Technical Note

To	:	Christian Taylor (PoHDA)
From	:	Rohan Hudson
Cc	:	Ben Gray
Date	:	1/04/2015 (Final Draft)
Subject	**:**	**Hydrodynamic input for 2D Vessel Simulations (HY- 0027)**

Introduction

This Technical Note presents the methodology and results of work undertaken to provide hydrodynamic input for the 2D vessel simulation. The 2D vessel simulation work will be undertaken in February 2015 by the Design and Engineering team (GHD-AECOM JV) (hereafter referred to as D&E team), supported by subconsultants Hydraulics Research Wallingford. Simulation of port layout scenarios and the required model output formats were based on consultation and agreement with the D&E team. The hydrodynamic simulations were undertaken using an existing DELFT3D model produced by Cardno for PoHDA as part of preliminary modelling. Simulations were carried out for a representative Spring Tide. A sensitivity check (using the hydrodynamic model) on the influence of non-tidal (i.e. storm surge) conditions is presented in an accompanying Technical Note, "Non Tidal Currents at Proposed Port Site" (see Appendix B).

The purpose of this Technical Note is to:

- Provide a background and definition of the hydrodynamic results that are to be used in 2D vessel simulation;
- Detail results of a sensitivity check on the influence of non-tidal (i.e. storm surge) conditions on current speeds in the channel and swing basin; and
- Provide an update to wave statistics along the existing navigation channel.

The port layouts to be included in the hydrodynamic simulations were provided by the D&E team and include:

- Existing channel and swing basins up to and including Long Island Point and Bluescope steel facilities (**Figure A1**).
- Stage 1 Development and a modified approach channel;
  - Swing Basin adjacent to the southern-most berths (**Figure A2**).
  - Swing Basin extending further north (**Figure A3**).
  - Extended Stage 1 with swing basin at southern berths (**Figure A4**).
- Full Development 'Along the Shore Option' and approach channel;
  - Swing basin along first facet only (**Figure A5**).
- Full Development 'Basin Option' and approach channel;
  - Swing Basin extending up to the entrance of the Basin with a short training wall (**Figure A6**).
  - Swing Basin extending up to the entrance of the Basin with a long training wall (**Figure A7**).

Investigations into the non-tidal components in observed data records are provided in **Appendix B**.

Hydrodynamic Simulation Methodology

Hydrodynamic input for the 2D vessel simulation has been generated by simulating the existing and port layout scenarios using the existing Cardno DELFT3D model.

The dual domain, DELFT-3D model produced by Cardno comprises a 20m fine grid in the Lower North Arm (the location of the proposed Port Development) and a 150m coarse grid for the remainder of Western Port and offshore area. The model bathymetry and extent is presented in **Figure 1**.

