Report to:
Jacobs Group (Australia) Pty Ltd

AGL Gas Import Jetty Project
Crib Point Jetty, Western Port

Effects of LNG Facility on Sea Level and Seabed at Crib Point Jetty

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Effects of LNG Facility on Sea Level and Seabed at Crib Point Jetty

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This report constitutes the professional opinion and judgement of Consulting Environmental Engineers

Effects of Shipping Associated with LNG Facility

1. Project overview

AGL Wholesale Gas Limited (AGL) is proposing to develop a Liquefied Natural Gas (LNG) import facility, utilising a Floating Storage and Regasification Unit (FSRU) to be located at Crib Point on Victoria's Mornington Peninsula. The project, known as the "AGL Gas Import Jetty Project" (the Project), comprises:

- The continuous mooring of the FSRU at the existing Crib Point Jetty, which will receive LNG carriers of approximately 300m in length
- The construction of ancillary topside jetty infrastructure (Jetty Infrastructure), including high pressure gas unloading arms and a high-pressure gas flowline mounted to the jetty and connecting to a flange on the landside component to allow connection to the Crib Point Pakenham Pipeline Project.

The FSRU will be continuously moored to receive LNG cargos from visiting LNG carriers, store the LNG and re-gasify it as required to meet demand for high pressure pipeline gas.

2. Purpose of this report

The scope of this assessment was to investigate the presence of the FSRU and LNG carrier in terms of the potential restriction to the flow of seawater in the western channel and, if so, what are the likely changes in water level in the upper part of Western Port. The potential for local erosion impacts associated with the shipping operations is also considered. This report was prepared in support of:

- A referral under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and
- A referral under the Victorian *Environment Effects Act 1978.*

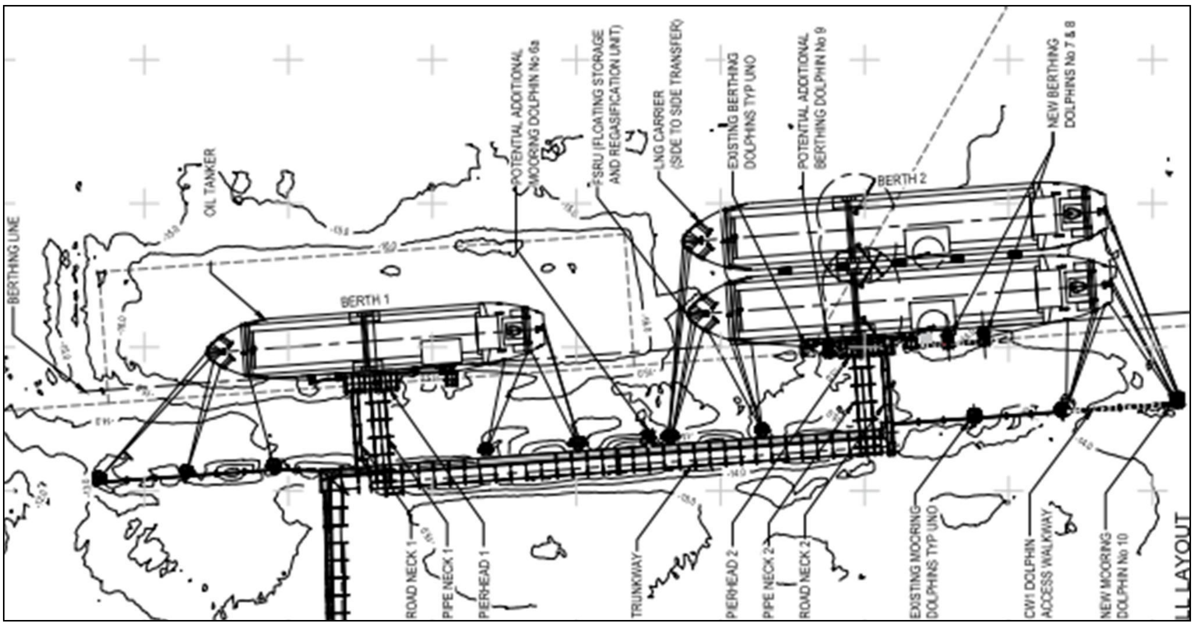

Figure 1. Proposed Berthing Arrangement for Vessels at Crib Point
(north is to left of figure)

3. Background

The FSRU and LNG carriers are both large vessels and will be frequently moored side by side at the Crib Point Jetty on the western side of the western channel of Western Port. Figure 1 shows the proposed berthing arrangement (north is to the left side of Figure 1).

