SUBSTATION 11KV SWITCHBOARD REPLACEMENTS

Program TS700 2017/18 – 2018/19

Including projects:

TS701 – North Rocks ZS 11kV switchboard replacement

TS702 – Kellyville ZS 11kV switchboard replacement

TS703 – Horsley Park ZS 11kV switchboard replacement

TS704 – Port Central ZS 11kV switchboard replacement

Prepared by Asset Strategy and Planning

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Endeavour Energy

REVIEW AND APPROVAL SCHEDULE

Responsibility	Position	Name	Signature	Date
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1.0 EXECUTIVE SUMMARY

This business case introduces a revised approach of replacement of 11kV switchboards in lieu of replacing just the oil insulated circuit breakers in Endeavour Energy's zone substations to improve the safety and reliability of the network. The business case also seeks approval for the first stage of the revised program to replace 11kV switchboards in four zone substations during 2017/18 – 2018/19.

The principal risk being addressed by program TS700 is the failure of an oil filled 11kV circuit breaker to clear a feeder fault, leading to the explosive failure of the circuit breaker and an oil fire in the substation control room with subsequent risks to personnel in the building at the time and significant customer reliability impacts. A reduction in maintenance costs of the modern vacuum circuit breakers compared to oil filled equipment is secondary driver for the program.

Previously, a cost and risk assessment concluded that replacing the oil circuit breaker trucks with vacuum trucks within the existing switchboard and thereby extending the life of the switchboard was the least expensive option available to remove oil from substation control rooms and provide a significant improvement in the safety of the substation. This assessment led to the program of circuit breaker truck replacement under program TS173 and is documented in the business case for TS173 – *11kV switchboard circuit breaker truck replacement*, approved in May 2015.

However, since that time, a re-evaluation of the safety risks in the network, particularly around low probability but high consequence events and a focus on improving operational efficiencies has led to the adoption of strategy to replace the whole 11kV switchboard wherever practicable rather than extending the life of the existing aged switchboard through circuit breaker truck replacement. This approach provides a fully arc-fault contained switchboard which complies with all current standards of safety and provides further reliability benefits associated with the modern busbar protection schemes which come with the switchboards.

The revised strategy includes replacement of switchboards by:

1) Substation renewal and redevelopment;
2) Replacement of whole switchboards within the existing control building where space permits or by extension of the control building; and finally
3) Replacement of the oil circuit breaker trucks with vacuum trucks where space does not permit either substation redevelopment or whole switchboard replacement.

The strategy also includes the replacement of the paper insulated transformer cables and paper insulated feeder cables from the switchboard to the first termination outside of the substation (at a padmount, indoor substation or underground to overhead transition) to reduce the risk of cable termination failures causing fires in the substation as recently occurred at Blaxland Zone Substation.

This business case includes the replacement of switchboards and cables at four zone substations - North Rocks, Kellyville, Horsley Park and Port Central where there is sufficient space for that purpose. The scope of works at each site includes the staged replacement of the existing 11kV switchboard with a new switchboard and the replacement of paper insulated cables. The works are presented as four separate projects within the overall TS700 program with estimated costs of $3.5, $2.7, $3.3 and $2.5 million respectively. A further risk-based contingency amount of 11 - 12% of the project cost estimate is also proposed for each project for unforeseen site conditions which may be encountered working in aged substations.

It is proposed that design works and purchase of switchgear and cables will be undertaken in 2017/18 and installation works in 2018/19. The funding required for the 2017/18 year will be included into the PIP using the PIP change control process and the funding for the 2018/19 year will be allocated in the next release of the PIP.

Accordingly, it is recommended that:

For project TS701 at North Rocks Zone Substation -

- A capital expenditure of $3.5 million for the works to replace the 11kV switchboard at North Rocks ZS during 2017/18 – 2018/19, as detailed in this business case, be approved;
- A contingency amount of $0.4 million be approved.

The complete project estimate including the base costs and the contingency sum totals $3.9 million.

For project TS702 at Kellyville Zone Substation -

- A capital expenditure of $2.7 million for the works to replace the 11kV switchboard at Kellyville ZS during 2017/18 – 2018/19, as detailed in this business case, be approved;
- A contingency amount of $0.3 million be approved.

The complete project estimate including the base costs and the contingency sum totals $3.0 million.

For project TS703 at Horsley Park Zone Substation -

- A capital expenditure of $3.3 million for the works to replace the 11kV switchboard at Horsley Park ZS during 2017/18 – 2018/19, as detailed in this business case, be approved;
- A contingency amount of $0.4 million be approved.

The complete project estimate including the base costs and the contingency sum totals $3.7 million.

For project TS704 at Port Central Zone Substation -

- A capital expenditure of $2.5 million for the works to replace the 11kV switchboard at Port Central ZS during 2017/18 – 2018/19, as detailed in this business case, be approved;
- A contingency amount of $0.3 million be approved.
- The complete project estimate including the base costs and the contingency sum totals $2.8 million.

2.0 INTRODUCTION

2.1 PURPOSE

This business case introduces a revised approach of replacement of 11kV switchboards in lieu of replacing just the oil insulated circuit breakers within the switchboards in Endeavour Energy's zone substations to improve the safety and reliability of the network.

The business case also seeks approval for the first stage of the revised program to replace 11kV switchboards in four zone substations during 2017/18 – 2018/19.

2.2 BACKGROUND

2.2.1 POPULATION OF CIRCUIT BREAKERS

Within Endeavour Energy's zone substations there are a wide variety of 11kV and 22kV circuit breakers of various types, ages and condition.

Table 1 below shows the different types of 11kV and 22kV circuit breakers installed in switchboards in zone substations and the quantities of each that are currently in service.

The age and condition of the newer SF_6 and vacuum insulated equipment is such that renewal is not likely to be required within the foreseeable future. This leaves 667 bulk-oil circuit breakers. 118 of these are currently approved for replacement under various projects and programs including program TS173 - *11kV truck replacement* and project *TS146 - Marayong ZS renewal.*

549 bulk-oil circuit breakers (in 41 zone substations) remain in service and these are the focus of the switchboard renewal plan and this business case.

TABLE 1 – TYPES OF 11KV AND 22KV CIRCUIT BREAKERS

Type of circuit breaker	Quantity in service
Bulk-oil circuit breakers	667
SF_6 circuit breakers	257
Vacuum circuit breakers	1,747
Total	**2,671**

2.2.2 RENEWAL STRATEGY

A renewal plan of these assets has previously been developed under Program TS173 *11kV truck replacement.* The principal purpose of this program was to improve the safety in substation control rooms by replacing the bulk-oil circuit breaker trucks with vacuum trucks within the existing switchboards. Secondary benefits of the program included improvement in network reliability and reducing circuit breaker maintenance costs.

The cost and risk assessment carried out as part developing program TS173 concluded that replacing the oil circuit breaker trucks with vacuum trucks within the existing switchboard and thereby extending the life of the switchboard was the least expensive option available to remove oil from substation control rooms and provide a significant improvement in the safety of the substation. This assessment led to the program of circuit breaker truck replacement under program TS173 up to FY25 which covered all oil circuit breakers in zone substations and is documented in the business case for TS173 – *11kV switchboard circuit breaker truck replacement*, approved in May 2015 [1].

However, since that time, a re-evaluation of the safety risks in the network, particularly around low probability but high consequence events and a focus on improving operational efficiencies has led to the adoption of strategy to replace the whole 11kV switchboard wherever practicable rather than extending the life of the existing aged switchboard through circuit breaker truck replacement. This approach provides a fully arc-fault contained switchboard which complies with all current standards of safety and provides further reliability benefits from the modern busbar protection schemes which come with the new switchboards.

In some substation control rooms, there is sufficient space to allow a new switchboard to be installed in a staged manner whilst the existing switchboard remains in service. In these situations the present cost of replacing the entire switchboard is similar to the truck replacement option thereby giving improved safety and reliability benefits at modest additional present cost. The first four of these sites are North Rocks, Kellyville, Horsley Park and Port Central zone substations. Within the overall revised plan for switchboard replacements, these sites present the most straightforward replacement solutions.

Port Central Zone Substation was previously scheduled for circuit breaker truck replacement in FY18 but delays in finalising a vacuum truck solution for the South Wales switchgear in the substation led to it being removed from the current TS173 project.

The remaining three sites (North Rocks, Kellyville and Horsley Park zone substations) have been brought forward from where previously scheduled under program TS173 to provide improved safety at these sites in a timely manner.

3.0 RENEWAL NEED

3.1 SWITCHBOARDS IN THIS BUSINESS CASE

The switchboards in the four substations noted above are South Wales D type equipment. South Wales D type switchboards contain air-insulated busbars, bulk oil circuit breakers and were installed in Endeavour Energy's zone substations from the mid-1960s to the mid-1980s. There are currently 16 substations in the company's network which contain 195 South Wales D-type circuit breakers.

The reliability of these circuit breakers has generally been good in the past but test results show that many units are now suffering from high contact resistances.

3.2 BULK OIL CIRCUIT BREAKER FAILURES

Endeavour Energy and Ausgrid have both experienced a number of failures of bulk-oil circuit breakers and a number of these have resulted in substation fires. Refer to TS173 - *11kV truck replacement - Business Case 2015-16 (1.7)* [1] for details of these failures.

3.3 PROTECTION SYSTEMS

All feeder protection systems associated with bulk oil 11kV feeder circuit breakers are currently proposed to be upgraded under Program PS012. This upgrade equips each feeder with duplicated numerical relays and circuit breaker failure protection which provides increased reliability performance at a zone substation level. Further, the new relays operate to clear feeder faults more rapidly than the original electromechanical relays which provide additional significant safety improvements for electricity workers and the public from distribution feeders.

The upgrade under program PS012 however cannot provide the switchboards with a busbar protection scheme such as busbar differential protection, which is available in a new switchboard, as this requires additional current transformers to be installed in the bus section panel for which space is not available in the existing switchboards.

Busbar differential protection provides instantaneous operation to isolate a single busbar section in the event of a busbar fault (including circuit breaker faults which impact the busbar).

In the existing switchboards busbar faults are cleared by the transformer overcurrent protection, which will de-energise the entire zone substation. The transformer overcurrent protection must be graded with the downstream feeder protection to ensure that the transformer protection does not operate for feeder faults. Therefore in the event of a busbar fault, the overcurrent protection will be delayed to operate by as much as half a second after the initial detection of the fault. This extra surge of energy in an 11kV switchboard panel can lead to significant damage to surrounding panels and other equipment in the substation. There is also a risk of initiating a substation fire.

Therefore, busbar differential protection which is provided in new switchboards, provides both improved reliability and improved safety and security in a zone substation.

3.4 ARC-FAULT CONTAINMENT

Retrofitting switchboards with vacuum circuit breaker trucks, will remove the risk of an explosive failure due to an oil circuit breaker failing to clear a feeder fault. However, on very rare occasions the vacuum interrupter can lose vacuum leading to a failure and explosion of the interrupter bottle when called on to clear a feeder fault or to switch load.