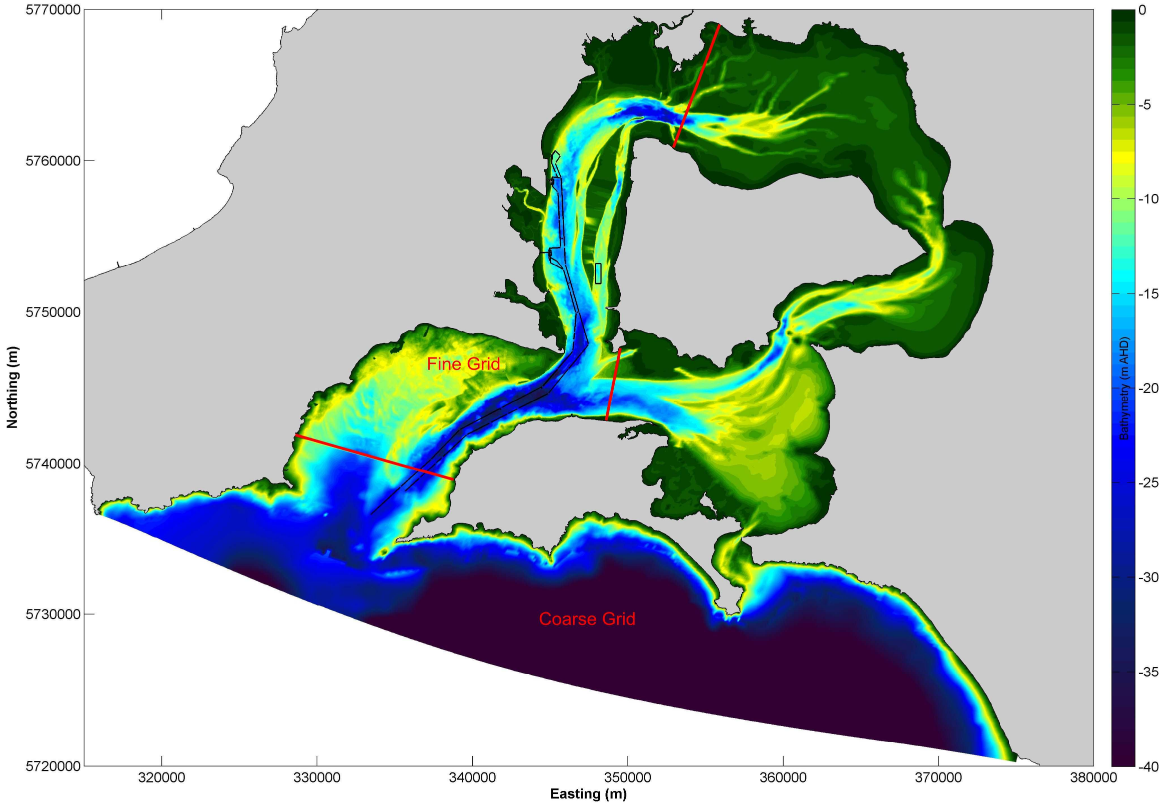

Figure 1: Model Bathymetry, Extent and grid domain (coarse, fine) extents

A review of the tidal boundary condition indicated that the adopted Cardno tidal lag across the offshore water level boundary produced unrealistic lateral currents to the south of Phillip Island. To reduce these from occurring, an updated set of tidal boundary conditions (as detailed in Haskoning Australia (2014)) were used which included:

- Western BC = Observed Stony Point WL x 0.9 applied 60 minutes earlier; and
- Eastern BC = Observed Stony Point WL x 0.9 applied 30 minutes earlier.

A suitable tide period that closely matched a Spring Tide (i.e. levels of 2.84 m CD (MHWS) and 0.61 m CD (MLWS) was selected from the existing period of model validation (16/12/2012 to 16/01/2013). The tide conditions over a Spring Tide period of time are presented in **Figure 2**. The closest 24 hour period of time to a Spring Tide was deemed to be the 19th December 2012. However, to ensure that the model was "warmed up" the full simulation period was 15th December 2012 to 20th December 2012, however only results from the 19th December 2012 were considered. Tidal levels were converted from m AHD to m CD by adding 1.6 m.

