APPENDIX D – UPDATED PRELIMINARY HAZARDS ASSESSMENT

Renew Estate Pty Ltd

Bomen 120 MWdc solar farm EIS

SEPP 33 Level 2 Preliminary Hazard Analysis

June 2018

Executive summary

GHD Pty Ltd (GHD) was commissioned by Renew Estate Pty Ltd (Renew Estate), to determine if the proposed Bomen Solar Farm proposal (“the proposal”) is “Potentially Hazardous or Offensive” as per the *State Environment Planning Policy No. 33 - Hazardous and Offensive Development* (SEPP 33).

The proposal site is located approximately 9 km north of Wagga Wagga in the Riverina region of NSW and includes 120 MWdc of solar cells, and a 40 MWh battery storage system.

This report includes a description of the proposal, summary of chemicals used on site, screening of dangerous goods as per SEPP 33 and an assessment that reviews potential hazards that may arise during the operation of the development.

According to SEPP 33, if any of the screening thresholds are exceeded then the proposed development should be considered a ‘potentially hazardous industry’ and a preliminary hazard analysis (PHA) is required. The results of the dangerous goods and transport screening indicate that the proposal does not exceed any of the thresholds. However, based off industry knowledge of the battery storage technology and taking into account that the lithium-ion batteries are a new technology that may not have been taken into account during the initial process determined for SEPP33, the proposal should be considered ‘potentially hazardous’ and a PHA should be required. Given the relative isolation of the site from any sensitive receivers, a level 2 PHA was considered an appropriate level of examination and has been included in this report.

The hazard identification process indicated that the following scenarios have the potential to cause off-site impacts.

- Latent battery failure in situ from manufacturing fault
- Thermal runaway from overcharging
- Thermal runaway from overheating within cabinets
- Release of combusted coolant or refrigerant from thermal runaway
- Loss of containment from APA gas pipeline

The PHA determined that the risks arising from the scenarios above do not exceed the individual fatality or injury risk criteria specified in NSW Department of Planning publication ‘Risk Criteria for Land Use Safety Planning’ [ref. 3]. Threats associated with the APA gas pipeline was analysed further within the Safety Management Study (SMS) [ref. 11] conducted with APA, see Appendix C for more details.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3 and the assumptions and qualifications contained throughout the report.

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1. Introduction

GHD Pty Ltd (GHD) was commissioned by Renew Estate Pty Ltd (Renew Estate) to determine if the proposed Bomen solar farm (the proposal) is "Potentially Hazardous or Offensive" as per the *State Environment Planning Policy No. 33 - Hazardous and Offensive Development* (SEPP 33).

Development consent is required for the proposal under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and is deemed a State Significant Development requiring the preparation of an Environmental Impact Statement (EIS).

GHD prepared a preliminary hazard analysis (PHA) to inform the EIS and address the NSW Secretary's Environmental Assessment Requirements (SEARs) Application number SSD8835. The Department of Planning and Environment (DP&E) has assessed the EIS and requested clarification of certain aspects of the PHA. This PHA has been updated to address clarifications requested by DP&E's and provided to GHD by Renew Estate on 18 June 2018.

1.1 The Proposal

Renew Estate is proposing a 120 megawatt (MWdc) solar farm in Bomen ("the proposal") located approximately 9 km north of Wagga Wagga in the Riverina region of NSW. The proposal is within a 250 hectare (ha) site, as shown by the red boundary line in Figure 1.1.

The proposal will include 120 MWdc of solar generation equipment, with the following components; solar modules, tracking systems, power conversion stations, onsite electrical switchyard and substation, transmission line, battery storage system, control building, internal DC and AC cabling, internal all-weather access tracks, security fencing, vegetation screening and meteorological stations. The proposal also includes subdivision of four lots to allow the purchase of the required land for the proposal site.

The solar modules would be mounted on single-axis tracking structures to follow the sun from east to west each day. The structures would be pile driven into the ground.

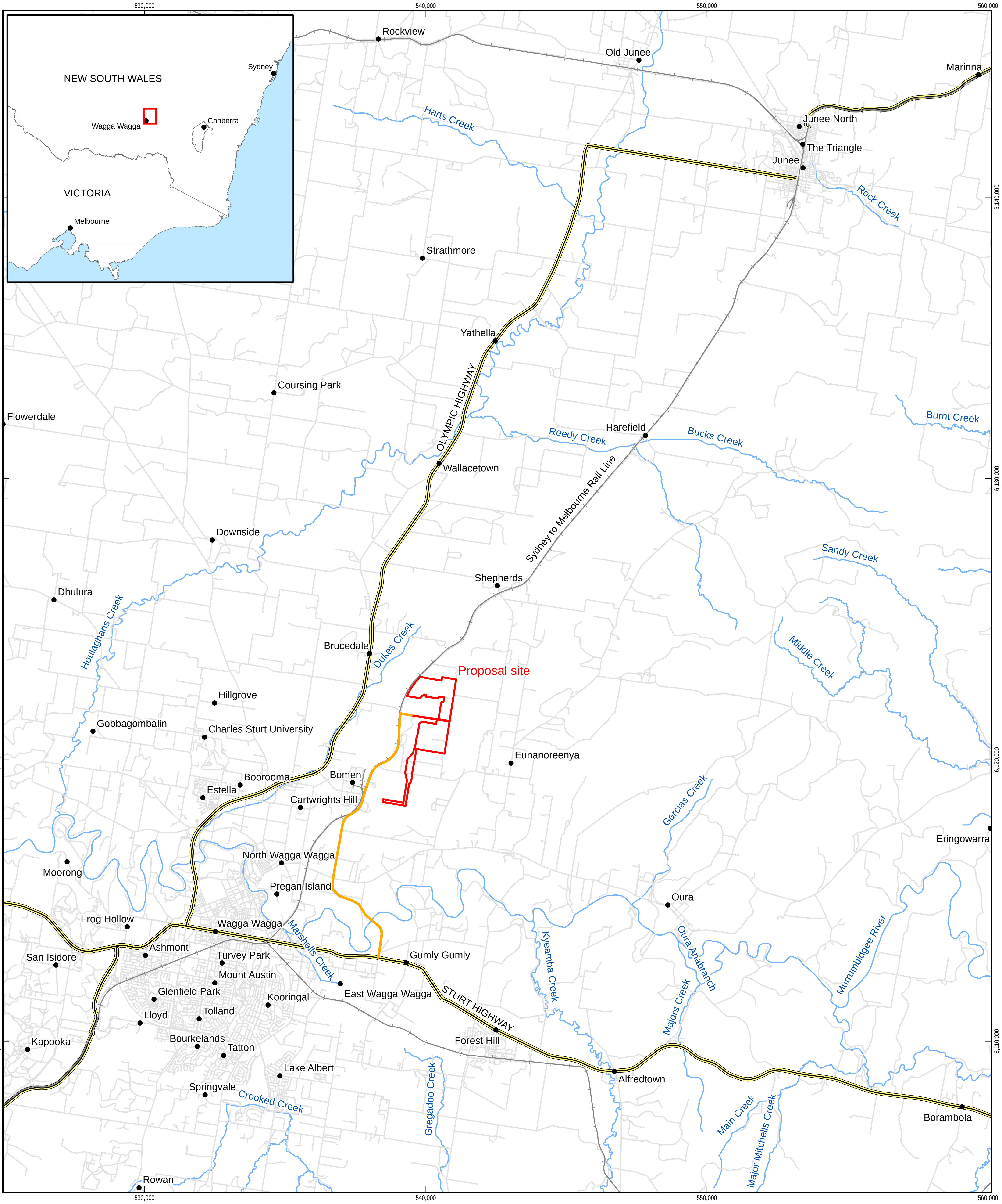
The onsite substation will lie in the North West corner of the southern development area from which a transmission line will be installed to connect to the existing TransGrid Wagga North substation (Figure 1.2). It is expected that the proposal will need to comply with transmission design guidelines as per the Australian Energy Market Operator (AEMO) standards and requirements.

