Renew Estate Pty Ltd

Bomen Solar Farm

PHA Supplementary Assessment

Rev 0, August 2018

Executive summary

A Preliminary Hazard Analysis (PHA) had been conducted to assess the risks from the proposed Bomen solar farm development on surrounding land users in accordance with the NSW Secretary's Environmental Assessment Requirements (SEARs) as part of the development consent requirements under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

Subsequent responses from NSW Department of Planning and Environment (DP&E) have required the completion of a quantitative risk assessment (QRA) of the APA owned high pressure gas pipelines (the older Young to Wagga Wagga pipeline and a newer looping pipeline) that traverse the proposed Bomen Solar Farm site. The PHA Supplementary Assessment assesses the impacts of the gas pipelines to the proposed solar farm and its occupants against the Department's Hazardous Industry Planning Advisory Paper (HIPAP) No.4 Risk Criteria for Land Use Safety Planning and HIPAP No.10 Land Use Safety Planning.

The PHA Supplementary Assessment utilised QRA information presented in a PHA conducted for one of the two pipelines that traverse the solar farm site (Planager, 2009). The PHA conducted in 2009 for the looping pipeline (referred to as the Looping Pipeline PHA) presented the relevant individual fatality, injury and property damage and accident propagation risk transects.

The Looping Pipeline PHA did not include an assessment of the older Young to Wagga Wagga pipeline, therefore this assessment has been conducted on a conservative basis assuming the Young to Wagga Wagga pipeline has the same consequence and risk as the looping pipeline, even though it is a smaller pipeline with a lower pressure. In addition, the Looping Pipeline PHA utilised failure frequency data based on European statistics up to 1992, however more recent Australian data is available that indicates much lower failure frequencies, therefore the cumulative risk results assessed are conservative.

Analysis of the consequence effect distances found that some loss of containment events from the pipelines, in particular the larger diameter releases of 100mm and full bore ruptures could lead to jet fire, flash fire and explosion overpressure effects at either of the proposed control building locations. However, due to the distance of option 2 from the pipelines, only the lower severity consequence effects reach that location.

By duplicating the risk results of the looping pipeline to assess the cumulative risk for both pipelines, it was determined that all HIPAP 4 risk criteria is met for both of the control building locations and battery storage area. This includes the cumulative risk from both pipelines for the individual fatality risk, injury risk and the property damage and accident propagation risk.

Although it has been demonstrated that the cumulative risk from the pipelines is sufficiently low and below the relevant HIPAP 4 risk criteria, options to reduce the risk to personnel at the solar farm site even further, and in particular at the control building could include:

- Selection of control building option 2 location as the lower risk location.
- If control building option 1 location is selected, orientate the entry / exit points from the control building away from the pipelines to allow safe egress in the unlikely event of an ignited gas release.
- If control building option 1 location is selected, install gas detection at the location of control building to provide notification in the unlikely event of a gas release.

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.

Table of contents

Table index

Figure index

1. Introduction

1.1 Background

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).

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). As such, a Preliminary Hazard Analysis (PHA) was completed in accordance with the NSW Secretary’s Environmental Assessment Requirements (SEARs) Application number SSD8835.

The PHA was documented into the report; SEPP 33 Level 2 Preliminary Hazard Analysis Report (GHD, 2018) and reviewed by the NSW Department of Planning and Environment (DP&E). Subsequent responses from DP&E have required the completion of a quantitative risk assessment (QRA) of the APA owned high pressure gas pipelines that traverse the proposed Bomen Solar Farm site to assess the risks from the pipelines to the proposed development.

1.2 Purpose of this report

The purpose of this PHA Supplementary Assessment is to address the request from the DP&E to undertake detailed assessment, in the form of a QRA of the APA owned high-pressure gas pipelines traversing the proposal site. The PHA Supplementary Assessment assesses the impacts of the high-pressure gas pipelines to the proposed solar farm and its occupants against the Department’s Hazardous Industry Planning Advisory Paper (HIPAP) No.4 Risk Criteria for Land Use Safety Planning and HIPAP No.10 Land Use Safety Planning.

1.3 Scope and limitations

The scope of the QRA is to assess the risks associated with loss of containment events from both APA high pressure gas pipelines that traverse the proposed Bomen Solar Farm site. The scope is specifically limited to the impacts from loss of containment events in the pipeline sections within the solar farm site and excludes analysis of the remainder of the pipelines.

The assessment includes analysis against the individual fatality, injury, property damage and accident propagation risk criteria outlined in HIPAP No. 4 based on the cumulative risk from the pipelines as requested by DP&E (DP&E, 2018).

This PHA Supplementary Assessment is not intended to be a complete analysis of the hazards and risks associated with the pipelines or the proposed development. Reference should be made to the SEPP 33 Level 2 Preliminary Hazard Analysis Report (GHD, 2018) and the Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW (Planager, 2009) for further details and analysis of other hazards.

Additionally, this report: has been prepared by GHD for Renew Estate and may only be used and relied on by Renew Estate for the purpose agreed between GHD and the Renew Estate as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Renew Estate 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. 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 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.

GHD has not been involved in the preparation of the Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW (Planager, 2009). GHD has had no contribution to the Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW (Planager, 2009) other than to apply the information available from that report into this report. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any part of the Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW (Planager, 2009).

2. Project and pipeline summary

2.1 Overview

The methodology applied for the PHA Supplementary Assessment is a desktop analysis incorporating a review of the PHA conducted in 2009 as part of the Young to Wagga Looping Pipeline Environmental Impact Statement (EIS).

