HV Aerial Bundled Cable Strategic Direction Analysis Plan

Document No. UE PL 2053

STRATEGIC DIRECTION ANALYSIS PLAN

This document outlines the strategic plan for High Voltage Aerial Bundled Cable assets on the United Energy network.

REPEX Road Map

1. Asset Replacement – Modelled

a. 6 modelled asset categories

2. Asset Replacement – Modelled & Unmodelled

a. Pole top structures + SCADA/protection

3. Other Repex - Unmodelled

a. ZSS Primary Asset Replacement

   (i) CEES - Capacitor Banks + Earth Grid + Neutral Earthing Resistors

   (ii) CEES - Buildings

b. Non VBRC Safety Projects

   (i) Intelligent Secure Substation Asset Management (ISSAM) – UE PL 2401 e.g.CCTV

c. Operational Technology

   (i) OT Safety

   - Service Mains Deterioration Field Works – PJ1385
   - In Meter Capabilities IMC) – PJ1386
   - Light Detection and Ranging (LiDAR) Asset Management – PJ1400
   - OT Security – PJ1500
   - DNSP Intelligent Network Device – PJ5002

   (ii) OT Reliability

   - Distribution Fault Anticipation Data Collection and Analytics (DFADCAA) – PJ1599
   - Fault Location Identification and Application Development – PJ1600

   (iii) OT Other

   - Dynamic Rating Monitoring Control Communication (DRMCC) – PJ1413
   - Test Harness – PJ1398
   - Pilot New and Innovative Technologies – PJ1407

d. Network Reliability Assessment UE PL 2304 – Projects

   (i) Automatic Circuit Re-closers (ACRs) and Remote Control Gas Switches (RCGSs)

   (ii) Fuse Savers

   (iii) Rogue Feeders

   (iv) Clashing

   (v) Animal Proofing

   (vi) Communications Upgrade

e. CEES – Environment

f. CEES – Power Quality Maintained

g. Terminal Station Redevelopment HTS and RTS - UE-DOA-S-17-002 & UEDO-14-003

4. VBRC Projects

a. HV Aerial Bundled Cable Strategic Analysis Plan - UE PL 2053

b. DMA and MTN Zone Substation Rapid Earth Fault Current Limiter (REFCL) Installation

c. Other VBRC projects

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1. PURPOSE

This paper provides the overarching strategy supporting United Energy's (UE's) plan to replace non-metallic screened HV Aerial Bundled Conductor (ABC) with metallic screened HV ABC across its network.

The strategy supports UE's strategies in other areas including bushfire mitigation, network reliability, health and safety and protection of the environment.

This strategy document will form part of the Connectors and Conductors Life Cycle Management Plan UE PL 2007. In addition, the principles captured within this document are derived from and consistent with the overall UE Asset Management Policy and UE Risk Management Framework. This document is also based on good practice guidance from internationally recognised sources, including the Global Forum on Maintenance and Asset Management (GFMAM) and the Institute of Asset Management (IAM). It has been specifically developed to align with key elements of ISO 55000.

This is a "live" document, and will continue to be updated and revised as new information, tools and technology become available.

2. EXECUTIVE SUMMARY

The potential for UE's electricity network assets to start bushfires is a major liability risk for UE and one that requires a suite of controls and risk management to be employed. This strategy paper seeks to guide the appropriate investment in one form of engineered control - replacement of non-metallic screened HV ABC with metallic screened HV ABC to reduce bushfire risk and realise other network benefits.

Non-metallic screened HV ABC has been used since the 1990's and early 2000's. HV ABC was used to replace bare overhead conductors that were susceptible to frequent faults and the risk of subsequent fire ignition in heavily vegetated environments. Replacement with insulated cables offers improved supply reliability and reduced risk of fire ignition.

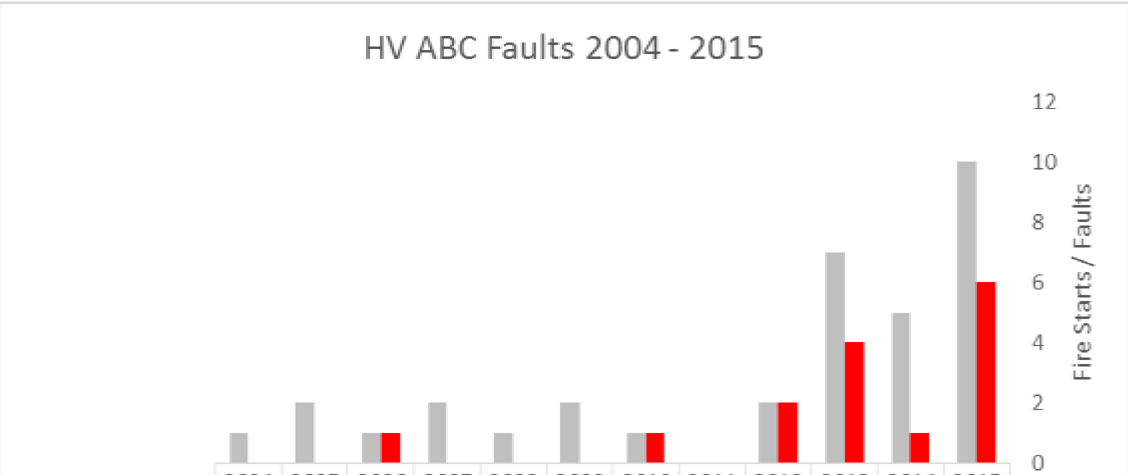
UE has in service approximately 60km of non-metallic screened HV ABC across its network, 50 km in High Bushfire Risk Area (HBRA) and 10 km in Low Bushfire Risk Area (LBRA). These assets are now demonstrating a rapid escalation of failures. From 2012 to 2015, the 22 kV HV ABC failure rate has been trending up rapidly from 2 per annum to 10 per annum and fire starts from 2 per annum to 6 per annum. HV ABC failure has become one of the top ten equipment failure modes on UE's network impacting fire safety and network reliability significantly. HV ABC failures in a HBRA environment result in fire starts with the potential of causing a major bushfire with serious threat to life and property. In addition, UE suffered losses of $3.7M in STPIS from 2012 to 2015 due to HV ABC faults.

In response to this issue UE developed a plan in early 2015 to manage this asset through the proactive replacement of non-metallic screen HV ABC with metallic screened HV ABC over a 10 year period. This program which has already commenced with the replacement of the first 4.5 km almost complete was targeting the worst performing cables based on criteria such as fault history, critical customers, fire starts and age of asset.

UE's plan provided flexibility for continuous improvement with the intention to consider new developments that come to light and modify the proposed replacement program and priorities accordingly.

Recently there has been a sharp escalation in fault frequency and fire starts as shown in figure below. This, and now the availability of Country Fire Authority/Department of Environment, Land, Water & Planning (CFA/DELWP) fire ignition risk areas are considered significant new developments which UE has taken into consideration.

Figure 1: HV ABC Faults 2004 - 2015



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
HV ABC Faults	1	2	1	2	1	2	1	0	2	7	5	10
Fire Starts	0	0	1	0	0	0	1	0	2	4	1	6

As a result UE has refined its HV ABC Strategic Direction Analysis Plan as detailed in this plan which seeks to guide the appropriate investment in one form of engineered control - replacement of non-metallic screened HV ABC with metallic screened HV ABC to reduce bushfire risk and address the escalating failure rate. The refined plan provides for a more aggressive replacement program targeting for total replacement within a five year period and adding CFA/DELWP fire ignition risk areas (see section 3.1.4) to the existing suite of HV ABC prioritization measures which include fault history, consequence of failure and feeder location.

This strategy aims to manage the impacts by a program of achievable targeted replacements to minimise customer and financial impacts to the business. The five year program of HV ABC replacements will result in a total expenditure of approximately $30M. This plan does not commit or authorize capital expenditure as this will be subject to an annual business case approval.

2.1 THE ISSUE

HV ABC has become one of the top two worst types of equipment failure on the network due to significant increase both in event frequency and severity. This trend has been increasing in recent years.

UE has experienced 34 failures over the period 2004 - 2015 and 22 of these have occurred in the last three years. HV ABC failures are generally explosive in nature, ejecting molten metal from the point in the cable that ruptures sometimes resulting in fire starts and the potential for bushfires in HBRA. This is a very undesirable consequence. Due to the fire start risk in HBRA regions, HV ABC was installed to mitigate the risk with the exclusive type being non-metallic screened HV ABC. Unfortunately, this cable is now shown to have poor service history and high failure rate resulting in an increased fire risk, as proven by the fire start statistics.

Since 2012 HV ABC failure has resulted in 13 fire starts in HBRA area. Financially, since 2012, HV ABC failures have contributed a total STPIS loss of $3.7M.

In light of the above, there is an urgency to address the HV ABC issue in order to mitigate bushfire risk especially in HBRA (where the majority of HV ABC installations are found) and maintain network reliability.

2.2 THE STRATEGY NEEDED

The HV ABC issue presented above is not limited to UE's network. Other Australian and overseas utilities have experienced similar failures on their 22 kV HV ABC. AusNet Services, in particular, have installed large quantities of HV ABC in HBRA areas and have experienced a similar mode of failure. The ongoing use of HV ABC in HBRA is, however, required as an alternative to bare overhead lines in heavily vegetated areas.

A common approach adopted by industry (and UE's preferred) is replacing non-metallic screened HV ABC with metallic screened HV ABC.

It is therefore recommended that:

- UE ceases the use of the current non-metallic screened HV ABC for new or replacement work with the exception of joint repair on faulty lines where a like cable is necessary and restoration of supply is priority. This recommendation has been implemented.
- UE develop and adopt a metallic screened HV ABC system similar to industry. Metallic screened HV ABC installation will not suffer from the mode of failure plagued by the non-metallic version and has been used and proven successful over time in other utilities such as Energex and AusNet Services. This recommendation has been implemented
- UE develop replacement projects for HV ABC replacement. It is proposed to implement a 5 year program to replace all HV ABC with an estimated total cost of $30M. Replacement prioritization will be based on CFA/DELWP fire ignition rankings, fault history, consequence of failure, type of cable and feeder location. The 5 year replacement program will form part of UE's submission to the AER for the period 2016-2020.

2.3 WORK DONE TO DATE

UE has presented a status report (reproduced in Appendix B for reference) and undertaken a detailed investigation into the causes of non-metallic screened HV ABC failures. In summary, HV ABC failures that occurred on the UE network over the last several years were caused by electrical discharges between the earthed catenary supporting the cable and the semi conductive core material around each phase leading to erosion of the semi conductive screen, creation of high electric stress points on the insulation and ultimately insulation failure.

UE has also trialled a number of detection methods to attempt to identify locations where the arcing is occurring, prior to asset failure. These include:

- Infra-red surveys on selected backbone sections
- Ultrasonic acoustic inspections
- PD Hawk Survey by EA technology
- Visual inspections

To date, no method of detection has yielded successful outcomes which result in adoption of a viable condition assessment tool.

The following summarizes progress to date on the HV ABC replacement program:

1. Stage 1 of DMA 15/23 feeders replacing 4.5 km due for completion January 2016
2. Stage 2 of DMA 15 feeder replacing 3.64 km approved and estimated for completion June 2016
3. Stage 3 of DMA 23 feeder replacing 4.16 km approved and estimated for completion September 2016
4. A further three projects on feeders DMA 23, DC1 & FSH 34 totalling approximately 0.6 km at approval stage with estimated completion November 2016

2.4 BUDGET SUMMARY

The recent escalation in fault frequency, the ensuing fire starts and the availability of CFA/DELWP fire ignition areas have been considered to develop a replacement program which not only looks at fault history but prioritises replacement programs based on fire consequence as defined in the CFA/DELWP fire ignition areas, 185mm2 over 35mm2 conductor and 22kV over 11kV areas.

The proposed works program is shown in table 1 below which outlines the replacement of non-metallic screened HV ABC up to FY 2020/21 which will see all HV ABC completely replaced.

The targeted feeder replacements for the HV ABC replacement program (over the next five years) are shown in Appendix C covering CFA areas 3, 4 and 5. Areas 6 and 7 are lower risk in the CFA/DELWP fire ignition rankings and proposed replacement programs for these areas will be developed in due course

Table 1: Proposed Replacement Program

Project	Length Replaced	Feeder	Estimated Completion	Major Risk Area	Cost
Stage 1 **FY 2014/15**	4.48km	DMA15 DMA 23	January 2016	4 / 6	$2.2M
Stage 2 **FY 2015/16**	3.64km	DMA15	June 2016	6	$1.82M
Stage 3 **FY 2016/17**	4.16km	DMA23	September 2016	3 / 4	$2.08M

Project	Length Replaced	Feeder	Estimated Completion	Major Risk Area	Cost
ABC minor replacement 1 **FY 2016/17**	259m	DMA23	Before November 2016 – Exact time pending material and service provider availability	3	$129.5K
ABC minor replacement 2 **FY 2016/17**	166.5m	DC1	Before November 2016 – Exact time pending material and service provider availability	3	$83.2K
ABC minor replacement 3 FY 2016/17	181.5m	FSH34	Before end of November 2016	3	$90.7K
ABC minor replacement 4 **FY 2016/17**	44.3m	FSH21	Before end of November 2016	3	$22.1K
Stage 4 **FY 2016/17**	1.56km	MTN32	Before end of November 2016	4	$780K
Stage 5 **FY 2016/17**	644m	HGS22	Before end of November 2016	4	$322K
ABC minor replacement 5 **FY 2016/17**	266m	DMA24	Before end of November 2016	4	$133K
Stage 6 **FY 2016/17**	900m	DMA23	Before end of November 2016	4	$450K
ABC minor replacement 6 **FY 2016/17**	498.5m	DMA15		5	$249.2K
Stage 7 **FY 2016/17**	755.6m	DMA15		5	$377.8K
Stage 8 **FY 2016/17**	616m	HGS33		5	$308K
Stage 9 **FY 2017/18**	2.79km	DMA23		5	$1.4M
Stage 10 **FY 2017/18**	3.36km	DMA15		5	$1.68M

Project	Length Replaced	Feeder	Estimated Completion	Major Risk Area	Cost
Stage 11 **FY 2017/18**	2.29km	RBD12		5	$1.14M
Stage 12 **FY 2017/18**	3.82km	RBD12		5	$1.9M
Stage 13 **FY 2017/18**	763m	RBD12		5	$381K
ABC minor replacement 7 **FY 2017/18**	144m	STO22		5	$72K
Stage 14 **FY 2018/19**	1.1km	MTN32		5	$550K
Stage 15 **FY 2018/19**	1.67km	MTN32		5	$835K
Stage 16 **FY 2018/19**	2.57km	MTN32		5	$1.28M
ABC minor replacement 8 **FY 2018/19**	433m	MTN32		5	$216K
The following areas of replacement have not yet been divided into specific projects					
FY 2018/19	5km	-		6	$2.5M
FY 2019/20	11.75km	-		6	$5.87M
FY 2020/21	5.14km	-		7	$2.57M

Note: HV ABC replacement taken as $500/m and based on actual costs of Stage1.

2.5 JUSTIFICATION

The costs and benefits arising from the replacement of non-metallic screened HV ABC have been assessed in this document. Benefits have been quantified on a financial basis including risk and losses from bushfires, STPIS losses, F-factor losses and ongoing costs of repairing existing HV ABC.

Replacements of non-metallic screened HV ABC with metallic screened HV ABC offers an affordable, practical and industry accepted way of reducing bushfire and health and safety risks, complying with regulatory requirements, and maintaining network reliability

3. NEEDS and ANALYSIS

3.1 CONTEXT (CURRENT STATE)

3.1.1. Bushfire Mitigation

Rural and semi-rural Victoria has always been threatened by bushfire. Victoria is one of the most fire-prone regions in the world with a long history of bushfires. All members of the community, business and government organisations must take reasonable steps to prepare for bushfire and must put controls in place to limit the risk of fires starting. On extreme bushfire risk days (days of total fire ban and code red days) when temperatures and wind speeds soar, fuel is dry and humidity is low, the community must implement additional strategies to limit risk.

Powerlines are thought to start a relatively small proportion of the total number of bushfires (around 1 to 4%). In Victoria however powerline faults are responsible for causing a disproportionate number of the most serious catastrophic bushfires resulting in major loss of life and property. For example powerline faults are reported as starting the following number of major fires:

- 9 of 16 major fires (56%) on 12th February 1977.
- 4 of 8 major fires (50%) on 16th February 1983 (Ash Wednesday).
- 5 of 15 major fires (33%) on 7th February 2009 (Black Saturday).

The most serious recent fires on Black Saturday have deeply scarred the Victorian people and the landscape despite the community's high awareness and experience responding to the fires which occur annually. Of the 173 people that lost their lives as a result of the fires on Black Saturday, 121 lost their lives as a result of fires started from powerline faults. The fires also destroyed over 2000 dwellings with an estimated economic loss exceeding $4 billion.

Following both the 1977 and 1983 bushfires, changes were made to reduce the risk of powerline faults starting bushfires. UE has a bushfire mitigation plan that incorporates several strategies. Chief amongst these include pruning of trees near powerlines, replacement of deteriorating assets, replacement of bare overhead lines with underground cable and insulated aerial bundled cable.

Despite all of UE's existing bushfire mitigation programs UE experiences fire starts due to HV ABC. Population growth at the rural-urban interface, ageing electricity assets and climate change which will increase the number of days of extreme hot and dry conditions are all expected to exacerbate the problem into the future unless UE continues to innovate and adopt new methods to manage the risk.

The fires on Black Saturday have demonstrated that more work can be done by all Victorian distribution businesses. Although none of the Black Saturday fires were started from UE assets, and the UE network does not supply electricity in the highest fire risk areas of the state, it does not mean that an incident on the UE network is not capable of starting a major fire in future. UE must strive for continuous improvement. Business as Usual (BAU) can no longer be considered tolerable if there are new ways that might reduce risk that UE is not adopting.