The failure can cause an arc which could be hazardous to any personnel who may be present in front of the switchgear at the time of the incident. Some of the replacement circuit breaker trucks have additional arc-fault containment doors on the front but modern switchboards direct any such arc away from the front of the circuit breakers and exhaust it out of vents on the top or back of the switchboard and providing a greater level of protection for personnel in the room at the time. Modifications to some bulk oil switchboards (such as arc-proof front panels) are being carried out during circuit breaker truck replacement works to achieve this effect to a substantial extent, however, there is no truck retrofit solution that provides the same level of protection as a new switchboard.

Further, arc-fault contained front panel doors are not available for South Wales 11kV circuit breakers and therefore this risk will remain as long as the switchboards in question remain in service.

On this basis, whole switchboard replacement provides an improved level of safety for personnel in the substation switch room over the truck replacement approach of program TS173 and particular in substations with switchboards where arc-fault contained circuit breaker front panels cannot be fitted.

3.5 RISK ASSESSMENT

Table 2 is based on the Company's risk assessment procedure, Board Policy 2.0.5 [2] and assesses the principal risks presented by the 11kV switchboards noted. In this instance, all switchboards under consideration exhibit generally the same safety and condition issues and therefore the same risk assessment is applicable to each.

TABLE 2 – RISK ASSESSMENT

Event	Likeli-hood	Impact	Risk rating	Consequence and Comments	Proposed Treatment	Expected Risk after Treatment
CB fails to operate	Likely (B)	Minor (2)	Medium (B2)	Fault will be cleared by back-up systems. Loss supply to customers supplied by the busbar section (providing PS012 has applied CB fail protection)	Replace CB truck or whole switchboard	Low (D2)

Event	Likeli-hood	Impact	Risk rating	Consequence and Comments	Proposed Treatment	Expected Risk after Treatment
CB fails to clear fault and fails destructively failure causing substation fire	Possible (C)	Major (4)	**High (C4)**	Consequential damage to other parts of the substation. Loss of supply from the entire substation for an extended period.	Replace oil CBs with vacuum CB or replace whole switchboard	Low (E2)
Busbar fault or CB failure which affects busbar – leading to fire	Possible (C)	Major (4)	**High (C4)**	Consequential damage to other parts of the substation. Loss of supply from the entire substation for an extended period.	Replace oil CBs with vacuum CBs.	Low (E3)
					Replace switchboard with new S/B with busbar differential protection	Low (E2)
Destructive failure with personnel in vicinity	Rare (E)	Severe (5)	Medium (E5)	Fatality of personnel inside substation switchroom.	Replace oil CBs with vacuum CBs	Low (E3)
					Replace oil CBs with vacuum CBs with arc-fault contained doors	Low (E2)
					Replace with new switchboard with full arc-fault containment features	Low (E1)

3.6 CONCLUSION

The risk assessment confirms the substantial safety and reliability benefits provided by replacing oil circuit breakers with vacuum circuit breakers and the further improvement in both safety and reliability of replacing the whole switchboard compared to replacing just the circuit breaker trucks.

4.0 NETWORK NEED

The four substations and their respective switchboards are required for continued service for the foreseeable future. The needs of the four individual 11kV distribution networks are discussed below.

4.1 NORTH ROCKS ZS

North Rocks ZS is a 33kV/11kV substation which includes two 25MVA power transformers which supply the 11kV switchboard with a firm capacity of 25MVA. The 11kV arrangement consists of two sections of switchgear with two transformer circuit breakers, two bus section circuit breakers (one spar on the end of the busbar) and 10 feeder breakers.

The current summer peak demand is 21.8MVA and the current winter peak is 16.8MVA. The demand is currently forecast to remain flat for the next 10 years reaching 18.5MVA in summer and 15.7MVA in winter (with a 50% POE) by the end of the forecast period as shown in Table 3 and Table 4 below.

However, there is a possibility that re-development may occur in the North Rocks industrial area. If this eventuates there will be a need to augment the firm capacity of North Rocks ZS to 50MVA by adding another 25MVA transformer and third section of 11kV busbar.

It is recommended that any 11kV switchgear renewal project include a 12 x 11kV feeder arrangement in two sections and make provision for a future third section of 11kV busbar with a further six feeder breakers.

TABLE 3 – NORTH ROCKS ZS SUMMER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
MVA	16.3	20.4	21.6	18.7	18.7	18.6	18.6	18.5	18.5	18.5	18.4	18.5	18.5

TABLE 4 – NORTH ROCKS ZS WINTER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected								
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
MVA	15.0	16.5	16.8	15.6	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.7

4.2 KELLYVILLE ZS

Kellyville ZS is a 33kV/11kV substation which includes two 25MVA power transformers which supply the 11kV switchboard with a firm capacity of 25MVA. The 11kV arrangement consists of two sections of switchgear with two transformer circuit breakers, two bus section circuit breakers (one spare on the end of the busbar) and 10 feeder breakers.

The current summer peak demand is 20.0MVA and the current winter peak is 13.4MVA. These peak demands are currently forecast to remain flat or declining marginally for the next 10 years to reach 17.1MVA in summer and 12.7MVA in winter (with a 50% POE) by the end of the forecast period as shown in Table 5 and Table 6 below.

However, there is significant development occurring in the North-West sector areas and north-west rail link areas around Kellyville. It is a probable that demand will increase in the Kellyville ZS catchment area or that Kellyville ZS will be required to expand its catchment due to development in nearby areas. If this eventuates there will be a need to augment the capacity of Kellyville ZS.

One option to do this is to install a third 25MVA transformer to provide a firm of 50MVA. Another possibility is to convert the primary voltage at Kellyville ZS to 132kV and install 2 new 45MVA TXs providing a firm capacity of 45MVA.

As a result, it is recommended that any 11kV switchgear renewal project should include a 12 x 11kV feeder arrangement in two sections and make provision for both of the above future arrangements.

TABLE 5 – KELLYVILLE ZS SUMMER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
MVA	20.4	19.9	20.0	17.6	17.8	17.7	17.6	17.5	17.3	17.2	17.2	17.1	17.1

TABLE 6 - KELLYVILLE ZS WINTER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
MVA	12.6	13.4	13.4	12.6	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.6	12.7

4.3 HORSLEY PARK ZS

Horsley Park ZS is a 33kV/11kV substation which includes two 25MVA power transformers which supply the 11kV switchboard with a firm capacity of 25MVA. The 11kV arrangement consists of two sections of switchgear with two transformer circuit breakers, two bus section circuit breakers (one spare on the end of the busbar) and 10 feeder circuit breakers.

The current summer peak demand is 10.3MVA and the current winter peak is 8.3MVA. These peak demands are currently forecast to remain relatively flat for the next 10 years reaching 9.1MVA in summer and 8.3MVA in winter (with a 50% probability of being exceeded (POE)) by the end of the forecast period as shown in Table 7 and Table 8 below.

However, development in the area may occur in the short term as there is much re-development occurring in the nearby Eastern Creak and Wetherill Park industrial areas. There is also a high probability that areas in Horsley Park will be rezoned for industrial use. If this eventuates there may be a need to augment the capacity of Horsley Park ZS by adding a third 25MVA transformer and a third section of 11kV busbar.

Consequently, it is recommended that any 11kV switchgear renewal project should include 12 x 11kV feeder arrangement in two sections with provision is for a future third busbar section with a further six feeder breakers.

TABLE 7 – HORSLEY PARK ZS SUMMER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
MVA	8.8	9.1	10.3	9.4	9.4	9.3	9.3	9.3	9.2	9.2	9.1	9.1	9.1

TABLE 8 – HORSLEY PARK ZS WINTER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
MVA	8.8	8.4	8.3	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3

4.4 PORT CENTRAL ZS

Port Central ZS is a 33kV/11kV substation which includes two 19MVA power transformers which supply the 11kV switchboard with a firm capacity 19MVA. The 11kV arrangement consists of two sections of switchgear with two transformer circuit breakers, one bus section circuit breaker and six feeder breakers.

The current summer peak demand is 10.4MVA and the current winter peak is 9.7MVA. The demand is currently forecast to remain flat for the next 10 years reaching 10.9MVA in summer and 9.5MVA in winter (with a 50% POE) by the end of the forecast period as shown in Table 9 and Table 10 below.

Future growth in the area may necessitate an augmentation of the power transformers to 25MVA providing the substation with a firm 25MVA supply.

As a result, it is recommended that any 11kV switchgear renewal project provide an 8 x 11kV feeder arrangement in two sections and make provision for an additional four circuit breakers to be added to this arrangement.

TABLE 9 – PORT CENTRAL ZS SUMMER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
MVA	10.5	12.4	10.4	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.9	10.9

TABLE 10 - PORT CENTRAL ZS WINTER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
MVA	9.8	12.8	9.7	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.5	9.5

5.0 REPLACEMENT OPTIONS

This section details the options considered to address the asset and network needs identified at the sites in question.

5.1 DO NOTHING

This option will not satisfy the safety, reliability and maintenance risks as discussed in section 3.0 and in the previous circuit breaker truck replacement business case TS173. Further, replacement of the circuit breaker trucks with vacuum switchgear has already been approved under that business case and therefore this option is rejected as not being an adequate response to the risks present.

5.2 REPLACE CIRCUIT BREAKER TRUCKS

This option is currently being carried out under program TS173 and provides the benefits of removing oil from the 11kV switchboards and substation switchrooms. In this option protection relays will also be replaced in the existing locations (under program PS012) to improve the safety and reliability performance of protection systems for distribution feeders.

However, this option will not provide busbar protection or full arc-fault containment capability. Notwithstanding this, the option is considered to be viable and will be assessed further.

5.3 REPLACE ENTIRE SWITCHBOARD IN SITU

This option involves replacing the switchboard in the existing control building. A new switchboard will remove oil from the switchroom and will provide busbar protection and full arc-fault containment capability.

At the four sites in question there is sufficient space for a staged approach of replacing one bus-section at a time with some temporary rearrangement of 11kV feeders and minimal interruption of supply to customers.

There are two different types of switchgear that are being considered for use in this project. The first is the switchboard under the current period contract with Tamco Australia. The second is more expensive but more compact switchgear from Reyrolle Pacific switchgear. The advantage of the Reyrolle switchboard is that when the works are complete, space will be available to facilitate the future augmentation of the switchboards in a cost effective manner as noted in

section 4.0 above. On the other hand, the Tamco switchboard is significantly larger and a building extension will be required in the future to accommodate augmentation of the switchboard capacity.

Further, due to its design and positioning of feeder cable terminations, use of the Tamco switchboard also creates additional complications for the staging of the installation works and will necessitate additional temporary feeder re-arrangements. This additional work increases the costs of the Tamco option to be similar to that of the Reyrolle option.

Therefore the Reyrolle switchboard has been selected as the most appropriate switchboard for this project.

5.4 RENEWAL OPTIONS UNDER CONSIDERATION

At all four sites there are two options which warrant further assessment – replacing just the circuit breaker trucks and replacing the entire switchboard. These options are summarised in Table 11 below and their respective costs for each of the four substation sites are detailed in Table 12.

