Appendix C

Port navigation

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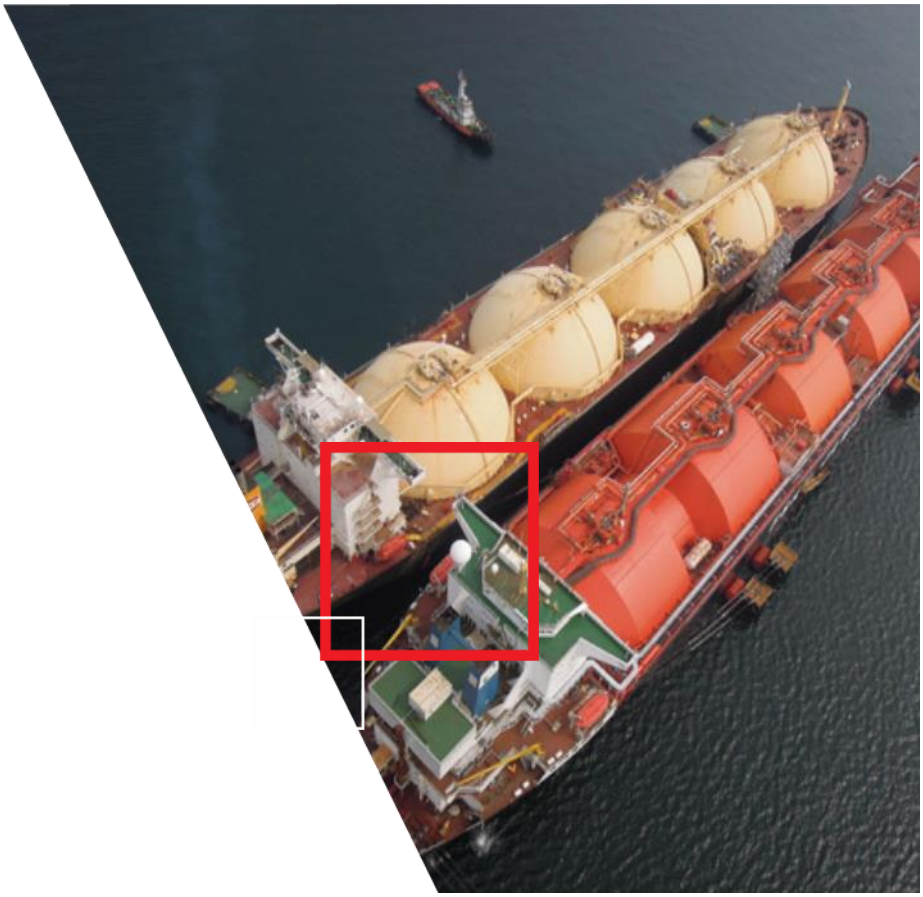
AIE

AUSTRALIAN INDUSTRIAL ENERGY

Navigation Simulation

Summary of Outcomes



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Synopsis

[This report documents the outcomes of the navigation simulation conducted at the Australian Maritime College Centre for Maritime Simulations.]

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PROJECT 401010-01496-MA-TEN-0011 Rev 1 – Navigation Simulation

Rev	Description	Original	Review	WorleyParsons Approval	Date	Customer Approval	Date
0	Issued	G. Tooker	T. Jones	F. Losty	28 Aug '18		
1	Additional details added	G. Tooker	T. Jones	F. Losty	6 Sept '18		

Contents

Appendices

1. Introduction

Australian Industrial Energy (AIE) is planning to develop a liquefied natural gas (LNG) terminal at Port Kembla, NSW to import up to 100 PJ per annum of gas to supply industrial and wholesale customers.

The Port Kembla Gas Terminal (PKGT) concept involves the installation of a Floating Storage and Regasification Unit (FSRU) at a suitable berth within the port of Port Kembla on the NSW east coast. LNG carriers (LNGC) will transport the LNG from worldwide suppliers to Port Kembla, where it will be transferred to the FSRU for regasification and injection into the existing NSW gas pipeline network, via a new gas pipeline. The new PKGT berth will be constructed in the Inner Harbour and replace the existing Berth 101 at the Port Kembla Coal Terminal.

Due to the channels leading to both the Outer and Inner Harbours of Port Kembla being quite narrow, combined with a small turning basin, vessel navigation simulations were undertaken to validate the design of the LNG terminal. The aims of the simulations were to determine if safe passage of an LNG vessel was possible and combined with the interaction of the proposed berth layout on other shipping movements in the Inner Harbour. The Vessel navigation simulations were held at the AMC Centre for Maritime Simulations, Launceston, during the week of the 13th of August 2018.