Table 1 lists the principal dimensions of the likely vessels at Crib Point. Moored together, the two vessels will occupy a width of 90 m and a depth of 12.5 to 12.6 m. An obvious question is whether this large volume creates a significant restriction to the flow of seawater in the western channel and, if so, what are the likely changes in water level in the upper part of Western Port.

Table 1. Likely Dimensions of FSRU and LNG Carrier Vessels

	FSRU	LNG Membrane Carrier	LNG Moss Carrier
Displacement, MD (T)	132,855	121,990	118,900
Deadweight Tonnage, DWT(T)	95,106	89,557	84,878
Net Tonnage	36,793	31,102	36,480
Overall length, LOA (m)	295	295	288
Length between perpendiculars, Lpp (m)	284	284	274
Beam (m)	46.4	43.4	49.0
Moulded Depth (m)	26.5	26.0	26.8
Laden Tropical Draft (m)	12.6	12.5	12.33
Wharfside operating draft (m)	TBA	TBA	TBA
Ballast Draft (m)	9.4	9.5	

To answer this question, the following analysis has been made:

- Calculate change of cross-sectional area of west channel;
- Calculate backwater and head loss using bridge pier formula;
- Check head loss using energy balance formula;
- Predict reduction in water level over tide cycle; and
- Compare to natural variations in average sea level and sea level rise.

4. Change in Cross-sectional Area

The first step is to determine the proportion of the channel area that would be occupied by the two vessels. Figure 2 shows the section taken across the west channel and the depth profile on this section.