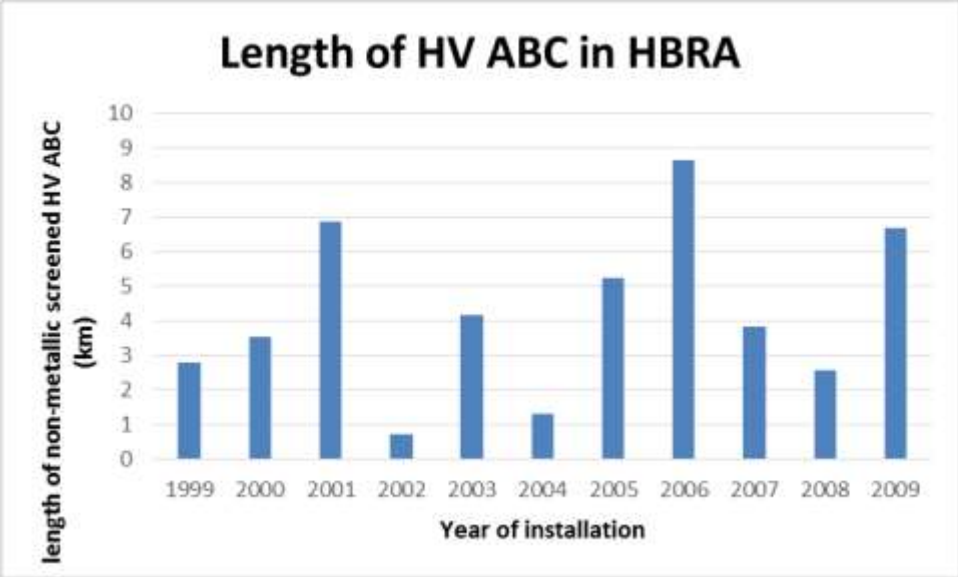
3.1.2. HV ABC Use, Age Profile & Service history

XLPE insulated non-metallic screened HV ABC was introduced into the UE's network by SECV in the early 1990's. It is predominantly used in the HBRA, especially on the Mornington Peninsula in UE's area, to address the noncompliance issues with vegetation overhanging of HV and reduce the ongoing vegetation management expenditure, as well as improve the reliability of supply.

UE has in service approximately 60km of non-metallic screened HV ABC across its network, 50 km in HBRA and 10 km in LBRA. The majority of UE's non-metallic screened HV ABC was installed during the 1990's and 2000's. The age profile of the bulk of the HV ABC installed over the period from 1999 to 2009 when UE rolled out most of the HV ABC in HBRA is illustrated in Figure 1 below.

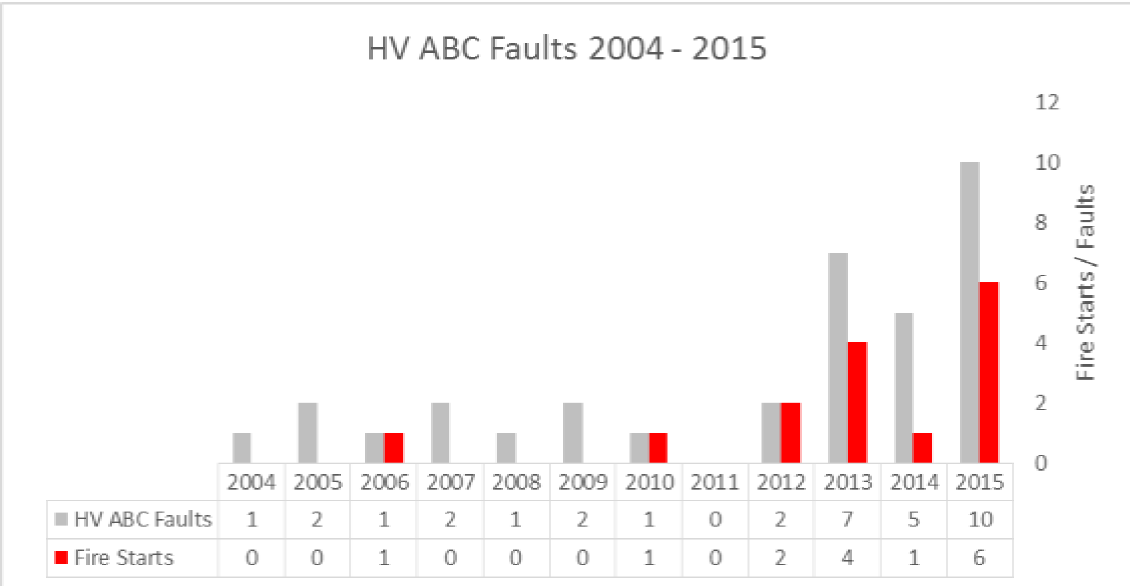
We are currently conducting an audit to confirm our data on the age and lengths of HV ABC on our network.

Figure 2: HV ABC Age Profile



The performance of HV ABC in the UE network area saw a step increase in cable failures since 2013 as shown in figure 2, with an accompanying increase in the number of fire related incidents also shown in figure 2.

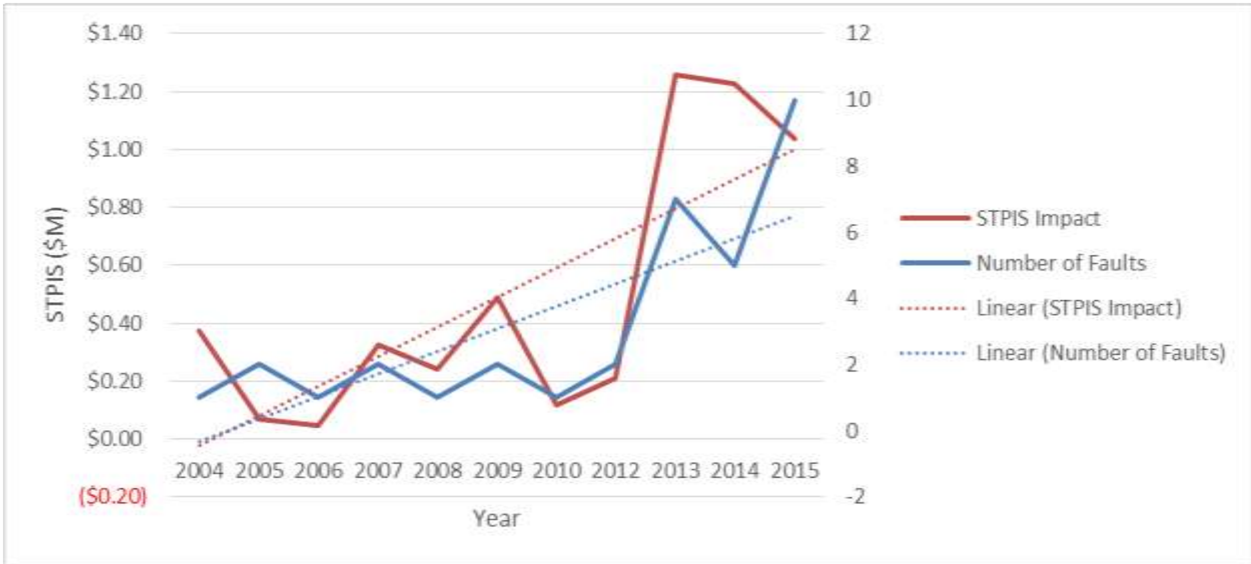
Figure 3 : HV ABC Faults & Fire Starts 2004-2015



The performance of the HV ABC was reviewed well before 2013, as a result of some faults. However, in the past three years from 2012 to 2015, the HV ABC failure rate has been trending up rapidly from 2 per annum in 2012 to 10 per annum in 2015, becoming one of the top ten equipment failure modes on UE's network, and impacting network reliability significantly. UE suffered losses of $3.7M in STPIS in the last four years due to HV ABC faults.

The graph below shows that over the past eleven years, the number of HV ABC events has been increasing on average by 55% per year, while the STPIS impact has been rising by $90k per annum.

Figure 4: HV ABC Faults 2004-2015



Apart from the adverse impact on STPIS, HV ABC failures also impose a risk of starting a fire in HBRA. Fifteen fires have been started by HV ABC faults over the past eleven years.

Other Distribution companies within Victoria and in other states are also experiencing increasing failure rates, with some already having replacement programs underway.

3.1.3. Root Cause for HV ABC Failure

Investigations done by external and internal experts reveal that the root cause for HV ABC failures which have occurred on UE's network, is the ongoing electrical discharge between the earthed catenary wire and the semi conductive core material around each phase. This leads to erosion of the semi conductive screen, creating high electric stress points on the insulation and ultimately insulation failure.

Discharge occurs when a potential (voltage) difference occurs between the outer layer of semi conductive material and the earthed catenary wire. Two factors that could contribute to this are:

- Absence of good electrical contact throughout the entire length of a phase core
- Damaged semi conductive insulation screened due to rubbing against the catenary and poor workmanship by dragging the cable along the ground, or damaged by external impact i.e. branches or birds puncturing sheath.

A metallic screened HV ABC will not suffer from the modes of failures which plague the non-metallic screened version. In screened cables the semi conductive insulation screen is always held at ground potential and is protected by a copper screen outside of it, additionally the tough HDPE sheath will provide increased mechanical protection for the semi conductive screen away from catenary wire rubbing and other external damage.

Key differences over non-metallic screened HV ABC currently used are:

- A tough HDPE outer sheath
- A copper wire metallic screened of 2 kA rating
- The support wire is 19/2.0 mm galvanized steel
- Typically 25 - 40% heavier
- Approximately 7% increase in overall cable diameter

The difference between the HV ABC previously used by UE and the adopted metallic screened HV ABC is demonstrated as below.

Figure 5: Non-Metallic Screened HV ABC

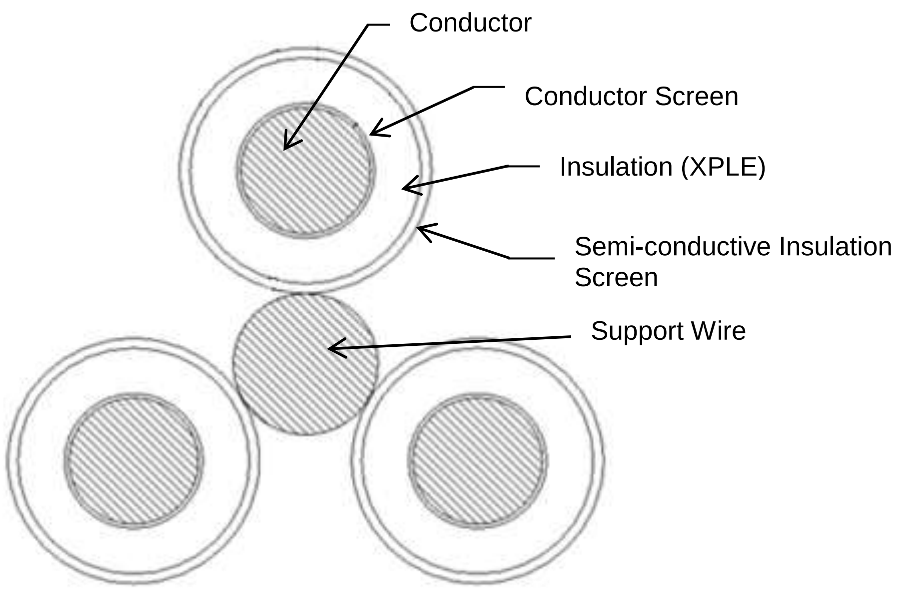
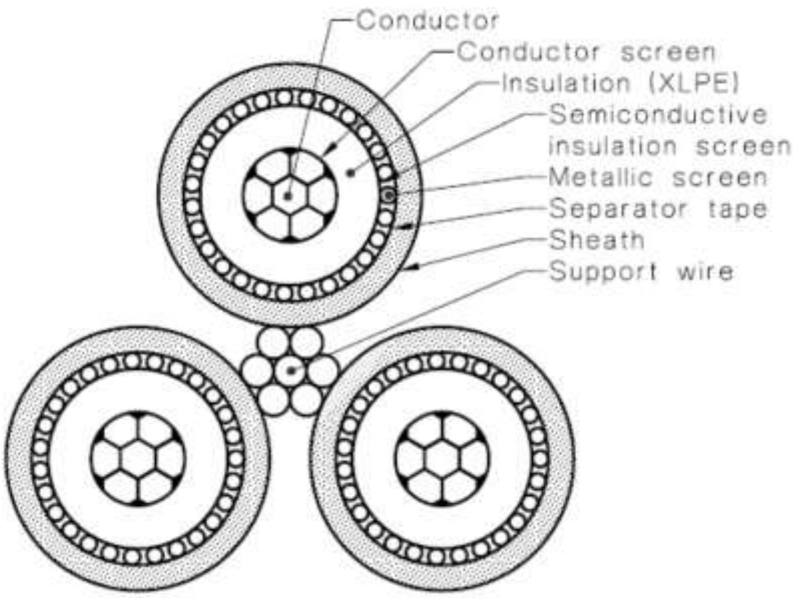


Figure 6: Metallic Screened HV ABC



3.1.4. CFA Ignition Threat Risk Ranking

The CFA/DELWP ignition threat risk rating uses the phoenix fire model to determine the number of residences impacted in the event of a fire start in any 1km x 1km area throughout the whole UE network under conditions equivalent to black Saturday. The ranking system is from 1 to 7 with one being the highest risk. UE's highest risk rating is rating 3.

Table 2 below shows the rankings against the affected residences. The colour coding is used to highlight the risk category of HV ABC programmed for replacement in the UE network area as shown in Appendix C.

Table 2 CFA/DELWP Fire Risk Area

Risk	Residences Impacted	Colour Code
3	900 - 300	
4	299 - 100	
5	99 – 30	
6	29 – 10	
7	< 10	

3.1.5. Analysis of Faults

An analysis of HV ABC faults for the period 2004 – 2015 was conducted which highlighted the recently increased rate of HV ABC failures and associated fire starts across the UE network. During this period, 34 HV ABC failures were recorded with 15 out of these 34 events resulting in small patch fires. In line with CFA / DELWP fire risk areas the lengths of HV ABC and the associated number of faults for each specific area was determined and is outlined in table 3 below. The table shows that there is a proportionally small amount of HV ABC (10.35km or 17% of total asset base) in fire risk rating 3 and 4 areas. Areas 3 and 4 account for 29% of total faults.

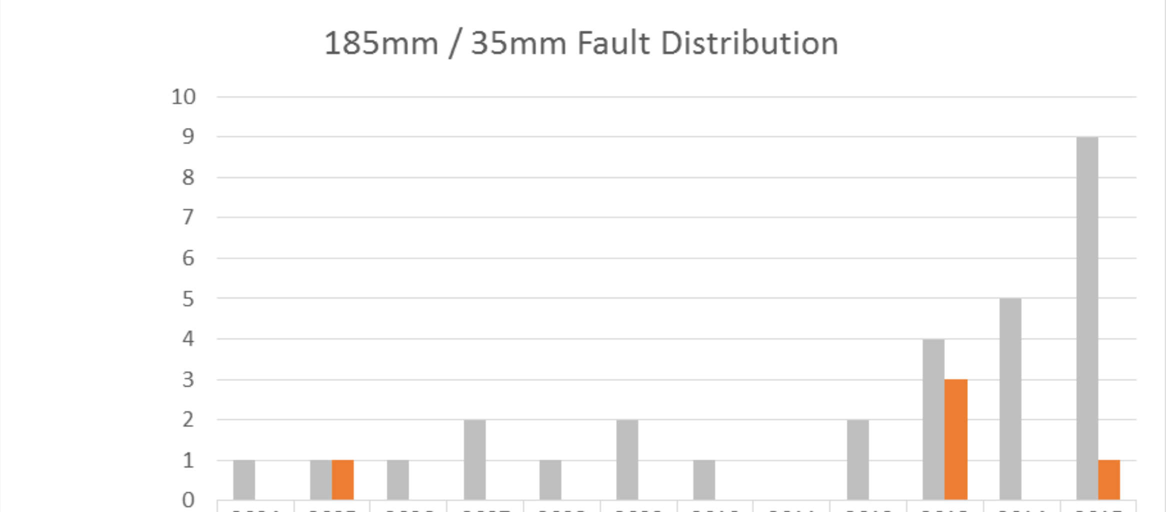
Table 3 Faults and Length of HV ABC by CFA risk areas

	Risk 3	Risk 4	Risk 5	Risk 6	Risk 7
Length (km)	2.72km	7.63km	21km	23.45km	5.14km
No. Of Faults	1	9	10	11	3
Faults Per km	0.37	1.36	0.48	0.46	0.58

3.1.5.1 185 mm2/35 mm2 Split

As can be seen in figure 6 below the number of faults that occurred on 185mm2 HV ABC far outweighs those that occurred on the 35mm2 HV ABC. This is disproportionate compared to the 185mm2 / 35mm2 asset split of HV ABC throughout the network which can be observed to be closer to a 50/50 split, specifically 56% 185mm2 and 44% 35mm2. This evidence suggests that there is more likelihood of a HV ABC failure on a 185mm2 section of HV ABC over 35mm2 HV ABC which has had a contributing factor to the prioritisation of HV ABC replacement across the UE network

Figure 7 185mm / 35 mm fault distribution



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
185mm Faults	1	1	1	2	1	2	1	0	2	4	5	9
35mm Faults	0	1	0	0	0	0	0	0	0	3	0	1

3.1.5.2 22 kV/11 kV Split

Currently there is approximately 97% 22kV HV ABC and only 3% 11kV HV ABC on the UE network. Analysis has shown that 100% of all HV ABC faults have occurred on the 22kV network. Due to this 22kV HV ABC replacement was prioritised in the replacement strategy going forward.

3.1.6. Regulation

UE is governed by a range of legislative and regulatory regimes designed to ensure the distribution network is effectively and efficiently planned, constructed, operated and maintained such that it is safe, reliable, compliant with standards, so that consumers receive access on reasonable terms and to ensure prices charged are fair and reasonable. These obligations are overseen by:

- The Australian Energy Regulator (AER).
- Energy Safe Victoria (ESV).
- Essential Services Commission (ESC).
- The Australian Energy Market Operator (AEMO).
- The Australian Energy Market Commission (AEMC).
- Energy and Water Ombudsman Victoria (EWOV).