Two LNG vessel classes were tested along with a range of other vessels that transit Port Kembla's Inner Harbour, for a range of scenarios.

Below is a list of people that attended the simulations:

- WorleyParsons / Advisian
  - Patrick McCallum
  - Laurent Le Berre
  - Gabriel Tooker
- Hoegh
  - Capt. Bjorn Berg
- Australian Industrial Energy
  - Hiroko Kobayashi
- Port Authority of NSW
  - Kell Dillon
  - Capt. Rob Tanner
  - Capt. Tapan Mukerjee
- NSW Ports
  - Peter Engelen
  - Sam Isaacs

- Svitzer Tugs
  - Dale Irwin
  - Dave McInnes
  - Adrianna Iacono

2. Methodology

Due to the limited time in the vessel simulator, multiple aims were tested in combination with different scenarios. The main aims of the simulations were to determine:

- Safe LNG vessel navigation and operation through the port
- Limiting weather conditions for LNGC navigation
- Number of required tugs and existing tug capabilities
- LNGC offset from the turning basin
- Berth pocket length and position
- Impact to existing shipping

The different scenarios tested were LNG vessel arrivals and departures to determine the limiting weather conditions and berth pocket length; and other vessel movements throughout the Inner Harbour to determine the berth layout and offset to the turning basin.

The range of vessels simulated are listed below; see the vessel data sheets in *Port Kembla LNG Simulations* report [Ref 1].

- 177k m^3 Moss LNG vessel
- 165k m^3 Membrane LNG vessel
- 187k t Capesize Bulk Carrier
- 31k t Handymax Bulk Carrier
- 265 m Tonsberg Ro-Ro[1] Vessel
- Svitzer Maitland Tug

The Membrane LNG vessel was used to simulate the FSRU and LNGC, however as the Moss LNG vessel had a larger length overall (LOA) and beam it was used as the base case for arrival and departures, and ship to ship (STS) mooring configurations.

The other bulk and vehicular vessels were used to simulate arrival and departure in worst case weather conditions from a variety of berths in the Inner Harbour. Emergency simulation runs were also conducted for the other shipping. Appendix A and *Port Kembla LNG Simulations* report [Ref 1] outline the runs for the simulations. The runs were stopped when the pilots were confident that the vessel was under control.

[1] Roll On Roll Off

3. Results and Analysis

Prior to the simulations commencing, failure criteria were set which would be discussed after each run. Listed below are the key failure criteria:

- Grounding of vessels
- Collision of vessels into structures or other vessels
- Leaving the designated channel
- Unable to turn the vessel inside the Inner and/or Outer Harbour turning basins
- Full tug power, rudder angle, and engine power (or combination of any) to manoeuvre during design conditions
- Berthing at a higher angle than 6 degrees and/or more than 0.11 m/s

3.1 Tugs

The first set of simulations determined that the LNGC could be brought into the port with minimal tug assistance. However, a fourth tug of at least 75 t bollard pull is required to act as an escort tug and as a contingency. This is common practice in many port when manoeuvring LNGCs.

3.2 Navigation Marker

Due to the bow of the LNGC blocking the view of the aid to navigation (AToN) in its current position at the western end of The Cut, as shown in Figure 1, it was relocated several times to improve visibility. However, the position of the navigational lead light was not finalised and a location fore of the bow of the FSRU was accepted pending further analysis and consultation.

Figure 1: (Left) Arrival through The Cut showing the bow of the LNGC protruding limiting the view of the Inner Harbour. (Right) Departure from Berth 102 showing reduced visibility of The Cut due to the bow of the LNGC

3.3 Wind Conditions

The existing port wind limitation of 20-25 knots for the car carriers is not suitable for the LNG vessels, and a lower value will be required. This was shown during departures of the LNGC with south westerly conditions pushing the vessel towards the navigation marker. The worst case occurred with the LNGC starboard-side-to the berth (i.e. bow to the north) when several runs were deemed failures. Figure 2 depicts this case with the wind pushing the turning LNGC into the navigational marker at the western entrance to The Cut.

Another condition set will be the use of two pilots for pilotage for LNGC arrival and departure.

Figure 2: LNGC departing Starboard-side-to in a 25 knot SW wind which was deemed a failure due to clearance to the navigational marker highlighted in red.