The operational lifetime of the solar farm is 30 years. After this time, if the site does not continue operation under renewed approval, the decommissioning process is intended to return the site to the pre-developed condition.

The proposal site and the majority of the surrounding industrial properties are located within the Bomen Industrial Precinct in the Wagga Wagga local government area.

The nearest residential properties to the proposal are located approximately 400 metres south of the solar farm site.

The location of the proposal is shown in Figure 1.1.



LEGEND

- Locality
- Rail line
- Highway
- Road
- Primary access route from Sturt Highway
- Stream
- Proposal site

Paper Size A3

0 1 2 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Renew Estate
Bomen 120 MW solar farm EIS

Job Number	23-16243
Revision	0
Date	18 Jan 2018

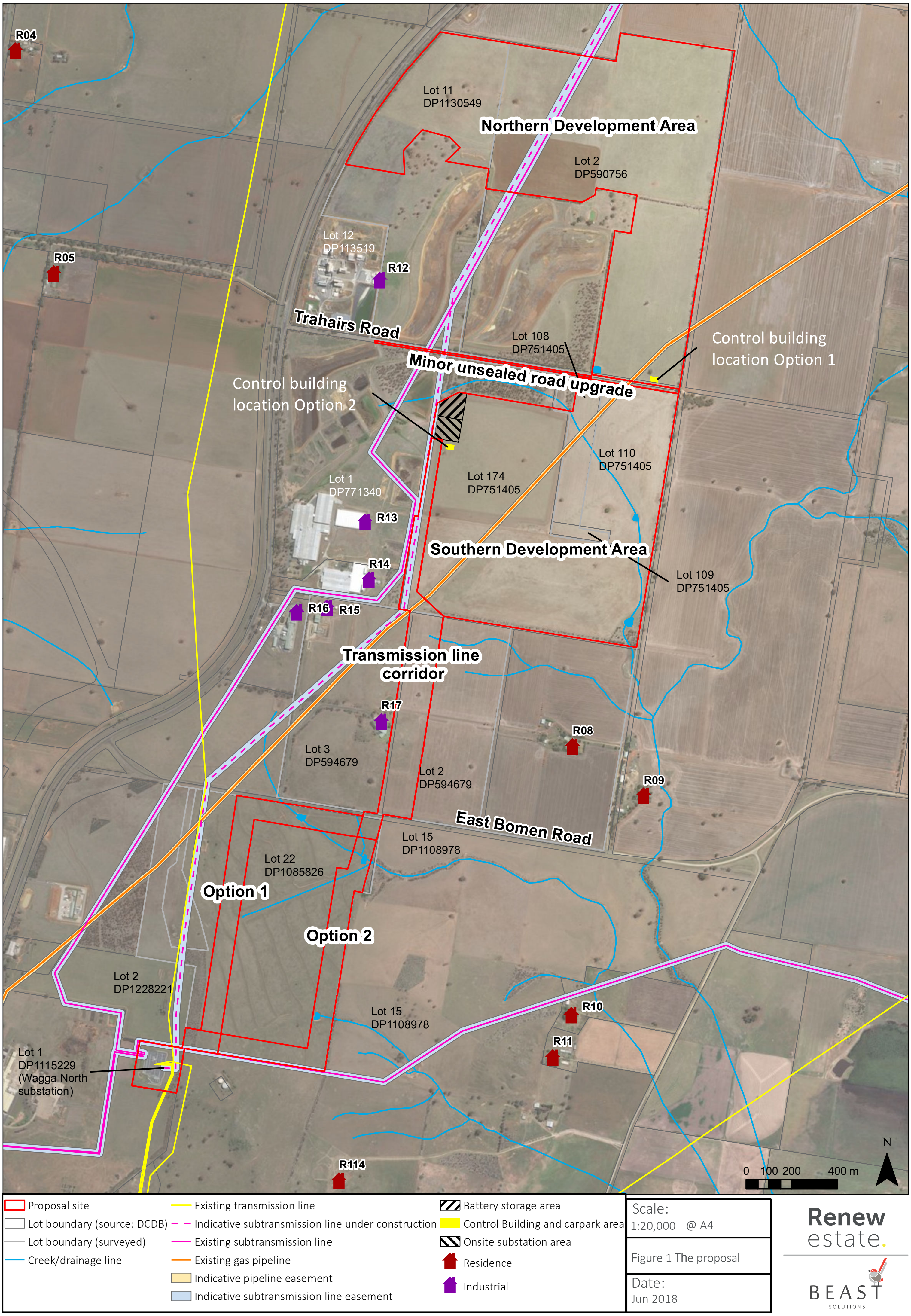
Site location

Figure 1.1

G:\23\16243\GIS\Maps\Deliverables\EIS\BomenSolarFarmEIS_Fig1-1.mxd

Suite 3, Level 1, 161-169 Baylis Street Wagga Wagga NSW 2650 Australia **T** 61 2 6923 7400 **F** 61 2 6971 9565 **E** wgamail@ghd.com **W** www.ghd.com

Data source: NSW Government (LPI): Localities, streams and roads - 2012. Created by:rtrobinson



Scale:
1:20,000 @ A4

Figure 1 The proposal

Date:
Jun 2018

Renew estate.

BEAST SOLUTIONS

1.2 Planning Development Requirements

This report provides risk screening and hazard analysis of the proposal in accordance with the requirements of SEPP 33 [ref. 1], to identify if SEPP 33 applies, and therefore if a preliminary hazard analysis (PHA) is required. The report includes a description of the proposal, screening of dangerous goods as per SEPP 33 and an assessment that reviews potential hazards that may arise during the operation of the development.

1.3 Scope and Limitations

SEPP 33 presents a systematic approach to planning and assessing proposals for potentially hazardous and offensive development for the purpose of industry or storage. SEPP 33 applies to any proposals which fall under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'.

For development proposals classified as a 'potentially hazardous or offensive industry' the policy establishes a comprehensive test by way of a PHA to determine the risk to people, property and the environment at the proposed location and in the presence of controls.

Additionally, this report: has been prepared by GHD for Renew Estate Pty Ltd and may only be used and relied on by Renew Estate Pty Ltd for the purpose agreed between GHD and the Renew Estate Pty Ltd as set out in section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Renew Estate Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.4, 4.4 and 5.4.2 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Renew Estate Pty Ltd and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.4 Assumptions

The following assumptions have been made in the preparation of this report:

- A construction phase Traffic Management Plan will be developed separate to this report.
- Tesla powerpack 2.0 models specifications were used for data analysis, however this product may change during the design of the proposal and therefore results should be reassessed if different specifications are chosen.
- A gas pipeline owned by a separate entity runs through and near the property, and the risks associated with this pipeline have been addressed in a Safety Management Study (SMS)

independent to this study. See Appendix C for the actions and threat register from this study.