The pipeline assessed in the Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW (Planager, 2009) is a 450 mm diameter steel pipeline with 10.2 MPa Maximum Allowable Operating Pressure (MAOP). This pipeline was installed by APA adjacent to an existing 300 mm, 8.5 MPa bi-directional gas pipeline between Young and Wagga Wagga.

Both pipelines are incorporated into this PHA Supplementary Assessment to determine the cumulative risks from the pipelines. As Quantitative Risk Assessment (QRA) information is only available for the newer looping pipeline, assumptions have been made regarding the risk from the older Young – Wagga Wagga pipeline. These assumptions are documented for clarity throughout the report.

2.2 Solar farm project summary

Renew Estate is proposing the construction, operation and decommissioning of a 120 megawatt (MWdc) solar farm and associated infrastructure in the suburb of Bomen, Wagga Wagga, New South Wales (NSW). The proposal site is located about seven kilometres north-east of the Wagga Wagga central business district (CBD) on the eastern side of Byrnes Road.

Subject to final detailed design, the primary components of the proposal include:

- about 400,000 photovoltaic solar modules
- about 4,500 trackers comprising single-axis tracking framing systems mounted on steel piles
- up to 44 containerised power conversion stations containing electrical switchgear, inverters and medium voltage transformers
- new on-site electrical switchyard and substation
- connection into the National Electricity Market via about 3.5 kilometres of 132 kV transmission line between the proposed on-site substation and the existing TransGrid Wagga North Substation.
- battery storage system
- control building including office, supervisory control and data acquisition systems (SCADA), operation and maintenance facilities, spare parts and staff amenities serviced by septic systems and rainwater tanks
- car park
- internal DC and AC cabling for electrical reticulation
- minor upgrade of the unsealed section of Trahairs Road, east of Byrnes Road, for site access (to be maintained as a single lane unsealed road)
- internal all-weather access tracks
- internal fire trail and bushfire asset protection zones
- security fencing around the solar farm

- vegetation screening
- meteorological stations
- subdivision of four lots to allow the purchase of the required land for the proposal site.

Following the close of the exhibition period for the EIS, Renew Estate submitted a report detailing responses to all issues raised in the submissions and the subsequent changes to the proposal. The changes to the proposal are summarised in Figure 1 and form the basis for the PHA Supplementary Assessment.

The response to submissions document (Renew Estate, 2018) highlights two control building location options. The control building represents an occupied building in which site personnel may be exposed to the hazards associated with the pipeline. The distances of the two location options from the pipelines are summarised in Table 1 and represent the basis for the PHA Supplementary Assessment. Also included in Table 1 are the distances to the battery storage area that could potentially be impacted by hazards posed by the pipelines causing property damage.

Table 1 Distance between pipelines and infrastructure of interest

Site infrastructure of interest	Distance from Looping Pipeline (m)	Distance from Young to Wagga Wagga Pipeline (m)
Control building option 1	41.5	48.5
Control building option 2	350.5	343.5
Battery storage area	419	412