The Tonsberg Ro-Ro vessel with westerly wind condition provided the worst case for the other vessel simulations due to this vessel's high windage. Initial simulations reflecting current practices indicated the Ro-Ro vessel was turning too early which led to the turning vessel being boxed in and hard to manoeuvre. Turning circles were added to the simulation charts to give the pilots a reference to keep within, which improved the performance as shown in Figure 3.

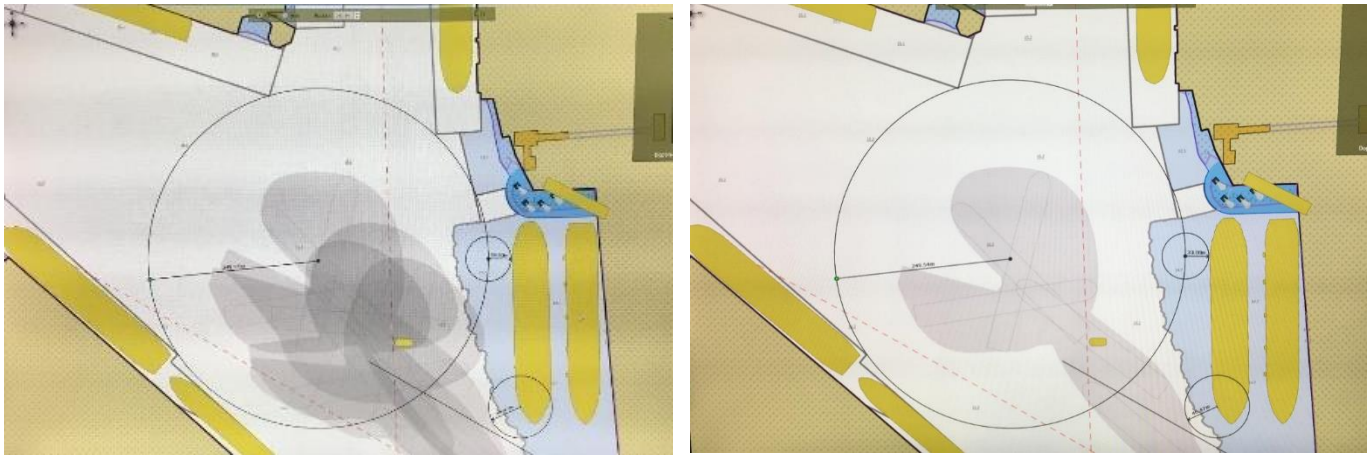

Figure 3: (Left) Tonsberg vessel track outlines prior to the circle being added to the chart, where it can be seen that it was being turned early. (Right) Tonsberg vessel track outline after the circle was added to the chart.

3.4 Offset of LNGC

Various offsets of the LNGC from the Inner Harbour turning basin were investigated throughout the simulation runs. These offsets ranged from 0 to 50 m. The 0 m offset condition was found to be restricting on the other vessel movements in the port, compared to the 50 m offset.

A 40 m offset was discussed as the minimal safe distance from the 500 m diameter turning basin. The new berth was also moved some 27 m north and aligned with Berth 102 to improve visibility through The Cut. The overall length of the new berth is reduced as a result. This design was successfully used for simulations during the last two days.

3.5 Berth Pocket

A simulated run of berthing the FSRU was conducted with reduced berth pocket length. This was deemed successful, although other requirements such as water flow around the FSRU for regasification processes and clearance aft of the FSRU for lifeboat deployment will need to be considered.

3.6 Impacts to Navigation

Both the 0 m and 50 m offsets from the Inner harbour turning basin reduced the visibility of the AToN whilst entering and exiting the Inner Harbour. The bows of the LNGC and FSRU also extended the effective length of The Cut as the entering vessels could not turn until further into the Inner Harbour. The LNGC and FSRU have been moved further north to improve visibility and clearance to The Cut.

The 0 m offset from the turning basin, which approximates the existing clearance for vessels at Berth 101, had a greater impact on navigation clearance as well as visibility for vessels departing berths in the Eastern Basin, compared to the 50 m offset.

The final layout of the new berth has a 40 m offset from the turning circle and is aligned to be parallel with Berth 102. This layout provides additional clearance from the turning basin whilst improving visibility of the AToN and for transiting vessels through the port. However, the height of the LNGC and FSRU do impact the current outlook from vessels transiting the port, but this does not impact navigation throughout the port.