Additional assumptions are detailed in sections 4.4 and 5.4.2.

2. Methodology

2.1 SEPP 33 Requirements

SEPP 33 applies to any proposal which falls under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'. If not controlled appropriately some activities within these industries may create an offsite risk or offence to people, property or the environment thereby making them potentially hazardous or potentially offensive. The purpose of this report is to determine if the proposal is potentially hazardous using the SEPP 33 risk screening process or potentially offensive using licencing requirements. If the screening indicates that the proposal is potentially hazardous then a PHA is required. The overall risk screening process, as outlined in SEPP 33 is summarised in Figure 2.1 [ref. 1]. If the proposal is potentially offensive then additional consideration to land use planning is required.

The risk screening process concentrates on the storage of specific dangerous goods classes that have the potential for significant offsite effects. Specifically the assessment involves the identification of classes and quantities of all dangerous goods (DG) to be used, stored or produced on site with an indication of storage locations. Details of the methodology are described in detail within SEPP 33 [ref. 1].

For development proposals classified as 'potentially hazardous industry' a PHA is completed to determine the risk to people, property and the environment at the proposed location and in the presence of controls. Criteria of acceptability are used to determine if the development proposal is classified as a 'hazardous industry'. If this is the case, the development proposal may not be permissible within most industrial zonings in NSW.

The methodology for a PHA is outlined in NSW Department of Planning (DoP) Hazardous Industry Planning Advisory Paper (HIPAP) publications [ref. 3 and ref. 4].

2.2 Hazard Identification

The aim of the hazard identification process is to highlight any risks associated with the interaction of the facility (as a whole) with the surrounding environment i.e. a systematic process to identify any potential offsite impacts.

Hazard identification is a form of a desktop qualitative risk assessment and involves documenting all possible events that could lead to a hazardous incident. It is a systematic process listing potential causes and health, safety and environmental consequences (in qualitative terms). Operational and organisational safeguards were developed to prevent hazardous events from occurring or, should they occur, to mitigate the impact on the proposed solar farm, its equipment, people and the surrounding environment.

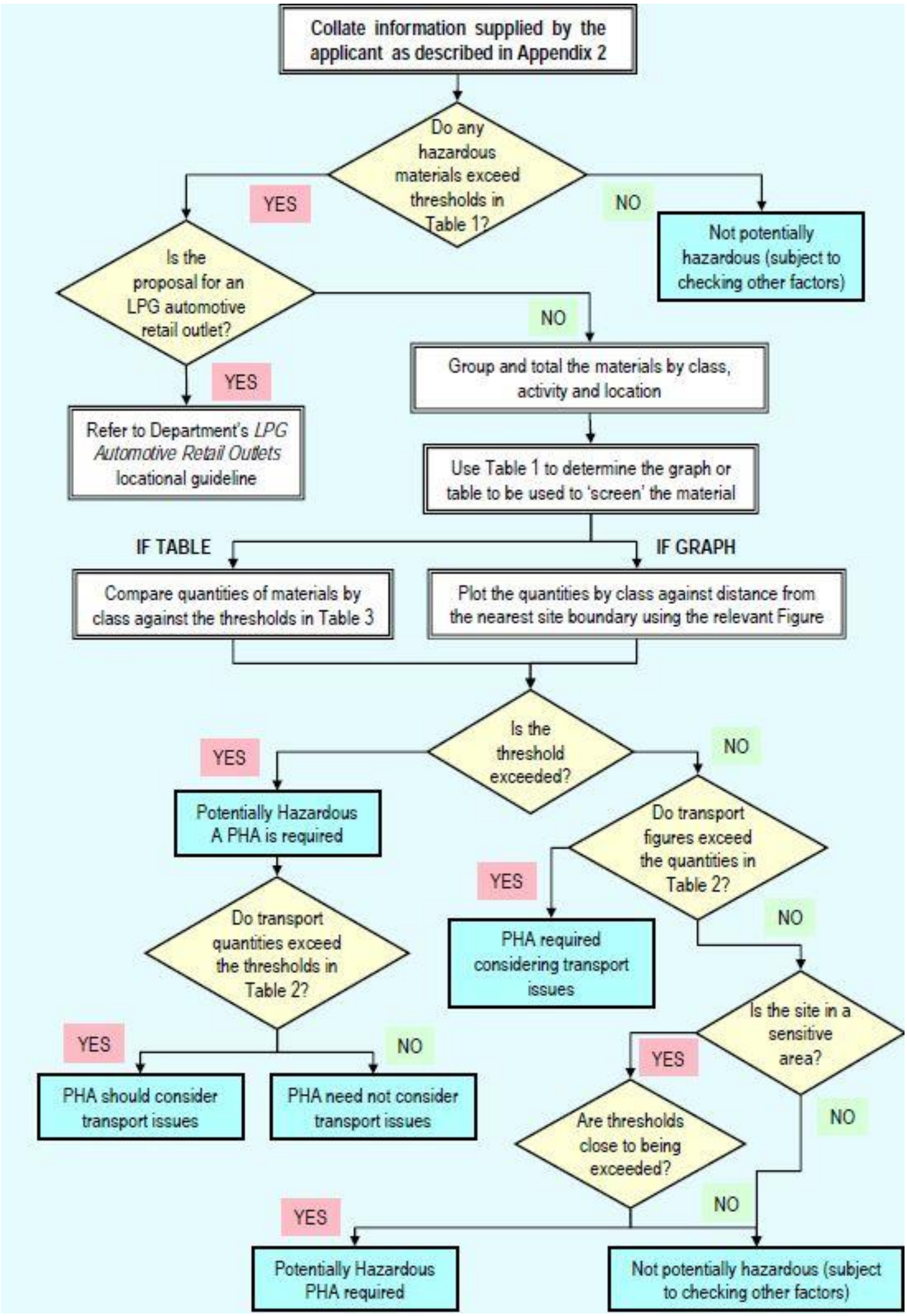


Figure 2.1 SEPP 33 Risk Screening Process [ref 1]

3. Preliminary Risk Screening and Emissions

3.1 Dangerous Goods Screening

A summary of the quantities of dangerous goods (DG) that are proposed to be handled and/or stored on-site as a result of the operation of the solar farm is shown in Table 1. The lithium-ion batteries will contain the amount of refrigerant and coolant as specified, however these materials will not be stored onsite in addition to what is needed inside the battery modules. The location of the battery storage area which contains the DGs is shown in Figure 1.2 on page 3.

The screening thresholds for onsite storage is shown in Table 2. The proposal will transport the amount of coolant and / or refrigerant when needed for maintenance purposes if required, therefore not requiring the storage of these chemicals onsite. Based on the DG class of Schedule 2.2 and Schedule 9 and that the chemicals are not being stored onsite, the SEPP33 storage thresholds are not exceeded.

Table 1 Summary of Dangerous Goods on Site

Chemical / product	DG Class	UN #	Maximum storage quantity	Exceedance of SEPP 33 Threshold
Lithium-Ion Batteries	9	3480	1,400 lbs of lithium-ion cells for 100 kWh powerpack 2 2,450 lbs of lithium-ion cells for 200 kWh powerpack 2	Pass (does not exceed)
Klea ® (refrigerant)	2.2	3159	400 g per powerpack system (200 units x 400g = 80 kg)	Pass (does not exceed)
Zerex ™ Antifreeze coolant	Not DG	N/A	26 L per powerpack system (200 units x 26L = 5,200 L)	Pass (does not exceed)

Table 2 SEPP Dangerous Goods Threshold Figures

DG Class	Combined Storage Threshold (tonnes)
2.1	10
2.2	-
4.1	5
5.1	5
6.1	2.5
8 – II	25
8 – III	50
9 – III	–

3.2 Transport Screening

Operation of the proposal would not require large traffic movements or heavy vehicle movements compared to the status quo. The proposal is estimated to have five operational staff predominately based in the control building office. The number of operational staff will be up to approximately ten people during the first two years. Occasionally there will be heavy vehicle movement for delivery of spare parts, periodic removal of waste and civil maintenance.