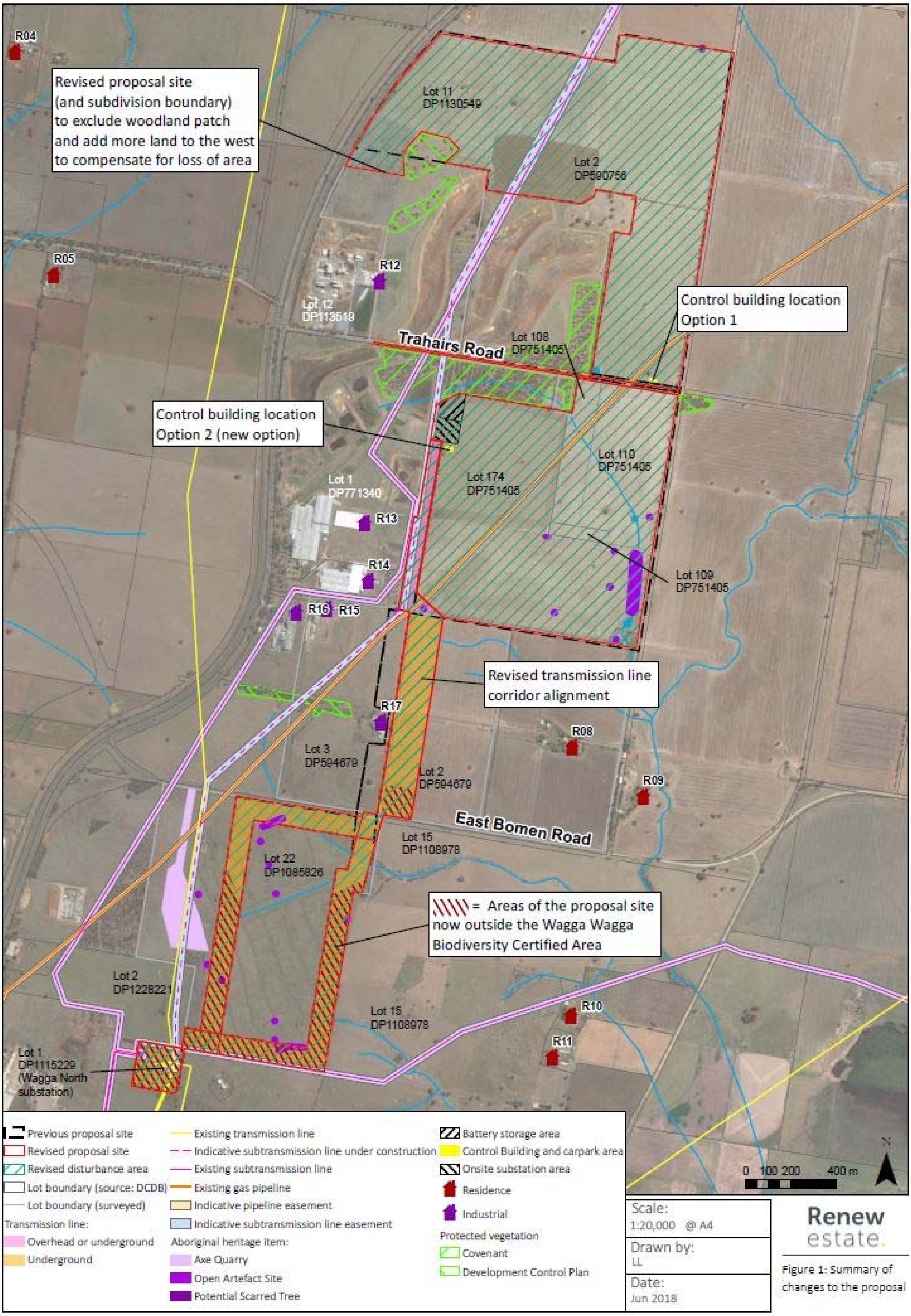

Figure 1 Summary of changes to the proposal

2.3 Pipeline details

The pipeline specifications are summarised in Table 2, reproduced from the Bomen Solar Farm Safety Management Study Report (Sage Consulting Solutions, 2018). This information represents the characteristics of the pipelines within the location of the proposal site.

Table 2 Pipeline specifications

Pipeline Details	Young to Wagga Wagga	Looping
Constructed/Commissioned	1981	~2010
Outside Diameter	323.8mm	457mm
Wall Thickness	6.35mm	9.7mm
Pipe specification	API 5L Grade X46	API-5L Grade X70
MAOP / MOP	8.5MPa	10.2MPa
Depth of cover at solar farm site	750mm, 1.2m under road	1.2m
Measurement Length	294m	452m
Critical Defect Length	85.1mm	89.2mm

As indicated in Figure 1, the pipelines run diagonally across the proposal site with options for the control building on either side of the pipelines.

Within the project site and immediately adjacent to the site, both pipelines are buried and there are no gas containing components above ground. Immediately to the south of where Trahairs Road crosses the pipelines is a cathodic protection unit.

Apart from cable crossing, road crossings and security fencing, which will be designed and installed in consultation with APA, no solar farm infrastructure will be constructed within the pipeline easement. There will be requirements for cable crossings of the easement from power conversion stations (inverters and medium voltage transformers) to the onsite substation (33 kV and communications) and from the onsite substation to the North Wagga Substation (132 kV and communications) (Sage Consulting Solutions, 2018).

3. Risk criteria

The *HIPAP No 4 – Risk Criteria for Land Use Safety Planning* (DPE, 2011) provides criteria for individual, societal and property damage risks. The criteria are used as a conservative tool for assessing these risks.

Individual risk is a measure of the risk to an individual continuously exposed at a specific location within the effect zone of a hazardous incident. The individual and property damage risk criteria for fires and explosions listed in Table 3 are suggested in HIPAP 4. The risk level represents the frequency at which the relevant exposure type should not be exceeded.

As the scope of this PHA Supplementary Assessment is focussed on the risk from the pipelines to the proposal site and personnel on site, only the individual fatality and property damage and accident propagation criteria are relevant (DP&E, 2018), however the injury risk at residential locations is also included for consistency with the Looping Pipeline PHA. For clarity, the HIPAP 4 criteria that are not relevant to this study have been indicated in grey text.

Table 3 HIPAP 4 risk criteria

Category	Exposure Type	Maximum tolerable risk
Fatality	Hospitals, schools, child-care facilities and old age housing developments	Half in a million per year (0.5×10^{-6} per year)
Fatality	Residential developments and places of continuous occupancy (hotels/resorts)	One in a million per year (1×10^{-6} per year)
Fatality	Commercial developments, including offices, retail centres, warehouses with showrooms, restaurants and entertainment centres	Five in a million per year (5×10^{-6} per year)
Fatality	Sporting complexes and active open space areas	Ten in a million per year (10×10^{-6} per year)
Fatality	Industrial sites	Fifty in a million per year (50×10^{-6} per year)
Injury	4.7kW/m^2 incident heat flux radiation at residential and sensitive use areas	Fifty in a million per year (50×10^{-6} per year)
Injury	7kPa incident explosion overpressure at residential and sensitive use areas	Fifty in a million per year (50×10^{-6} per year)
Injury	Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10 in a million per year (10×10^{-6} per year)
Irritation	Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	Fifty in a million per year (50×10^{-6} per year)
Property damage & accident propagation	23kW/m^2 incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations	Fifty in a million per year (50×10^{-6} per year)
Property damage & accident propagation	14kPa incident explosion overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings	Fifty in a million per year (50×10^{-6} per year)

The effects of heat radiation and explosion overpressure are described in Table 4 and Table 5 (DP&E, 2011), as used for the basis of the HIPAP risk criteria in Table 3.

