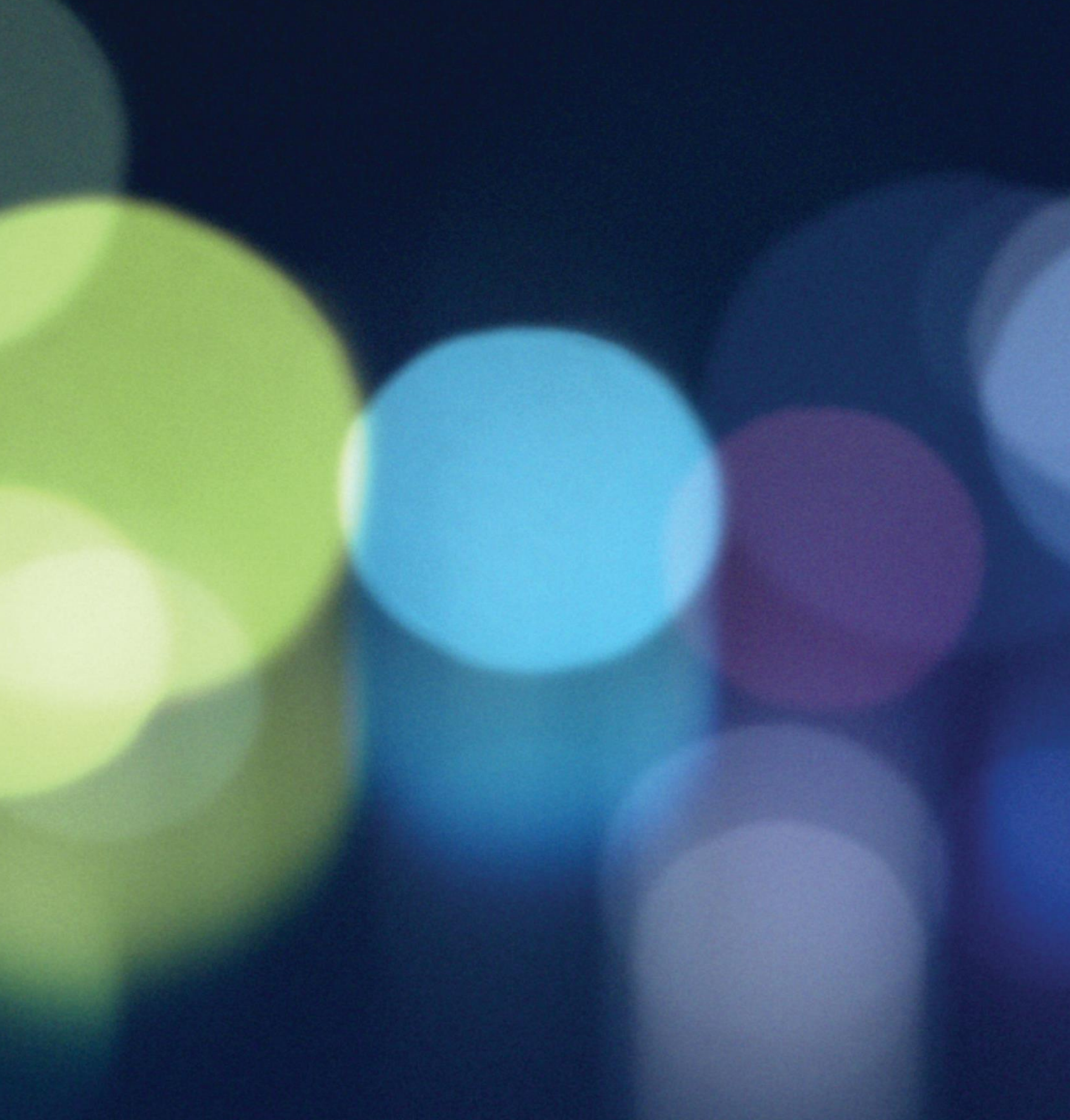
132kV Cable (Generic)

Parameters	Initial	Adjusted
Alpha - (Default = "3.6")	3.6	3.6
Beta	107.6	107.6
Shift - (Default = "0")	0	0

Input Data Statistics	Value
Mean failure age	24
Population size	159
Avg number of historical annual failures	0.2







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