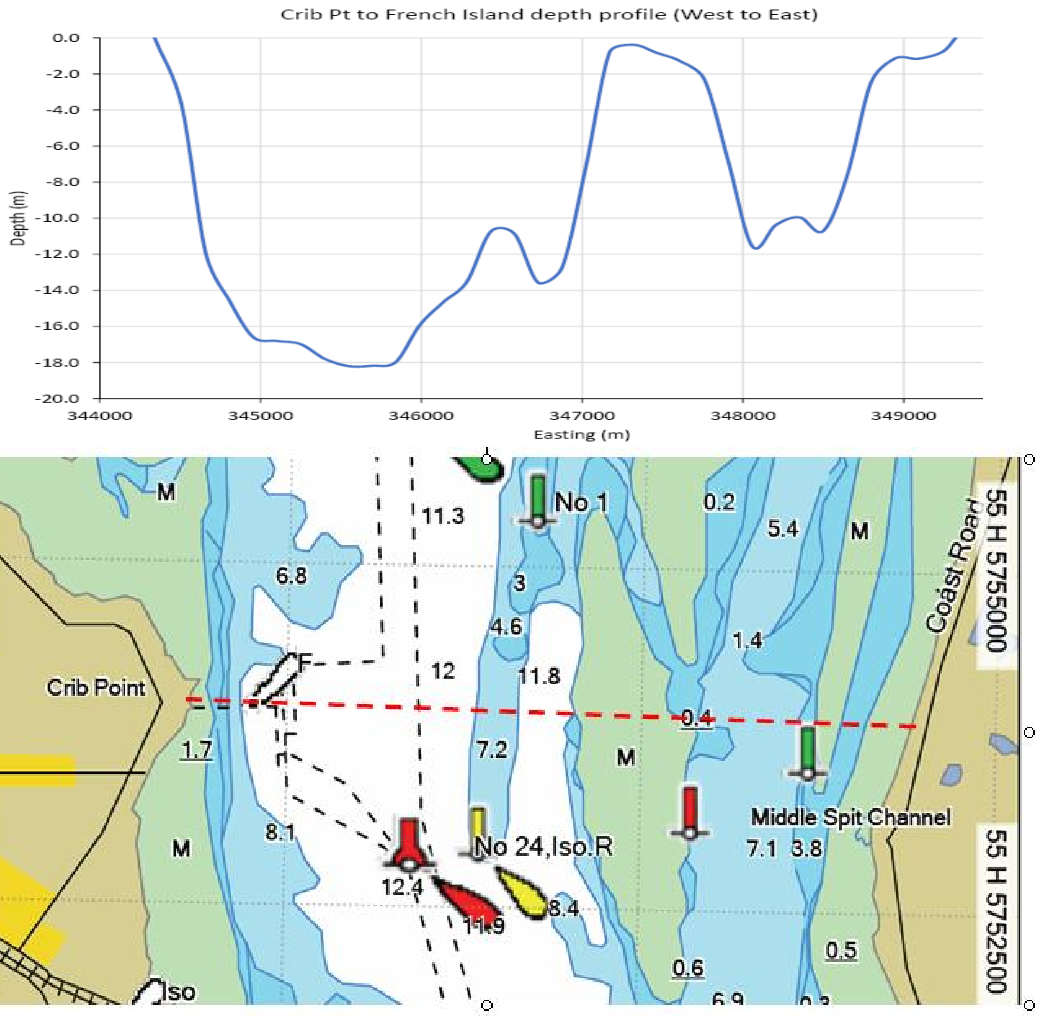

Figure 2. Cross Section through West Channel of WPB

By integration of depths across the section, it was calculated that the cross-sectional area of the western channel at MSL is 47,300 m^2. From the vessel dimensions in Table A1 the submerged cross-sectional area of the two vessels is 1,000 m^2. Thus the two vessels represent an approximate 2.1 per cent reduction in the cross-sectional area of the channel. This reduction in cross-section has occurred in the past - Crib Point has been used as a port for many years and double-berthing occurs at this jetty.

5. Calculate Backwater Head Loss Using Bridge Pier Formula

There are several methods that can be used to calculate the head loss due to the constriction caused by the vessels. One established method is to assume the vessels are similar to a streamlined bridge pier, and use the results of studies of head loss at bridges as a basis for calculation.

The head loss formula is based on an extensive series of measurements as described by Charbeneau and Holley (2001). Their experiments considered a reduction of channel area from 2.5 per cent (close to the Crib Point situation) to 15 per cent, and for flow Froude Numbers of 0.1 to 0.9 (somewhat higher than the condition at Crib Point because of the large depth of flow at the berth).

They compared six methods to calculate the head loss and found all give similar results. Their preferred formula is:

$$\left(\frac{\Delta y}{y}\right)_{\text{calculated}} = \beta K \left(K + \mu 5 \, Fr^2 - 0.6\right)\left(\alpha + 15\alpha^4\right) Fr^2$$

where Δy is the reduction in depth, y is the head (or water level) upstream of the vessel, β and µ are constants derived from the experiments, K is effectively a drag coefficient (and equal to 0.9 for a ship-shaped bridge pier), α is the proportional reduction in cross section and equals 0.979 in this case and F is the Froude Number of the flow (calculated from the tidal velocity V and the water depth y).

The tidal velocities at the Crib Point berth are taken from measurements summarised by RJH-DNV (2015) in a report to the Port of Hastings and are summarised in Table 2. Flood current speeds range from 0.05 to 0.55 m/s.