Following the Black Saturday bushfires on 7th February 2009, The Electricity Safety Act 1998 was amended (Electricity Safety Amendment (Bushfire Mitigation) Bill 2013) to impose additional obligations on Victorian distribution businesses to undertake works that will mitigate the risk of powerline faults starting bushfires. ESV was also given additional obligations to audit the programs implemented by distributors. The Act more explicitly requires the electricity distributors to minimise as low as reasonably practicable the bushfire danger arising from above ground supply networks that are in a hazardous bushfire risk area.

BAU can no longer be considered tolerable where changes to regulation require UE to find new ways of reducing the risk of powerlines starting bushfires.

3.1.7. United Energy Vision

UE has a vision:

"We will create The Intelligent Utility by focussing on industry leadership and innovation and working in the best interests of all our stakeholders."

Maximise long term value by aligning the interests of our business and our stakeholders, through delivering:

- Good customer service.
- An efficient cost structure.
- A good corporate reputation.

BAU behaviour will not deliver upon the UE vision which requires innovation and change.

3.1.8. Financial Need

Unless UE implements all reasonably practical measures to prevent network faults starting bushfires there will exist a probable risk that a fault on the UE network will start a serious bushfire and that UE will face prosecution and significant financial loss. For example the 2009 Black Saturday bushfires destroyed over 2000 dwellings with an estimated economic loss of more than $4 billion. The distribution businesses that were responsible for starting these fires paid several hundred million dollars in compensation.

UE is penalised via the f-factor scheme at a rate of $25k per fire start (minor or major) governed by the AER. There is a direct financial incentive to prevent fires starting from faults on the electricity distribution network.

BAU behaviour, absent of a strategy to address the HV ABC issues, will result in moderate to high financial loss and is not recommended.

3.1.9. Risk Analysis

Risks under BAU are summarised below in Table 4. Refer to section 7.0 for an in depth analysis of risk.

Table 4: Risk Matrix under BAU

Hazard	Consequence	Likelihood	Risk
HV ABC failures resulting in a bushfire causing loss of public and private assets, loss of life and/or trauma, loss of livestock, pets and native animals, damage to the environment.	Catastrophic	Rare	Very High
Prosecution from bushfires started from HV ABC failures and payment of compensation	Catastrophic	Exceptional	High
Increased insurance premiums for public liability because of the bushfire risk associated with HV ABC failure	Moderate	Likely	High
F-factor scheme penalties	Minor	Likely	Medium
Electric shock or burns to members of the general public from a HV ABC failure.	Major	Rare	High
Network HV ABC fault injuring employees and contractors	Major	Rare	High

3.2 STRATEGIC OBJECTIVES & ASSESSMENT CRITERIA

3.2.1. General Strategic Objectives

UE is committed to maximising the long-term value of our stakeholders' investment in a legally and environmentally compliant, safe and sustainable manner through a structured framework for stewardship of the network over its total life cycle. The following key asset management objectives have been set to ensure that corporate requirements are met:

- Employ good industry asset management practice to prudently manage the assets over the total life cycle, without compromising the health and safety of our employees, stakeholders or the public.
- Ensure compliance with applicable laws, rules and regulations.
- Undertake all activities and execute our obligations in adherence to good industry practice.
- Be prudent and efficient in the deployment of capital to optimise the performance of the business in the long term for the benefit of all stakeholders.
- Prudently manage reasonably foreseeable and credible hazards and risks to ALARP by maintaining a robust and transparent framework to ensure a systematic and strategic approach for the continual identification, management and mitigation of risk.
- Build our reputation with customers and key stakeholders by striving for innovation, reliability, safety and excellent customer service in the face of increasing customer and community expectations.
- Undertake continuous improvement, through constant and timely review of asset management practices.
- Engage in all relevant industry issues to ensure that the business, its stakeholders and customers positions are well understood and effectively represented to deliver superior outcomes.

More specific objectives relating to this plan are contained below. These criteria shall be used to evaluate the various options available that satisfy the need.

3.2.2. Specific Strategic Objectives

In this strategy paper, UE is aiming to achieve the following:

- To improve the safety of its distribution network, i.e. reduce the risk of electric shock, electric burns and loss of life and injury from bushfires started from electrical fires.
- To minimise the impact of the distribution network on the natural environment and private and public property.
- To comply with all legal and moral obligations to minimise the above risks to as low as reasonably practicable.
- To minimise financial penalties under the f-factor scheme and STPIS.
- To achieve the above objectives without reducing network supply reliability to customers and where possible to improve network supply reliability.
- To achieve the above objectives using innovation and leadership to work intelligently in the best interests of all our stakeholders.
- To achieve the above objectives in a fiscally responsible way without dramatic increases in network expenditure that increase network tariffs which would not be supported by the majority of UE's customers.

3.2.3. Assessment Criteria

This section highlights the specific criteria used to assess the options available to achieve the business objectives.

Table 5: Assessment Criteria for HV ABC Replacement

Objective	Assessment Criteria
Health and safety	In accordance with UE's policy, health and safety risks and decisions to implement controls shall be assessed using a risk assessment. Where a risk exists and reasonable practicable controls are available to reduce or eliminate such risks then UE shall adopt the control.
Environment	UE shall assess environmental risks using a risk assessment (same as health and safety).
Protection of public and private property	Risks associated with the loss of public and private property will be evaluated on a financial basis by estimating the value of the property at risk and multiplying by the probability of loss to determine the expected loss. The expected loss will be compared against the cost of implementing control options and where the cost of the control is lower than the expected loss such controls should be implemented.
Network reliability	Network reliability shall be valued based on the STPIS and where options exist to improve reliability with net financial gain such options should be implemented.
Fire starts	The direct financial cost to UE from fires started from UE assets shall be based on the f-factor rate of $25k per fire.
Maximise financial return and security	All business risks are to be identified, quantified and minimised where economic.
Innovation	Where options exist for problems that require the trial of new technology or unproven methods UE shall downplay the risks associated with start-up costs and potential failure and shall focus on the potential upside. This will ensure UE remains innovative. Nonetheless the selected option(s) shall need to provide the best economic return even if optimistic assumptions are made in favour of the innovative option.
Technology availability, maturity and commercial risk	The robustness and maturity of new technology shall be assessed when making a decision to ensure UE selects solutions which will perform reliably and provide value over the full life cycle. Commercial conditions and risk shall also be a consideration when selecting a solution which is dependent upon particular vendors.
Financially economic	All inaction and proposed options to address risks shall be assessed using a discounted cash flow analysis. The final decision to implement options shall consider economic drivers but shall also consider minimisation of health, safety and environmental risk in accordance with the risk assessment.

4. OPTION EVALUATION

4.1 OPTIONS IDENTIFICATION

Six options are considered for the management of HV ABC issues these being;

- Business as usual (BAU) i.e. continuing with the status quo
- Proactive detection prior to damage and failure and replacement of associated sections
- Application of a Covered Conductor System
- Application of the Hendrix Cable System
- Replacing HV ABC with underground HV Cable
- Replacing HV ABC with metallic screened HV ABC

4.1.1. Business as Usual (BAU)

This option will involve only repairing failed HV ABC without any proactive programs of replacement.

This does not address the key issue of the safety hazard that is posed by the conductor type and its failure mode. It is not expected to address the increasing failures and fire start risk. In addition, the time required to find and repair the fault(s) will mean increasing contributions to SAIDI and costs through STPIS. UE will be knowingly leaving an asset with a known type issue with an associate high risk failure mode on the network.

This option is not recommended however it is considered as the “Status Quo” option in the economic evaluation.

4.1.2. Proactive Detection prior to Damage and Failure and Replacement of associated Sections

This option involves developing an approach to detect arcing prior to significant damage to the HV ABC and enabling replacement prior to failure. However, as discussed in Section 2.3, UE has trialled a number of detection methods in an attempt to identify locations where arcing has occurred. Unfortunately, no method of detection has been consistently successful.

Since proactive detection has not been successful, only reactive detection (identifying tracking on the sheath or post failure) is possible. As such, this option is not recommended and will not be subjected to any feasibility and financial analysis.

4.1.3. Covered Conductor System

Covered conductor is basically non screened cable with XLPE insulation supported on insulators. The Australian Strategic Technology Program (ASTP) undertook a survey of Australian utilities, manufacturers and safety regulators and produced a report on the issues influencing the take up of covered conductor systems in Australia. The key findings were:

- There are no performance based Australian Standards covering the components and line hardware for covered conductor systems
- There is a lack of in depth knowledge of covered conductor systems. Many utilities consider covered conductor as not a “mature system”
- A significant effort would be required to develop a complete covered conductor system
- As this is not a screened cable prolonged contact with vegetation may affect performance

To address some of these issues the Powerline Bushfire Safety Program is commissioning an R&D project with the aim to develop a covered conductor solution that could be used to replace bare open wire construction in HBRA.

This option is not recommended.

4.1.4. Hendrix Cable System

This system has tough covered conductors separated by plastic spacers spaced every 9m hung off a catenary wire. It has the advantage that the catenary offers a degree of protection from falling trees as it is above the conductor. Also the insulation is very tough compared to the softer HVABC insulations – the tougher Hendrix insulation will offer more protection from damage when the conductors fall to the ground. Also joints can be performed by linesmen i.e. do not require specialist jointing techniques which will reduce repair time. The disadvantage is that it is visually more obtrusive than HV ABC due to the spacers every 9 metres.

Other disadvantages:- Similar to covered conductor systems and as such is not recommended.

4.1.5. Replace Overhead HV ABC with Hybrid Underground HV Cable

This option will utilise a hybrid underground system to accommodate the supply along the nominated section. Underground cable will exit at substation, switch, ACR and tee-off poles.

The advantages of utilising an underground system are listed as follows:

- Less subject to damage from severe weather conditions, mainly lightning, storm and high speed wind,
- No vegetation management involved, An underground system will have the greatest advantage in terrain with very heavy vegetation and large overhanging trees (e.g. the Dandenongs) which frequently shed limbs and may damage any overhead supply network

The disadvantages of an underground system are:

- Much more expensive compared with other supply system. More civil work and underground switches/Substations will be required,
- Hard to locate the faults once the cable is faulty and significantly longer repair times leading to longer restoration time
- It does not take advantage of the existing poles to support an aerial cable and requires trenching work

The cost of implementing this option is in the order of $0.9M per km. Total expenditure of $54M can be expected over 5 years to replace all existing HV ABC with underground cables

Given the expensive nature of the underground system, this option is not recommended. This is an option considered in the economic evaluation.

4.1.6. Replace with Metallic Screened HV ABC

This option will involve replacing existing HV ABC with metallic screened HV ABC. It is proposed to implement a 5 year program to replace all HV ABC. Replacement prioritization will be based on CFA/DELWP fire ignition rankings, fault history, consequence of failure, type of cable and feeder location.

UE has completed detailed investigations on non-metallic screened ABC failures and updated the construction standards and technical standards from the non-metallic screened ABC to metallic screened ABC. It is believed that metallic screened ABC will behave as an underground cable and should not suffer from electrical insulation erosion issues like the non-metallic screened version.

This option will address the reliability issue caused by non-metallic screened ABC failures on multiple feeders and continue to comply with regulatory requirements regarding the clearance between the power line and vegetation in HBRA. The Electricity Safety (Electric Line Clearance) Regulations 2015 recognises HV ABC as an insulated overhead system in HBRA.

This solution also sees the continuing utilisation of existing poles, switches and substations along the applicable sections of the feeders incorporating HV ABC which will significantly reduce the cost compared with an underground system.

This program will involve anticipated expenditure in the order of $30M over 5 years.

This option is recommended and is the third option considered in the economic evaluation.

4.2 OPTION FEASIBILITY ANALYSIS

4.2.1. BAU

Table 6: BAU Feasibility Analysis

Objective	Assessment Criteria
Health and safety	Option does not reduce the risk of fire starts/serious bushfire which threaten life as adequately as the alternatives.
Environment	Option does not address the risks associated with HV ABC faults starting fires as adequately as alternatives. Major bushfires have the risk of doing substantial damage to the natural environment with loss of fauna and flora causing long term damage to the ecosystem.
Protection of public and private property	Option does not address the risks associated with fire starts leading to bushfires as adequately as alternatives. Major bushfires have the risk of destroying public and private property and livestock. It is very difficult to place a financial value on this risk. The financial loss to property and livestock of the Black Saturday bushfires is estimated at $4B. Much of this loss was attributable to powerline faults. Likewise during the Ash Wednesday bushfires many of the fires were started from faults on distribution networks. Bushfires equivalent to Black Saturday or Ash Wednesday occur about once every 25 years and every summer major fires occur. Recent work by Victorian state government assesses that total state-wide risk from fires due to powerlines is $40.5M per annum. The majority of this risk is in rural Victoria and UE portion of risk is estimated at approximately 0.5% representing an annual loss of $0.2M.
Network reliability	Option will not stem UE's declining reliability performance. For example, UE suffered losses of $3.7M in STPIS from 2012 to 2015 due to 24 HV ABC faults. This equates to 2.9 minutes of SAIDI and 0.05 SAIFI interruptions.
Fire starts	Option will not help to reduce losses under the f-factor scheme. In the last three years, HV ABC failures accounted for no less than seven fire starts.
Maximise financial return and security	Under this option, UE is exposed to the risk that should a fault on HV ABC start a serious bushfire that UE could be prosecuted for not adopting all reasonably practicable options available to alleviate the risk. This could result in the payment of compensation and increases to insurance premiums. SP AusNet and its subcontractors paid claimants a total of $495M for the Black Saturday bushfires. Given this precedent, if a similar incident was to occur on the UE network it is certain that UE would also need to fund a very significant amount in compensation.
Innovation	This option is not innovative and does not demonstrate leadership to address the problems and risks UE faces.

Objective	Assessment Criteria
Technology availability, maturity and commercial risk	Option is a continuation of existing technology and suppliers and has low commercial risk.
Financially economic	Option does not require a step increase in expenditure but will not reduce the financial loss associated with STPIS and f-factor schemes nor reduce the financial risks associated with loss of property and livestock and legal proceedings should a fault on the network cause a major bushfire. The economic evaluation demonstrates this is not the least cost option

4.2.2. Covered Conductor System and Hendrix Cable System

Table 7: Covered Conductor and Hendrix Cable System Feasibility Analysis

Objective	Assessment Criteria
Health and safety	A better option than BAU but inferior to metallic screened HV ABC.
Environment	As covered conductor is not a screened cable, these options are still susceptible to the BAU risks identified above (albeit to a lesser extent) as a result of tracking and contact with vegetation.
Protection of public and private property	As covered conductor is not a screened cable, these options are still susceptible to the BAU risks identified above (albeit to a lesser extent) as a result of tracking and contact with vegetation
Network reliability	There are currently no performance based Australian Standards covering the components and line hardware for covered conductor systems. There is also a lack of in depth knowledge of covered conductor systems amongst utilities. Also, as covered conductor is a not a screened cable, prolong contact with vegetation may affect the performance of the cable
Fire starts	As covered conductor is not a screened cable, these options are still susceptible to the BAU risks identified above (albeit to a lesser extent) as a result of tracking and contact with vegetation.
Maximise financial return and security	As covered conductor is not a screened cable, these options are still susceptible to the BAU risks identified above (albeit to a lesser extent) as a result of tracking and contact with vegetation.
Innovation	Covered conductor and the Hendrix Cable system has been used by other distributors in Australia. It would however require some research and the development of new design standards if used by UE. Some limited innovation would be required
Technology availability, maturity and commercial risk	Covered Conductor and the Hendrix Cable System are considered by utilities as not a “mature system” and correspondingly, there is some technical/commercial risk regarding the performance and expected lifespan of the new materials. It would be necessary to trial small quantities before widespread use of the technology.
Financially economic	Not considered in economic evaluation.

4.2.3. Replace Overhead HV ABC with Underground HV Cable

Table 8: Underground HV Cable Feasibility Analysis

Objective	Assessment Criteria
Health and safety	Replacing HV ABC with underground cable will significantly reduce the risk of fire starts. .
Environment	This option has greatest potential to prevent bushfires in HBRA. Undergrounding assets also allows trees to grow naturally improving habit for birds and animals and improve streetscapes
Protection of public and private property	Replacing HV ABC with underground cable reduces the risk of fire starts/bushfires which lead to loss of property and livestock.
Network reliability	Underground cable is expected to be more reliable than HV ABC as it is not subject to the impacts of vegetation, cars into pole etc.
Fire starts	The direct financial cost to UE from fires started from UE assets based on the f-factor is $25k per fire. This will almost be eliminated with this option however a small risk still exists at locations where underground cable exits to a cable head pole.
Maximise financial return and security	Widespread undergrounding of HV ABC in HBRA would substantially reduce the risk of network assets starting bushfires. In turn this would reduce overall business risk and improve financial security with the reduced risk of prosecution and legal action.
Innovation	Replacing HV ABC with underground cable is not innovative as cable technology a mature technology. This option will require the development of a new suite of construction standards for cable head poles incorporating substations, cable tee-offs, switchgear etc.
Technology availability, maturity and commercial risk	Underground cable and other technology required to replace HV ABC has been available for many years from many suppliers and is robust and low risk.
Financially economic	Replacing all HV ABC in HBRA is expected to cost approximately $54M. Savings will be realised with a reduction in vegetation management improved STPIS, F-factor savings and expenditure associated with repairing HV ABC. Despite these benefits the investment to underground all 60km of HV ABC is not economic because of the enormous upfront capital expenditure.