Table 4 Heat radiation effects

Heat radiation (kW/m^2)	Effect
1.2	Received from the sun at noon in summer
4.7	Will cause pain in 1 5-20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur)
12.6	Significant chance of fatality for extended exposure. High chance of injury Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures which can cause failure Pressure vessel needs to be relieved or failure would occur
35	Cellulosic material will pilot ignite within one minute's exposure. Significant chance of fatality for people exposed instantaneously

Table 5 Explosion overpressure effects

Overpressure (kPa)	Effect
3.5	90% glass breakage. No fatality, very low probability of injury
7	Damage to internal partitions & joinery 10% probability of injury, no fatality
14	Houses uninhabitable and badly cracked
21	Reinforced structures distort, storage tanks fail 20% chance of fatality to person in a building
35	Houses uninhabitable Wagons & plant items overturned. Threshold of eardrum damage 50% chance of fatality for a person in a building, 15% chance of fatality for a person in the open
70	Threshold of lung damage 100% chance of fatality for a person in a building or in the open Complete demolition of houses

4. Cumulative risk assessment

The following risk results are reproduced from the Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW (Planager, 2009) (referred to as the Looping Pipeline PHA) and represents the relevant information utilised in assessment of the risks to the proposal site. As noted above, the Looping Pipeline PHA only includes an assessment of the looping pipeline risk and does not include risk results for the older Young – Wagga Wagga pipeline. Additional information has been sought and discussed where relevant from the Bomen Solar Farm Safety Management Study Report (Sage Consulting Solutions, 2018).

4.1 Input summary

The pipeline design assumptions used as the basis for the Looping Pipeline PHA are summarised in Table 6 and are consistent with the information available for the ‘as constructed’ pipeline details provided in Table 2.

Table 6 Looping Pipeline PHA assumptions

Pipeline Details	Looping
Pipeline Diameter	450 mm
Wall Thickness	6.8 to 9.7 mm
Pipe length	130 km
Pipe specification	API-5L Grade X70
MAOP	10.2 MPa
Depth of cover	At least 900 mm
Temperature	25 °C

A number of specific assumptions were made in the QRA for the pipeline. Reference should be made to the Looping Pipeline PHA (Planager, 2009) for details on these assumptions.

As the Looping Pipeline PHA was conducted on the basis of the looping pipeline only, the results presented in the PHA report are reflective of those pipeline parameters and do not represent the risk from the Young to Wagga Wagga pipeline.

For ease of assessment, it is assumed that the risk results from the looping pipeline are reflective of the risk results from the Young to Wagga Wagga pipeline. However, it should be noted that in reality, this is a very conservative approach as the looping pipeline parameters, in particular the pipeline diameter, wall thickness and MAOP are such that the looping pipeline would pose a greater risk than the Young to Wagga Wagga pipeline. Where this assumption influences the risk results, specific discussion is provided within each section below.

4.2 Hazards identified

The Looping Pipeline PHA identified 10 potentially hazardous scenarios that could lead to a loss of containment of gas from the pipeline. It is assumed that the same hazardous scenarios are relevant for the Young – Wagga Wagga pipeline and include:

1. Mechanical damage to the pipeline
2. Corrosion
3. Nearby explosion at neighbouring natural gas pipeline
4. Pressure excursion
5. Spontaneous loss of integrity of pipe (rupture)
6. Erosion
7. Land subsidence
8. Aircraft, train or heavy vehicle crash
9. Damage to pipeline through terrorism / vandalism
10. Neighbouring bush fire

These hazardous scenarios represent the potential events that could lead to an impact on the solar farm site and personnel. It is assumed that the same hazardous scenarios apply to both pipelines – this is justified on the basis that both are owned and operated by APA and are within the same pipeline easement.

In addition to the 10 hazardous scenarios identified in the Looping Pipeline PHA, 30 threats were identified to the pipelines in the SMS conducted as part of the proposal EIS. The specific features of the solar farm site and construction activities that will be required were discussed and documented as the basis for the SMS (refer to Sage Consulting Solutions, 2018). The SMS also incorporated the presence of both pipelines within the easement. It is considered that this detailed assessment is sufficient to demonstrate that the specifics of the solar farm site have been considered concerning potential causes of loss of containment from the pipelines.

Although there were more threats identified in the SMS than hazardous scenarios in the Looping Pipeline PHA, they represent very similar causes and each threat from the SMS could be classified and grouped based on the hazardous scenarios presented in the Looping Pipeline PHA. On the basis that both the SMS and Looping Pipeline PHA have identified a similar suite of loss of containment causes, it is considered reasonable that the loss of containment leak frequencies presented in the Looping Pipeline PHA are representative of the location specific frequencies within the solar farm site.

4.3 Consequence analysis

The below summary represent the heat radiation and explosion overpressure results calculated in the looping pipeline PHA (Planager, 2009) and a discussion on the potential impacts of those events to the solar farm site.

4.3.1 Jet fires

Table 7 presents the heat radiation distances produced by jet fires from immediate ignition of gas released from the looping pipeline (Planager, 2009).

Table 7 Jet fire heat radiation distances

Hole size	Distance to heat radiation (metres)		
	4.7kW/m^2	12.5kW/m^2	23.5kW/m^2
Small leak (5mm)	6	4	3
Intermediate leak (25 mm)	30	18	14
Massive leak (100 mm)	120	74	55
Full bore (guillotine)	525	310	240

The information regarding the distance to the control building provided in Table 1 and jet fire heat radiation effects in Table 7 indicates the following:

- Both control building option 1 and option 2 locations are outside all jet fire heat radiation effect zones from the smaller hole sizes (5mm and 25mm) of both pipelines.
- Control building option 2 location is outside all jet fire heat radiation effect zones with the exception of the 4.7kW/m^2 heat radiation from a full bore rupture from either pipeline.
- Control building option 1 location is within all heat radiation effect zones from the larger (100mm and full bore rupture) releases from either pipeline.
- The battery storage area is outside all jet fire heat radiation effect zones with the exception of the south east corner of the storage area potentially being exposed to the 4.7kW/m^2 heat radiation from a full bore rupture of either pipeline.
- The 23kW/m^2 property damage and accident propagation heat radiation level does not reach the location of control building option 2 and only larger releases (100mm and full bore rupture) reach the location of control building option 1.