Table 2. Tidal Velocities at Crib Point (from RH-DNV)

MetOcean Parameter	Crib Point (CP1, CP2, CP3)
Currents	
Flood Tide direction (TN)	355, 355, 355
Ebb Tide direction (TN)	178, 178, 175
Current Speed Statistics / Exceedances (m/s)	s include non-tidal effect (e.g. storm surge
Max flood tide (exceeded 15 minutes in 1 year)	0.58, 0.59, 0.57
99%ile flood tide (exceeded 87 hours in 1 year)	0.55, 0.54, 0.49
90%ile flood tide (exceeded 876 hours in 1 year))	0.49, 0.49, 0.45
50%ile flood tide (exceeded half the time)	0.35, 0.35, 0.33
Spring Tidal Stream (flood tide)[2]	0.56, 0.56, 0.51
Neap Tidal Stream (flood tide)[3]	0.39, 0.39, 0.38
Max ebb tide (exceeded 15 minutes in 1 year)	0.76, 0.77, 0.55
99%ile ebb tide (exceeded 87 hours in 1 year)	0.71, 0.72, 0.49
90%ile ebb tide (exceeded 876 hours in 1 year))	0.63, 0.63, 0.44
50%ile ebb tide (exceeded half the time)	0.39, 0.39, 0.30
Spring Tidal Stream (ebb tide)[2]	0.60, 0.60, 0.42
Neap Tidal Stream (ebb tide)[3]	0.43, 0.43, 0.29

Charbeneau and Holley present the results for head loss in terms of non-dimensional flow and depth parameters. The head loss increases as a function of Froude Number (or current speed). For the convenience of the reader, the results have been converted to a dimensional plot showing the reduction in depth (Δy in mm) as a function of the tidal velocity (V in m/s).