4.2.4. Replace with Metallic Screened HV ABC

Table 9: Metallic Screened HV ABC Feasibility Analysis

Objective	Assessment Criteria
Health and safety	Screened HV ABC will behave in similar fashion with underground cables and as such will almost eliminate the risk of fire starts.
Environment	This solution will utilise existing poles, switches and substations along the applicable sections of the feeders incorporating HV ABC thus not having any additional adverse impact on the environment.
Protection of public and private property	As per the underground option, screened HV ABC reduces the risk of fire starts/bushfires which lead to loss of property and livestock.
Network reliability	Metallic Screened HV ABC is expected to be far more reliable than the BAU option. There will be an overall significant network reliability improvement
Fire starts	The direct financial cost to UE from fires started from UE assets based on the f-factor is $25k per fire. This will almost be eliminated with this option however a small risk still exists at locations where HV ABC interfaces with plant and bare conductor network.
Maximise financial return and security	Screened HV ABC would substantially reduce the risk of network assets starting fires. In turn this would reduce overall business risk and improve financial security with the reduced risk of prosecution and legal action.
Innovation	Replacing HV ABC with screened HV ABC requires minimal innovation.
Technology availability, maturity and commercial risk	Screened HV ABC is available from many suppliers with robust installation methods and carries minimal risk.
Financially economic	Replacing all HV ABC with screened HV ABC is expected to cost approximately $30M. Savings will be realised with a reduction in vegetation management. There will be economic benefits associated with improved STPIS, F-factor savings and expenditure associated with repairing HV ABC.

This option is considered the most prudent approach to address the risk posed by the existing HV ABC for the following reasons:

- Given the high probability of a fault of HV ABC causing a fire, the location being predominately in HBRA regions and the majority of faults occurring during the summer, the risk is too high to allow this asset to remain on the network.
- There has also been a dramatic increase in the rate of failures and contribution to SAIDI during the past three years (refer to Figure 2.0). This is not sustainable from a network reliability or business cost perspective.
- It is the least cost technically acceptable solution.

4.2.5. Summary of Options

A summary of the options is presented below.

Table 10: Summary of Options

Option	Health and safety	Environment	Protection of public and private property (risk)	Network reliability	Fire starts avoided per annum	Innovation	Technology availability, maturity and commercial risk	Upfront CAPEX	Financially economic
Business As Usual (BAU)	×	×	×	×	$0M	×	✓✓	$0M	×
Proactive Detection*	-	-	-	-	-	-	-	-	-
Covered Conductor System**	-	-	-	-	-	-	-	-	-
Hendrix Cable System**	-	-	-	-	-	-	-	-	-
Replace HV ABC with Underground HV Cable	✓✓✓	✓✓✓	✓✓	✓✓	$50K	×	✓✓	$54M	××
Replace HV ABC with Metallic Screened HV ABC	✓✓✓	✓✓✓	✓✓	✓✓	$50K	×	✓✓	$30M	✓

*Proactive Detection was not subject to any feasibility and financial analysis due to the fact that this option could not mitigate the safety risk associated with fire starts in HBRA regions.

**Both Covered Conductor and the Hendrix Cable Systems are not fully screened insulated cable options, can be subject to issues from contact with vegetation and lack a mature and established design and construction standard and as such are not recommended. UE will, however, continue to monitor these assets with learning/experience gathered from other DBs and will re-asses their use in the future.

4.2.6. Economic Analysis

Economic analysis on the management of HV ABC issues was undertaken for the aforementioned options – BAU: Status Quo, Replacement with Underground HV Cable and Replacement with Metallic Screened HV ABC. A summary of the modelling parameters, assumptions applied and results are summarised below. Refer to Appendix A for the detailed Financial Evaluation outputs from the Capex Evaluation Economic Model.

4.2.6.1 Modelling Parameters, Assumptions and Results

The following modelling parameters and assumptions were used in the economic analysis of the HV ABC options.

- OMS Reporting Data - Actual HV ABC fault data since 2004 i.e. first recorded HV ABC fault, based on OMS reporting, was used in the economic analysis. There have been a total of 34 recorded HV ABC faults from 2004 to date.

- Replacement Cost due to a HV ABC fault – The replacement cost associated with an existing HV ABC fault is based on a unit rate of $20k per fault. This is consistent with the current unit rates used for underground cable termination replacements.
- F-factor Fire Starts - 24 HV ABC faults occurred during 2012 – 2015. This coincided with the DNSP F-factor reporting to the ESV from 2012 to 2015 where UE's HV ABC network was accountable for thirteen fire starts. A fire start factor of 0.54 for HV ABC faults was then derived using the reported ESV fire starts divided by the HV ABC faults during 2012-2015 i.e. 13/24 = 0.54 fire starts/HV ABC fault.
- STPIS Inputs – The average SAIDI and SAIFI contributions per HV ABC fault used in the economic analysis was 0.19 and 0.003 respectively. These values were derived by calculations based on the OMS reporting data mentioned above and in consultation with the Network Performance group.
- Safety Risk – A risk of damage to residences resulting from a fire start was calculated with the CFA fire risk region mapping. The mapping takes into consideration the number of residences impacted in an event of comparable magnitude to Black Saturday. The risk was calculated from the multiplication of the following inputs
    - Average number of customers impacted from a bushfire (CFA number of residences impacted modelling)
    - A Black Saturday event is a 1 in 100 year event
    - Length in km of HV ABC in installed in each CFA risk rating
    - Spatial factor of 0.5 for conversion of length (km) of HV ABC installed to the CFA modelling based on 1km x 1km grid mapping
    - Forecast F-factor fire starts
    - A discounted cost of $50k per residence to reflect the likelihood of a residence being impacted by a fire start and the magnitude of the damage to the residence
- Reputational and Media Cost – This cost to the business has been benchmarked at $10k/annum and will vary annually in accordance with forecast HV ABC faults on the network. As above, this cost has been derived in consultation with the Network Performance group.

The number of HV ABC faults per km per year from 2004 to date has been modelled and the faults per km per year from 2016 to 2025 were projected based on trending analysis. The resultant graph and fault projections for the Status Quo, Underground Cable and Metallic Screened Replacement options are presented below.

Figure 8: HV ABC Faults/KM/Year

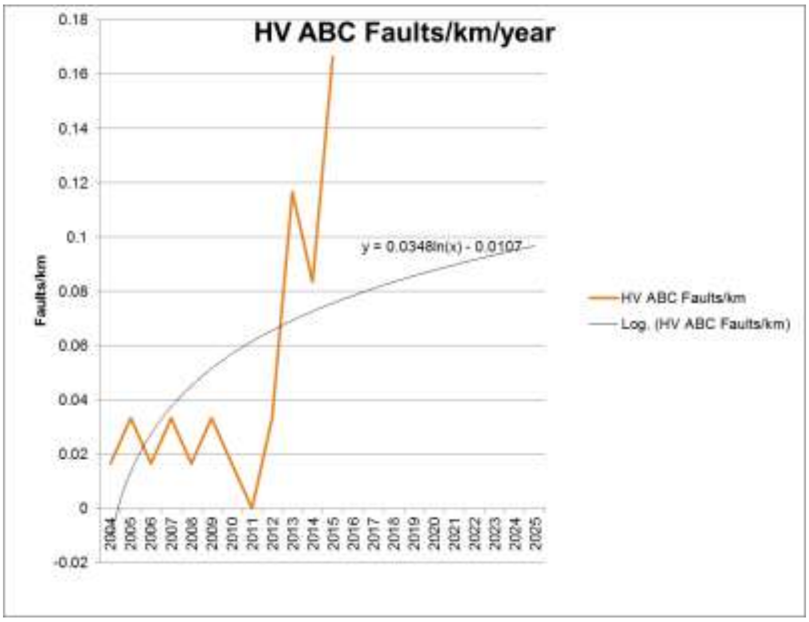


Table 11: Status Quo - HV ABC Fault/KM/Year

Year	HV ABC Faults/km	HV ABC Faults
2004	0.0167	1
2005	0.0333	2
2006	0.0167	1
2007	0.0333	2
2008	0.0167	1
2009	0.0333	2
2010	0.0167	1
2011	0.0000	0
2012	0.0333	2
2013	0.1167	7
2014	0.0833	5
2015	0.1667	10
2016	0.0786	5
2017	0.0811	5
2018	0.0835	5
2019	0.0858	5
2020	0.0879	5
2021	0.0899	5
2022	0.0918	6
2023	0.0936	6
2024	0.0952	6
2025	0.0969	6
2026	0.0984	6
2027	0.0999	6
2028	0.1013	6
2029	0.1027	6
2030	0.1040	6
2031	0.1053	6
2032	0.1065	6
2033	0.1077	6
2034	0.1088	7
2035	0.1099	7
2036	0.1110	7

Table 12: Underground and Metallic Screened HV ABC Replacement Fault/KM/Year

Year	HV ABC Faults/km	HV ABC Faults
2004	0.0167	1
2005	0.0333	2
2006	0.0167	1
2007	0.0333	2
2008	0.0167	1
2009	0.0333	2
2010	0.0167	1
2011	0.0000	0
2012	0.0333	2
2013	0.1167	7
2014	0.0833	5
2015	0.1667	10
2016	0.0786	4
2017	0.0811	3
2018	0.0835	2
2019	0.0858	1
2020	0.0879	0
2021	0.0899	0
2022	0.0918	0
2023	0.0936	0
2024	0.0952	0
2025	0.0969	0
2026	0.0984	0
2027	0.0999	0
2028	0.1013	0
2029	0.1027	0
2030	0.1040	0
2031	0.1053	0
2032	0.1065	0
2033	0.1077	0
2034	0.1088	0
2035	0.1099	0
2036	0.1110	0

4.2.6.2 Financial Summary

The following is a financial summary of the technically feasible options on a least cost basis.

Table 13: Financial Summary of Options

	"Status Quo" Reference Case	Option 1: Underground	Option 2: Metallic Screen HV ABC
Net Capex ($)	$1,254,588	$44,557,997	$24,862,631
Opex ($)	$121,412	$21,050	$21,050
STPIS ($)	$5,766,909	$558,537	$558,537
Loss of F Factor Benefit	$656,143	$68,252	$68,252
Risk* ($)**	$20,136,167	$615,143	$615,143
Least Net Cost ($) (PV)	$27,935,219	$45,820,979	$26,125,613
Project Ranking	**2**	**3**	**1**

The associated costs relating to each of the options are also presented below.

Table 14: Status Quo – BAU Costs

Project Costs: Status Quo		
BUSINESS COSTS	Driver	PV Cost
Net Capex		$1,254,588
Maintenance Opex Costs		$0
SAIDI Costs	0.92 (minutes per annum)	$2,746,147
SAIFI Costs	0.015 (Interuptions per annum)	$3,020,762
Network Outage Costs	$56,500 per min	$0
Loss of F Factor Benefit	$25,000 per fire start	$656,143
Opex costs		$121,412
Risk* ($)**		$20,136,167

Table 15: Underground Option Costs

Project Costs: Option 1 - Underground		
BUSINESS COSTS	Driver	PV Cost
Net Capex		$44,557,997
Maintenance Opex Costs		$0
SAIDI Costs	0.59 (minutes per annum)	$265,970
SAIFI Costs	0.009 (Interuptions per annum)	$292,567
Network Outage Costs	$56,500 per min	$0
Loss of F Factor Benefit	$25,000 per fire start	$68,252
Opex costs		$21,050
Risk* ($)**		$615,143

Table 16: Metallic Screen HV ABC Option Costs

Project Costs: Option 2 – Metallic Screen HV ABC		
BUSINESS COSTS	Driver	PV Cost
Net Capex		$24,862,631
Maintenance Opex Costs		$0
SAIDI Costs	0.59 (minutes per annum)	$265,970
SAIFI Costs	0.009 (Interuptions per annum)	$292,567
Network Outage Costs	$56,500 per min	$0
Loss of F Factor Benefit	$25,000 per fire start	$68,252
Opex costs		$21,050
Risk* ($)**		$615,143

5. Replacement Program by CFA Risk Areas

The replacement program based on the preferred option in section 4.1.6 is shown in table 17 below. This program not only looks at fault history but prioritises replacement programs based on fire consequence as defined in the CFA/DELWP fire ignition areas, 185mm2 over 35mm2 conductor and 22kV over 11kV areas.

The proposed works program as shown in table 17 below which outlines the replacement of non-metallic screened HV ABC up to FY 2020/21 which will see all HV ABC completely replaced.

The targeted feeder replacements for the HV ABC replacement program (over the next five years) are shown in Appendix C covering CFA areas 3, 4 and 5. Areas 6 and 7 are lower risk in the CFA/DELWP fire ignition rankings and proposed replacement programs for these areas will be developed in due course.

Table 17: HV ABC Replacements Works Program

Project	Length Replaced	Feeder	Estimated Completion	Major Risk Area	Cost
Stage 1 **FY 2014/15**	4.48km	DMA15 DMA 23	January 2016	4 / 6	$2.2M
Stage 2 **FY 2015/16**	3.64km	DMA15	June 2016	6	$1.82M
Stage 3 **FY 2016/17**	4.16km	DMA23	September 2016	3 / 4	$2.08M
ABC minor replacement 1 **FY 2016/17**	259m	DMA23	Before November 2016 – Exact time pending material and service provider availability	3	$129.5K
ABC minor replacement 2 **FY 2016/17**	166.5m	DC1	Before November 2016 – Exact time pending material and service provider availability	3	$83.2K
ABC minor replacement 3 **FY 2016/17**	181.5m	FSH34	Before end of November 2016	3	$90.7K
ABC minor replacement 4 **FY 2016/17**	44.3m	FSH21	Before end of November 2016	3	$22.1K
Stage 4 **FY 2016/17**	1.56km	MTN32	Before end of November 2016	4	$780K
Stage 5 **FY 2016/17**	644m	HGS22	Before end of November 2016	4	$322K

Project	Length Replaced	Feeder	Estimated Completion	Major Risk Area	Cost
ABC minor replacement 5 **FY 2016/17**	266m	DMA24	Before end of November 2016	4	$133K
Stage 6 **FY 2016/17**	900m	DMA23	Before end of November 2016	4	$450K
ABC minor replacement 6 **FY 2016/17**	498.5m	DMA15		5	$249.2K
Stage 7 **FY 2016/17**	755.6m	DMA15		5	$377.8K
Stage 8 **FY 2016/17**	616m	HGS33		5	$308K
Stage 9 **FY 2017/18**	2.79km	DMA23		5	$1.4M
Stage 10 **FY 2017/18**	3.36km	DMA15		5	$1.68M
Stage 11 **FY 2017/18**	2.29km	RBD12		5	$1.14M
Stage 12 **FY 2017/18**	3.82km	RBD12		5	$1.9M
Stage 13 **FY 2017/18**	763m	RBD12		5	$381K
ABC minor replacement 7 **FY 2017/18**	144m	STO22		5	$72K
Stage 14 **FY 2018/19**	1.1km	MTN32		5	$550K
Stage 15 **FY 2018/19**	1.67km	MTN32		5	$835K

Project	Length Replaced	Feeder	Estimated Completion	Major Risk Area	Cost
Stage 16 **FY 2018/19**	2.57km	MTN32		5	$1.28M
ABC minor replacement 8 **FY 2018/19**	433m	MTN32		5	$216K
The following areas of replacement have not yet been divided into specific projects					
FY 2018/19	5km	-		6	$2.5M
FY 2019/20	11.75km	-		6	$5.87M
FY 2020/21	5.14km	-		7	$2.57M

6. Risk Assessment

6.1 Risk Analysis

Risks have been evaluated in accordance with UE's risk management framework (version 2.1, dated January 2015). Undesirable and hazardous scenarios are identified and the risks are quantified according to the table below based on the consequence and likelihood of an undesirable scenario occurring.

Figure 9: Risk Matrix

RISK MATRIX

LIKELIHOOD	1. Minor	2. Moderate	3. Severe	4. Major	5. Catastrophic
6. Almost Certain	M	H	VH	E	E
5. Likely	M	H	VH	E	E
4. Possible	M	M	H	VH	E
3. Unlikely	L	M	H	VH	VH
2. Rare	L	L	M	H	VH
1. Exceptional	L	L	L	M	H
	CONSEQUENCE				

Rating
Extreme
Very High
High
Medium
Low

The following undesirable scenarios have been identified which this strategy is intended to address:

- A fault on an HV ABC line starts a serious bushfire leading to loss of public and private assets, loss of life and/or trauma, loss of livestock, pets and native animals, damage to the environment and natural ecosystems.
- UE faces financial loss associated with payment of compensation associated with the losses resulting from serious bushfires starting from faults on HV ABC lines.
- UE faces increased insurance premiums for public liability because of the risk associated with HV ABC failures starting serious bushfires.
- Increase in the number of fires starting from faults on the UE network resulting in financial losses from the f-factor scheme.
- A fault on an overhead HV ABC results in electric shock or burns to members of the general public.
- A fault occurs on UE assets injuring employees and contractors.

These hazards have been evaluated based on the business as usual (BAU) scenario to obtain a risk baseline as documented below. Consequence is ranked from 1-Minor through to 5-Catastrophic. Likelihood is ranked from 1-Exceptional through to 6-Almost certain.

Table 18: Risk under BAU

Hazard	Consequence	Likelihood	Risk	Comments
HV ABC failures led to/ignited bushfire causing loss of public and private assets, loss of life and/or trauma, loss of livestock, pets and native animals, damage to the environment.	5	2	Very High	Powerline faults will cause many fires on the UE network each year however most of these have minor to moderate consequences. For these fires the risk is deemed high. Of significantly greater concern are the fires which start on the once in 25 year code red days where the consequence is catastrophic. While the likelihood is rare the overall risk is very high.
Prosecution from bushfires started from HV ABC failures and payment of compensation	5	1	High	During the Black Saturday bushfires both AusNet Service and Powercor paid hefty compensation payments (around $500M) so the consequence is catastrophic. These events are extremely uncommon for the UE territory thus the likelihood is less than 2.5% per annum
Increased insurance premiums for public liability because of the bushfire risk associated with HV ABC failure	2	5	High	Insurance premiums will inevitably increase resulting from the compensation payments made by AusNet Service and Powercor and the UE business will be assessed as a higher risk as a result unless new controls are put in place.
F-factor scheme penalties	1	5	Medium	UE is penalised at the rate of $25k per fire start and can have well over 100 fires start in any year however UE is provided with a quota and therefore on average losses in any year are not expected to be significant unless performance declines from the BAU levels.
Electric shock or burns to members of the general public from a HV ABC failure.	4	2	High	From time to time a member of the general public comes into contact with live conductors and receives a fatal electric shock and burns. However, this has yet to occur on HV ABC installations and as such remains as a rare but high risk to UE.
Network HV ABC fault injuring employees and contractors	4	2	High	From time to time a contractor or employee receives a fatal electric shock and burns while working on UE assets. This has yet to occur on HV ABC installations and as such remains as a rare but high risk to UE.