As there are no excess DGs to be stored onsite other than the chemicals needed for the operation of the batteries, there will be no movement of DGs. Therefore the SEPP33 movement thresholds are not exceeded. However, if changes occur in the transport of DGs, it is recommended that the screening process be repeated in order to determine if the route evaluation is still valid.

A Traffic and Transport Impact Assessment has been prepared as part of the EIS in accordance with the SEARs.

3.3 Summary of Risk Screening Results

According to SEPP 33, if any of the screening thresholds are exceeded then the proposed development should be considered a ‘potentially hazardous industry’ and a PHA is required.

The results of the dangerous goods and transport screening indicate that the proposal does not exceed any of the thresholds. However, based on industry knowledge of the battery storage technology and taking into account that the lithium-ion batteries are a new technology that may not have been considered during the initial process determined for SEPP33, the proposal should be considered ‘potentially hazardous’ and a PHA should be required. Given the relative isolation of the site from any sensitive receivers, a level 2 PHA is considered appropriate.

3.4 Summary of Emissions

Review of the air quality and odour, noise and vibration and visual impacts of the proposal will be completed through the EIS. Based on the EIS findings, the proposal meets the relevant amenity criteria, therefore the proposal is not considered to be ‘potentially offensive’ and Clause 13 of SEPP 33 does not apply.

4. Hazard Identification and Management

4.1 Hazard Identification

The results of the hazard identification are provided in Table 3. The hazard identification was conducted as a desktop study and focussed specifically on the operational activities of the proposal. The study identified that the lithium-ion battery overheating and exploding is the most credible scenario to have an off-site impact. Safeguards are also outlined in Table 3 and are required to ensure the risk scenarios that were identified are contained or at least controlled to an acceptable level.

4.2 Chemical and Spill Management

Chemicals brought on site for maintenance activities should be stored in accordance with Australian Standards. It is recommended that each chemical have appropriate labelling, separation where necessary and disposal in accordance with Australian Standards. Emergency services require access to the safety data sheet (SDS) register of all chemicals that are located on site.

Additionally, appropriate safe work procedures should be implemented for the handling of all chemicals including transfer, storage, spill prevention and clean up requirements.

4.3 Management Procedures

Following the hazard identification shown in Table 3, there were a few procedural controls that are to be developed before the construction of the proposal. Therefore it is recommended that the following management procedures be implemented that incorporate practices that will prevent risk scenarios occurring through:

- Ensuring ISO 9001 quality for the manufacture of the batteries and associated equipment
- Verification of installation quality and operational values of each cabinet
- Minimising build-up of combustible materials on-site
- Installing bollards/protective barriers around key battery areas
- Inspection and maintenance regime for the batteries, filters and associated equipment
- A bushfire management plan (developed with the local Rural Fire Service district office), including access requirements and any hazards on the site. This would be reviewed annually through consultation with the local district office.

4.4 Assumptions

In undertaking the Hazard Identification Study a number of assumptions were made. These include:

- All plant and equipment is installed and operated in accordance with appropriate Australian Standards, codes and guidelines.
- Dangerous goods are stored in accordance with the ADG Code, relevant standards and guidelines even if not a licensable quantity.
- All equipment and systems are designed to be inherently safe.

Table 3 Hazard Identification

<table>
<tr><th>Hazard Scenario</th><th>Causes</th><th>Consequence</th><th>Potential for Off Site Impact</th><th>Identified / Recommended Safeguards</th></tr>
<tr><td>Vehicle interactions</td><td>Vehicle movements in vicinity of personnel</td><td>Personal injury</td><td>No</td><td>Prepare a construction traffic management plan including standard traffic rules and signage
Implement site speed limits
Provide designated pedestrian areas
Ensure driver competency</td></tr>
<tr><td>Natural hazards</td><td>Flooding, earthquake, lightning, bushfire</td><td>Personal injury
Plant shut down
Possible fire</td><td>No</td><td rowspan="2">A bushfire management plan will be prepared in consultation with the Rural Fire Service. This plan will include but not limited to the following:
• management of activities with a risk of fire ignition
• management of fuel loads on site
• storage and maintenance of firefighting equipment including siting and provision of adequate water supplies
• the below requirements of ‘Planning for Bush Fire Protection 2006’ [ref. 10]:
– identifying asset protection zones
– providing adequate egress/access to the site
– emergency evacuation measures
• operational procedures relating to mitigation and suppression of bush fire relevant to the operation of a solar farm
Design structures to appropriate codes and standards
Manage fuel for vehicles and machinery on site to appropriate standards
Design buildings to appropriate codes
Provide fire protection systems</td></tr>
<tr><td>External fire (adjacent to site)</td><td>Fire or explosion from adjacent land users</td><td>Asset damage
Plant shut down
Personal injury</td><td>No</td></tr>
</table>

Hazard Scenario	Causes	Consequence	Potential for Off Site Impact	Identified / Recommended Safeguards
Loss of containment of chemicals, including dangerous goods	Damage to storage containers e.g. due to external impact Wear & tear Overheating	Environmental damage Personal injury	No	Store chemicals in line with appropriate standards Implement a regular inspection and maintenance regime for chemical storage areas Implement standard handling procedures Provide a Safe Work Method Statement detailing methods for handling chemicals Provide spill kits to be used in the event of an incident involving release of chemicals Implement standard transfer and handling procedures Provide Personal Protective Equipment (PPE) to all staff
Contact with chemicals, including dangerous goods	Maintenance of batteries	Personal injury	No	
Fall from heights	Working at height	Personal injury / fatality	No	Implement working at heights procedures Ensure all staff working at heights have completed the necessary training Use fall prevention equipment
Contact with electricity	Contact with live electrical source Cranes impacting overhead lines Hitting underground services	Personal injury / fatality	No	Implement isolation procedures Install fit for purpose electrical systems Follow underground utility identification protocols, including Dial Before You Dig. Flash protective PPE
Mechanical or chemical damage of lithium-ion Battery assemblies	Rapid heating of individual cells (e.g. lack of venting, thermal runaway reactions) Vehicle impact into batteries	Release of fluorinated hydrocarbons Personal injury / fatality Asset Damage	Yes	Ensure batteries are Quality Assured to AS 9001 Install bollards/protective barriers around key battery areas Batteries to be stored as per suppliers specifications The battery system will be containerised and bunded Implement a regular inspection and maintenance regime for the battery assemblies