Consequence impact distances of gas releases are heavily influenced by the parameters of the pipeline. In the case of jet fires, the pressure of the gas at the time of release plays a significant part in the distance the flame can travel. For large bore releases, there is typically a rapid pressure loss that also influences the extent of the flame. When considering the results presented in Table 7 with regards to the same loss of containment events from the Young to Wagga Wagga pipeline, the lower pressure of 8.5 MPa compared to 10.2 MPa for the looping pipeline would mean that the heat radiation distances would be substantially less. In effect, this would mean that for the smaller (5mm and 25mm) releases, it is unlikely there would be any effects that extend beyond the 20m easement and even the 4.7kW/m^2 heat radiation from a full bore rupture of the Young to Wagga Wagga pipeline may not reach the location of the control building option 2.

As the direction of release is not specified in the Looping Pipeline PHA, it is assumed that the jet fire results represent the worst case scenario of a horizontal release. In reality, given that the pipelines are buried, any large bore releases are more likely to be angled and impinged releases, thus reducing the distance of the flame from the source.

Although there is potential for some heat radiation effects to reach the location of the control building and extend across the solar farm site, the likelihood of a large release occurring that could extend such distances is relatively low, as discussed in Section 4.4.

4.3.2 Flash fires

Table 8 presents the heat radiation distances produced by flash fires from delayed ignition of gas released from the looping pipeline (Planager, 2009).

Table 8 Flash fire heat radiation distances

Hole size	Distance to heat radiation (metres)		
	4.7kW/m²	23.5kW/m²	100% fatality
Small leak (5mm)	25	15	12
Intermediate leak (25 mm)	40	35	30
Massive leak (100 mm)	150	80	70
Full bore (guillotine)	350	315	250

The information regarding the distance to the control building provided in Table 1 and flash fire effects in Table 8 indicates the following:

- Both control building option 1 and option 2 locations are outside all flash fire effect zones from the smaller hole sizes (5mm and 25mm) of both pipelines.
- Control building option 2 location is outside all flash fire effect zones with the exception of the 4.7kW/m² heat radiation from a full bore rupture from the Young to Wagga Wagga pipeline.
- Control building option 1 location is within all flash fire effect zones from the larger (100mm and full bore rupture) releases from either pipeline.
- The battery storage area is outside all flash fire effect zones.
- The 23kW/m² property damage and accident propagation heat radiation level does not reach the location of control building option 2 and only larger releases (100mm and full bore rupture) reach the location of control building option 1.

The Looping Pipeline PHA does not indicate the height at which the flash fire results are reported. Upon release, an unignited gas cloud will rise rapidly and disperse into a concentration below the flammable limit. If the results have been reported in the Looping Pipeline PHA at the cloud centreline, this will be at a height typically above the location of where personnel would be present and therefore represents a conservative effect distance. For conservancy, it is assumed that the flash fire results are reported at a height in which personnel may be located.

As with jet fires, the flash fire effects are influenced by the pressure of the gas and diameter of the pipeline. Therefore, a loss of containment from the Young to Wagga Wagga pipeline would have reduced flash fire heat radiation distances as compared to those provided in Table 8 based on the lower pressure of the pipeline. On this basis, the location of control building option 2 and the battery storage area would most likely be outside all flash fire effect distances from the Young to Wagga Wagga pipeline in addition to the looping pipeline.

Although there is potential for some flash fire effects to reach the location of the control building and extend across the solar farm site, the likelihood of a large release occurring that could extend such distances is relatively low, as discussed in Section 4.4.

4.3.3 Explosions

Table 9 presents the overpressure distances produced by explosions resulting from delayed ignition of gas released from the looping pipeline (Planager, 2009).

Table 9 Explosion overpressure distances

Hole size	Distance to explosion overpressure (metres)		
	7kPa	14kPa	70kPa
Small leak (5mm)	30	25	15
Intermediate leak (25 mm)	120	75	40
Massive leak (100 mm)	300	200	75
Full bore (guillotine)	450	380	220

The information regarding the distance to the control building provided in Table 1 and explosion overpressure in Table 9 indicates the following:

- Both control building option 1 and option 2 locations are outside all explosion overpressure effect zones from the smallest hole size (5mm) of both pipelines.
- Control building option 2 location is outside all explosion overpressure effect zones with the exception of the 7kPa and 14kPa overpressures from a full bore rupture from either pipeline.
- Control building option 1 location is within all explosion overpressure effect zones from the larger (100mm and full bore rupture) releases from either pipeline and the 7kPa and 14kPa overpressures from a 25mm release.
- The battery storage area is outside all explosion overpressure effect zones with the exception of the south east corner of the storage area potentially being exposed to 7kPa overpressures from a full bore rupture of either pipeline.
- The 14kPa property damage and accident propagation explosion overpressure level reaches the location of control building option 1 for the 25mm, 100mm and full bore rupture releases and it reaches the location of control building option 2 for the full bore rupture releases only.

Although the explosion overpressure results are provided and assessed, it must be noted that for an explosion to occur, a loss of containment must occur, followed by dispersion of the gas and accumulation in a confined / congested area and the gas must contact an ignition source. Within the solar farm site, the only credible location of accumulation and confinement of gas would be the control building. Assuming the 100% fatality results presented in Table 8 represent the Lower Flammable Limit (LFL) flash fire envelope, the gas cloud could travel up to 250m within flammable concentrations due to a full bore rupture. This means that there is no risk of explosion at the control building option 2 location as it is outside the flammable cloud footprint, however there is potential for the gas to accumulate leading to an explosion in the control building option 1 location.