TABLE 11 – REDEVELOPMENT OPTIONS

Option	Redevelopment works
Option 1	• Replace oil circuit breaker trucks with vacuum trucks • Replace protection systems under program PS012
Option 2	• Replace switchboard with new a vacuum switchboard. (Protection systems are included on the new switchboard) • Provide space in the 11kV switchroom for a future extension of the switchboard

TABLE 12 – OPTION COST ESTIMATES ($ REAL 2017/18)

	North Rocks ZS		Kellyville ZS		Horsley Park ZS		Port Central ZS	
Items	Option 1	Option 2	Option 1	Option 2	Option 1	Option 2	Option 1	Option 2
Retrofit vacuum CBs	698,000	0	586,000	0	586,000	0	315,000	0
11kV switchboard cost	0	1,689,400	0	1,677,400	0	1,689,400	0	1,167,700
11kV VT replacement	20,000	0	20,000	0	20,000	0	10,000	0
Cable box change from compound to air insulation	30,000	0	30,000	0	30,000	0	30,000	0
New protection panels/relays	320,000	0	0	0	320,000	0	230,000	0
Building works	0	152,500	0	152,500	0	152,500	0	145,000
Mains works (terminations + replacement of paper insulated cables with XLPE)	0	366,600	0	480,100	0	406,600	0	290,900
Distribution works (replacement of paper insulated 11kV feeder cables with XLPE)	0	842,000	0	0	0	636,000	0	517,000
Electrical works	65,800	0	65,800	0	65,800	0	42,300	0
SCADA updates	0	40,000	0	40,000	0	40,000	0	40,000
Major equipment storage	0	24,200	0	24,200	0	24,200	0	16,600
Staging and change-over costs	0	77,600	0	77,600	0	77,600	0	51,700
Project management, project definitions	32,000	160,200	32,000	160,200	32,000	160,200	32,000	160,200
Total initial capital costs ($)	1,166,000	3,352,000	734,000	2,611,000	1,054,000	3,187,000	659,300	2,389,000

6.0 ASSESSMENT OF THE OPTIONS

In order to determine the preferred option, the identified options for addressing the renewal needs of the substation have been assessed against a number of key risk indicators and for their present cost.

6.1 TREATMENT OF RISK

The risk assessment categories include:

- Safety impact;
- Construction risk;
- Operating and maintenance requirements;
- Reliability and supply security impact;
- Sustainability impact.

6.2 RISK RATINGS

Each of the viable options have been assessed against each other for each of the above risks as shown below. All risks are assessed based on the Company's risk assessment procedure, Board Policy 2.0.5 by assessing the likelihood and consequence of an event. Refer to Appendix B for further detail of the assessment.

6.2.1 SAFETY IMPACT

This indicator is applied to the final outcome of the project and also to the actual construction process itself. It is assumed that all equipment and procedures used by Endeavour Energy for all options will provide a safe work environment for staff and workers and will comply with the relevant safety standards. However, some options are inherently safe by design whereas others require more effort through the application of procedures and work methods to ensure safety. An option which is inherently safe will therefore achieve a lower risk score than an option which requires more effort to ensure it is safe.

Both options remove the hazards presented by the bulk-oil 11kV switchgear. However, *Option 2* provides an additional level of safety by providing full arc-fault containment capability to current modern safety standards. Further, *Option 1* retains the existing busbar with the existing limited busbar protection schemes. The aged components of the busbar are more likely to fail and clearance of the fault will be slower than that provided by *Option 2* which will renew the busbar and provide instantaneous busbar differential protection.

Further, under *Option 2* the opportunity is proposed to be taken to replace all paper insulated cables in the basement of the substation to lessen the risk of a cable termination failure (as occurred at Blaxland ZS in January 2017). This will lead to reduced safety risk for workers in the cable basement and switchroom.

Therefore *Option 2* scores above *Option 1* for this indicator.

6.2.2 CONSTRUCTION FEASIBILITY

Construction feasibility considers the risks to the cost and delivery schedule of the project due to issues surrounding the complexity of the construction procedures required. This will be affected by:

- Complexity of construction (number of temporary works required);
- Staging requirements for construction (number of basic construction stages);
- The availability of space for construction works.

Option 1 will require minimal staging works as the circuit breaker trucks can be replaced within the existing panels. However, experience of truck retrofits at other sites has proven that there are often complex modifications that are required to the switchboard panels to fit the new trucks leading to delays and cost increases. Further, South Wales switchboards have not been retro-fitted previously within the industry and therefore encountering such problems at these four sites is very likely. Therefore, this option scores poorly for this indicator.

Option 2 requires a modest degree of staging works and temporary feeder arrangements and may result in some minor delays but otherwise is considered to be more straightforward than *Option 1*.

6.2.3 OPERATING AND MAINTENANCE REQUIREMENTS

This indicator assesses the ongoing operating and maintenance requirements in terms of cost and resource demand and is influenced by issues including:

- The maintenance requirements of the equipment;
- The use of established and well understood equipment and procedures to reduce O&M risks;
- The flexibility of the substation arrangement for carrying out switching and maintenance tasks;
- The ease of access to the equipment for switching and maintenance tasks; and
- The susceptibility of the equipment to damage due to environmental or human factors.

Option 1 retains the existing busbars and switchboard panels. Although they are in satisfactory condition at present, they will likely require an increasing level of maintenance as they age.

Option 2 removes all of the aged equipment in the 11kV switchboards and replaces it with new equipment with minimal maintenance requirements and therefore scores better than *Option 1* for this indicator.

6.2.4 RELIABILITY AND SUPPLY SECURITY RISK

This indicator considers the risk posed to the reliability of the supply to customers and the security of the supply provided by the substation (at 11kV busbar level) during the development works and also by the completed asset.

Both options maintain a secure level of supply to customers and pose a reasonably low level of risk for this indicator during construction. However, *Option 2* includes temporarily rearranging 11kV feeders in doubled up arrangements during works. This will require an increased amount of planned outages and will put greater strain on the distribution network when unplanned outages occur. However, unplanned outages which may occur should only be limited to individual 11kV feeders and should not result in large scale outages.

Option 1 does not require temporary arrangements and will provide greater security during construction. However, the final result is a switchboard which lacks busbar differential protection. If an internal fault in the switchboard was to occur it will likely do significantly more damage to the substation than in *Option 2* leading to increased reliability impacts on customers.

Further, as noted above, under *Option 2* the opportunity is proposed to be taken to replace all paper insulated cables in the basement of the substation to lessen the risk of a cable termination failure (as occurred at Blaxland ZS in January 2017). This will lead to reduced reliability risks.

As a result of this range of impacts, overall, *Option 2* is considered to present a reduced reliability risk than *Option 1*.

6.2.5 SUSTAINABILITY IMPACT

This indicator considers the energy and resource use during construction and also for the life-cycle of the asset. It also considers how well the option supports the business objective of strategically managing the network (ie to avoid future bottle necks in resource demand). This indicator includes consideration of:

- Provision for the future needs and/or further development of the substation as may be required in the future;
- Minimisation of returns to the site for additional work;
- Utilisation of assets;
- Provision for reuse of redundant equipment;
- Minimisation of usage of materials (as compact as practicable);
- Minimisation of wastage of materials and resources (temporary works); and
- Minimisation of the ongoing use of energy.

Option 2 will result in an arrangement which will be suitable for service for the long term. Sufficient space will be provided for future arrangements and therefore presents a low risk in terms of the sustainability indicator. It is noted that at Port Central ZS there is sufficient space to install two a four feeder bus-section and a three feeder bus-section. This is smaller than the two by four feeder bus-section switchboard described in 4.0. However, this is sufficient for the distribution network for the foreseeable future. The arrangement allows for the addition of three extra breakers if required in the future.

Option 1 maintains an aged busbar which will require replacement in the medium term. It is also noted that at Port Central ZS there is currently insufficient space to extend section No. 1 and therefore future circuit breakers are expected to be required will be limited to section 2 only which will not be optimum from a network arrangement and load distribution perspective. Therefore, this option scores poorly for this indicator.

6.2.6 SUMMARY OF RISKS

Based on the above analysis, Table 13 below gives a visual representation of the risks presented by each of the options. It shows that Option 2 provides substantial improvements to safety, construction feasibility, operation and maintenance costs, customer reliability and business sustainability compared to Option 1.

TABLE 13 – QUALITATIVE RISK ASSESSMENT

Option	Option detail	Safety	Construction	Operating & maintenance	Reliability	Sustainability
1	Replace CB trucks					
2	Replace entire switchboard					
Code	Extreme risk	High risk	Moderate risk	Low risk		

Accordingly, Option 2, which includes the complete replacement of the switchboard in the existing control building, is the preferred redevelopment approach from a risk perspective.

6.3 NET PRESENT COST OF OPTIONS

The present cost of each option has been assessed including the initial capital costs and the present value of future capital expenditure requirements. The assessment includes future works to replace the 11kV switchboard under Option 1. The life of an 11kV switchboard (as distinct from the circuit breakers within the switchboard) is not well understood and therefore a nominal remaining life of 15 years, after circuit breaker truck replacement, has been assumed for all switchboards.

The analysis also includes the residual value of the 11kV equipment installed in this project based on a 45 year life span.

It is also noted that, as discussed in section 4.0, at some time in the future (possibly less than 10 years in some substations) an augmentation of each substation may be required to increase its capacity. It has been estimated that the cost of this augment would be in the order of $4 million at each site. However, this cost is common for both options and therefore is not shown in the analysis.

The results of the assessment are summarised in Table 14 - Table 17 below. Option 2 provides a significant reduction in risk for a modest increase in present cost at less than $0.7 million per site over Option 1.

Therefore, Option 2 is the preferred option for renewal of the 11kV switchboards at these four sites. Refer to Appendix B for further detail of the present cost analysis.