Hazard Scenario	Causes	Consequence	Potential for Off Site Impact	Identified / Recommended Safeguards
Overheating of lithium-ion batteries	Over- and under- voltage during discharge of batteries Thermal runaway reactions Over discharge of the batteries	Release of fluorinated hydrocarbons Personal injury / fatality Asset Damage	Yes	Provide ventilation systems in cabinets Batteries to be stored as per suppliers specifications Fusible separators to isolate cells Provide insulation around batteries Battery Management System (BMS) to properly manage the batteries state of change Integrated circuit control systems, to avoid voltage drift Current sensing circuits, to avoid short circuiting Thermal sensing of the cells, to avoid over heating of cells Battery balancing devices, to avoid deterioration and individual cell over/under voltage Factory cell matching
APA high pressure gas pipeline	Impact to pipeline from excavation works	Loss of gas containment Asset damage Personal injury / fatality	Yes	Pipeline easement delineated on site as a no go zone Positive location during detailed design Electrical studies in accordance with AS 4853 and AS 2832 Pipeline Safety Management Study AS 2885 with APA Battery storage site located outside pipeline to avoid cascading consequential loss
Battery storage site located adjacent to substation and / or control building	Fire spreading from battery storage to substation or control area	Asset damage Personal injury / fatality	No	Separation distances between battery storage and other equipment as per AS 2067, or installation of a blast wall if separation distances cannot be achieved Construct to National Construction Code & AS 2067 Installation of equipment in accordance with manufacturer's instructions and by qualified personnel

5. Preliminary Hazard Analysis

5.1 Level 2 PHA

As a result of the hazard identification, it is deemed that there is some potential for harm and that a level two PHA is required. The PHA follows the process shown in Figure 5.1, which complies with DoP's Multi-level Risk Assessment Guideline [ref. 2].

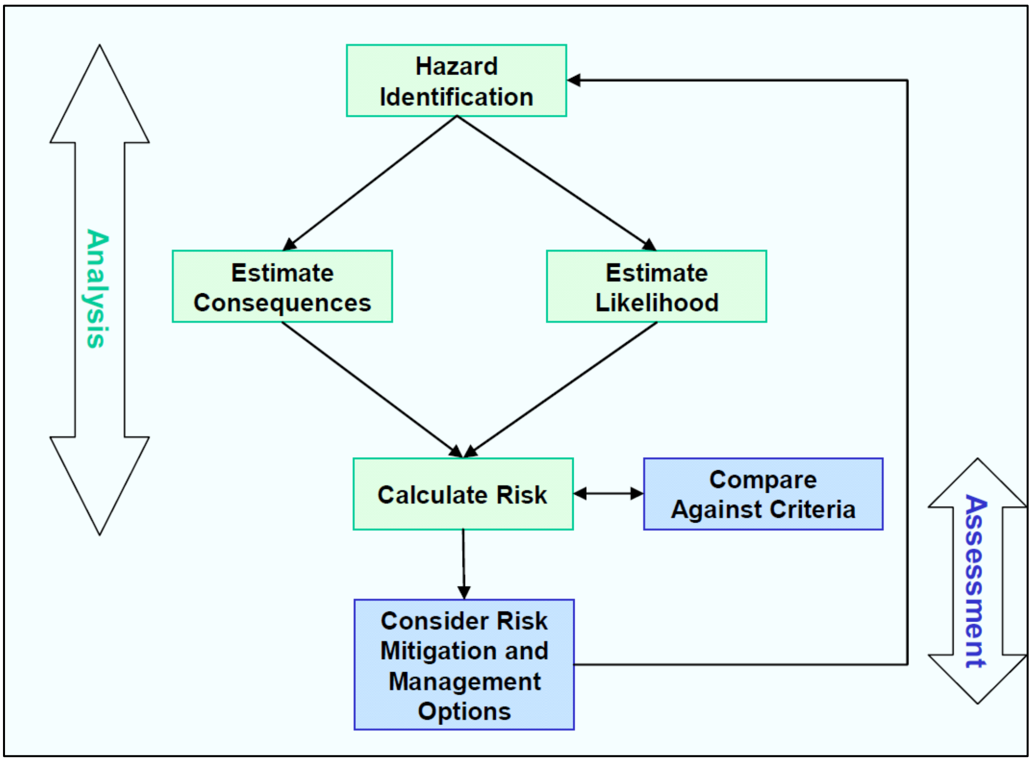


Figure 5.1 Risk Assessment Process [ref 1]

5.2 Hazardous Materials

Lithium-ion batteries are regulated as Class 9 Miscellaneous DG (also known as "hazardous materials") and are the only material with the potential to cause off-site impacts from a release of the contents.

The refrigerant used in the batteries is a DG class 2.2 by virtue of the pressure at which it is stored, but with release and partial combustion, could form a range of fluorinated hydrocarbons of small quantities of hydrofluoric acid.

Lithium-ion batteries contain electrolyte and lithium in various forms, along with other metals. Lithium-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in a non-rechargeable lithium battery. The electrolyte, which allows for ionic movement, and the two electrodes are the constituent components of a lithium-ion battery cell.

Lithium-ion batteries can pose unique safety hazards since they contain a flammable electrolyte and may be kept pressurised. If a battery cell is charged too quickly, it can cause a short circuit, leading to explosions and fires. Because of these risks, testing standards are more stringent than those for acid-electrolyte batteries, requiring both a broader range of test conditions and additional battery-specific tests. There have been battery-related recalls by some companies, including the 2016 Samsung Galaxy Note 7 recall for battery fires.

Significant focus has been on quality of manufacture, and the ISO 9001 certification is seen as an important aspect of hazard management of lithium-ion batteries. There are several patents to do with hazard management of thermal runaway of lithium batteries. These include fusible separators, which slow down conduction over certain temperatures, pressure relieving mechanisms, and separation of the anode and cathode to minimise dendrite formation and short circuits.

One of the options being considered for the lithium-ion battery specifications include the Tesla Powerpack 2.0 models for this facility. Data from the associated equipment guides have been utilised and referenced for the following consequence and likelihood calculations.

5.3 Hazard Scenarios

The following scenarios were identified as being worthy of a further analysis:

- Latent battery failure in situ from manufacturing fault
- Thermal runaway from overcharging
- Thermal runaway from overheating within cabinets
- Release of coolant or refrigerant during thermal runaway
- Loss of containment from APA gas pipeline

Staff from Renew Estate and the APA attended a facilitated Safety Management Study (SMS) workshop on 7th June 2018 to identify potential risks that the solar farm might pose to APA's high pressure transmission gas pipelines and identify measures to control these risks [ref. 11]. The outcome of this workshop (see Appendix C for detail) was a threat register from brainstorming all possible risks and an action list of controls to be implemented during the design, construction, operation and decommissioning of the solar farm. All risks were considered controlled and risks could remain as low as reasonably practicable (ALARP) and therefore were not considered further in this report.

5.4 Consequence Determination

5.4.1 Background

The release, dispersion and flammable effect for lithium-ion batteries has been tested with smaller battery assemblies. Not many events have happened at larger scale commercial size, versus retail equipment thermal events such as hoverboards or mobile phones. One event did occur with a US navy test submarine where thermal runaway occurred, apparently during charging. The battery was approximately 1 MWh in size. The submarine was closed off and cooled from the outside with water until the reaction had run to completion. A cabinet of batteries could exhibit some similar features of release, such as a gaseous release from electrolyte, refrigerant or coolant. Depending on the materials, heated chlorinated and fluorinated hydrocarbons could be released. The separation distances between cabinets will reduce escalation potential, and slow down propagation of a thermal event from one battery cabinet to adjacent equipment.

It should be noted that consequence modelling is not the same as risk modelling. Consequence modelling only represents the impact zone that would be affected in the event that a release should occur. It does not take into account the following important risk considerations:

- Likelihood of a release, i.e. a leak frequency.
- Probability of a wind direction towards a particular location.