As with jet fires and flash fires, although there is potential for some explosion effects to reach the location of the control building and extend across the solar farm site, the likelihood of a large release occurring that could extend such distances is relatively low, as discussed in Section 4.4.

4.4 Frequency analysis

The frequencies used for the Looping Pipeline PHA were based on incident statistics between 1988 and 1992, gathered by the European Gas Pipeline Incident Data Group (EIGPIDG)

(Dawson, 1994). That data was selected at the time of the Looping Pipeline PHA, based on the statistical significance of the data available compared to Australian data. The EIGPIDG data only provided details of leak rates for small and large holes, therefore rupture frequency data was taken from the British Gas failure data (Fearnehough, 1992).

The resulting failure frequencies used for the Looping Pipeline PHA are provided in Table 10 (Planager, 2009).

Table 10 Failure frequencies for >100mm NB pipelines

Type of failure	Failure rate (per 1000km per year)	
	6.8mm pipe thickness	9.7mm pipe thickness
<20mm hole	0.055	0.027
<80mm hole	0.138	0.076
Guillotine failure (full bore)	0.0015	0.0007
Total	0.1945	0.1037

4.4.1 Young to Wagga Wagga vs looping pipeline frequencies

As noted in Table 2, the Young to Wagga Wagga pipeline has a smaller diameter and wall thickness compared to the looping pipeline. Although these differences exist, the 6.8mm wall thickness results of the looping pipeline are used as the basis for the Young to Wagga Wagga pipeline.

The latest EIGPIDG data produced in their 10th report (EGIG, 2018) indicates the 6.35mm and 9.7mm wall thicknesses of the Young to Wagga Wagga and looping pipeline respectively are typically grouped into the same category, as per Figure 2. Therefore, although the Looping Pipeline PHA reported different failure frequencies for the two wall thickness, it is assumed, based on subsequent EIGPIDG data that the two wall thickness produce failure frequencies of a similar value.

Additionally, Appendix 1 of the Looping Pipeline PHA (Planager, 2009) indicates a total hole failure rate of 156 per million kilometre per year for a 5.9mm pipe thickness compared to the 138 per million kilometre per year for the 6.8mm pipe thickness. Given a total difference of 18 incidents per million kilometre per year between the looping pipeline and a pipeline with a smaller wall thickness than the Young to Wagga Wagga pipeline, again it is reasonable to assume that the 6.8mm results are applicable for the Young to Wagga Wagga pipeline.

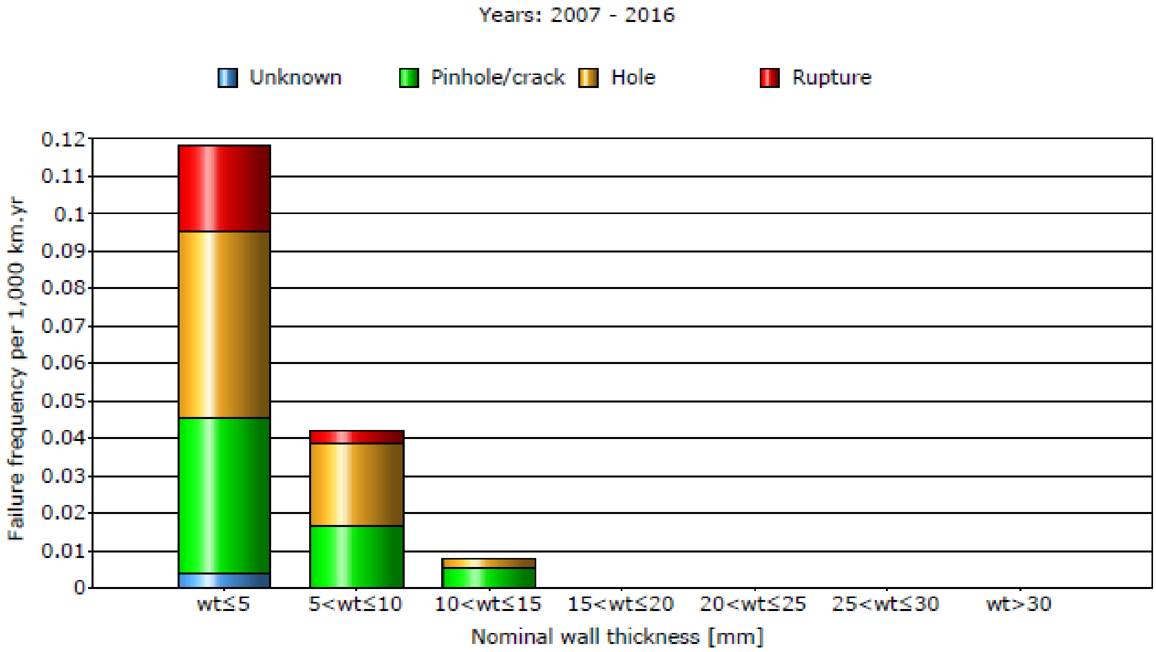

Figure 2 Relationship between external interference, size of leak and wall thickness (EGIG, 2018)

Similarly, although the Young to Wagga Wagga pipeline has an outer diameter of 323.8mm compared to the looping pipeline outer diameter of 457mm, the looping pipeline failure frequencies are used for the Young to Wagga Wagga pipeline. The latest EIGPIDG data (EGIG, 2018) indicates the two pipeline dimeters have a similar failure frequency as highlighted in Figure 3.