TABLE 14 – NORTH ROCKS ZS NET PRESENT COST OF OPTIONS ($ REAL 2017/18)

Item	Option 1 ($)		Option 2 ($)	Option difference ($)
	Year 0 - Retrofit trucks	Year 15 - Replace switchboard	Year 0 - Replace switchboard	
Retrofit vacuum CBs	698,000	0	0	654,000
11kV switchboard cost	0	1,689,400	1,689,400	
11kV VT replacement	20,000	0	0	
Cable box change from compound to air insulation	30,000	0	0	
New protection panels/relays	320,000	0	0	
Building works	0	152,500	152,500	
Mains works (terminations + replacement of paper insulated TX, auxiliary and capacitor cables with XLPE)	0	366,600	366,600	
Distribution works (replacement of paper insulated 11kV feeder cables with XLPE)	0	842,000	842,000	
Electrical works	65,800	0	0	
SCADA updates	0	40,000	40,000	
Major equipment storage	0	24,200	24,200	
Staging and change-over costs	0	77,600	77,600	
Project management, Project Definitions	32,000	160,200	160,200	
Totals	**1,166,000**	**3,353,000**	**3,352,000**	
Totals (not discounted)		**4,519,000**	**3,352,000**	
Residual value of 11kV equipment at 45 years		**1,117,000**	**0**	
Totals (discounted to the present)		**2,698,000**	**3,352,000**	

TABLE 15– KELLYVILLE ZS NET PRESENT COST OF OPTIONS ($ REAL 2017/18)

Item	Option 1 ($)		Option 2 ($)	Option difference ($)
	Year 0 - Retrofit trucks	Year 15 - Replace switchboard	Year 0 - Replace switchboard	
Retrofit vacuum CBs	586,000	0	0	685,000
11kV switchboard cost	0	1,677,400	1,677,400	
11kV VT replacement	20,000	0	0	
Cable box change from compound to air insulation	30,000	0	0	
New protection panels/relays	0	0	0	
Building works	0	152,500	152,500	
Mains works - (terminations + replacement of paper insulated TX, auxiliary and capacitor cables with XLPE)	0	480,100	480,100	
Distribution works - (replacement of paper insulated 11kV feeder cables with XLPE)	0	0	0	
Additional works	65,800	141,800	141,800	
Project management, Project Definitions	32,000	160,200	160,200	
Totals	**734,000**	**2,612,000**	**2,612,000**	
Totals (not discounted)		**3,346,000**	**2,612,000**	
Residual value of 11kV equipment at 45 years		**871,000**	**0**	
Totals (discounted to the present)		**1,927,000**	**2,612,000**	

TABLE 16 – HORSLEY PARK ZS NET PRESENT COST OF OPTIONS ($ REAL 2017/18)

Item	Option 1 ($)		Option 2 ($)	Option difference ($)
	Year 0 - Retrofit trucks	Year 15 - Replace switchboard	Year 0 - Replace switchboard	
Retrofit vacuum CBs	586,000	0	0	677,000
11kV switchboard cost	0	1,689,400	1,689,400	
11kV VT replacement	20,000	0	0	
Cable box change from compound to air insulation	30,000	0	0	
New protection panels/relays	320,000	0	0	
Building works	0	152,500	152,500	
Mains works - (terminations + replacement of paper insulated TX, auxiliary and capacitor cables with XLPE)	0	406,600	406,600	
Distribution works - (replacement of paper insulated 11kV feeder cables with XLPE)	0	636,000	636,000	
Additional works	65,800	141,800	141,800	
Project management, Project Definitions	32,000	160,200	160,200	
Totals	**1,054,000**	**3,187,000**	**3,187,000**	
Totals (not discounted)		**4,241,000**	**3,187,000**	
Residual value of 11kV equipment at 45 years		**1,062,000**	**0**	
Totals (discounted to the present)		**2,510,000**	**3,187,000**	

TABLE 17 – PORT CENTRAL ZS NET PRESENT COST OF OPTIONS ($ REAL 2017/18)

Item	Option 1 ($)		Option 2 ($)	Option difference ($)
	Year 0 - Retrofit trucks	Year 15 - Replace switchboard	Year 0 - Replace switchboard	
Retrofit vacuum CBs	315,000	0	0	638,000
11kV switchboard cost	0	1,167,700	1,167,700	
11kV VT replacement	10,000	0	0	
Cable box change from compound to air insulation	30,000	0	0	
New protection panels/relays	230,000	0	0	
Building works	0	145,000	145,000	
Mains works - (terminations + replacement of paper insulated TX, auxiliary and capacitor cables with XLPE)	0	290,900	290,900	
Distribution works – (replacement of paper insulated 11kV feeder cables with XLPE)	0	517,000	517,000	
Additional works	42,300	108,300	108,300	
Project management, Project Definitions	32,000	160,200	160,200	
Totals	**659,000**	**2,389,000**	**2,389,000**	
Totals (not discounted)		**3,048,000**	**2,389,000**	
Residual value of 11kV equipment at 45 years		**796,000**	**0**	
Totals (discounted to the present)		**1,751,000**	**2,389,000**	

7.0 PROJECT DETAILS

7.1 TS701 NORTH ROCKS ZS

7.1.1 PROJECT SCOPE OF WORKS

The scope of works at North Rocks ZS includes:

- Staged section by section replacement of the 11kV switchboard with a new Reyrolle LMVP switchboard;
- New protection relays on the new switchboard;
- Replacement of paper insulated transformer and feeder cables with XLPE;
- Testing and commissioning of the new switchboard and cables;
- Disposal of the old switchboards and relays.

7.1.2 DISTRIBUTION WORKS

North Rocks ZS contains seven outgoing 11kV feeder aluminium paper cables. As new cables will be run from the new switchboard for these feeders it is proposed that the entire lengths of the aluminium paper cables should be replaced with XLPE. The remaining two cables are XLPE and can remain as they are and any additional lengths required to connect to the new switchboard should be jointed in the substation, outside the cable basement as appropriate. Refer to Appendix C for further detail.

7.1.3 OTHER PROGRAMS

7.1.4 PS012

The protection systems at North Rocks ZS are proposed to be upgraded under program PS012. As new protection systems to current standard are included with the new switchboard proposed in this project the works in PS012 for North Rocks ZS should be cancelled via change control after this business case is approved. The total funding allocation for PS012 at North Rocks ZS is $320,000 which can be transferred to this project.

7.1.5 TS009

The auxiliary switchgear at North Rocks ZS is currently being replaced under program TS009 *Auxiliary switchgear replacement*. The 11kV cables installed under that program should accommodate the installation of the new switchboard under this program.

7.1.6 PROJECT ESTIMATE

The estimated costs of the preferred option (Option 2) are summarised in Table 18 below. Refer to Appendix A for further detail of the cost estimates.

TABLE 18 – SITE COST ESTIMATES AT NORTH ROCKS ZS ($ REAL 2017/18)

Item	Estimated costs ($)
11kV Reyrolle LMVP switchboard – supply and installation	1,689,385
Building works – floor penetrations for the new switchgear	152,500
SCADA updates	40,000
Mains – replacement of TX 1 and TX 2 cables and joint to capacitor cable	366,579
Distribution – replace 7 paper insulated feeder cables	842,000
Major equipment storage	24,180
Staging and change-over costs	77,596
Project management, Project Definitions	160,213
Total (to nearest $10,000)	$3,350,000

7.2 TS702 KELLYVILLE ZS

7.2.1 PROJECT SCOPE OF WORKS

The scope of works at Kellyville ZS includes:

- Staged section by section replacement of the 11kV switchboard with a new Reyrolle LMVP switchboard:
- New protection relays on the new switchboard;
- Testing and commissioning of the new switchboard and cables;
- Disposal of the old switchboard and relays.

7.2.2 DISTRIBUTION WORKS

All outgoing 11kV cables at Kellyville ZS are XLPE and can remain as they are. Any additional lengths required to connect to the new switchboard should be jointed in the substation, outside the cable basement as appropriate.

7.2.3 OTHER PROGRAMS

7.2.4 PS012

The PS012 works at Kellyville ZS are complete. The new relays installed on the existing switchboard as part of PS012 are to be reclaimed for use at other sites.

7.2.5 TS009

The auxiliary switchgear at Kellyville ZS is currently being replaced under TS009 *Auxiliary switchgear replacement*. The 11kV cables installed under that program should accommodate the installation of the new switchboard under this program.

7.2.6 PROJECT ESTIMATE

The estimated costs of the preferred option (Option 2) are summarised in Table 19 below. Refer to Appendix A for further detail of the cost estimates.

TABLE 19 – SITE COST ESTIMATES KELLYVILLE ZS ($ REAL 2017/18)

Item	Estimated costs ($)
11kV Reyrolle LMVP switchboard – supply and installation	1,677,385
Building works – floor penetrations for the new switchgear	152,500
SCADA updates	40,000
Mains – replacement of TX 1 and TX 2 cables and joint to capacitor cable	480,113
Distribution – additional lengths of XLPE feeder cable and jointing	24,180
Major equipment storage	77,596
Staging and change-over costs	160,213
Total	$2,610,000

7.3 TS703 HORSLEY PARK ZS

7.3.1 PROJECT SCOPE OF WORKS

The scope of works at Horsley Park ZS includes;

- Staged section by section replacement of the 11kV switchboard with a new Reyrolle LMVP switchboard;
- New protection relays on the new switchboard;
- Replacement of paper insulated transformer and feeder cables with XLPE;
- Testing and commissioning of the new switchboard and cables;
- Disposal of the old switchboards and relays.

7.3.2 DISTRIBUTION WORKS

Horsley Park ZS contains five outgoing 11kV feeder aluminium paper cables. As new cables will be run from the new switchboard for these feeders it is proposed that the entire lengths of the aluminium paper cables should be replaced with XLPE. The remaining feeder cables are XLPE and can remain as they are and any additional lengths required to connect to the new switchboard should be jointed in the substation, outside the cable basement as appropriate. Refer to Appendix C for further detail.

7.3.3 OTHER PROGRAMS

Protection systems at Horsley Park ZS are proposed to be upgraded under program PS012. As new protection systems to current standards are included with the new switchboard proposed under this project the works in PS012 for North Rocks ZS should be cancelled via change control after this business case is approved. The total funding allocation for PS012 at Horsley Park ZS is $320,000 which can be transferred to this project.

7.3.4 PROJECT ESTIMATE

The estimated costs of the preferred option (Option 2) are summarised in Table 20 below. Refer to Appendix A for further detail of the cost estimates.

TABLE 20 – SITE COST ESTIMATES AT HORSLEY PARK ZS ($ REAL 2017/18)

Item	Estimated costs ($)
11kV Reyrolle LMVP switchboard – supply and installation	1,689,385
Building works – floor penetrations for the new switchgear	152,500
SCADA updates	40,000
Mains – replacement of TX 1 and TX 2 cables and joint to capacitor cable	406,634
Distribution – replace 5 paper insulated feeder cables	636,000
Major equipment storage	24,180
Staging and change-over costs	77,596
Project management, Project Definitions	160,213
Totals	$3,190,000

7.4 TS704 PORT CENTRAL ZS

7.4.1 PROJECT SCOPE OF WORKS

The scope of works at Port Central ZS includes;

- Staged section by section replacement of the 11kV switchboard with a new Reyrolle LMVP switchboard;
- New protection relays on the new switchboard;
- Replacement of paper insulated transformer and feeder cables with XLPE;
- Testing and commissioning of the new switchboard and cables;
- Disposal of the old switchboards and relays.

7.4.2 DISTRIBUTION WORKS

Port Central ZS contains five outgoing 11kV feeder aluminium paper cables. As new cables will be run from the new switchboard for these feeders it is proposed that the entire lengths of the aluminium paper cables should be replaced with XLPE. The remaining feeder cables are XLPE and can remain as they are and any additional lengths required to connect to the new switchboard should be jointed in the substation, outside the cable basement as appropriate. Refer to Appendix C for further detail.

7.4.3 OTHER PROGRAMS

The protection systems at Port Central ZS are proposed to be upgraded under program PS012. As new protection systems to current standard are included with the new switchboard proposed in this project the works in PS012 for North Rocks ZS should be cancelled via change control after this business case is approved. The total funding allocated for PS012 at Port Central ZS is $230,000 which can be transferred to this project.