3.7 Summary

The main outcomes from the simulations are listed below:

- LNG vessels can enter and depart the port and berth within the current limitations, however the wind conditions may need to be reduced for contingency until the pilots are familiarised with the LNGC manoeuvring
- A fourth ocean-going tug is required as an escort for LNGC operations
- Two pilots are required for arrival and departure of the LNGC until the pilots are familiarised with the LNGC manoeuvring
- The berth pocket has been moved north and rotated to align parallel with Berth 102
- The stern of the 52 m beam LNGC moved to a 40 m offset from the turning basin
- The berth pocket length may be reduced
- Navigational lead light repositioned for better visibility, with the final position to be confirmed

4. Impacts to Existing Operations

The 40 m offset layout presents minimal impact to existing navigational operations within the port. This is due to the berth being outside the bounds of the existing channels and turning basin. This was tested in the simulators with emergency and extreme weather scenarios where all runs were deemed successful. It is also noted that the LNGC only visits the port every two weeks and is alongside the FSRU for about 24 hours.

As mentioned previously, one AToN at the south of the berth will be impacted by the facility and it will need to be relocated and/or raised to a new height to increase the visibility. This is to be confirmed with further consultation with the Port Authority of NSW.

There will need to be a change to the operating practices when turning vessels in the Inner Harbour to maintain clearances. Currently vessels commence turning once they cross the Eastern Basin leads (eastern side of the turning basin). When an LNGC is alongside, vessel turning will have to occur further towards the north-west quadrant of the turning basin to allow for vessel leeway under westerly wind conditions. This was successfully tested in the simulators by the addition of a turning circle onto the pilots' charts.

The proposed layout still presents a visual impact due to the height and location, especially at night as the vessels are brightly illuminated which could not be properly simulated as shown in Figure 4. As a result, there may be difficulty identifying AToN lights, although experienced pilots would recognise the specific navigation lights. During daylight hours this is less of an issue with AToN visible from vessels entering and exiting the port (see Figure 1 in Section 3.2).

In conclusion, the navigation simulation study found that the new PKGT facility will have little impact on the existing port operations and that the visual impact of the FSRU and LNGC vessels will not limit the ability to safely navigate the port.

Figure 4: Twilight entry of a Ro-Ro vessel into the Inner Harbour

5. Conclusions and Recommendations

For the arrival and departure of the LNG vessel, the simulations demonstrated:

- Safe LNG vessel navigation and operation through the port
- A lower wind speed than the current port limits should be set to a reasonable level to reduce the likelihood of potential demurrage events until the pilots are familiarised with the LNGC manoeuvring
- A fourth ocean-going tug
- Two pilots required for LNGC movements until the pilots are familiarised with the LNGC manoeuvring

The navigation simulations resulted in a final layout incorporating a 40 m offset to the turning basin and repositioning to improve visibility through The Cut. This layout will require further assessment and refinement including consideration of:

- Mooring loads imposed by passing vessels and Infragravity (IG) waves.
- The berth pocket length to ensure suitable fore and aft clearance for both the FSRU and LNGC to allow safe manoeuvring during (un)berthing operations.
- Water flow for the regasification process aboard the FSRU to ensure sufficient water flow around the vessel.
- The location of a secondary egress point from the vessels in case of an emergency, with the ability to deploy the lifeboat.
- The placement of the navigational lead light.

Based on the results of the navigation simulation study, it is recommended that:

a. Lower wind conditions and two pilots until the pilots are familiarised with the LNGC manoeuvring, and provision of a fourth tug

b. The final layout incorporated a 40 m offset to the turning basin and repositioning to improve visibility through The Cut be approved

c. Assessment of mooring loads, berth pocket length, water flows, access requirements and navigation aid location be undertaken

6. References

[1] AMC Search Ltd. (2018). *Port Kembla LNG Simulations - Project No. 18/S/20*. Launceston: AMC Search.