Under BAU, bushfires started by HV ABC failures carry the highest risk followed by network reliability and electric shock and burns to members of the general public and UE employees and contractors. The risk associated with prosecution and increased insurance premiums are also notable.

UE also has an obligation to comply with the Electricity Safety Act 1998 which requires distribution businesses to design, construct, operate, maintain and decommission its supply network to minimise the following hazards far as practicable:

- Electric shock and burn hazards to any person arising from the electricity distribution supply network.
- Property and asset damage hazards arising from the electricity distribution supply network.
- Bushfire hazards arising from the electricity distribution supply network.

The Act more explicitly requires the electricity distributors to minimise as far as practicable the bushfire danger arising from above ground supply networks that are in a hazardous bushfire risk area (section 151A).

7. Risk Treatment

Controls used to limit the risk for each of the hazards identified in the preceding section are proposed below. Hazards which represent the highest risk warrant the greatest attention to find and implement the most appropriate controls.

Hazards with high to catastrophic consequences that only have very low likelihood of occurring; representing modest risk must also be thoroughly investigated. If practical ways exist to reduce the likelihood even lower then these controls should be implemented given the extreme consequences of the hazard.

Table 19: Risk Treatment

Hazard	Consequence	Likelihood	Risk	Possible Controls
HV ABC failures led to/ignited bushfire causing loss of public and private assets, loss of life and/or trauma, loss of livestock, pets and native animals, damage to the environment.	5	2	Very High	Fire prevention options listed in section 4.1 (underground HV cable, metallic screened HV ABC). Despatch of firefighting response teams following power line faults to reduce response times and minimise impact. Community education and supply of PPE and assistance with firefighting equipment.
Prosecution from bushfires started from HV ABC failures and payment of compensation	5	1	High	Fire prevention options listed in section 4.1 (underground HV cable, metallic screened HV ABC). Despatch of firefighting response teams following power line faults to reduce response times and minimise impact. Improve insurance cover and government backing.
Increased insurance premiums for public liability because of the bushfire risk associated with HV ABC failure	2	5	High	Fire prevention options listed in section 4.1 (underground HV cable, metallic screened HV ABC). Despatch of firefighting response teams following power line faults to reduce response times and minimise impact. Government Underwriting.
F-factor scheme penalties	1	5	Medium	Replacement of HV ABC with either underground HV cable or metallic screened HV ABC.
Electric shock or burns to members of the general public from a HV ABC failure.	4	2	High	All options listed in section 4.1. Increased public education regarding the dangers of powerlines especially HV ABC installations.
Network HV ABC fault injuring employees and contractors	4	2	High	All options listed in section 4.1. Improved work practices.

The hierarchy of risk controls is as follows:

1. Eliminate the hazard.
2. Substitute with a lesser hazard.
3. Use engineering controls to reduce hazard.
4. Use administrative controls such as workplace procedures.
5. Use personal protective equipment (PPE).

For the most part, the hazards listed in Table 19 cannot be eliminated. Where there are electricity distribution networks there will always be a risk of fire, electric shock and burns, electricity supply failure or prosecution should any losses result in an undesirable incident. Most of the hazards identified in Table 19 can be well controlled by replacing HV ABC with either underground cable or metallic screened HV ABC.

The use of administrative controls such as workplace procedures and the use of PPE are effective at reducing the risk for UE employees and contractors however cannot be used effectively by UE to reduce risk for members of the public because UE's control and influence is too limited beyond UE's normal work activities.

Several of the possible controls listed in Table 19 would be impracticable for UE to consider implementing or are the responsibility of other authorities. This includes activities such as public education on the safety of powerlines and bushfire preparation and firefighting which are better managed by authorities such as Energy Safe Victoria (ESV) and the Country Fire Authority (CFA). It is recommended that UE focus on the management of its network to ensure it is well maintained and operated and that UE use technologies effectively to minimise risk.

With the replacement of HV ABC with metallic screened HV ABC, the residual risk will be as per Table 20 below.

Table 20: Residual Risk

Residual Risk associated with HV ABC	Consequence	Likelihood	Residual Risk
HV ABC failures led to/ignited bushfire causing loss of public and private assets, loss of life and/or trauma, loss of livestock, pets and native animals, damage to the environment.	5	1	High
Prosecution from bushfires started from HV ABC failures and payment of compensation	5	1	High
Increased insurance premiums for public liability because of the bushfire risk associated with HV ABC failure	2	3	Medium
F-factor scheme penalties	1	5	Medium
Electric shock or burns to members of the general public from a HV ABC failure.	4	1	Medium
Network HV ABC fault injuring employees and contractors	4	1	Medium

8. Recommendation

The potential for HV ABC to start bushfires is a risk for UE and one that requires suitable risk mitigation measures. This plan recommends replacement of non-metallic screened HV ABC with metallic screened HV ABC to reduce bushfire risk and realise other network benefits.

To this end, it is recommended that:

- UE ceases the use of the current non-metallic screened HV ABC for new or replacement work with the exception of joint repair on faulty lines where a like cable is necessary and restoration of supply is priority. This recommendation has been implemented.
- UE develop and adopt metallic screened HV ABC system similar to industry. This recommendation has been implemented.
- UE develop replacement projects for HV ABC replacement. It is proposed to implement a 5 year program to replace all HV ABC with an estimated total cost of $30M. Replacement prioritization will be based on CFA/DELWP fire ignition rankings, fault history, consequence of failure, type of cable and feeder location.

The key benefit of this plan is to address the escalating bushfire risk associated with HV ABC.

Replacements of non-metallic screened HV ABC with metallic screened HV ABC offers an affordable, practical and industry accepted way of reducing bushfire and health and safety risks, complying with regulatory requirements.

9. Appendix A – Financial Evaluation Summary 70% VCR

Table 21: HV ABC Replacement Financial Summary

	"Status Quo" Reference Case	Option 1: Underground	Option 2: Metallic Screen HV ABC
Net Capex ($)	$1,254,588	$44,557,997	$24,862,631
Opex ($)	$121,412	$21,050	$21,050
STPIS ($)	$5,766,909	$558,537	$558,537
Loss of F Factor Benefit	$656,143	$68,252	$68,252
Risk* ($)**	$20,136,167	$615,143	$615,143
Least Net Cost ($) (PV)	$27,935,219	$45,820,979	$26,125,613
Project Ranking	**2**	**3**	**1**

Table 22: Project Costs: Status Quo

Project Costs: Status Quo		
BUSINESS COSTS	Driver	PV Cost
Net Capex		$1,254,588
Maintenance Opex Costs		$0
SAIDI Costs	0.92 (minutes per annum)	$2,746,147
SAIFI Costs	0.015 (Interuptions per annum)	$3,020,762
Network Outage Costs	$56,500 per min	$0
Loss of F Factor Benefit	$25,000 per fire start	$656,143
Opex costs		$121,412
Risk* ($)**		$20,136,167

Table 23: Project Costs: Underground

Project Costs - Option 1: Underground		
BUSINESS COSTS	Driver	PV Cost
Net Capex		$44,557,997
Maintenance Opex Costs		$0
SAIDI Costs	0.59 (minutes per annum)	$265,970
SAIFI Costs	0.009 (Interuptions per annum)	$292,567
Network Outage Costs	$56,500 per min	$0
Loss of F Factor Benefit	$25,000 per fire start	$68,252
Opex costs		$21,050
Risk* ($)**		$615,143

Table 24: Project Costs: Metallic Screen HV ABC

Project Costs - Option 2: Metallic Screen HV ABC		
BUSINESS COSTS	Driver	PV Cost
Net Capex		$24,862,631
Maintenance Opex Costs		$0
SAIDI Costs	0.59 (minutes per annum)	$265,970
SAIFI Costs	0.009 (Interuptions per annum)	$292,567
Network Outage Costs	$56,500 per min	$0
Loss of F Factor Benefit	$25,000 per fire start	$68,252
Opex costs		$21,050
Risk* ($)**		$615,143

Project Details

Project Name : **HV ABC Replacement**

Asset : United Energy

Year in which project will begin : 2016

Discount Rate : 8.67%

**Business WACC (Pre-tax Nominal WACC)*

Project Type : Discretionary (asset replacement or refurbishment)

Regulatory Asset Category Proportion (Percentage)

Customer Initiated	0%
Demand (Reinforcement)	0%
Reliability & Power Quality Maintained	100%
Reliability & Power Quality Improved	0%
SCADA & Network Control	0%
Environmental, Safety & Legal	0%
Non-Network IT	0%
Non-Network general other	0%
Non-Standard Control	0%

Gas reg categories - to be completed

	0%
	0%
	0%
	0%
	0%
	0%
	0%
	0%
	0%

Economic Assessment

Budget :

Is the project included in the budget?	No
If yes, how much is allocated?	$ -

Results:

$000

Least Cost Option **Option 2: Metallic Screen HV ABC**

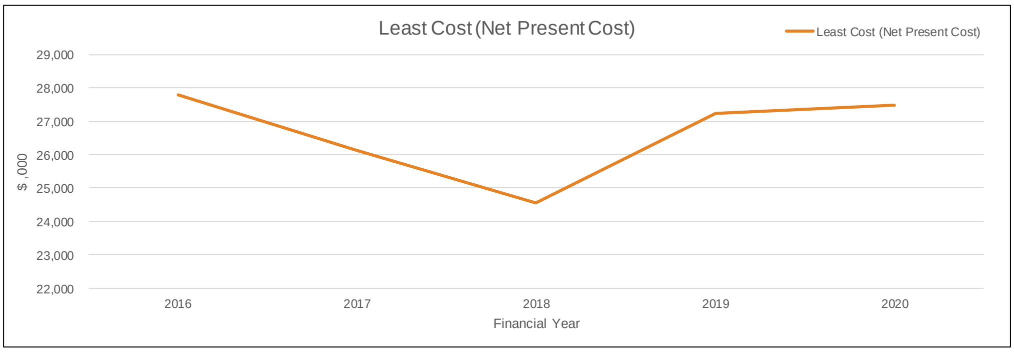
Least Cost (Present Value) **26,126**

Options	"Status Quo" Reference Case	Option 1 Underground	Option 2 Metallic Screen HV ABC	Option 3	Option 4	Option 5
Capital Costs	3,076.8	57,370.9	32,029.5	-	-	-
Maintenance Costs	-	-	-	-	-	-
Negative Impact on Revenue (STPIS)	16,105.8	823.6	823.6	-	-	-
Network Outage Costs	-	-	-	-	-	-
Loss of F Factor Benefit	1,593.4	85.1	85.1	-	-	-
Cost 1	311.4	27.6	27.6	-	-	-
Cost 2	-	-	-	-	-	-
Cost 3	-	-	-	-	-	-
Cost 4	-	-	-	-	-	-
Cost 5	-	-	-	-	-	-
Risks	51,486.8	748.7	748.7	-	-	-
Total Costs	**72,574.1**	**59,055.8**	**33,714.5**	**-**	**-**	**-**

Present Value of Total Costs	**27,935.2**	**45,821.0**	**26,125.6**			
Project Ranking	***2***	***3***	***1***			

Notes:	
Option 1: Underground	
Option 2: Metallic Screen HV ABC	
Option 3:	
Option 4:	
Option 5:	

Timing Analysis - HV ABC Replacement



Sensitivities

Best Case Scenario

Options	"Status Quo" Reference Case	Option 1 Underground	Option 2 Metallic Screen HV ABC	Option 3	Option 4	Option 5
Capital Costs	2,769.1	51,633.8	28,826.6	-	-	-
Opex	62,547.6	1,516.5	1,516.5	-	-	-
Total Costs	**65,316.7**	**53,150.3**	**30,343.1**	**-**	**-**	**-**

Discount Rate *7.7%*

Present Value of Total Costs	**27,658.1**	**42,390.5**	**24,173.0**			
Project Ranking	***2***	***3***	***1***			

Worst Case Scenario

Options	"Status Quo" Reference Case	Option 1 Underground	Option 2 Metallic Screen HV ABC	Option 3	Option 4	Option 5
Capital Costs	3,384.5	63,108.0	35,232.5	-	-	-
Opex	73,225.9	1,688.8	1,688.8	-	-	-
Total Costs	**76,610.4**	**64,796.7**	**36,921.3**	**-**	**-**	**-**

Discount Rate *9.7%*

Present Value of Total Costs	**29,597.9**	**53,680.4**	**30,552.1**			
Project Ranking	***1***	***3***	***2***			

10. Appendix B – HV ABC Photos Showing Asset Failure

Figure 10: Sample report of visual inspection performed by Tenix

DownerTenix

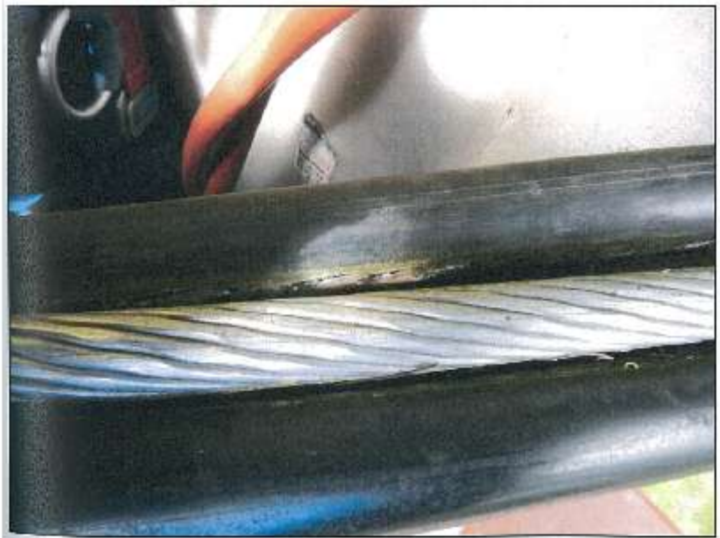
	LIS 1308499 – LIS 9816151 Midspan No damage visible to catenary or cables Degradation level: 0
	LIS 1308499 – LIS 9816151 Midspan No damage visible to catenary or cables Degradation level: 1 - Some beginning of corrosion present

Figure 11: Varying levels of degradation of replaced DMA13 cable where discharge was observed

Figure 12: Recent failures on DMA13 & MTN12 feeders

Figure 13: Old Cable joints in replaced section of cable

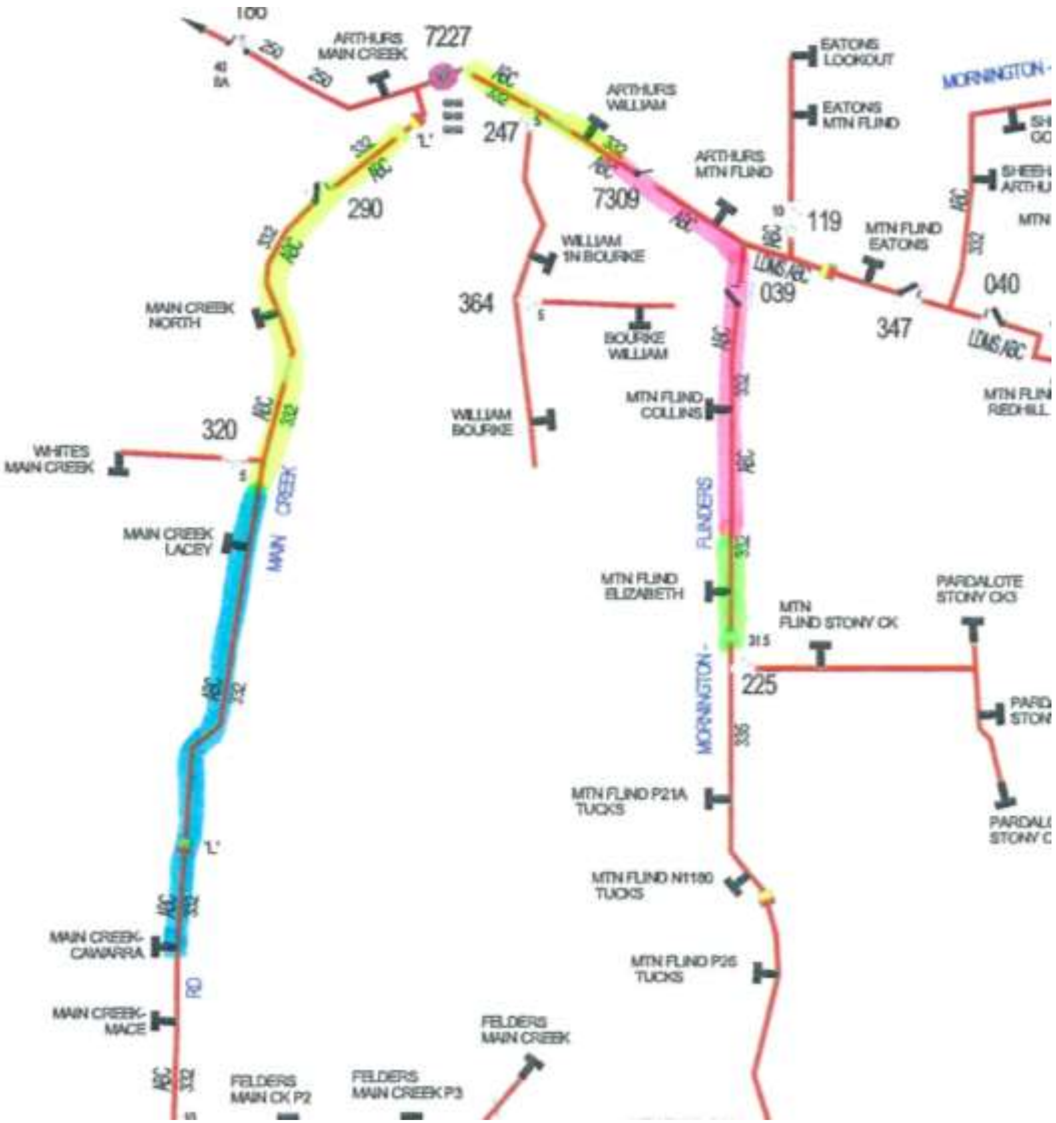
11. Appendix C – HV ABC Replacement Schematics

The targeted feeder replacements for the HV ABC replacement program (over the next five years) covering CFA areas 3, 4 and 5 are presented below.