Furthermore, this substation is included in the approved program TS173 to have its circuit breaker trucks replaced in 2018/19. These works will be removed from program TS173 once this project is approved.

7.4.4 PROJECT ESTIMATE

The estimated costs of the preferred option (Option 2) are summarised in Table 21 below. Refer to Appendix A for further detail of the cost estimates.

TABLE 21 – SITE COST ESTIMATES AT PORT CENTRAL ZS ($ REAL 2017/18)

Item	Estimated costs ($)
11kV Reyrolle LMVP switchboard – supply and installation	1,167,711
Building works – floor penetrations for the new switchgear	145,000
SCADA updates	40,000
Mains – replacement of TX 1 and TX 2 cables and joint to capacitor cable	290,871
Distribution – replace 7 paper feeder cables	517,000
Major equipment storage	16,620
Staging and change-over costs	51,730
Project management, Project Definitions	160,213
Totals	$2,390,000

8.0 PROJECT FUNDING

8.1 FUNDING ARRANGEMENT

These four projects are new and have not been included in the Portfolio Investment Plan (PIP) v8.3. As noted above, the previous strategy for these substations under PIP 8.3 was to retrofit circuit breaker trucks and therefore funding was allocated under TS173 - *11kV truck replacement*. However, except for Port Central ZS, the funding for these sites under TS173 was in future years beyond the period of this project. Therefore funding requirements for these new projects in 2017/18 will be added to the PIP via PIP change control and funding requirements in 2018/19 will be included in the in next release of the PIP.

8.2 CONTINGENCY

A contingency amount is proposed to allow for delays and cost increases caused by unforeseen issues which may arise as a result of the works being conducted in aged substations. The sites may also require additional works to strengthen the switchroom floors after floor penetrations are complete. A further allowance is made for unforseen additional procurement costs.

These risks are reflected in Table 22 against the various functional activities or work packets required to implement the project.

TABLE 22 – CONTINGENCY PROVISIONS

		Contingency provisions	
Substation	Item	Amount ($ Real)	Explanation
TS701 – North Rocks ZS	Substation procurement	126,000	Unforeseen price increases
	Work in aged sites	125,000	Unforeseen site conditions (including asbestos), program duration increase, additional labour costs
	Floor penetrations	36,000	Possible need to strengthen substation floor
	Distribution works	93,000	Unforeseen site conditions
	Total (rounded to nearest $100,000)	**400,000**	
TS702 – Kellyville ZS	Substation	126,000	Unforeseen price increases

		Contingency provisions	
Substation	Item	Amount ($ Real)	Explanation
	procurement		
	Work in aged sites	139,000	Unforeseen site conditions, program duration increase, additional labour costs
	Floor penetrations	36,000	Possible need to strengthen substation floor
	Total (rounded to nearest $100,000)	**300,000**	
TS703 – Horsley Park ZS	Substation procurement	126,000	Unforeseen price increases
	Work in aged sites	134,000	Unforeseen site conditions, program duration increase, additional labour costs
	Floor penetrations	30,000	Possible need to strengthen substation floor
	Distribution works	70,000	Unforeseen site conditions
	Total (rounded to nearest $100,000)	**400,000**	
TS704 – Port Central ZS	Substation procurement	91,000	Unforeseen price increases
	Work in aged sites	98,000	Unforeseen site conditions, program duration increase, additional labour costs
	Floor penetrations	32,000	Possible need to strengthen substation floor
	Distribution works	57,000	Unforeseen site conditions
	Total (rounded to nearest $100,000)	**300,000**	

8.3 EXPENDITURE CASHFLOW

A cashflow representing the expected expenditure spread and including contingency for the expenditure for each of the four projects is shown in Table 23 below.

TABLE 23 – PROJECT EXPENDITURE SPREAD

Project	Estimated cost ($ M)	2017/18	2018/19	Total
TS701 North Rocks ZS	PIP8.3 provision (TS173) (nominal)	0.0	0.0	**0.0**
	PIP8.3 provision (PS012) (nominal)	0.0	0.0	**0.0**
	PIP8.3 provision (Total) (nominal)	0.0	0.0	**0.0**
	Estimated project TS701 (real 2017/18)	1.7	1.7	**3.4**
	Estimated project TS701 cost (nominal)	1.7	1.8	**3.5**
	Contingency			**0.4**
	Total project costs (nominal)			**3.9**
TS702 Kellyville ZS	PIP8.3 provision (TS173) (nominal)	0.0	0.0	**0.0**
	PIP8.3 provision (PS012) (nominal)	0.0	0.0	**0.0**
	PIP8.3 provision (Total) (nominal)	0.0	0.0	**0.0**
	Estimated project TS702 (real 2017/18)	1.3	1.3	**2.6**
	Estimated project TS702 cost (nominal)	1.3	1.4	**2.7**
	Contingency			**0.3**
	Total project costs (nominal)			**3.0**

Project	Estimated cost ($ M)	2017/18	2018/19	Total
TS703 Horsley Park ZS	PIP8.3 provision (TS173) (nominal)	0.0	0.0	**0.0**
	PIP8.3 provision (PS012) (nominal)	0.0	0.3	**0.3**
	PIP8.3 provision (Total) (nominal)	0.0	0.3	**0.3**
	Estimated project TS702 (real 2017/18)	1.6	1.6	**3.2**
	Estimated project TS702 cost (nominal)	1.6	1.7	**3.3**
	Contingency			**0.4**
	Total project costs (nominal)			**3.7**
TS704 Port central ZS	PIP8.3 provision (TS173) (nominal)	0.5	0.0	**0.5**
	PIP8.3 provision (PS012) (nominal)	0.0	0.2	**0.2**
	PIP8.3 provision (Total) (nominal)	0.5	0.2	**0.7**
	Estimated project TS702 (real 2017/18)	1.2	1.2	**2.4**
	Estimated project TS702 cost (nominal)	1.2	1.3	**2.5**
	Contingency			**0.3**
	Total project cost (nominal)			**2.8**

9.0 RECOMMENDATIONS

9.1 TS701 - NORTH ROCKS ZS

It is recommended that:

- A capital expenditure of $3.5 million to replace the 11kV switchboard at North Rocks ZS over the period of 2017/18 – 2018/19 as detailed in this business case be approved;
- A contingency sum of $0.4 million, representing 11% of the project estimated cost to cover unforseen events be approved;

The complete project estimate including the base costs and the contingency sum totals $3.9 million.

9.2 TS702 – KELLYVILLE ZS

It is recommended that:

- A capital expenditure of $2.7 million to replace the 11kV switchboard at Kellyville ZS over the period of 2017/18 – 2018/19 as detailed in this business case be approved;
- A contingency sum of $0.3 million, representing 11% of the project estimated cost to cover unforseen events be approved;

The complete project estimate including the base costs and the contingency sum totals $3.0 million.

9.3 TS703 – HORSLEY PARK ZS

It is recommended that:

- A capital expenditure of $3.3 million to replace the 11kV switchboard at Horsley Park ZS over the period of 2017/18 – 2018/19 as detailed in this business case be approved;
- A contingency sum of $0.4 million, representing 12% of the project estimated cost to cover unforseen events be approved;

The complete project estimate including the base costs and the contingency sum totals $3.7 million.

9.4 TS704 – PORT CENTRAL ZS

It is recommended that:

- A capital expenditure of $2.5 million to replace the 11kV switchboard at Horsley Park ZS over the period of 2017/18 – 2018/19 as detailed in this business case be approved;
- A contingency sum of $0.3 million, representing 12% of the project estimated cost to cover unforseen events be approved;

The complete project estimate including the base costs and the contingency sum totals $2.8 million.

10.0 APPENDICES

Appendix A – Cost estimate

Appendix B – Cost and risk assessment

Appendix C – Distribution works

Appendix D – Images of switchboards

11.0 REFERENCES

[1] Asset Strategy and Planning, “TS173 - 11kV truck replacement - Business Case 2015-16 (1.7),” 2015.

North Rocks ZS TS701	SUMMARY					
ITEM	**QTY**	**Labour Cost ($)**	**Store Costs ($)**	**Plant Costs ($)**	**Direct Charge ($)**	**Total Cost ($)**
Outdoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	12	$446,194	$20,842	$35,104	$664,088	$1,166,228
Outdoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	2	$85,549	$76	$3,480	$183,090	$272,196
Joggle Chamber/Bus Ducting	0	$0	$0	$0	$0	$0
Transformer Bays						
Bays	2	$91,117	$4,476	$5,628	$149,740	$250,961
Transformer Costs	0	$0	$0	$0	$0	$0
Bunds / Sound Walls / Blast Walls / Fire Suppression		$0	$0	$0	$0	$0
AFIC Equipment						
SFU & Injection Cells		$0	$0	$0	$0	$0
Building & Switchyard						
Building/Transformer Runway/Fencing/						
Landscaping/Building Fire Suppression		$0	$0	$0	$152,500	$152,500
Ancillary Equipment						
11kV Aux Switchboard/Aux. Transf./						
Batteries & chargers/Radio System/ New SCADA		$17,000	$0	$0	$23,000	$40,000
Underfrequency Load Shedding						
	0	$0	$0	$0	$0	$0
Capacitor Banks						
	0	$0	$0	$0	$0	$0
General Arrangment Update						
		$0	$0	$0	$0	$0
Project Management & Project Definitions						
						$160,213
Control Panels						
	0	$0	$0	$0	$0	$0
Mains						
		$252,693	$23,077	$35,184	$55,625	$366,579
Distribution						
		$0	$0	$0	$842,000	$842,000
Additional Costs						
Major Equipment Storage					$24,180	$24,180
On Site Security					$0	$0
0					$ -	$0
Outages		$77,596	$ -	$ -	$ -	$77,596
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
SUB TOTAL:						**$3,352,452**
CPI:						
TOTAL (to the nearest $100k):						**$3,400,000**
Contingency (to the nearest $100k):						**$ 400,000**