5.4.2 Assumptions

The following conditions were used in the consequence determination.

Table 4 Consequence Assumptions

Parameter	Value	Comment
Surrounding Air Temperature	25 °C	
Temperature thermal runaway reaction occurs	400 °C	Typical Tesla Powerpack 2.0 gas temperatures can exceed 600 °C
Quantity of release	400 grams of liquid refrigerant per cabinet 26 L of coolant liquid per cabinet (ethylene glycol)	Typical amounts for Tesla Powerpack 2.0
Height of Powerpack	2.19 m	Height of a Telsa Powerpack 2.0
Height of an average person	1.80 m	Average height of a person

5.4.3 Results

A summary of the determined heat radiation consequences is provided in Table 5. Details of the calculations are in Appendix A. The release events are worst case as they assume no intervention to limit the release. For the release scenarios some level of intervention would be expected. As such, the zones of effect can be considered conservative.

Table 5 Summary of heat radiation consequences

Release Scenario	Maximum Distance Downwind of Release to Heat Radiation (m)		
	4.7 kW/m² (injury)	12.6 kW/m² (fatality)	23 kW/m² (property damage)
Single cabinet battery thermal runaway (cabinet reaches 400 °C)	Approx. 3 m	Approx. 1.5 m	Approx. 0.7 m

The risk criteria for land use and safety planning suggest that incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m² at a frequency of more than 50 chances in a million per year [ref. 3]. Therefore, based off the above calculations, it is suggested to ensure the battery storage should be located a minimum of 3 metres from the facility border to ensure compliance with HIPAP guidelines. A distance greater than this measurement will provide the facility with the potential for future growth and expansion of battery storage capacity.

5.5 Likelihood Estimation

The likelihood of the worst case scenarios resulting in a fatality or injury was calculated using the calculations shown in Appendix B. The assignment of the frequency and probability values has been made based on industry failure frequencies, specialist risk management judgement and the quantified consequences.

It is important to note that the determination of 'absolute values' for assigned probabilities is less important than consistently using 'comparative' or 'relative' values. The overall aim is to provide a ranking to compare with risk criteria.

A summary of the results is shown in Table 6. Details of the calculations are in Appendix B.

Table 6 Likelihood results

Scenario	Probability per year	Interval years	Comment
Manufacturing fault leading to thermal runaway. Frequency of gas release (per annum)	4.65×10^{-03}	215	Based on a 2170 cell size format, see Appendix B for calculation
Excessive charging leading to fire (per annum) (cumulative value of all cabinet chargers on site)	4.60×10^{-03}	200	Conservative figure, more likely about 10% of this value and 1 in 2,000 years (data on charger failure rate has to be estimated)

5.6 Risk Assessment

While there may be events where smoke and heat may occur, the relative frequency of these events is quite low. The off-site effects are low, unless there is a strong wind to carry the smoke laterally. Heat radiation is low, based on the distance to the boundary, and the likely temperature of the container during an event.

With the low potential for off-site effects, and the low likelihood, the risks posed by the lithium-ion batteries do not exceed the threshold levels of SEPP 33.

6. Conclusion

This report involved a preliminary risk screening of the proposal in accordance with the requirements of SEPP 33. While the results of the dangerous goods and transport screening indicated that the proposal does not exceed any of the thresholds within the SEPP 33 requirements, due to the potential for explosion and fire associated with the chemicals required to operate the lithium-ion battery storage, the proposal is considered "potentially offensive" and a level 2 PHA was conducted.

Based on the information provided by Renew Estate and the assessment as outlined in this report, the PHA determined that the risk arising from the dangerous goods stored and used on site does not exceed the individual fatality or injury risk criteria specified in NSW DoP publications HIPAP No. 4 'Risk Criteria for Land Use Safety Planning'.

It is recommended that management procedures be implemented that incorporate practices that will prevent risk scenarios occurring through:

- Ensuring ISO 9001 quality for the manufacture of the batteries and associated equipment
- Verification of installation quality and operational values of each cabinet
- Minimising build-up of combustible materials on-site
- Installing bollards/protective barriers around key battery areas
- Inspection and maintenance regime for the batteries, filters and associated equipment
- A bushfire management plan (developed with the local Rural Fire Service district office), including access requirements and any hazards on the site. This would be reviewed annually through consultation with the local district office.

It is important to note that any new equipment should have procedures developed for their safe operation. This is particularly important for the operation of any new fixed or mobile machinery to prevent injury to people.

Any changes to the assumptions used in this report should result in a review of the PHA and update as required.

7. Terms and Abbreviations

Abbreviation	Description
°C	Degrees Celsius
AC	Alternating Current
ADG	Australian Dangerous Goods Code
AEMO	Australian Electricity Market Operator
AS	Australian Standard
AS/NZS	Australian and New Zealand Standard
bar	Barometric pressure
DC	Direct Current
DG	Dangerous Good
DoP	Department of Planning
EIS	Environmental Impact Statement
EP&A	Environmental Planning and Assessment
g	Grams
GHD	GHD Pty Ltd
HIPAP	Hazardous Industry Planning Advisory Paper
km	Kilometres
kPag	Kilopascals gauge
kW/m^2	Kilowatts per meters squared
kWh	Kilowatt hour
m	Metres
MW	Mega Watt
MWh	Mega Watt Hour
NEM	National Electricity Market
NSW	New South Wales
PHA	Preliminary Hazard Analysis
Renew Estate	Renew Estate Pty Ltd
SDS	Safety Data Sheet
SEARs	Secretary's Environmental Assessment Requirements
SEPP 33	State Environment Planning Policy Number 33
SMS	Safety Management Study
SWMS	Safe Work Method Statement
UN	United Nations

8. References

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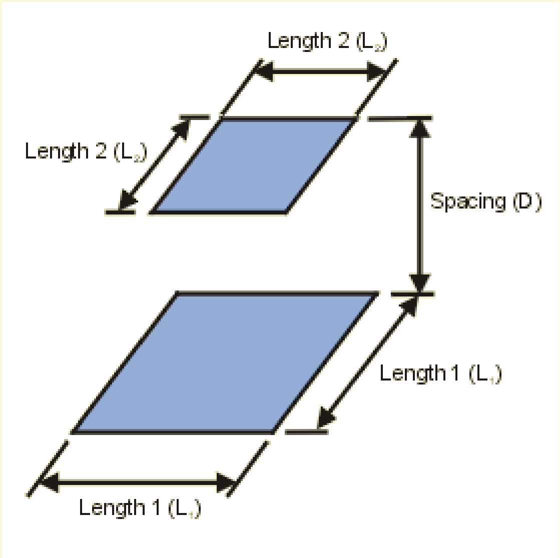
2. Multi-level Risk Assessment Guideline, Department of Planning (DoP), NSW 2011
3. Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning, Department of Planning (DoP), NSW 2011
4. Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis, Department of Planning (DoP), NSW 2011
5. AS/NZS 4452 – The storage and handling of toxic substances Storage and Handling, Standards Australia, 1997
6. Safe Work Australia, Code of Practice: Managing risks of hazardous chemicals in the workplace, 2012
7. Google Earth Pro, © 2017 Google, Image © 2017 CNES / Airbus
8. Lithium-Ion Battery Emergency Response Guide, Tesla Powerpack System, Powerwall, and Sub-assembly, All Sizes, Document Number TS-0004027, Revision 04, Tesla, 30 June 2017
9. Tesla Powerpack: Fire Code RAQ, Revision 1.02, 11 October 2016
10. Planning for Bush Fire Protection. Prepared by NSW Rural Fire Service in cooperation with the Department of Planning, 2006.
11. Safety Management Study Report, Renew Estate Pty Ltd, Boman Solar Farm, 20/06/2018, Revision 0, Sage Consulting Solutions Pty Ltd, Brisbane, Australia

Appendices

Appendix A – Consequence Calculation Summary

Radiation between parallel square surfaces of different edge lengths

It was estimated that the heat experienced between the batteries and a person in range during a fire, can be estimated by two plates. This calculation estimated the net radiant heat exchanged between two plates using the diagram below.