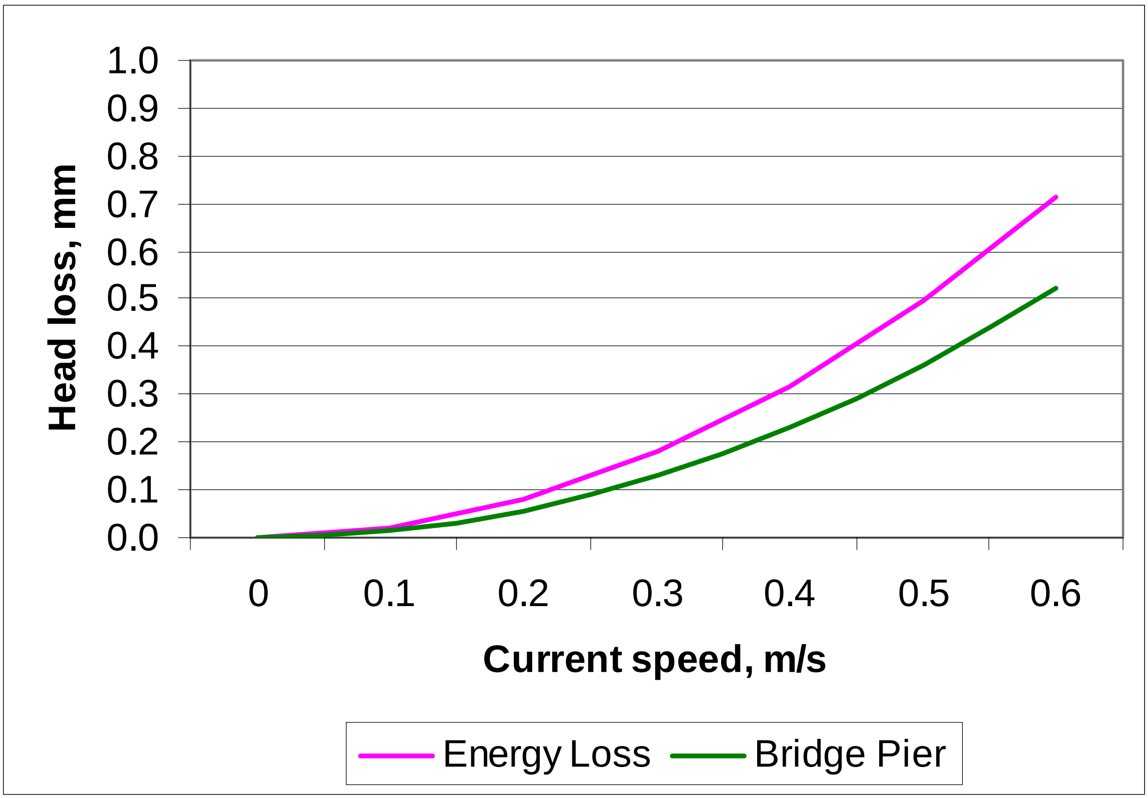

Figure 3. Head Loss at Crib Point in West Channel of WPB

The green curve in Figure 3 shows the reduction in water level as a function of the flood tide speed, based on the bridge pier results. It can be seen that even at the peak current speed of 0.55 m/s, the change in upstream water level is less than 0.5 mm. Integrating over the full flood tidal cycle, the reduction in upstream water level would be smaller, as explained below.

6. Head Loss Using Energy Balance Formula

As a check, the head loss has been calculated by a different method, which determined the energy lost from the flow due to the form drag of the two vessels (Pun and Law, 2015). Essentially this method is equivalent to adding the constriction and expansion losses, and can be expressed as:

$$\Delta y = C_d \left(V_a^2 - V_b^2\right) / 2g$$

where Δy is the reduction in depth, Cd is the overall drag coefficient, V_a is the upstream velocity, V_b is the velocity at the constriction and g is gravity.

The pink curve in Figure 3 shows the reduction in water level as a function of the flood tide speed, based on the energy balance approach. It can be seen that even at the peak current speed of 0.55 m/s, the change in upstream water level is about 0.7 mm. Integrating over the full flood tidal cycle, the reduction in upstream water level would be smaller, as explained below.

7. Reduction in Water Level over Tide Cycle

The seawater entering the upper part of Western Port through the flood tide cycle travels at a range of speeds through the tide cycle, as indicated in Table A2. Thus the overall (or tidally-averaged) reduction in water level obtained by integrating flow and head loss over the cycle. This process results in the estimated loss of upstream water level, as follows:

- For bridge per formula, water level is 0.24 mm
- For energy balance formula, energy loss is 0.33 mm.
- On average, the reduction in water level is 0.3 mm.

8. Assessment of Results

The reduction in water level of 0.3 mm is very small in relation to the typical neap tidal range of 1.5 m or the spring tide range of 2.4 m. It also is small in relation to the monthly variation in sea level in Western Port which is determined from tide records at Stony Point to be +/- 150 mm/month.