Kellyville ZS TS702	SUMMARY					
ITEM	**QTY**	**Labour Cost ($)**	**Store Costs ($)**	**Plant Costs ($)**	**Direct Charge ($)**	**Total Cost ($)**
Outdoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	12	$434,194	$20,842	$35,104	$664,088	$1,154,228
Outdoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	2	$85,549	$76	$3,480	$183,090	$272,196
Joggle Chamber/Bus Ducting	0	$0	$0	$0	$0	$0
Transformer Bays						
Bays	2	$91,117	$4,476	$5,628	$149,740	$250,961
Transformer Costs	0	$0	$0	$0	$0	$0
Bunds / Sound Walls / Blast Walls / Fire Suppression		$0	$0	$0	$0	$0
AFIC Equipment						
SFU & Injection Cells		$0	$0	$0	$0	$0
Building & Switchyard						
Building/Transformer Runway/Fencing/						
Landscaping/Building Fire Suppression		$0	$0	$0	$152,500	$152,500
Ancillary Equipment						
11kV Aux Switchboard/Aux. Transf./						
Batteries & chargers/Radio System/ New SCADA		$17,000	$0	$0	$23,000	$40,000
Underfrequency Load Shedding						
	0	$0	$0	$0	$0	$0
Capacitor Banks						
	0	$0	$0	$0	$0	$0
General Arrangment Update						
		$0	$0	$0	$0	$0
Project Management & Project Definitions						
						$160,213
Control Panels						
	0	$0	$0	$0	$0	$0
Mains						
		$321,342	$27,030	$41,949	$89,792	$480,113
Distribution						
		$0	$0	$0	$0	$0
Additional Costs						
Major Equipment Storage					$24,180	$24,180
On Site Security					$0	$0
0					$ -	$0
Outages		$77,596	$ -	$ -	$ -	$77,596
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
SUB TOTAL:						**$2,611,986**
CPI:						
TOTAL (to the nearest $100k):						**$2,600,000**
Contingency (to the nearest $100k):						**$ 300,000**

Horsley Park ZS TS703	SUMMARY					
ITEM	**QTY**	**Labour Cost ($)**	**Store Costs ($)**	**Plant Costs ($)**	**Direct Charge ($)**	**Total Cost ($)**
Outdoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	12	$446,194	$20,842	$35,104	$664,088	$1,166,228
Outdoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	2	$85,549	$76	$3,480	$183,090	$272,196
Joggle Chamber/Bus Ducting	0	$0	$0	$0	$0	$0
Transformer Bays						
Bays	2	$91,117	$4,476	$5,628	$149,740	$250,961
Transformer Costs	0	$0	$0	$0	$0	$0
Bunds / Sound Walls / Blast Walls / Fire Suppression		$0	$0	$0	$0	$0
AFIC Equipment						
SFU & Injection Cells		$0	$0	$0	$0	$0
Building & Switchyard						
Building/Transformer Runway/Fencing/						
Landscaping/Building Fire Suppression		$0	$0	$0	$152,500	$152,500
Ancillary Equipment						
11kV Aux Switchboard/Aux. Transf./						
Batteries & chargers/Radio System/ New SCADA		$17,000	$0	$0	$23,000	$40,000
Underfrequency Load Shedding						
	0	$0	$0	$0	$0	$0
Capacitor Banks						
	0	$0	$0	$0	$0	$0
General Arrangment Update						
		$0	$0	$0	$0	$0
Project Management & Project Definitions						
						$160,213
Control Panels						
	0	$0	$0	$0	$0	$0
Mains						
		$271,256	$21,759	$44,957	$68,662	$406,634
Distribution						
		$0	$0	$0	$636,000	$636,000
Additional Costs						
Major Equipment Storage					$24,180	$24,180
On Site Security					$0	$0
0					$ -	$0
Outages		$ 77,596	$ -	$ -	$ -	$77,596
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
SUB TOTAL:						**$3,186,507**
TOTAL (to the nearest $100k):						**$3,200,000**
Contingency (to the nearest $100k):						**$ 400,000**

Port Central ZS TS704	SUMMARY					
ITEM	**QTY**	**Labour Cost ($)**	**Store Costs ($)**	**Plant Costs ($)**	**Direct Charge ($)**	**Total Cost ($)**
Outdoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	8	$293,963	$13,894	$23,403	$449,392	$780,652
Outdoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
11kV	1	$42,775	$38	$1,740	$91,545	$136,098
Joggle Chamber/Bus Ducting	0	$0	$0	$0	$0	$0
Transformer Bays						
Bays	2	$91,117	$4,476	$5,628	$149,740	$250,961
Transformer Costs	0	$0	$0	$0	$0	$0
Bunds / Sound Walls / Blast Walls / Fire Suppression		$0	$0	$0	$0	$0
AFIC Equipment						
SFU & Injection Cells		$0	$0	$0	$0	$0
Building & Switchyard						
Building/Transformer Runway/Fencing/						
Landscaping/Building Fire Suppression		$0	$0	$0	$145,000	$145,000
Ancillary Equipment						
11kV Aux Switchboard/Aux. Transf./						
Batteries & chargers/Radio System/ New SCADA		$17,000	$0	$0	$23,000	$40,000
Underfrequency Load Shedding						
	0	$0	$0	$0	$0	$0
Capacitor Banks						
	0	$0	$0	$0	$0	$0
General Arrangment Update						
		$0	$0	$0	$0	$0
Project Management & Project Definitions						
						$160,213
Control Panels						
	0	$0	$0	$0	$0	$0
Mains						
		$207,538	$13,517	$27,066	$42,750	$290,871
Distribution						
		$0	$0	$0	$517,000	$517,000
Additional Costs						
Major Equipment Storage					$16,620	$16,620
On Site Security					$0	$0
0					$ -	$0
Outages		$51,730	$ -	$ -	$ -	$51,730
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
0		$ -	$ -	$ -	$ -	$0
SUB TOTAL:						**$2,389,145**
TOTAL (to the nearest $100k):						**$2,400,000**
Contingency (to the nearest $100k):						**$ 300,000**

Term (years)	45					
TS701						
ITEM	**Option 1 - Vacuum trucks**			**Option 2 - New 11kV switchboard**		
	Year 0	**Year 15**	**Year 45 (residual)**	**Year 0**	**Year 15**	**Year 45 (residual)**
11kV Switchgear						
Retrofit vacuum CBs	698,000					
11kV switchboard cost		1,689,385		1,689,385		
11kv VTs	20,000					
cable boxes	30,000					
New protection panels/relays	320,000					
Subtotal	**1,068,000**	**1,689,385**		**1,689,385**	**0**	
Building works						
Floor penetrations and structural support		152,500		152,500		
Subtotal	**0**	**152,500**		**152,500**	**0**	
Additional works						
Electrical works	65,800					
Anciliary equipment		40,000		40,000		
Mains		366,579		366,579		
Distribution		842,000		842,000		
Transformer works						
Major equipment storage		24,180		24,180		
Cangeover of cables						
Outages		$77,596		$77,596		
33kV works						
Subtotal	**65,800**	**1,350,355**		**1,350,355**	**0**	
Project management, Project Definitions						
PM & PDs	32,000	160,213		160,213		
Subtotal	**32,000**	**160,213**		**160,213**	**0**	
Totals	**$1,165,800**	**$3,352,452**	**-$1,117,484**	**$3,352,452**	**$0**	**$0**
Totals (not discounted for time-value of money)		**4,518,252**			**3,352,452**	
Year works planned to be undertaken (Next year = 1)	0	15	45	0	15	45
Discount rate (%)	**4.76%**					
Discount factor	1.000	0.498	0.123	1.000	0.498	0.123
Sub-totals discounted to the present (year 0) ($)	1,165,800	1,669,521	-137,451	3,352,452	0	0
Totals (discounted to the present) ($)		**2,698,000**			**3,352,000**	
Term (years	45					
TS702						
ITEM	**Option 1 - Vacuum trucks**			**Option 2 - New 11kV switchboard**		
	Year 0	**Year 15**	**Year 45 (residual)**	**Year 0**	**Year 15**	**Year 45 (residual)**
11kV Switchgear						
Retrofit vacuum CBs	586,000					
11kV switchboard cost		1,677,385		1,677,385		
11kv VTs	20,000					
cable boxes	30,000					
New protection panels/relays	0					
Subtotal	**636,000**	**1,677,385**		**1,677,385**	**0**	
Building works						
Floor penetrations and structural support		152,500		152,500		
Subtotal	**0**	**152,500**		**152,500**	**0**	
Additional works						
Electrical works	65,800					
Anciliary equipment		40,000		40,000		
Mains		480,113		480,113		
Distribution		0		0		
Transformer works						
Major equipment storage		24,180		24,180		
Cangeover of cables						
Outages		$77,596		$77,596		
33kV works						
Subtotal	**65,800**	**621,889**		**621,889**	**0**	
Project management, Project Definitions						
PM & PDs	32,000	160,213		160,213		
Subtotal	**32,000**	**160,213**		**160,213**	**0**	
Totals	**$733,800**	**$2,611,986**	**-$870,662**	**$2,611,986**	**$0**	**$0**
Totals (not discounted for time-value of money)		**3,345,786**			**2,611,986**	
Year works planned to be undertaken (Next year = 1)	0	15	45	0	15	45
Discount rate (%)	**4.76%**					
Discount factor	1.000	0.498	0.123	1.000	0.498	0.123
Sub-totals discounted to the present (year 0) ($)	733,800	1,300,769	-107,091	2,611,986	0	0
Totals (discounted to the present) ($)		**1,927,000**			**2,612,000**	