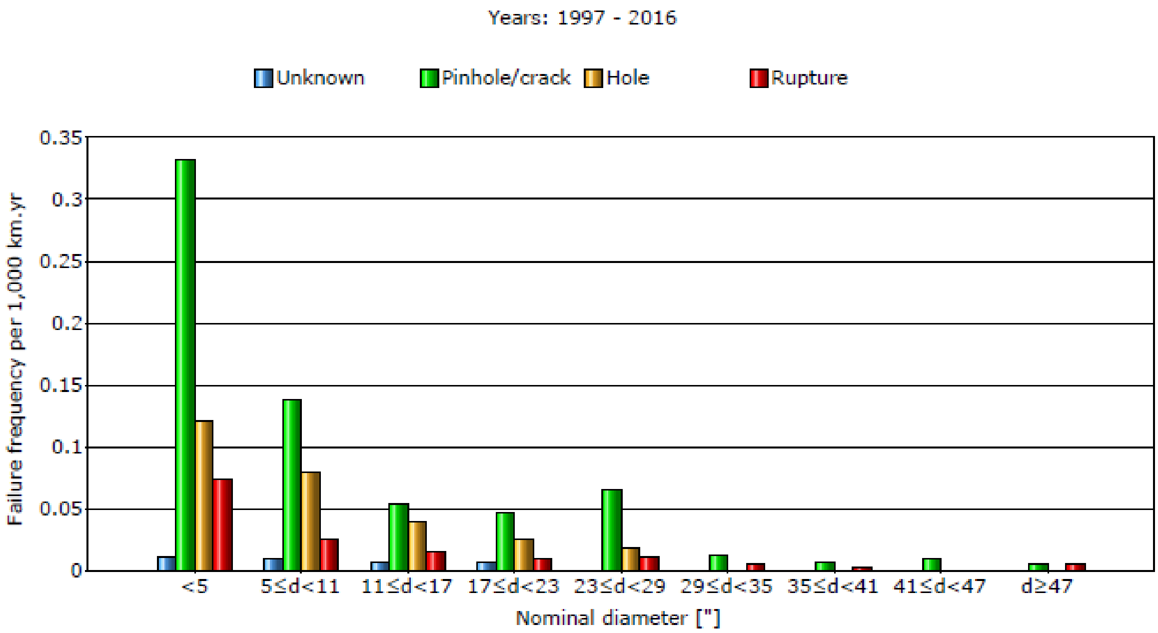

Figure 3 Relationship between diameter class and size of leak (EGIG, 2018)

It is concluded that although the looping pipeline is a larger diameter and greater wall thickness, the 6.8mm wall thickness failure data from the looping pipeline may be used as a conservative estimate for the failure frequencies from the Young to Wagga Wagga pipeline.

4.4.2 Comparison to recent Australian data

As noted above, the Looping Pipeline PHA used data for a period from 1988 to 1992. Numerous data sources are available with information on loss of containment frequencies from more recent time periods and there has been substantial improvements in the data available for Australian pipelines.

A paper comparing international pipeline failure rates was presented at the 2013 Joint Technical Meeting between APIA, the European Pipeline Research Group and the Pipeline Research Council International (Tuft & Cunha, 2013). This paper suggests, that although there are significant differences between the Australian and international pipeline failure frequencies, the Australian data is valid. The failure frequencies assessed in the paper are based on the data reported through the Australian Pipelines and Gas Association (APGA) for buried steel pipes.

The APGA reported for buried steel pipes an average loss of containment frequency of 0.034 per 1000km per year (Tuft & Cunha, 2013). This figure is based on the 2002 to 2012 period as it is conservative, and it reflects the time period in which data collection has been soundly based. Furthermore, an analysis of the loss of containment events that occur within Australia undertaken by Tuft and Bonar (Tuft & Bonar, 2009), estimated that 27% of the loss of containment events have been ruptures and 73% have been leaks. A summary of the Australian failure frequencies is provided in Table 11.

Table 11 Failure frequencies for Australian pipelines

Type of failure	Failure rate (per 1000km per year)
Leak	0.0248
Rupture	0.0092
Total	0.034

Comparing the data in Table 10 and Table 11, it can be seen that the Australian statistics of buried pipeline releases are significantly lower than the European data used in the Looping Pipeline PHA. Therefore, although the results from the Looping Pipeline PHA are used in this assessment, they represent a highly conservative analysis of the risks associated with the pipelines.

4.5 Risk assessment

A summary of the risk results provided in the Looping Pipeline PHA (Planager, 2009) are tabulated below at distances representative of the location of the two control building options. As mentioned above, the risk results for the Young to Wagga Wagga pipeline are based on the 6.8mm pipe thickness results and the Looping pipeline values are based on the 9.7mm pipe thickness results from the Looping Pipeline PHA.

Table 12 (Planager, 2009) shows the cumulative individual fatality risk of both pipelines. It highlights that the risk at the control building option 2 location and battery storage area is negligible and the risk at the control building option 1 location (9.5 x 10^{-7} per year) is below the fifty in a million per year (5 x 10^{-5} per year) individual fatality criteria for industrial sites as specified in HIPAP 4.

Table 12 Cumulative individual fatality risk

Pipeline	Risk of fatality (per year)			Looping Pipeline PHA Reference
	Control building option 1 location	Control building option 2 location	Battery storage area	
Young to Wagga Wagga	7.00E-07	N/A	N/A	Figure 3
Looping	2.50E-07	N/A	N/A	Figure 4
Total	9.50E-07	N/A	N/A	

Table 13 (Planager, 2009) shows the cumulative injury risk of both pipelines. It highlights that the risk at the control building option 2 location and battery storage area is negligible and the risk at the control building option 1 location (1.8 x 10^{-6} per year) is below the combined heat radiation and explosion overpressure injury risk criteria of 1 x 10^{-4} per year (for residential developments) specified in HIPAP 4. Although not defined within the Looping Pipeline PHA, it is assumed that the injury risk results presented are based on the cumulative heat radiation and explosion overpressure risks from the pipeline.