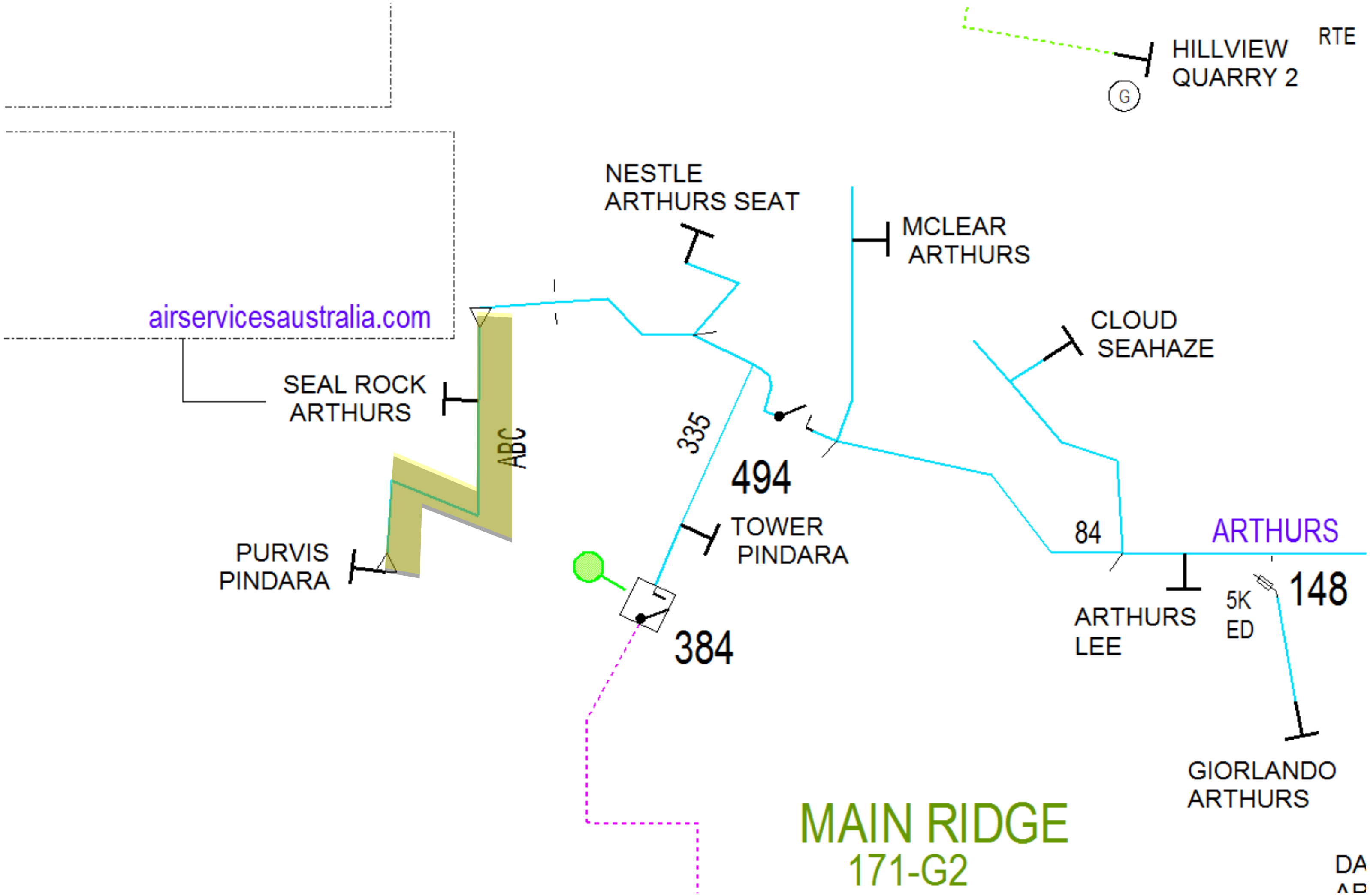
Stage 1 – DMA15 & DMA23

Stage 2 – DMA15

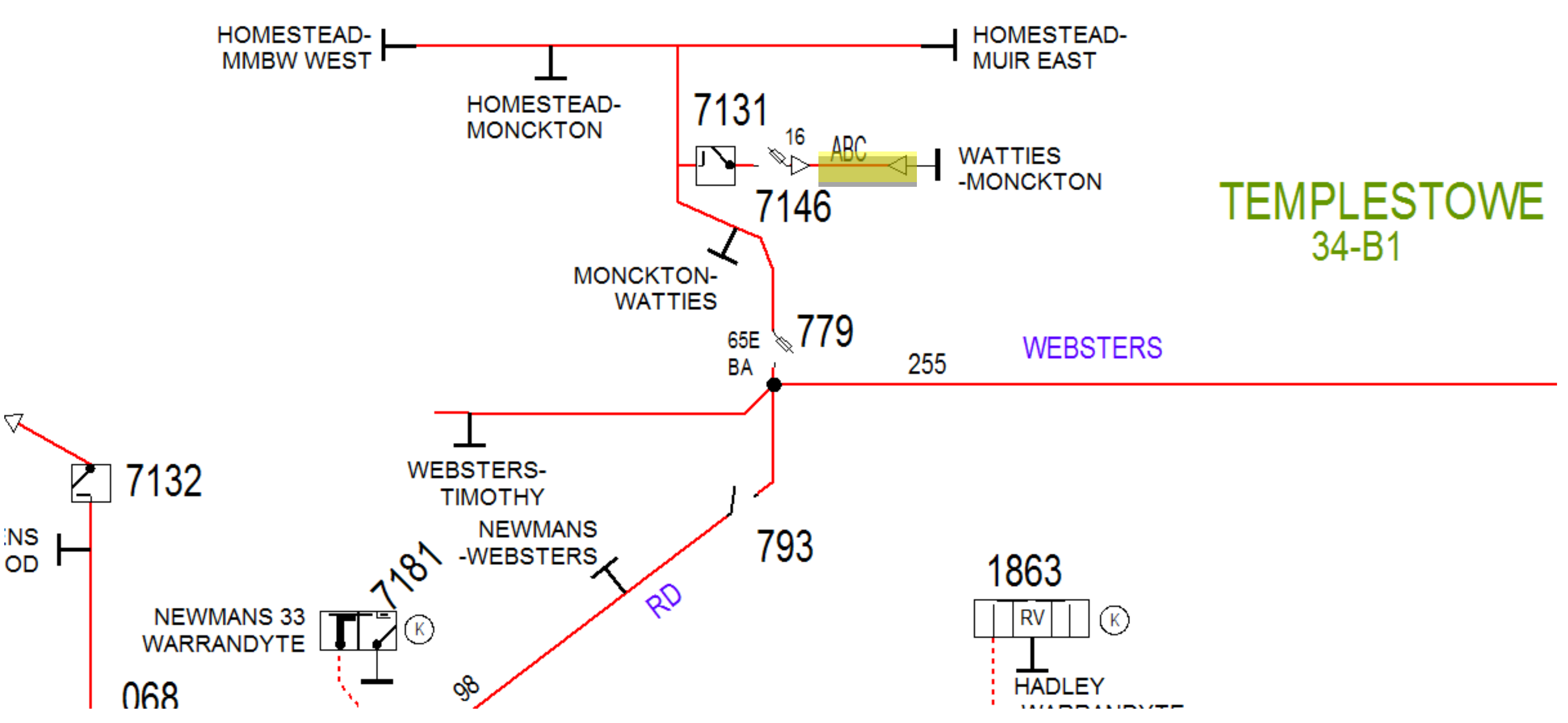
Stage 3 – DMA23



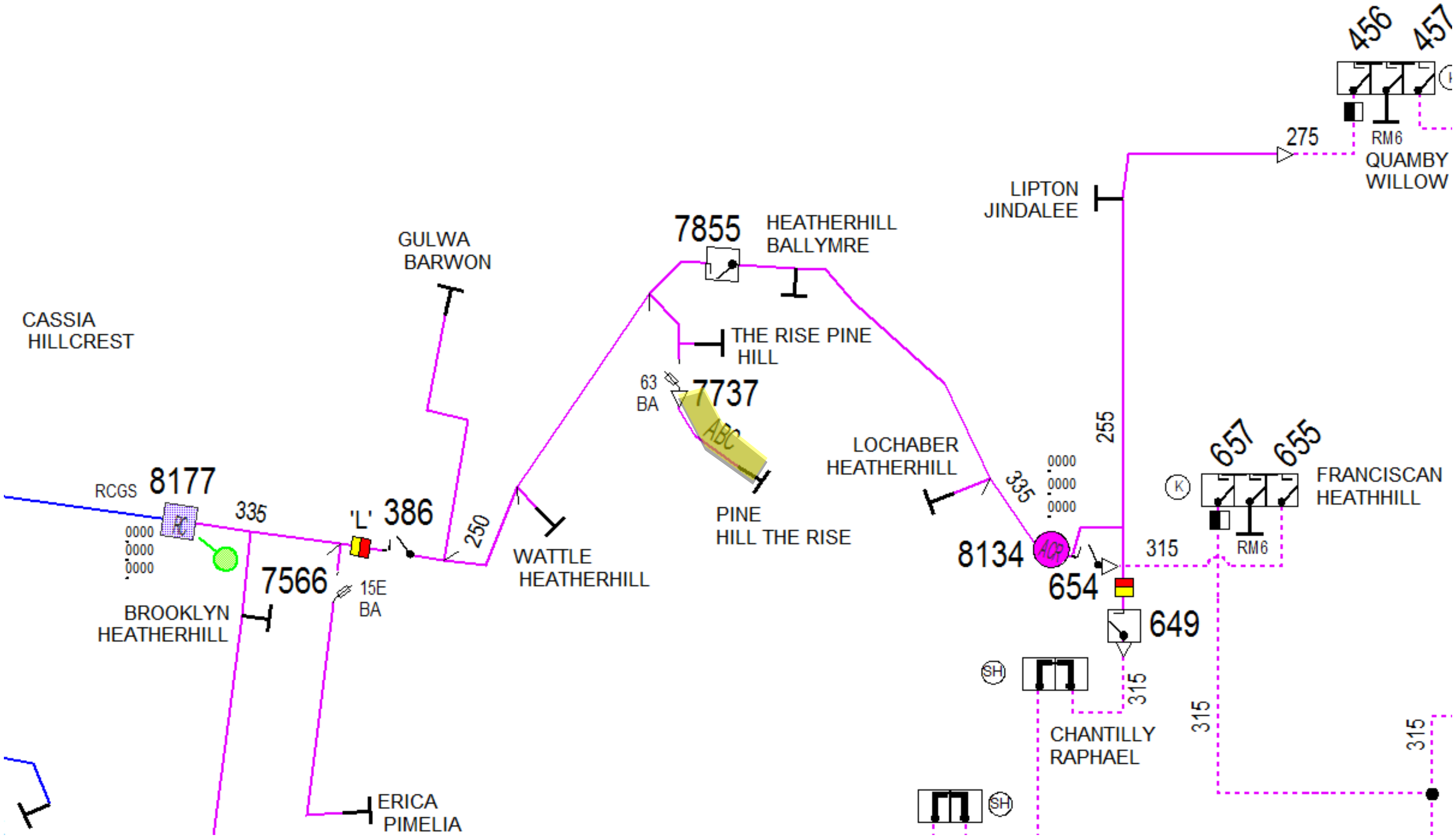
ABC Minor Replacement 1 – DMA23



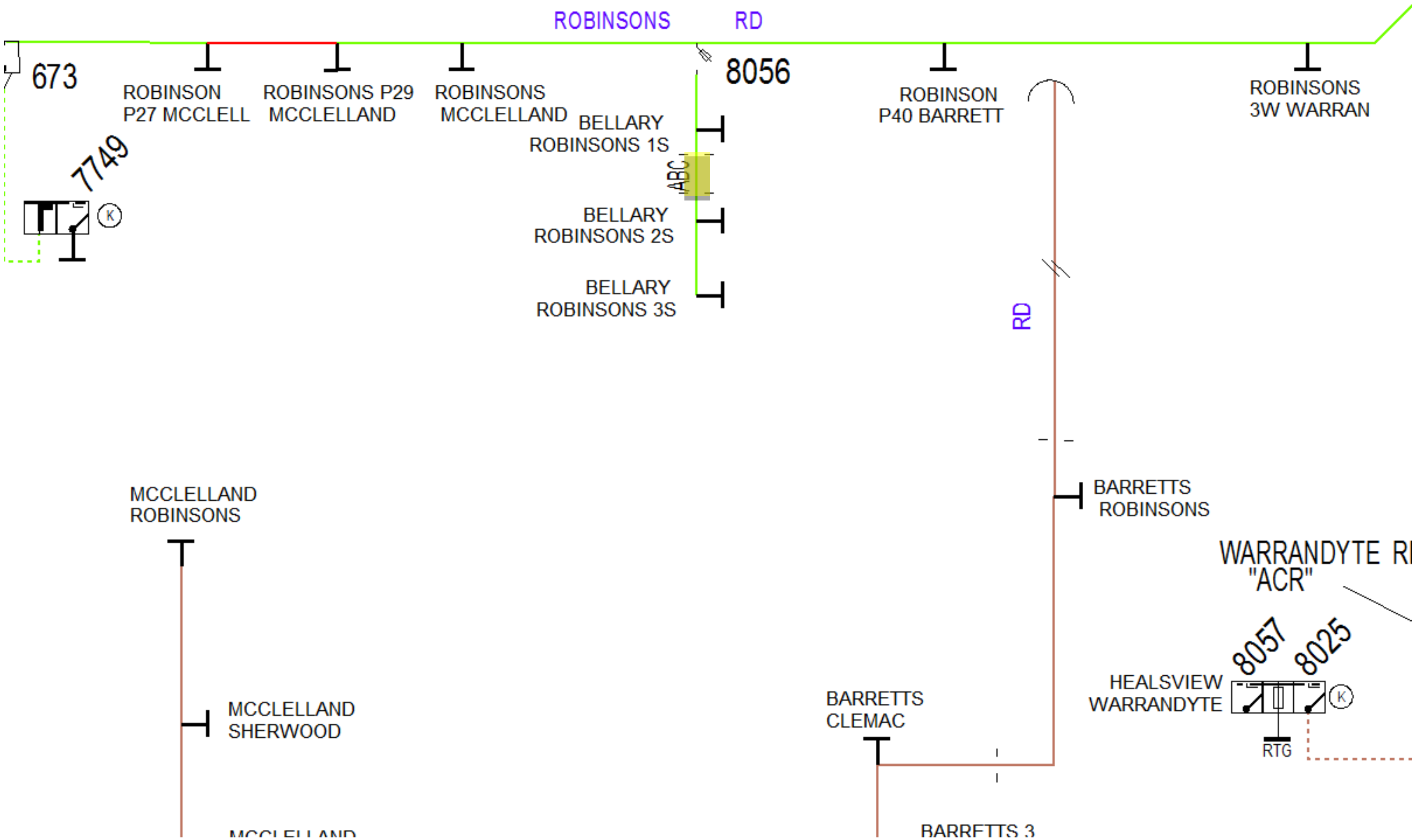
ABC Minor Replacement 2 – DC1



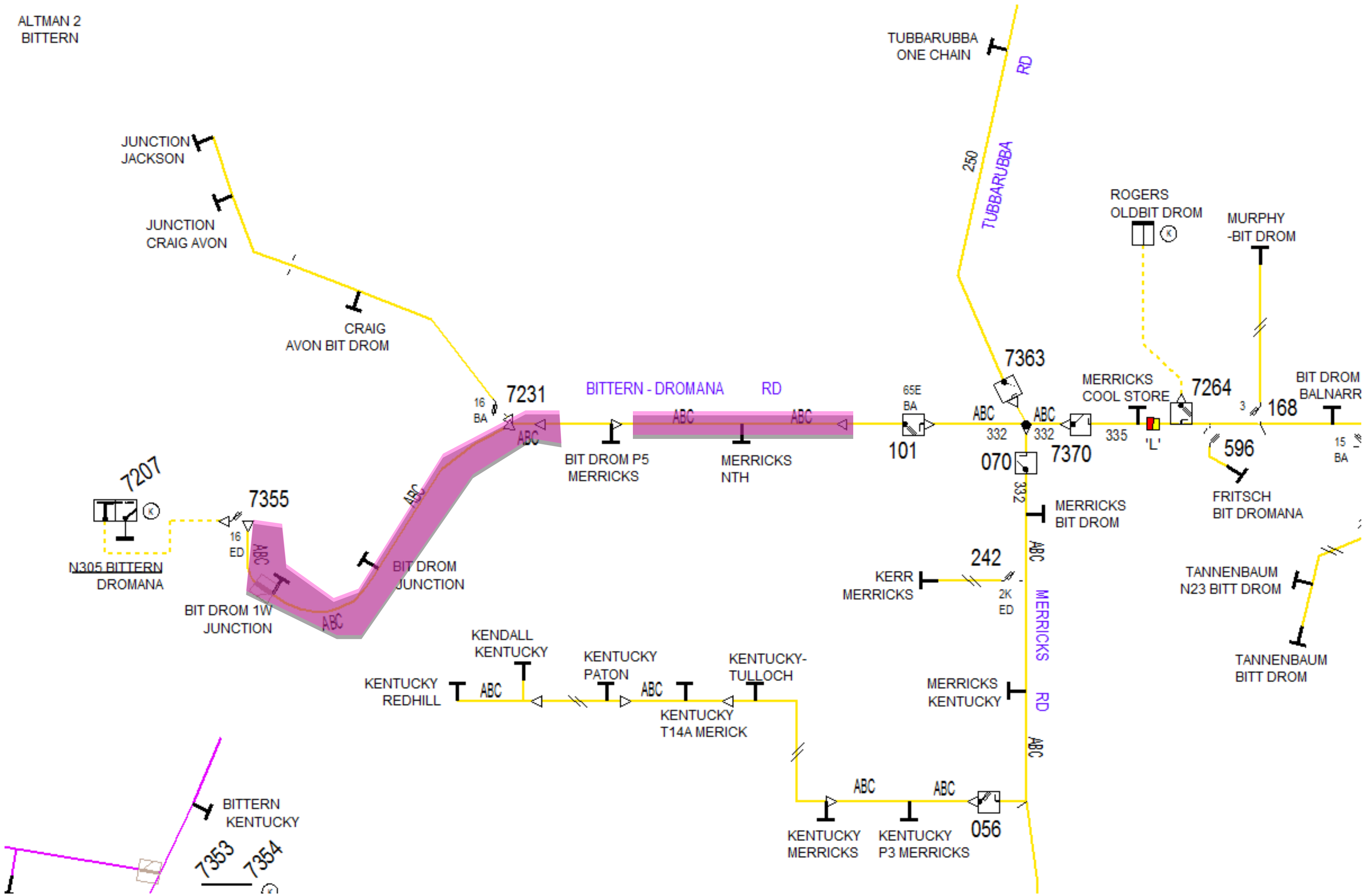
ABC Minor Replacement 3 – FSH34