Appendix A. Run Summary

Section 4

Run Summary

AUSTRALIAN MARITIME COLLEGE

AMC Simulation Schedule for

Advisian

Summary of Runs: Day 1, 13 August 2018

Run	Pilot	Wind	Tide	Current
1	**Rob Tanner**	13kts from 139°	0.00m (HW)	none
	Pacific Triangle Inbound from Sea. Wind: SE x 10kts. Swell: Nil. Current: Nil Familiarisation Run			
2	**Tapan Mukherjee**	13kts from 141°	0.00m (HW)	none
	Tonsberg Inbound from Outer Harbour. Wind: SE x 10kts. Swell: Nil. Current: Nil Familiarisation Run			
3	**Rob Tanner**	10kts from 135°	0.00m (HW)	none
	177k LNG Inbound from Sea. Wind: SE x 10kts. Swell: Nil. Current: Nil 50m Offset Familiarisation Run			
4	**Tapan Mukherjee**	10kts from 135°	0.00m (HW)	none
	177k LNG Depart for Sea. Wind: SE x 10kts. Swell: Nil. Current: Nil 50m Offset Familiarisation Run			
5	**Rob Tanner**	25kts from 44°	0.00m (HW)	none
	177k LNG Inbound from Sea. Wind: NE x 20-25kts. Swell: E x 1.5m at 12s. Current: Nil 50m Offset			
6	**Tapan Mukherjee**	25kts from 55°	0.00m (HW)	none
	177k LNG Inbound from Outer Harbour. Wind: NE x 20-25kts. Swell: E x 1.5m at 12s. Current: Nil 50m Offset			
7	**Rob Tanner**	25kts from 52°	0.00m (HW)	none
	177k LNG Depart for Sea. Wind: NE x 20-25kts. Swell: E x 1.5m at 12s. Current: Nil 50m Offset			
8	**Tapan Mukherjee**	40kts from 55°	0.00m (HW)	none
	177k LNG Inbound from Sea. Wind: NE x 35-40kts. Swell: NE x 2.0m at 12s. Current: Nil 50m Offset			

AMC Simulation Schedule for

Advisian

Summary of Runs: Day 2, 14 August 2018

Run	Pilot	Wind	Tide	Current
9	**Tapan Mukherjee**	18kts from 269°	0.00m (HW)	none
	177k LNG Inbound from Sea. Wind: W x 15kts. Swell: SE x 1.0m at 8s. Current: Nil 50m Offset			
10	**Rob Tanner**	28kts from 276°	0.00m (HW)	none
	177k LNG Inbound from Sea. Wind: W x 25kts. Swell: SE x 1.0m at 8s. Current: Nil 50m Offset			
11	**Rob Tanner**	45kts from 262°	0.00m (HW)	none
	177k LNG Inbound from Sea. Wind: W x 35kts - With Gusts. Swell: SE x 1.0m at 8s. Current: Nil 50m Offset			
12	**Tapan Mukherjee**	28kts from 276°	0.00m (HW)	none
	Pacific Triangle Inbound from Outer Harbour to Berth PST 102. Wind: W x 25kts. Current: Nil 50m Offset			
13	**Rob Tanner**	28kts from 277°	0.00m (HW)	none
	Pacific Triangle Inbound from Outer Harbour to Berth PST 102. Wind: W x 25kts. Swell: SE x 1.0m at 8s. Current: Nil 0m Offset			
14	**Tapan Mukherjee**	28kts from 280°	1.50m	none
	Pacific Triangle Depart from PST 102 for Sea. Wind: W x 25kts. Swell: SE x 1.0m at 8s. Current: Nil Tide: HW 0m Offset			
15	**Rob Tanner**	28kts from 280°	0.00m	none
	Tonsberg Inbound from Outer Harbour to Berth PST 107. Wind: W x 25kts. Current: Nil 0m Offset			
16	**Tapan Mukherjee**	41kts from 263°	0.00m	none
	Tonsberg Inbound from Outer Harbour to Berth PST 107. Wind: W x 25kts - With Gusts. Current: Nil 0m Offset. Night.			
17	**Rob Tanner**	41kts from 271°	0.00m	none
	Pacific Triangle Inbound from Outer Harbour to Berth PST 102. Wind: W x 25kts - With Gusts. Current: Nil 0m Offset. Night.			
18	**Tapan Mukherjee**	43kts from 268°	0.00m	none
	Tonsberg Inbound from Outer Harbour to Berth PST 107. Wind: W x 25kts - With Gusts. Current: Nil 50m Offset. Night.			
19	**Rob Tanner**	28kts from 268°	1.50m	none
	Pacific Triangle Depart PST Berth 102 for Sea. Wind: W x 25kts - With Gusts. Current: Nil 50m Offset. Night.			