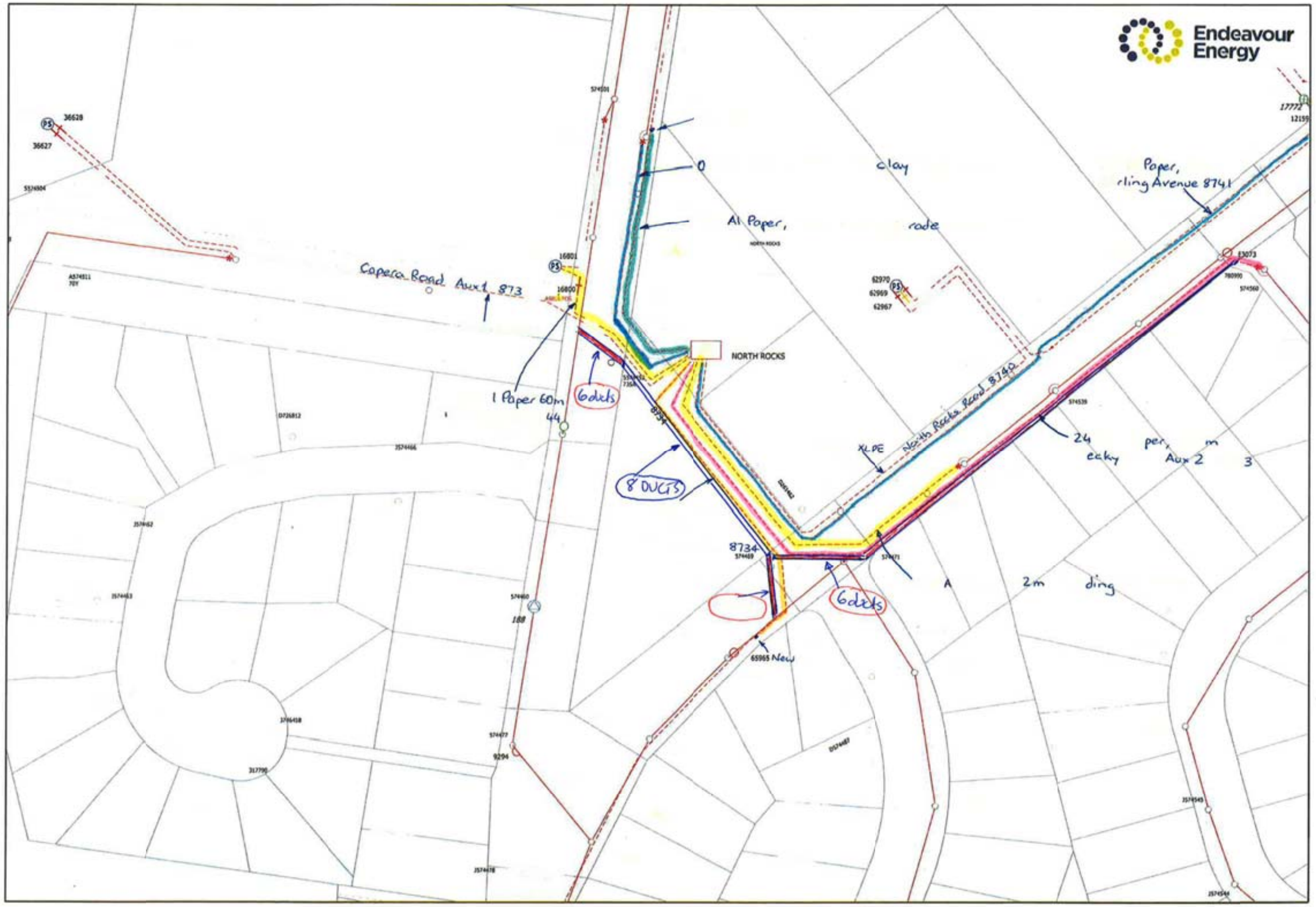
Term (years)	45					
TS703						
ITEM	**Option 1 - Vacuum trucks**			**Option 2 - New 11kV switchboard**		
	Year 0	**Year 15**	**Year 45 (residual)**	**Year 0**	**Year 15**	**Year 45 (residual)**
11kV Switchgear						
Retrofit vacuum CBs	586,000					
11kV switchboard cost		1,689,385		1,689,385		
11kv VTs	20,000					
cable boxes	30,000					
New protection panels/relays	320,000					
Subtotal	**956,000**	**1,689,385**		**1,689,385**	**0**	
Building works						
Floor penetrations and structural support		152,500		152,500		
Subtotal	**0**	**152,500**		**152,500**	**0**	
Additional works						
Electrical works	65,800					
Anciliary equipment		40,000		40,000		
Mains		406,634		406,634		
Distribution		636,000		636,000		
Transformer works						
Major equipment storage		24,180		24,180		
Cangeover of cables						
Outages		$77,596		$77,596		
Subtotal	**65,800**	**1,184,410**		**1,184,410**	**0**	
Project management, Project Definitions						
PM & PDs	32,000	160,213		160,213		
Subtotal	**32,000**	**160,213**		**160,213**	**0**	
Totals	**$1,053,800**	**$3,186,507**	**-$1,062,169**	**$3,186,507**	**$0**	**$0**
Totals (not discounted for time-value of money)		**4,240,307**			**3,186,507**	
Year works planned to be undertaken (Next year = 1)	0	15	45	0	15	
Discount rate (%)	**4.76%**					
Discount factor	1.000	0.498	0.123	1.000	0.498	
Sub-totals discounted to the present (year 0) ($)	1,053,800	1,586,881	-130,647	3,186,507	0	
Totals (discounted to the present) ($)		**2,510,000**			**3,187,000**	
Term(years)	45					
TS704						
ITEM	**Option 1 - Vacuum trucks**			**Option 2 - New 11kV switchboard**		
	Year 0	**Year 15**	**Year 45 (residual)**	**Year 0**	**Year 15**	**Year 45 (residual)**
11kV Switchgear						
Retrofit vacuum CBs	315,000					
11kV switchboard cost		1,167,711		1,167,711		
11kv VTs	10,000					
cable boxes	30,000					
New protection panels/relays	230,000					
Subtotal	**585,000**	**1,167,711**		**1,167,711**	**0**	
Building works						
Floor penetrations and structural support		145,000		145,000		
Subtotal	**0**	**145,000**		**145,000**	**0**	
Additional works						
Electrical works	42,300					
Anciliary equipment		40,000		40,000		
Mains		290,871		290,871		
Distribution		517,000		517,000		
Transformer works						
Major equipment storage		16,620		16,620		
Cangeover of cables						
Outages		$51,730		$51,730		
Subtotal	**42,300**	**916,221**		**916,221**	**0**	
Project management, Project Definitions						
PM & PDs	32,000	160,213		160,213		
Subtotal	**32,000**	**160,213**		**160,213**	**0**	
Totals	**$659,300**	**$2,389,145**	**-$796,382**	**$2,389,145**	**$0**	**$0**
Totals (not discounted for time-value of money)		**3,048,445**			**2,389,145**	
Year works planned to be undertaken (Next year = 1)	0	15	45	0	15	45
Discount rate (%)	**4.76%**					
Discount factor	1.000	0.498	0.123	1.000	0.498	0.123
Sub-totals discounted to the present (year 0) ($)	659,300	1,189,794	-97,955	2,389,145	0	0
Totals (discounted to the present) ($)		**1,751,000**			**2,389,000**	

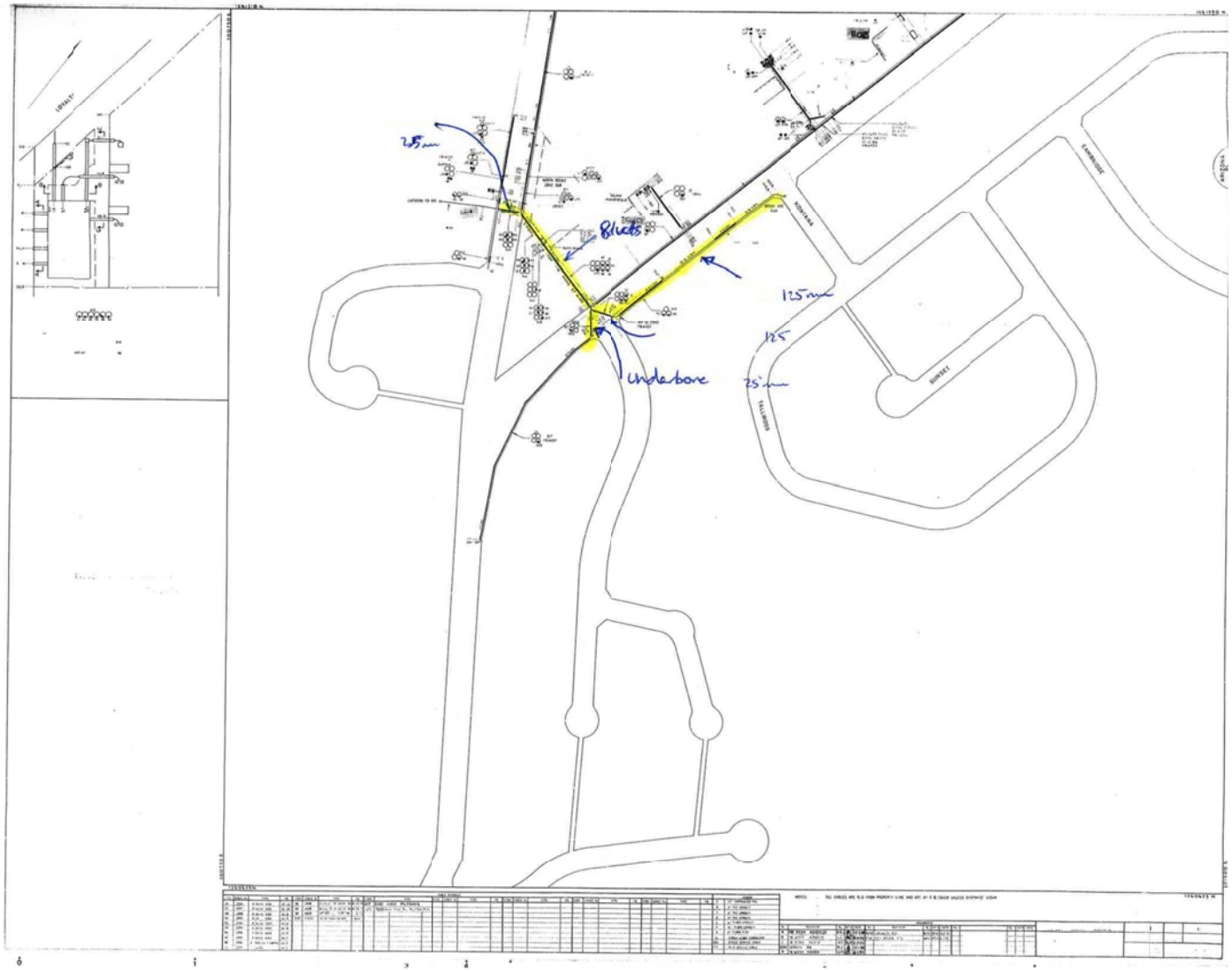
TS700 - Qualitative Option Risk Assessment

Option No	Option Detail	Safety					Construction					Operating & Maintenance					Reliability					Sustainability					All Risks
		Detail	Likelihood of event	Consequence	Item Score	Total Score	Detail	Likelihood of event	Consequence	Item Score	Total Score	Detail	Likelihood of event	Consequence	Item Score	Total Score	Detail	Likelihood of event	Consequence	Item Score	Total Score	Detail	Likelihood of event	Consequence	Item Score	Total Score	Total Ris
1	Retrofit trucks	Existing busbar protection remains (Risk of staff exposed to busbar fault)	A	5	40		Modifications required to existing panels to fit new trucks	D	2	100		Existing busbar protection remains (Risk of staff exposed to busbar fault)	C	2	20		Existing busbar protection remains (Risk of busbar fault)	C	3	100		Aged busbar will requre replacement in the medium term	C	2	20		280
2	New 11kV switchboard	Instentanious busbar differential protection is installed					Staged replacement of bus sections requiring temporary feeder arrangements	C	1	1							Temporarily feeder arrangements. More planned outages and may increase restoration time to customers during	D	1	5							6