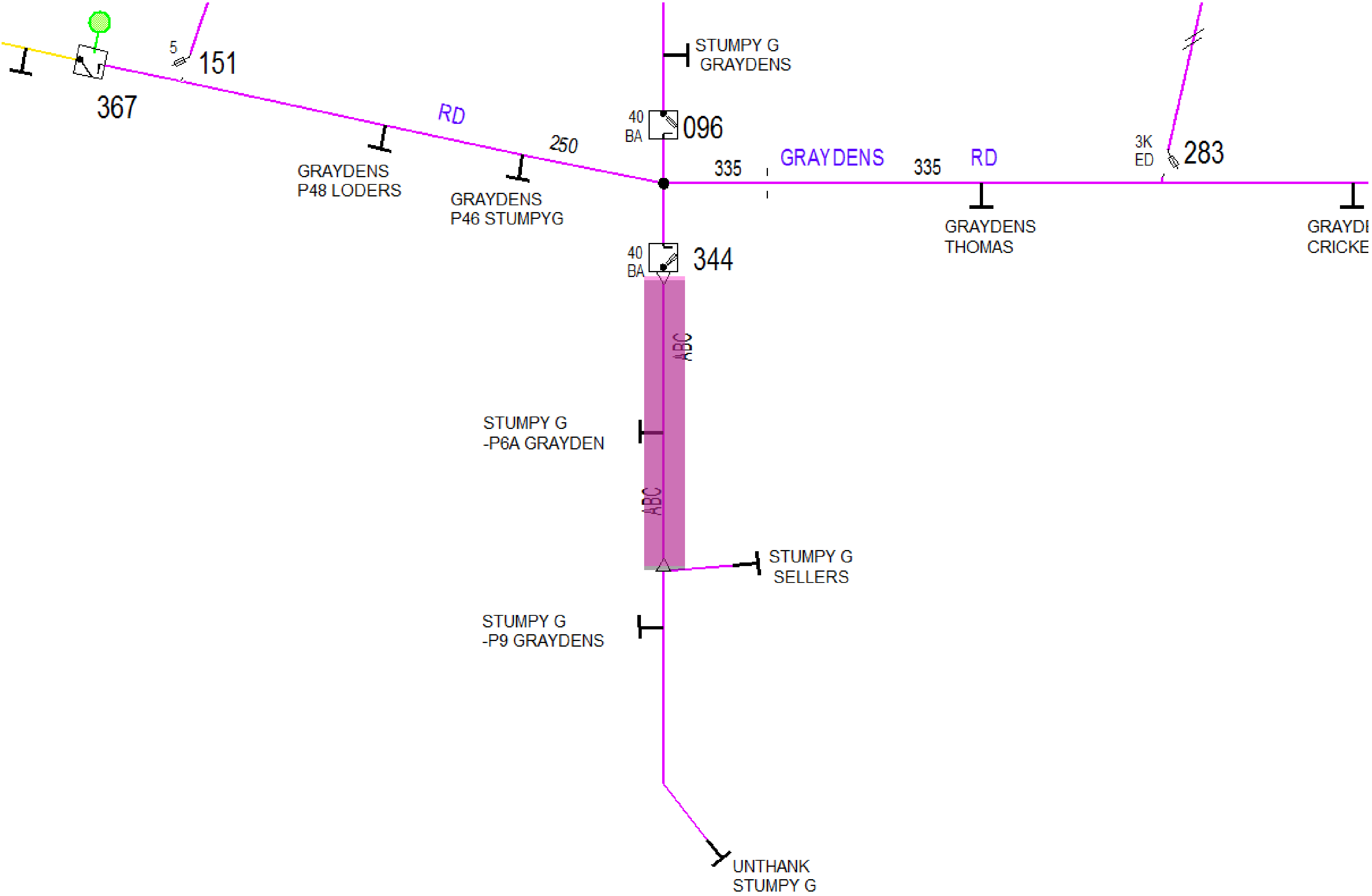
ABC Minor Replacement 4 – FSH21



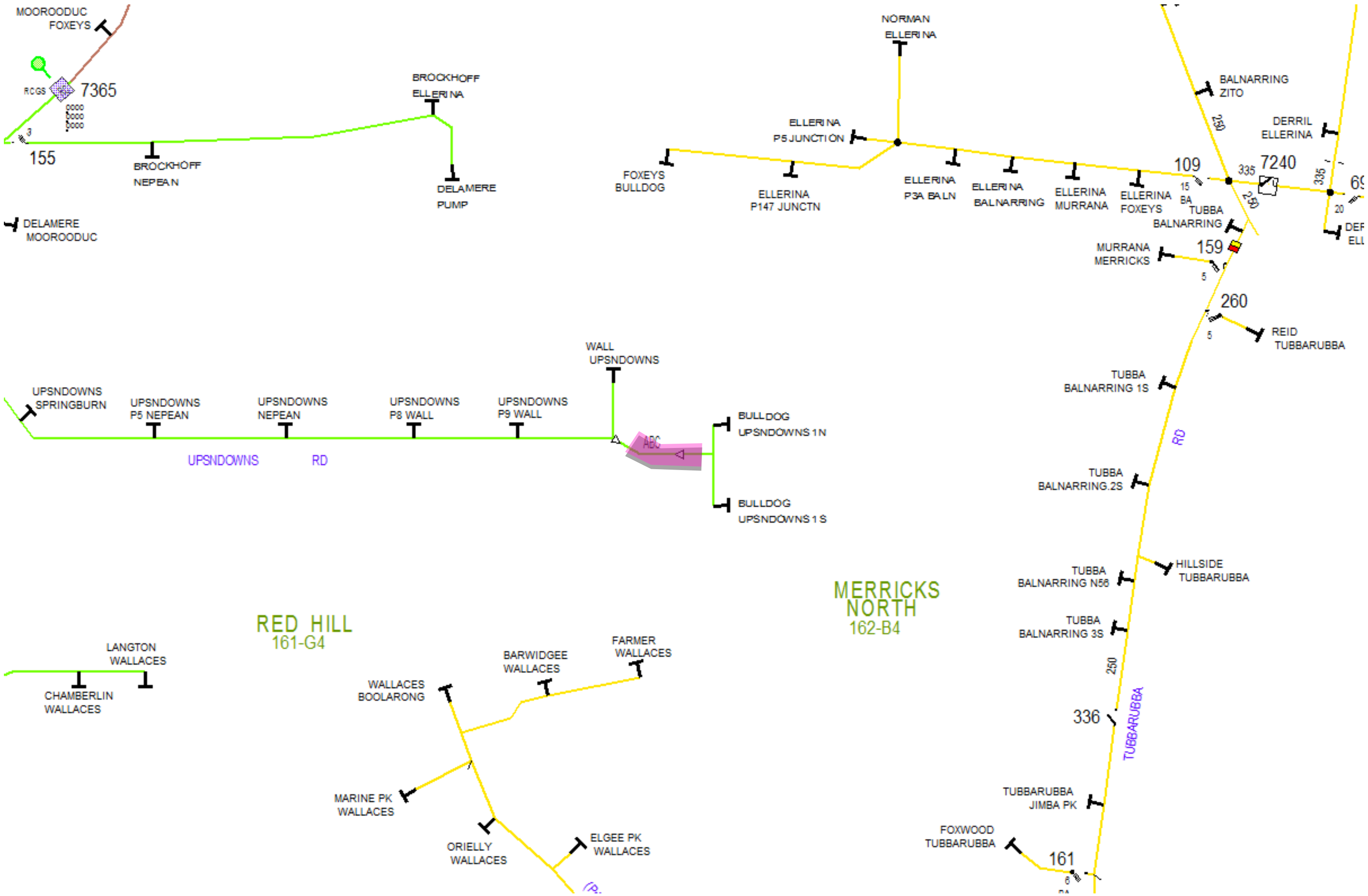
Stage 4 – MTN32



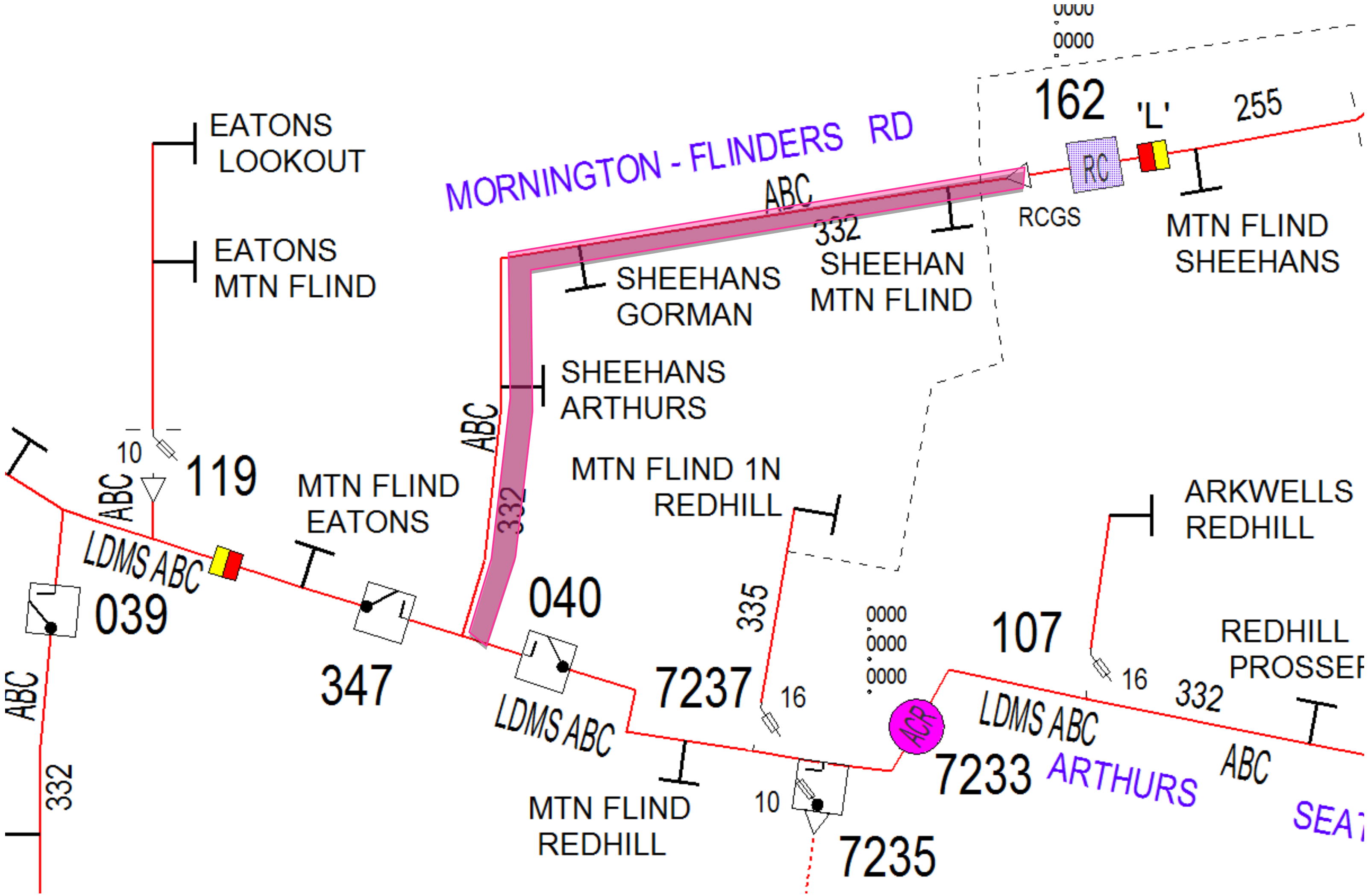
Stage 5 – HGS22



ABC Minor Replacement 5 – DMA24



Stage 6 – DMA 23

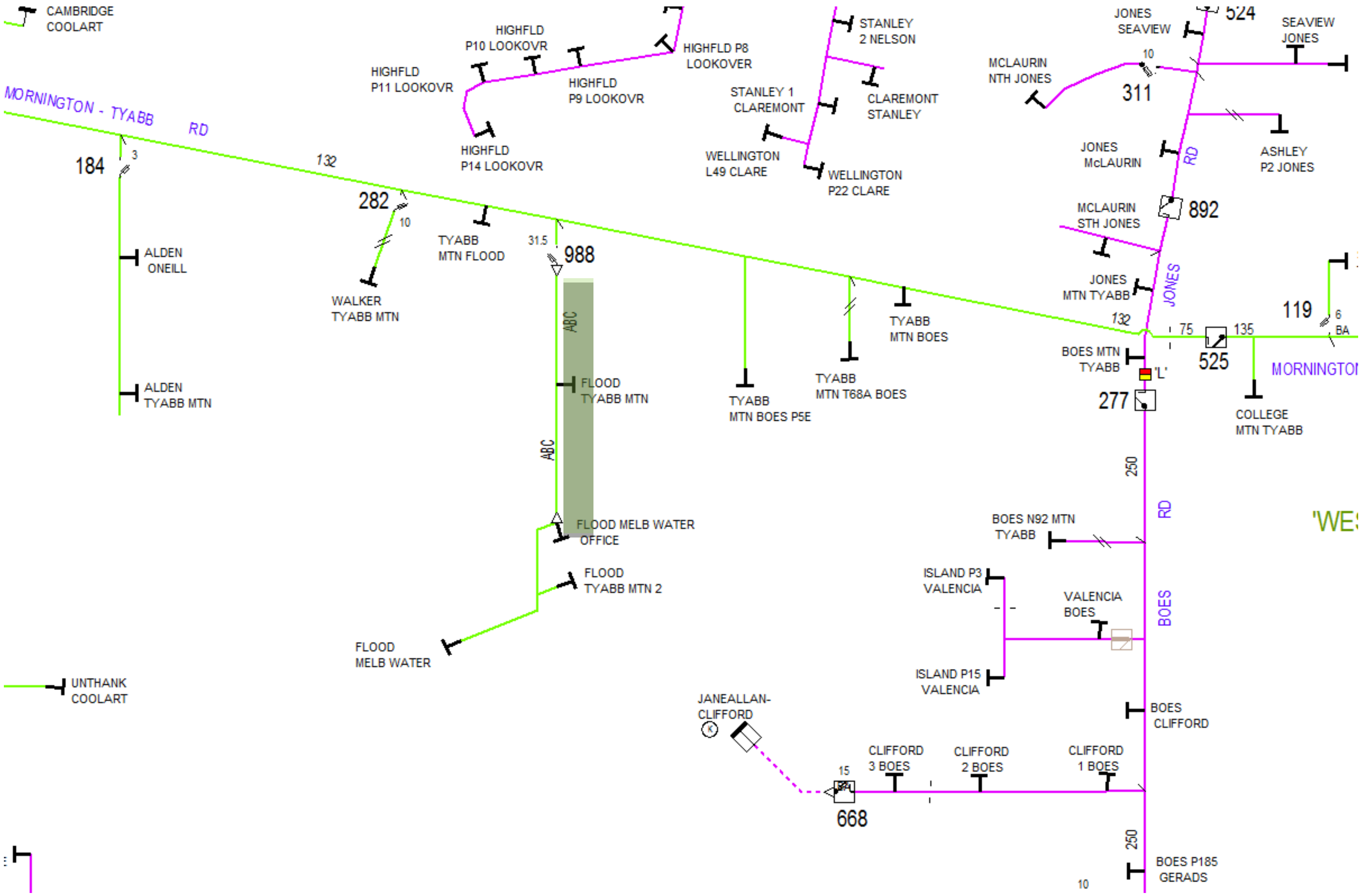


ABC Minor Replacement 6 – DMA15

Stage 7 – DMA15

UNITED ENERGY

Stage 8 – HGS33

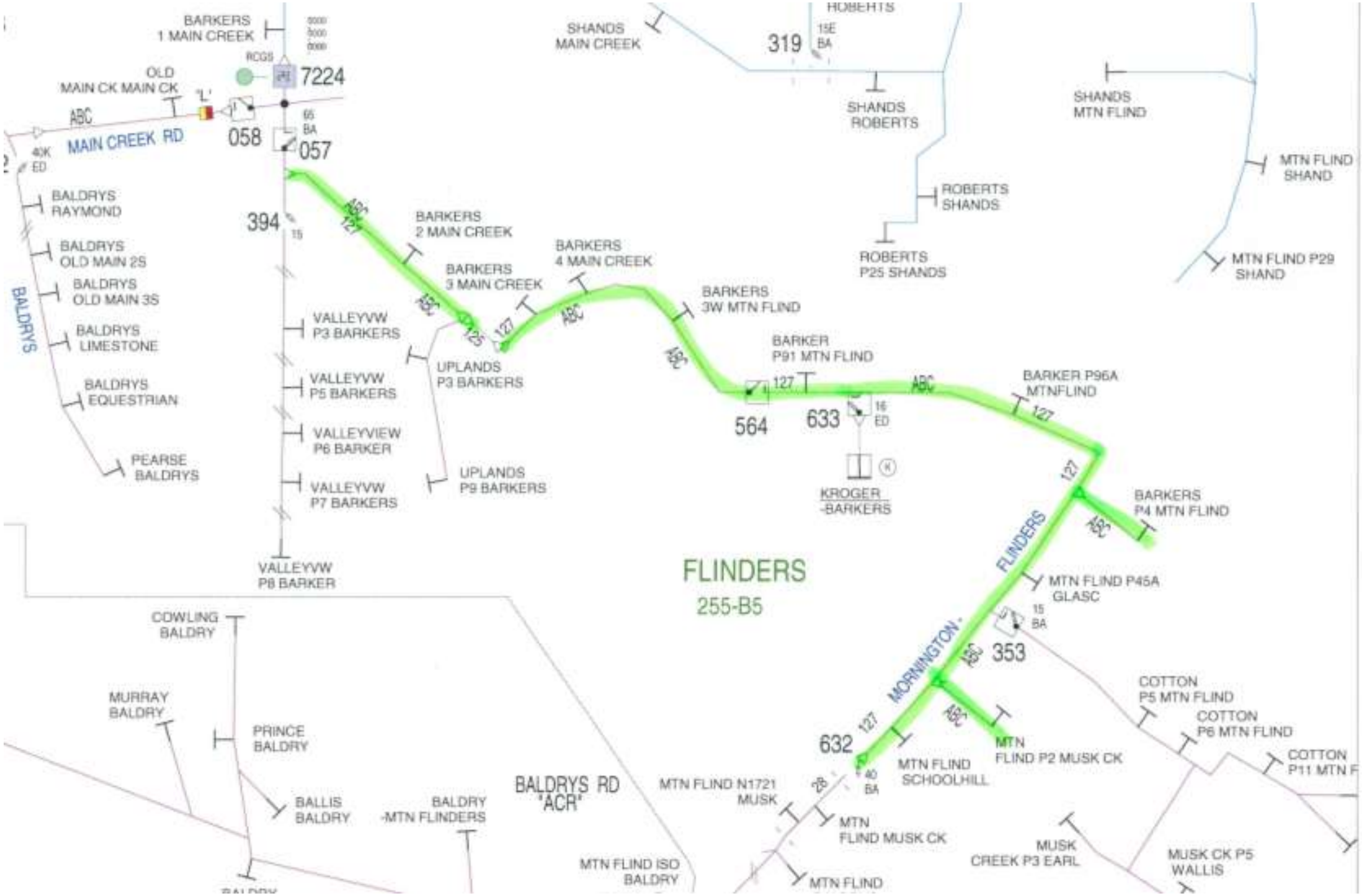