Table 13 Cumulative injury risk

Pipeline	Risk of injury (per year)			Looping Pipeline PHA Reference
	Control building option 1 location	Control building option 2 location	Battery storage area	
Young to Wagga Wagga	1.15E-06	N/A	N/A	Figure 5
Looping	6.50E-07	N/A	N/A	Figure 6
Total	1.80E-06	N/A	N/A	

Table 14 (Planager, 2009) shows the cumulative property damage and accident propagation risk of both pipelines. It highlights that the risk at the control building option 2 location and battery storage area is negligible. It also shows the risk at the control building option 1 location (1.6×10^{-6} per year) is below the combined heat radiation and explosion overpressure property damage and accident propagation risk criteria of 1×10^{-4} per year at neighbouring potentially hazardous installations as specified in HIPAP 4. Although not defined within the Looping Pipeline PHA, it is assumed that the property damage and accident propagation risk results presented are based on the cumulative heat radiation and explosion overpressure risks from the pipeline.

Table 14 Cumulative propagation risk

Pipeline	Risk of property damage or accident propagation (per year)			Looping Pipeline PHA Reference
	Control building option 1 location	Control building option 2 location	Battery storage area	
Young to Wagga Wagga	9.00E-07	N/A	N/A	Figure 7
Looping	6.80E-07	N/A	N/A	Figure 8
Total	1.58E-06	N/A	N/A	

5. Conclusions and recommendations

Using the information presented in a previous PHA study conducted for the APA looping pipeline, the following conclusions are made:

- The Looping Pipeline PHA only considered one of the two pipelines within the easement that traverses the solar farm site, however the use of the smaller (6.8mm) wall thickness risk results for the Young to Wagga Wagga pipeline has been justified based on the consistency of failure rates.
- The use of the consequence results from the Looping Pipeline PHA is a conservative approach to estimating the consequences from the Young to Wagga Wagga pipeline due to the differences in pressure and pipeline diameter.
- There is potential for some jet fire, flash fire and explosion overpressure consequence distances to reach the control building at both location options, however due to the distance to option 2, less effects reach the location of option 2.
- The Looping Pipeline PHA utilised failure frequency data based on European statistics up to 1992, however more recent Australian data is available that indicates much lower failure frequencies, therefore the cumulative risk results assessed are conservative.
- The cumulative individual fatality risk at the location of both control building options and the battery storage area is below the HIPAP 4 risk criteria.
- The cumulative injury risk at the location of both control building options and the battery storage area is below the HIPAP 4 risk criteria.
- The cumulative property damage and accident propagation risk at the location of both control building options and the battery storage area is below the HIPAP 4 risk criteria.

Although it has been demonstrated that the cumulative risk from the pipelines is sufficiently low and below the relevant HIPAP 4 risk criteria, options to reduce the risk to personnel at the solar farm site even further, and in particular at the control building could include:

- Selection of control building option 2 location as the lower risk location.
- If control building option 1 location is selected, orientate the entry / exit points from the control building away from the pipelines to allow safe egress in the unlikely event of an ignited gas release.
- If control building option 1 location is selected, install gas detection at the location of control building to provide notification in the unlikely event of a gas release.

6. References

New South Wales Department of Planning and Environment (DP&E) Email from Nicholas Hon DP&E RE: Clarifications for Bomen Solar Farm PHA addendum, 30 July 2018

New South Wales Department of Planning and Environment (DP&E), Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning, 2011

Dawson F. J., *Gas Pipeline Incidents*, EIPIDG – European Gas Pipeline Incident Data Group, as presented at the International Gas Union Conference, Milan, Italy, June 1994

European Gas Pipeline Incident Data Group (EGIG) Gas Pipeline Incidents 10th Report of the European Gas Pipeline Incident Data Group (period 1970 – 2016), 2018

Fearnehough, G. D. *Pipeline Safety*, Pipeline Technology Conference, Royal Flemish Society of Engineers, Oostende, Belgium, 1990; and Fearnehough, G. D. & Corder, I, *Application of Risk Analysis Techniques to the Assessment of Pipeline Routeing and Designs Criteria,* International Conference on Pipeline Reliability, Calgary, Canada, 1992

GHD, SEPP 33 Level 2 Preliminary Hazard Analysis Report, 2018

Planager, Preliminary Hazard Analysis of the Natural Gas Delivery Pipeline between Young and Bomen in NSW, 2009

Renew Estate, Bomen Solar Farm Response to Submissions, 29 June 2018

Sage Consulting Solutions Pty Ltd, Bomen Solar Farm Safety Management Study Report, 20 June 2018

Tuft, P. and Bonar, C., (2009). *Experience with the pipeline incident database,* APIA Convention 2009

Tuft, P. and Cunha, S., (2013) Comparing International Pipeline Failure Rates, Presented at the Joint Technical Meeting between APIA, the European Pipeline Research Group and the Pipeline Research Council International, Australian Pipeliner, 2013

GHD

145 Ann Street Brisbane QLD 4000
GPO Box 668 Brisbane QLD 4001
T: (07) 3316 3000   F: (07) 3316 3333   E: bnemail@ghd.com

\\ghdnet\ghd\AU\Orange\Projects\23\16243\Tech\QRA of APA pipeline addendum\2316243-PHA Supplementary Assessment_Rev 0.DOCX

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	R Freeman	M. Erskine		P. Carson		6/8/18
0	R Freeman	M. Erskine	M. Erskine	P. Carson	Peter Carson	8/8/18

www.ghd.com