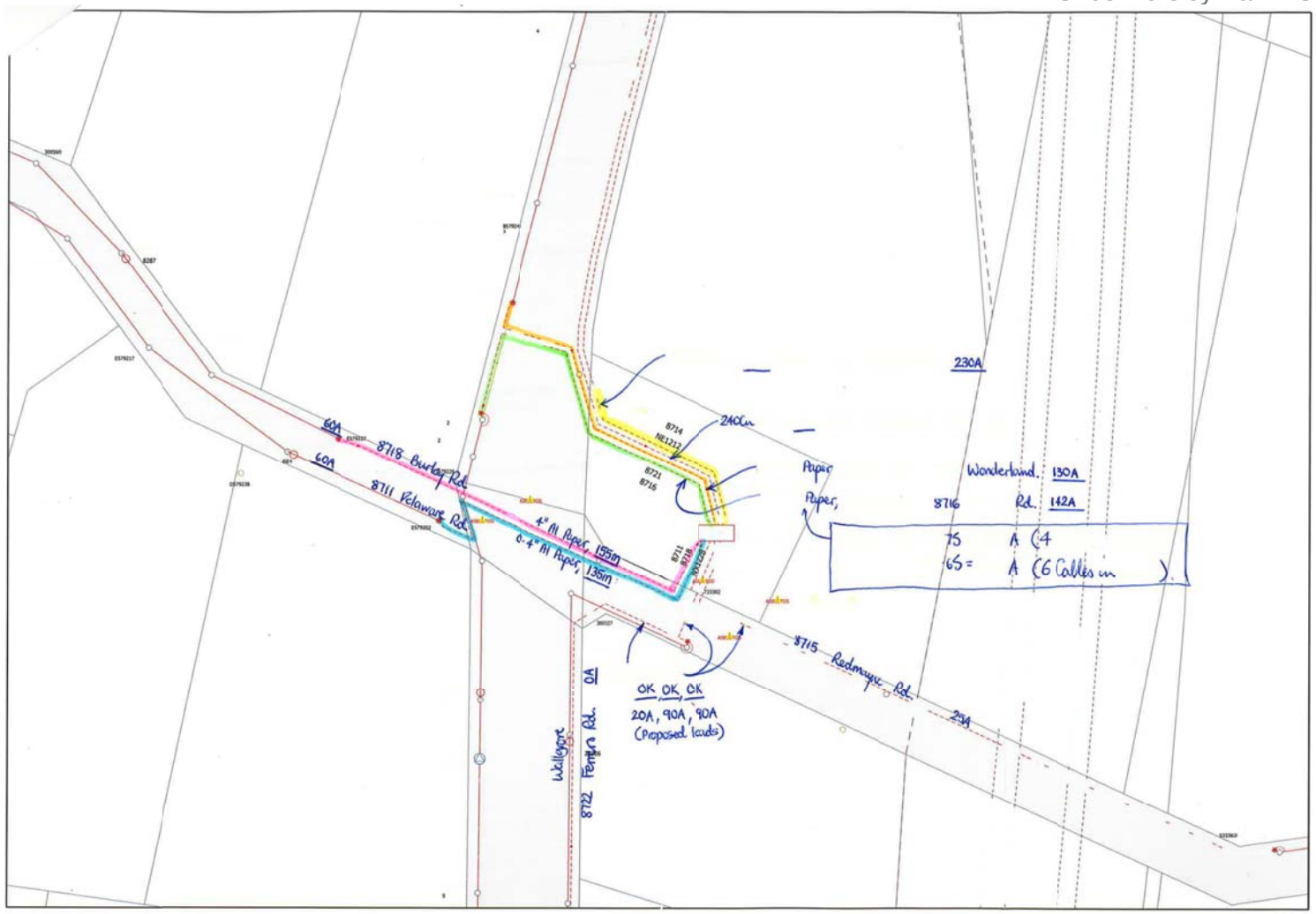
CODE	Extreme risk	High risk	Moderate risk	Low risk

Endeavour Energy

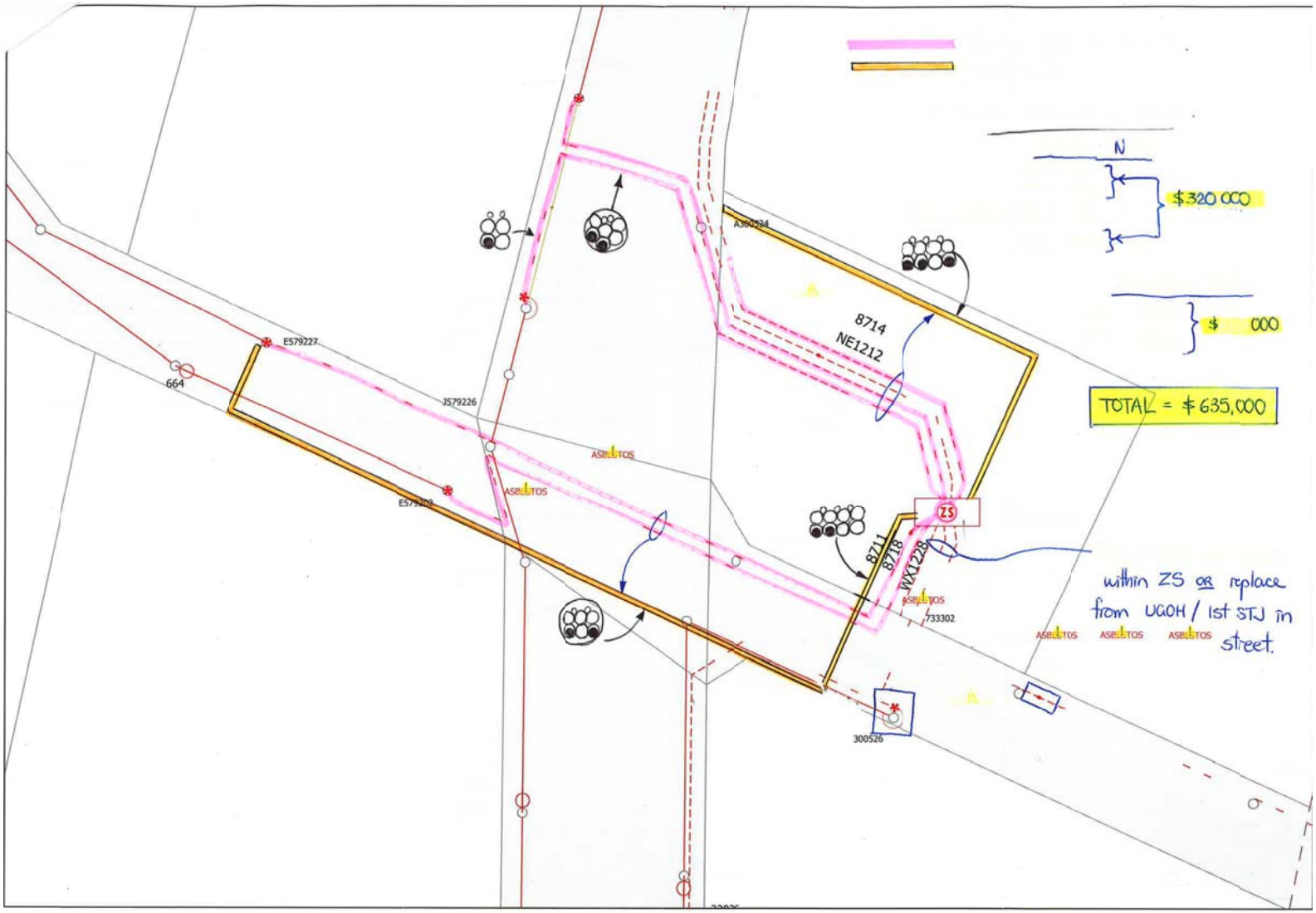

Endeavour Energy
Capera Road Aux1 873
1 Paper 60m
6ducts
8 DUCTS
NORTH ROCKS
Al Paper,
clay
Paper,
rling Avenue 8741
XLPE
North Rocks Road 8740
8734
6ducts
65965 New



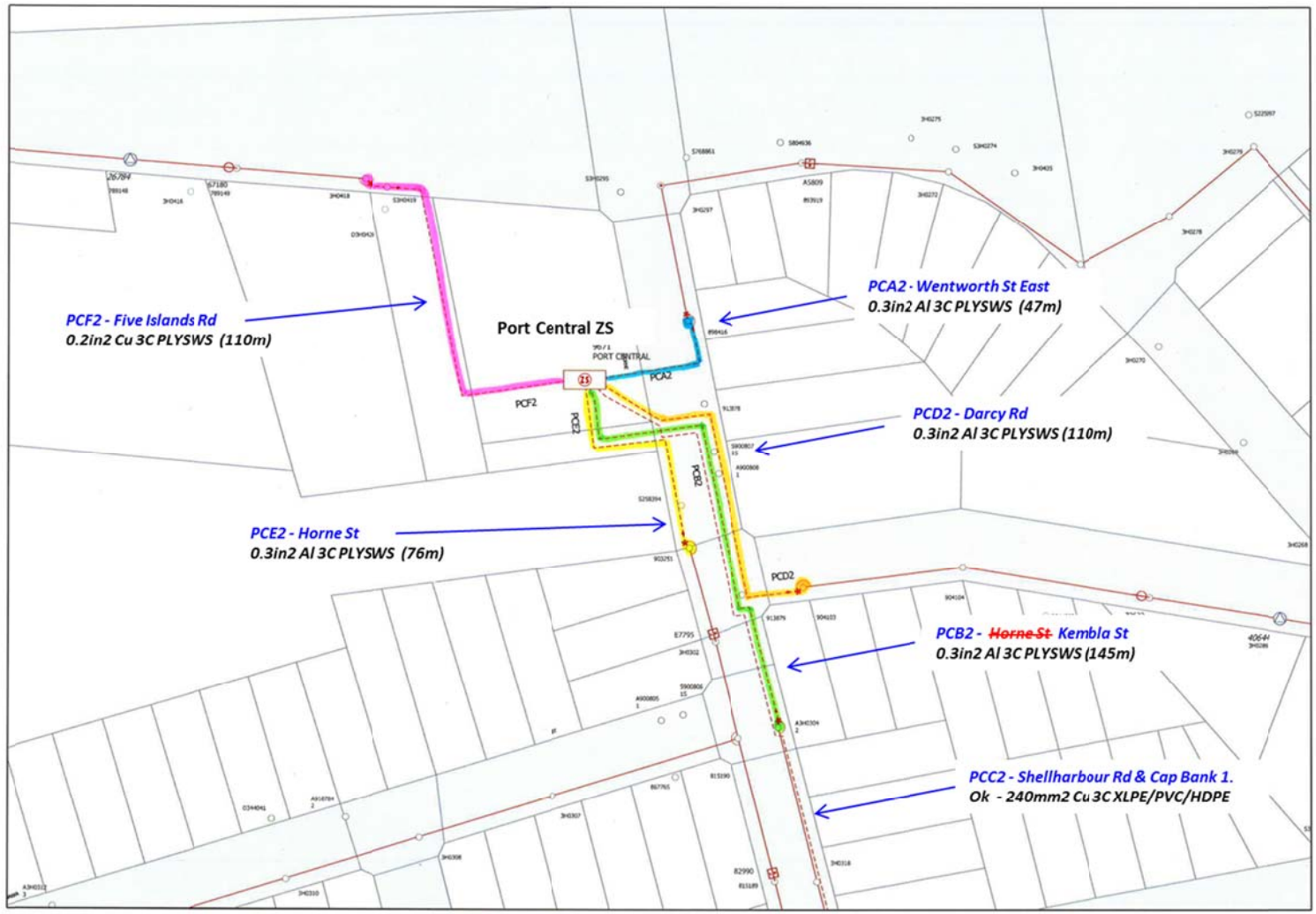
Endeavour Energy



Endeavour Energy



Endeavour Energy



Endeavour Energy

North Rocks ZS 11kV switchboard

Kellyville ZS 11kV switchboard

Horsley Park ZS 11kV switchboard

Port Central ZS 11kV switchboard

Endeavour Energy