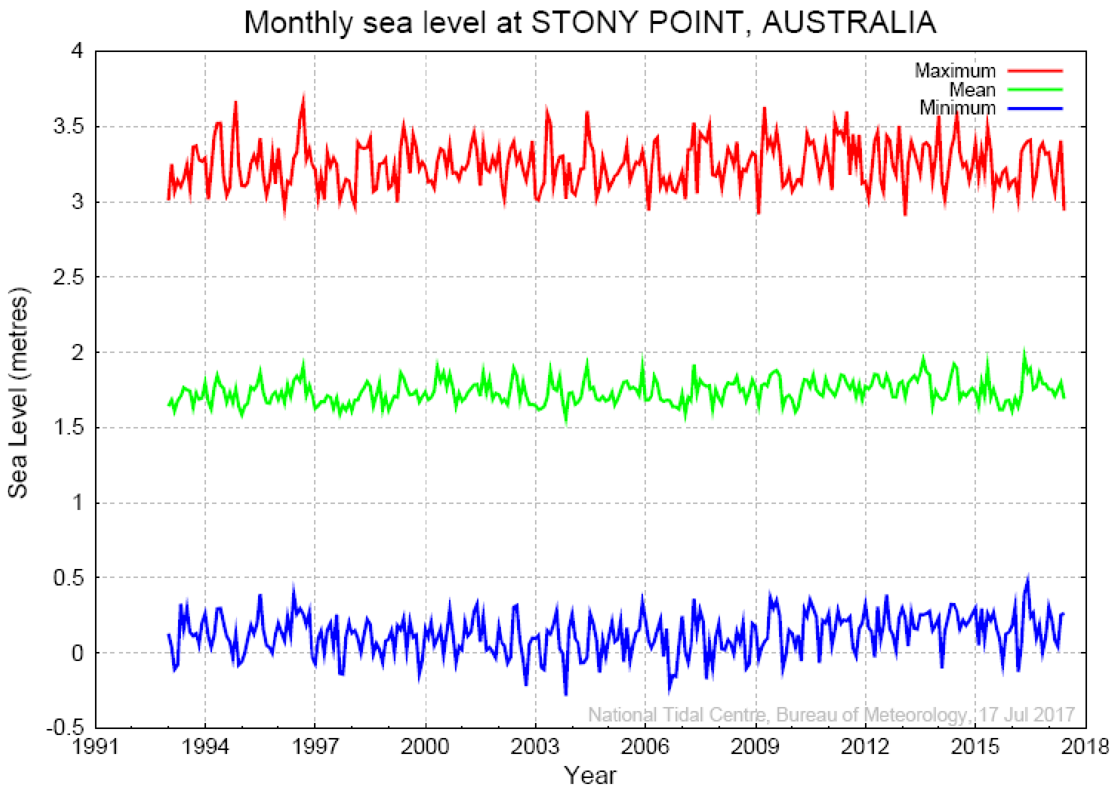

Figure 4. Monthly Sea Level Variation at Stony Point WPB

The rise in sea level with time is not visually obvious in the tide measurements shown in Figure 4 but according to the United Nations Intergovernmental Panel on Climate Change (IPCC), the ocean in south-eastern Australia is rising at a rate of 1.8 mm/yr (see extract below from National Tide Centre (2015).

> The IPCC AR4, 2007 estimates that global average eustatic sea level rise over the last century was 1.7 ± 0.5 mm/yr. From 1961 to 2003, the average rate of sea level rise is estimated as 1.8 ± 0.5 mm/yr. IPCC AR4, 2007 also recognises that sea level records contain a considerable amount of inter-annual and decadal variability.

If, as reported by the IPCC, sea level is rising at 1.8 mm/yr, then the 0.3 mm reduction in water level that can be attributed to two vessels in port will be overcome in 9 weeks.

If the current CSIRO (2016) forecast of a 110 mm rise in sea level by the year 2030 is considered, then the 0.3 mm reduction in water level that can be attributed to two vessels in port will be overcome in 3 weeks.

9. Local Erosion

There is expected to be local erosion of the seabed near the vessels due to the presence of the vessels causing a local acceleration of the water velocity. Other factors expected to cause erosion in the vicinity of the vessels are propeller wash (when the LNG carrier is underway) and propeller wash from tugs manoeuvring the LNG carrier. This erosion is a normal part of port operations, and expected to cause disturbance to the seabed within the port turning basin and within 150 m of the berth.

Another factor likely to cause local scour is the impact of the discharge from the FSRU reaching the seabed, as explored in Section 14 of the associated report on plume modelling (CEE, 2018). The water discharge will descend to the seabed with sufficient momentum to form a local depression in the seabed within the shipping berth. Plume calculations for the six-port discharge arrangement show that the discharge will have a downward velocity of approximately 0.22 m/s when it reaches the seabed. This will have negligible effect outside the shipping basin and will not impact on Ramsar values of Western Port.

10. Conclusion

Overall, it is considered that there would be a very small reduction in water level in the upper part of Western Port due to the constriction in flow caused by any two ships berthed abreast at Crib Point. Based on two methods of calculation, the reduction in water level is estimated to be 0.3 mm.

This reduction is considered to be insignificant in relation to tidal and monthly variations in sea level in Western Port. In any event, rising sea level will counterbalance this reduction in 3 to 9 weeks.

Local erosion effects are expected due to the presence and operation of the FSRU and LNG carriers. The extent of disturbance will be to the seabed within the port turning basin and within 150 m of the berth. This is considered to be a normal part of port operations. The water discharge from the FSRU will also cause a local depression in the seabed within the shipping berth. This will have negligible effect outside the shipping basin and will not impact on Ramsar values of Western Port.

11. References

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