AMC Simulation Schedule for

Advisian

Summary of Runs: Day 3, 15 August 2018

Run	Pilot	Wind	Tide	Current
20	**Rob Tanner**	28kts from 274°	0.00m (HW)	none
	Pacific Triangle Depart PST Berth 111 for Sea. Wind: W x 25kts - With Gusts. Current: Nil Option C.			
21	**Tapan Mukherjee**	28kts from 261°	0.00m (HW)	none
	Pacific Triangle (Ballast) Depart PST Berth 102 for Sea. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset			
22	**Rob Tanner**	28kts from 266°	0.00m (HW)	none
	Pacific Triangle (Ballast) Depart PST Berth 102 for Sea. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved 70m WNW to Improve Visibility			
23	**Tapan Mukherjee**	28kts from 276°	0.00m (HW)	none
	Tonsberg Inbound from Outer Harbour to Berth PST 107. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
24	**Tapan Mukherjee**	28kts from 262°	0.00m (HW)	none
	Pacific Triangle Inbound from Outer Harbour to Berth PST 102. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
25	**Rob Tanner**	28kts from 280°	0.00m (HW)	none
	177k Moss Inbound from Outer Harbour. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
26	**Tapan Mukherjee**	28kts from 280°	0.00m (HW)	none
	165k Membrane Inbound from Outer Harbour. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
27	**Rob Tanner**	28kts from 264°	0.00m (HW)	none
	Tonsberg Depart SST 105/6 for Sea. Wind: W x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
28	**Tapan Mukherjee**	28kts from 220°	0.00m (HW)	none
	177k Moss Inbound from Outer Harbour to Berth SST. Wind: SW x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
29	**Rob Tanner**	28kts from 219°	0.00m (HW)	none
	177k Moss Depart SST for Sea. Wind: SW x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
30	**Tapan Mukherjee**	28kts from 217°	0.00m (HW)	none
	177k Moss Depart SST for Sea. Wind: SW x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			
31	**Rob Tanner**	28kts from 219°	0.00m (HW)	none
	177k Moss Depart SST for Sea. Wind: SW x 25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved Slightly to North of Line of Cut. Clearance 30m to Bow of Import Vessel			

AMC Simulation Schedule for

Advisian

Summary of Runs: Day 4, 16 August 2018

Run	Pilot	Wind	Tide	Current
32	**Rob Tanner**	23kts from 229°	0.00m (HW)	none
	177k Moss Depart PST for Sea. Wind: SW x 20kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU			
33	**Tapan Mukherjee**	23kts from 231°	0.00m (HW)	none
	177k Moss Depart PST for Sea. Wind: SW x 20kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU			
34	**Rob Tanner**	25kts from 217°	0.00m (HW)	none
	Tonsberg Inbound From Outer Harbour to Berth PST 107. Wind: SW x 20-25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU Contingency Response Exercise			
35	**Tapan Mukherjee**	25kts from 235°	0.00m (HW)	none
	Imme Oldendorff Depart SST 103 for Sea. Wind: SW x 20-25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU			
36	**Rob Tanner**	40kts from 241°	0.00m (HW)	none
	Tonsberg Inbound From Outer Harbour to Berth PST 107. Wind: WSW x 20-25kts - With Gusts. Current: Nil Option E - Azimuth 178(T) 20m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU Contingency Response Exercise			
37	**Tapan Mukherjee**	25kts from 254°	1.50m	none
	Pacific Triangle Depart PST 102 for Sea. Wind: WSW x 20-25kts - With Gusts. Current: Nil Tide: HW Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU Contingency Response Exercise			
38	**Rob Tanner**	30kts from 257°	0.00m (HW)	none
	Pacific Triangle Depart PST 111 for Sea. Wind: WSW x 20-25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU Contingency Response Exercise			
39	**Tapan Mukherjee**	42kts from 252°	0.00m (HW)	none
	Imme Oldendorff Inbound from Outer Harbour to Berth SST 113. Wind: WSW x 20-25kts - With Gusts. Current: Nil Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU Contingency Response Exercise			
40	**Rob Tanner**	30kts from 242°	0.00m (HW)	none
	Hual Trooper Depart SST 105 for Sea. Wind: WSW x 20-25kts - With Gusts. Current: Nil. Night. Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU Contingency Response Exercise			
41	**Tapan Mukherjee**	13kts from 129°	0.00m (HW)	none
	FSRU Inbound from Sea to Berth PST. Wind: SE x 10kts. Current: Nil. Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU.			

AMC Simulation Schedule for

Advisian

41a	**Rob Tanner**	13kts from 129°	0.00m (HW)	none
	FSRU Inbound from Sea to Berth PST. Wind: SE x 10kts. Current: Nil. Option D - Azimuth 178(T) 40m Offset Green Beacon Moved in Line of Northern Face of Cut, Directly Ahead of FSRU. Continuation of Previous Exercise - Pushing Vessel Towards Berth			