Description	Symbol	Value	Units
Height of Tesla Powerpack 2	L_1	2.19	Meters
Height of an average person	L_2	1.80	Meters
Temperature of Telsa Powerpack 2	T_1	673	Kelvin
Temperature outside	T_2	273	Kelvin
Distance between batteries and person	D	Values provided in Table 5	meters

The heat flow *q* from the plate is calculated as:

$q = 56.69 \times 10^{-9} \text{ x } VF_{(1-2)} \text{ x } L_1^2 \text{ x } (T_1^4 - T_2^4)$

Where 56.69×10^{-9} is the average Stefan-Bolzmann constant, L_1 is the length of plate 1, T_1 is the plate 1 temperature and T_2 is the plate 2 temperature. The view factor $VF_{(1-2)}$ (also known as radiation shape factor, angle factor, and configuration factor) is defined as:

Length of plate 1 divided by the distance between the plates (L_1 / D) must be greater than 0.2 for this calculation.

$$VF_{(1-2)} = \frac{1}{\pi \left(\frac{L_1}{D}\right)^2}(A + B + C)$$

Where:

$$A = \ln \frac{\left[\left(\frac{L_1}{D} \right)^2 \left(1 + \left(\frac{L_2}{L_1} \right)^2 \right) + 2 \right]^2}{\left(y^2 + 2 \right) \left(x^2 + 2 \right)}$$

$$B = \sqrt{y^2 + 4} \left[y \tan^{-1} \frac{y}{\sqrt{y^2 + 4}} - x \tan^{-1} \frac{x}{\sqrt{y^2 + 4}} \right]$$

$$C = \sqrt{x^2 + 4} \left[x \tan^{-1} \frac{x}{\sqrt{x^2 + 4}} - y \tan^{-1} \frac{y}{\sqrt{x^2 + 4}} \right]$$

Where *X* and *Y* are defined as:

X = (C) x (1 +E)
Y = (C) x (1 - E)
C = L_1 / D
D = L_2 / L_1

Where L_1 is the plate 1 length, L_2 is the plate 2 length, and *D* is the distance between the plates.

References

Lithium-Ion Battery Emergency Response Guide, Tesla Powerpack System, Powerwall, and Sub-assembly, All Sizes, Document Number TS-0004027, Revision 04, Tesla, 30 June 2017

Rosenow, W. M., J. P. Hartnett, Y. I. Young, *Handbook of Heat Transfer*, 3rd Ed., McGraw-Hill Handbooks, New York, 1998. p. 7.3 - 7.19, 7.81.

Appendix B – Frequency Calculation Summary

The frequencies of all hazard scenarios are calculated in the following section. The expected frequency is needed to enable a calculation of the risk. The scenarios are:

1. Latent battery failure in situ from manufacturing fault
2. Thermal runaway; caused by overcharging, overheating in cabinets, or release of coolant / refrigerant

Value	Parameter	Value	Reference
A	Storage Capacity of the battery system	40,000,000 Whr	Design specs
B	Type of ion battery	21.5	Design specs
C	Number of cells needed for the battery system	1,860,465 cells	Calculated = A/B
D	Fail rate of cell per year (failure per year per cell)	1/10,000,000	Assumed
E	Percentage of faults leading to thermal runaway	30 %	Assumed
F	Effectiveness of fusible separators	95 %	Assumed
G	Number of chargers	1860	Calculated = B/1000
H	Failure rate per charger per year	1/1,000,000	Estimated from circuit and protective components

The failure of all the battery cells due to cascading fires impacting neighboring cells was calculated by:

$$\frac{1}{\frac{1}{C \times D} \times \frac{1}{E} \times \frac{1}{(1-F)}} = 358\ years$$

The failure rate of the charging fault rate was calculated by:

$$\frac{1}{\frac{1}{G \times H}} = 538\ years$$

Therefore the failure of the battery cells or the failure of the charging fault will result in the overall probability of a potential thermal runaway of a lithium-ion battery to be (the summation of the two above values) equates to an estimated thermal runaway event of **every 215 years**.

Appendix C – Pipeline SMS Threat Register and Actions

Location = **BOMEN SOLAR FARM** **APA - Young-Wagga Wagga (Note: looped pipeline, DN 300 and DN 450)**

Threat ID #	Feature/Aspect	Threat Description	Threat Credible? / if not, why not	Detail Damage Description or describe why not credible	Prevention/Controlled by Design and / or Procedures	Physical Protection	Procedural Protection	Are these controls effective?	Failure Possible (y/n)	Additional Controls?	Now controlled?	Failure scenario	Severity	Frequency	Risk Ranking	ALARP?
1 - Threats associated with **Construction** of solar farm, including prepartory works						Note - there should be no uncontrolled threats during construction (encroachment).										
1	Access road improvements (Trahairs Road)	No excavation planned. Grader only Confirm pipeline depth of cover	No	Action: APA to confirm DoC, if standard xing design is followed, no threat												
2	Heavy equipment crossing pipeline	Standard road crossing to be installed at all points needed. Prior to installation/upgrade = Grader	No	Standard road crossing allowances. Crossing of pipeline easement with vehicle transporting transformer is to be avoided												
3	Earthworks over easement	No earthworks over easement anticipated	No	No earthworks over easement Posts and bunting to be installed during construction to prevent access Induction procedures												
4	Stormwater drainage	No change to current flows; construction windrows not significant	No	No change due to this development												
5	Marker signage installation	Install bunting or similar during construction across right of way to prevent inadvertent access	No	Easement flagged and inaccessible												
6	Turning vehicles	Not a threat	No	No scenario described												
7	installation of solar farm perimeter fencing (permanent installation)	Gates to be installed at right-of-way crossings (2 off) Might be a permitted activitiy, TBC	Yes	Installation of postholes punctures pipeline	yes	depth of cover, wall thickness	Permitted, controlled activity	yes	no							
8	cable installation	HDD	Yes	HDD goes off course and punctures pipeline, results in leak	Experienced HDD contractor APA to review methodology Permitted event - supervisor must be present Inspection pits Validation hole	nil	Permitted, controlled activity	yes	no							
9	Excavation / earthworks	Pile-driver goes off design and ends up over the pipeline	No	roped and flagged parallel to RoW QA would have to fail												
10	Excavation / earthworks	Pile-drivers cause more vibration than expected	No	APA to measure on site; will depend on location of closest pile to pipeline												
11	Excavation / earthworks	Excavation parallel to easement deviates, impacting on the pipe.	No	Not applicable												
12	Excavation / earthworks	Depth of cover reduction during construction	No	No works over pipeline except crossings which will be managed separately												