Stage 9 – DMA 23

Stage 10 – DMA15

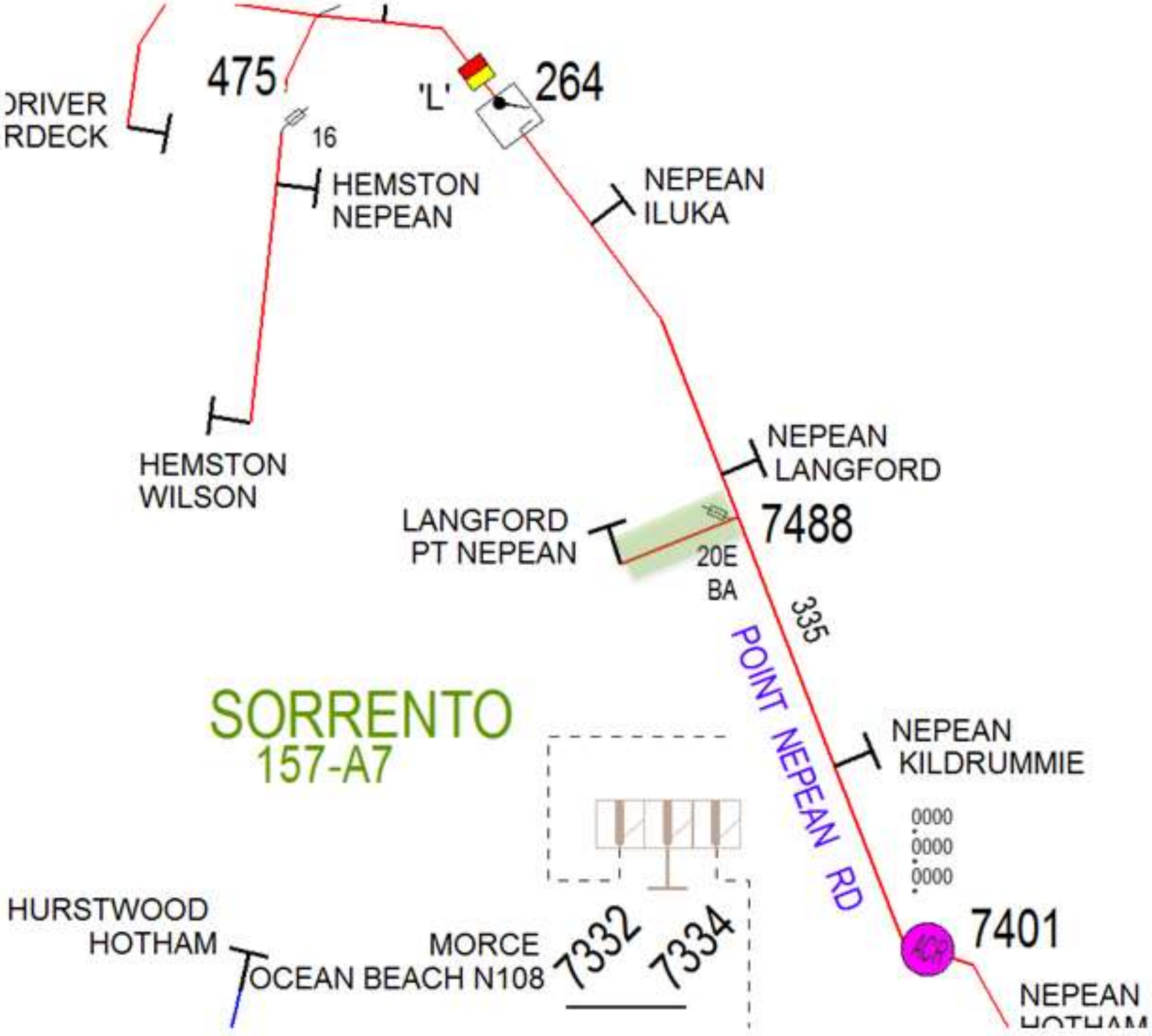
Stage 11 – RBD12

Stage 12 – RBD12

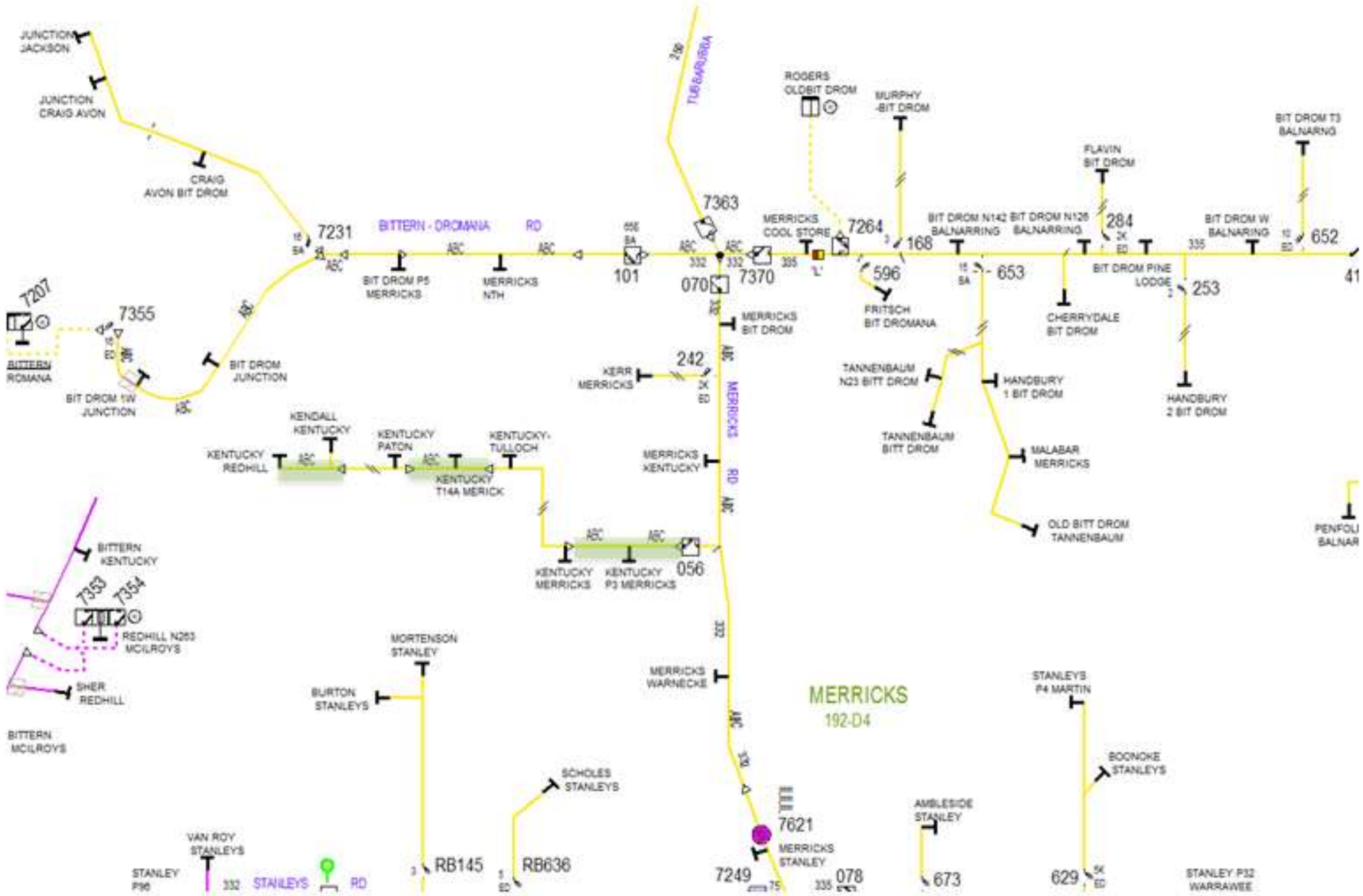


Stage 13 – RBD12

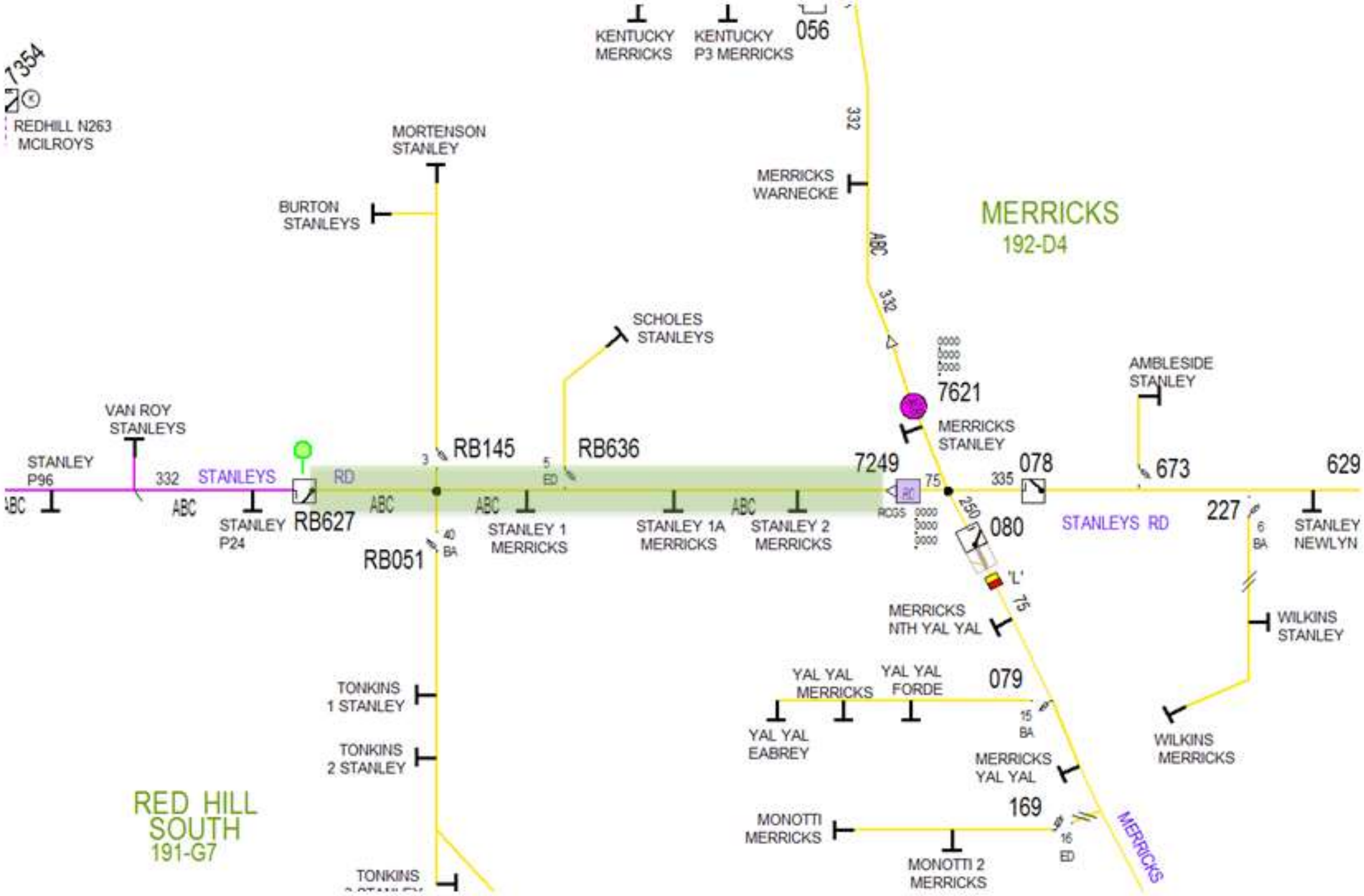
ABC Minor Replacement 7 – STO22



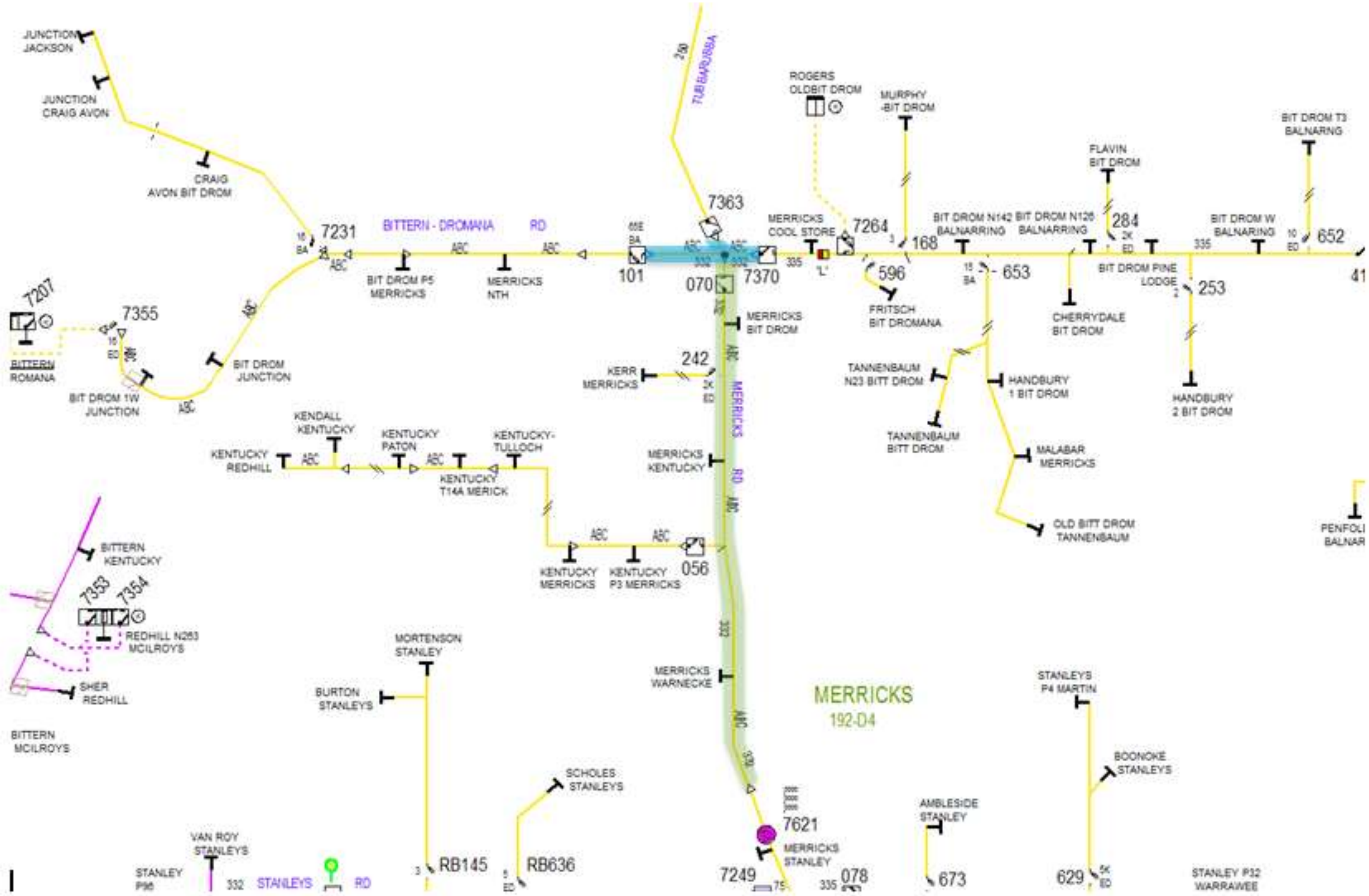
Stage 14 – MTN32



Stage 15 – MTN32



Stage 16 – MTN32



ABC Minor Replacement 8 – MTN32