Location = **BOMEN SOLAR FARM** **APA - Young-Wagga Wagga (Note: looped pipeline, DN 300 and DN 450)**

Threat ID #	Feature/Aspect	Threat Description	Threat Credible? / if not, why not	Detail Damage Description or describe why not credible	Prevention/Controlled by Design and / or Procedures	Physical Protection	Procedural Protection	Are these controls effective?	Failure Possible (y/n)	Additional Controls?	Now controlled?	Failure scenario	Severity	Frequency	Risk Ranking	ALARP?
13	Excavation / earthworks	35T excavator with Tiger Teeth excavates over pipeline	No	Maximum 20T excavator on site stipulated by APA Inductions / info session If 35T, general purpose teeth only permitted activity												
14	Garden / Landscaping	New tree planted near pipeline; during installation the location of pipeline is not allowed for.	No	No trees to be planted on easement												
15	Landscaping - tree choice	Tree installation - root system associated with tree choice (TEE on landscaping drawings) affects pipeline	No	Short trees only near pipelines; no trees to be planted on easement												
16	Vehicular traffic	Vehicle crosses easement at non-designated crossing	No	Easement flagged and inaccessible												
17	Vehicular traffic	Heavy vehicle crosses, exceeding allowable limit	No	Design for heaviest expected vehicle or max road allowable												
18	Erosion / land movement during construction	Heavy rain during construction result in land movement affecting pipe	No	Flat area; erosion & sediment control plans												
19	Vehicular traffic	Bogged vehicle in wet weather; spins wheels and contacts pipe.	No	No crossing of easement except at all-weather crossings.												
20	Installation of Control building	No new threat (but recognise that consequences change)	No	No scenario described												
21	Electrical interference	Intereference AC/DC	Yes	Study to be completed by Renew Estate	Typical outcomes = 1) ok no change 2) separation distance 3) sacrificial zinc ribbon			To be advised								

Location = **BOMEN SOLAR FARM** **APA - Young-Wagga Wagga (Note: looped pipeline, DN 300 and DN 450)**

Threat ID #	Feature/Aspect	Threat Description	Threat Credible? / if not, why not	Detail Damage Description or describe why not credible	Prevention/Controlled by Design and / or Procedures	Physical Protection	Procedural Protection	Are these controls effective?	Failure Possible (y/n)	Additional Controls?	Now controlled?	Failure scenario	Severity	Frequency	Risk Ranking	ALARP?
22	CP Anode Bed	Anode bed is rendered ineffective by interference or dug up by proponent	No	May stay in current location but may be replaced in future Electrical studies to advise if an issue Orientation of security fencing to exclude CP Bed												
23	11KV overhead line	Not a threat to the pipeline, but if removed it needs to be replaced.	N/A	Renew Energy to find alternative power supply for CP Bed												
2 - Threats associated with ongoing operation of pipeline **after construction** of solar farm																
	APA unable to access to pipeline easement		No	No change to easement Gates in fencing with APA locks												
21	Vehicular traffic	Vehicular accident / plowing into easement	No	No scenario described												
22	Failure of utilities services / repair work impinges on pipeline	Transgrid - at substation	No	No third party crossings of pipeline easement												
23	Subsidence	Due to construction works and soil disturbance, land subsides and pipe is deflected/strained	No	Not anticipated at this location												
25	Marker signs	Marker signs removed by Solar Farm personnel	Yes	Induction material to advise (0 - 15 max on site)												
3 - Corrosion																
31	External corrosion	A future anomaly requires direct access inspection to assess defect for possible repair	n/a	Not a threat - access is not impeded to investigate.												
32	Corrosion	Existing flaw is undetected, grows to be a through-wall crack	No	APA integrity management program for pipeline												
4- Check robustness: all controls fail																
33	HDD installation goes off course and punctures pipe	Pilot hole drill bit diameter 75mm	Yes	HDD drills hole in pipe, gas escapes and catches fire, HDD operator fatalites + APA fellow.	nil	nil	nil	no	y	Distance to cribb hut installation at low numbers	no	HDD drills hole in pipe, gas escapes and catches fire, HDD operator fatalites + APA fellow.	hypothetical	major	low	ALARP

ACTION ITEMS

#	Description	By Whom	What does completion look like?	Consequence if not completed	Expected Completion Date
1	The pipeline must be positively located prior to detail design being undertaken	Joint / Coordinated	Pipeline depth of cover and alignment within the easement is verified within the property	If the pipeline is not at the expected depth or location, some of the 'controlled threat' conclusions of this study may be invalid.	
2	Electrical studies in accordance with AS 4853 and AS 2832 are required	Renew Estate	Studies completed, documented and endorsed by APA Group. Recommended actions are implemented.	Long term issues with electrical interference could result in either accelerated corrosion issues on APA's pipeline or safety risk to personnel working on the pipeline.	
3	Crossings design (vehicle or cable) must be approved by APA.	Submitted by Renew to APA	Approved crossing designs are available and on file.	APA could delay the project or stop construction if there are concerns with the crossings if not approved.	
4	During construction, the easement must be delineated on site and marked as a no go zone	Renew Estate	Easement boundaries clearly delineated so all construction personnel are aware of its existence.	Unapproved activities over the pipeline easement could affect the integrity of the pipeline, leading to leaks or ruptures.	
5	All plans must have the easement clearly identified so that contractors are aware of it	Renew Estate	Construction plans and documents refer to the pipeline easement so that there is full awareness	Unapproved activities over the pipeline easement could affect the integrity of the pipeline, leading to leaks or ruptures.	
6	Access to the easement by APA Operations personnel must be maintained at all times	Renew Estate	APA personnel can access the pipeline at any time.	Destruction of property to get access to easement, if required.	
7	Existing 11 KV overhead power line is requested to be replaced by a remote power system	APA: provide example existing remote systems Renew Estate: incorporate into design	A resolution is available in regards to the removal of the overhead power line.	The power line dissects the property and would make installation of the solar panels as designed not possible.	

#	Description	By Whom	What does completion look like?	Consequence if not completed	Expected Completion Date
8	Anode Bed: Study regarding DC currents from the solar farm and their possible interference with the anode bed that is in the property.	APA	Study is available that advises on interference with anode bed. A view on the future life of the anode bed should be considered as well.	Interference causes accelerated corrosion issues on APA's pipelines	
9	Update the APA SMS database spreadsheet between KP 125.7 to KP 128.5 to be R1 / HI (protections equivalent to R2)	APA	The APA SMS database for this pipeline shows the revised location class designation, and a reference to this report for clarity.	Information is inaccurate, and the incorrect requirements are applied at this location.	
10	Potholing at Trahairs Road crossing is to be coordinated via APA	APA / Renew	Potholing to verify depth of cover at Trahairs road is completed safely.	Risks of external impact if location is not verified.	
11	The RFQ documentation for the EPC contract shall address the restrictions and requirements identified in this study.	Renew Estate	Documentation is clear, in particular the crossing locations, cable conduit design, and requirements for APA approval of design of works on the easement.	EPC Contractor is unaware of requirements and puts in claims for compensation.	
12	For works on the easement, an APA third party works authorisation must be in place, and onsite supervision arranged.	Renew Estate	Agreements are in place, and supervision is on site. A minimum 2 weeks' advance notice is requested; APA approvals may take up to 1 month to obtain.	Unapproved activities over the pipeline easement could affect the integrity of the pipeline, leading to leaks or ruptures.	

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