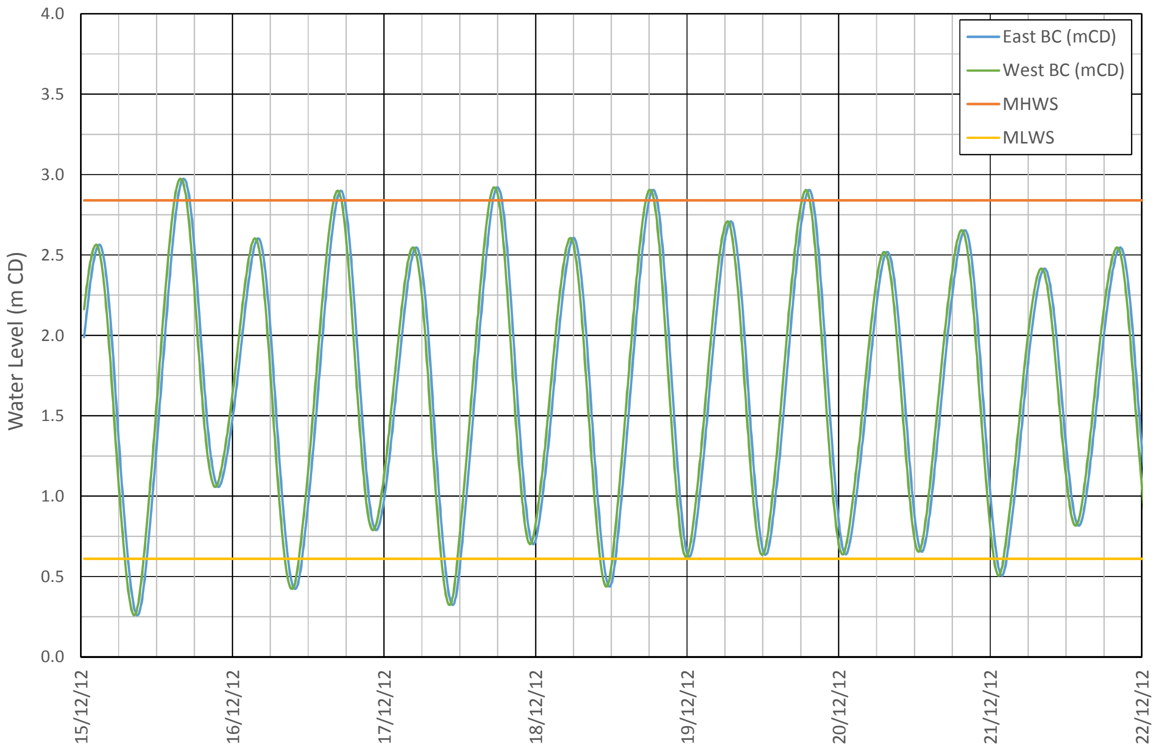

Figure 2 Water levels within the Spring Tide Period selected for simulations

Coarse and Fine grid bathymetry data for the existing situation was also converted from m AHD (used in the Cardno model) to m CD. Bathymetry data for the scenario options was provided by the D&E team in an ascii grid format and is defined in **Table 1**. This was imported to DELFT3D and used to update the model bathymetry. Where no new data was provided the existing model bathymetry was applied. For the "Basin_Long" option a "thin dam" was used in DELFT3D to represent the emergent training wall. Model schematisation of the seven scenarios are presented in **Figures A1 – A7**.

Table 1: *Bathymetry Data Provided by D&E Team*

Zip file Name	Layout Name
AlongShore	Along the Shore with swing basin along first facet
Basin_Long	Basin with swing basin along the first facet and long training wall
Basin_Short	Basin with swing basin along the first facet and short training wall
ExStage1	Extended Stage 1 with swing basin at southern berths
Stage1_BerthALL	Stage 1 with swing basin along all berths
Stage1_BerthSTH	Stage 1 with swing basin at southern berths
-	Existing

Hydrodynamic Output

As requested, digital model output files have been provided to the D&E team for each simulation. The DELFT3D model output files are at a 15 minute resolution for the 25 hour period (19/12/2012 0:00 to 21/12/2012 01:00) to ensure a full tidal period was included. For each simulation fine and coarse grid results have been provided. Results for each scenario have been zipped into a folder which contains four files, namely:

- trim-Coarse.dat – coarse grid model result data file;
- trim-Coarse.def – coarse grid model result definition file;
- trim-Fine.dat – fine grid model result data file; and
- trim-Fine.def – fine grid model result definition file.

Definition of each of the filenames for each of the port layout scenarios are presented in **Table 2**.

Table 2: *Hydrodynamic Model Output Provided to the D&E Team by Haskoning Australia*

Zip file Name	Layout Name
2DModel_AlongShore_02a.zip	Along the Shore with swing basin along first facet
2DModel_BasinLong_02c.zip	Basin with swing basin along the first facet and long training wall
2DModel_BasinShrt_02a.zip	Basin with swing basin along the first facet and short training wall
2DModel_ExtStage1_02a.zip	Extended Stage 1 with swing basin at southern berths
2DModel_BerthAll_02a.zip	Stage 1 with swing basin along all berths
2DModel_BerthSth_02a.zip	Stage 1 with swing basin at southern berths
2DModel_Existing_02a.zip	Existing

Wave Conditions

In addition to hydrodynamic outputs, the 2D vessel simulation study also requires information regarding wave conditions along the navigation channel (Western Entrance and Lower North Arm). The following provides a minor update (i.e. the inclusion of 1% exceedance statistics) to information previously presented by Haskoning Australia (2014), which should be referred to for background, methodology and limitations. The wave statistics (swell only) presented in **Table 3** provide the 1% and 10% exceedance significant wave height (H_s) and peak wave period (T_p) based on simulating a years' worth of "typical" (i.e. the year 2006) wave conditions at 33 model output points as shown in **Figure 3**. Please note that the modelling does not consider locally generated wind waves.

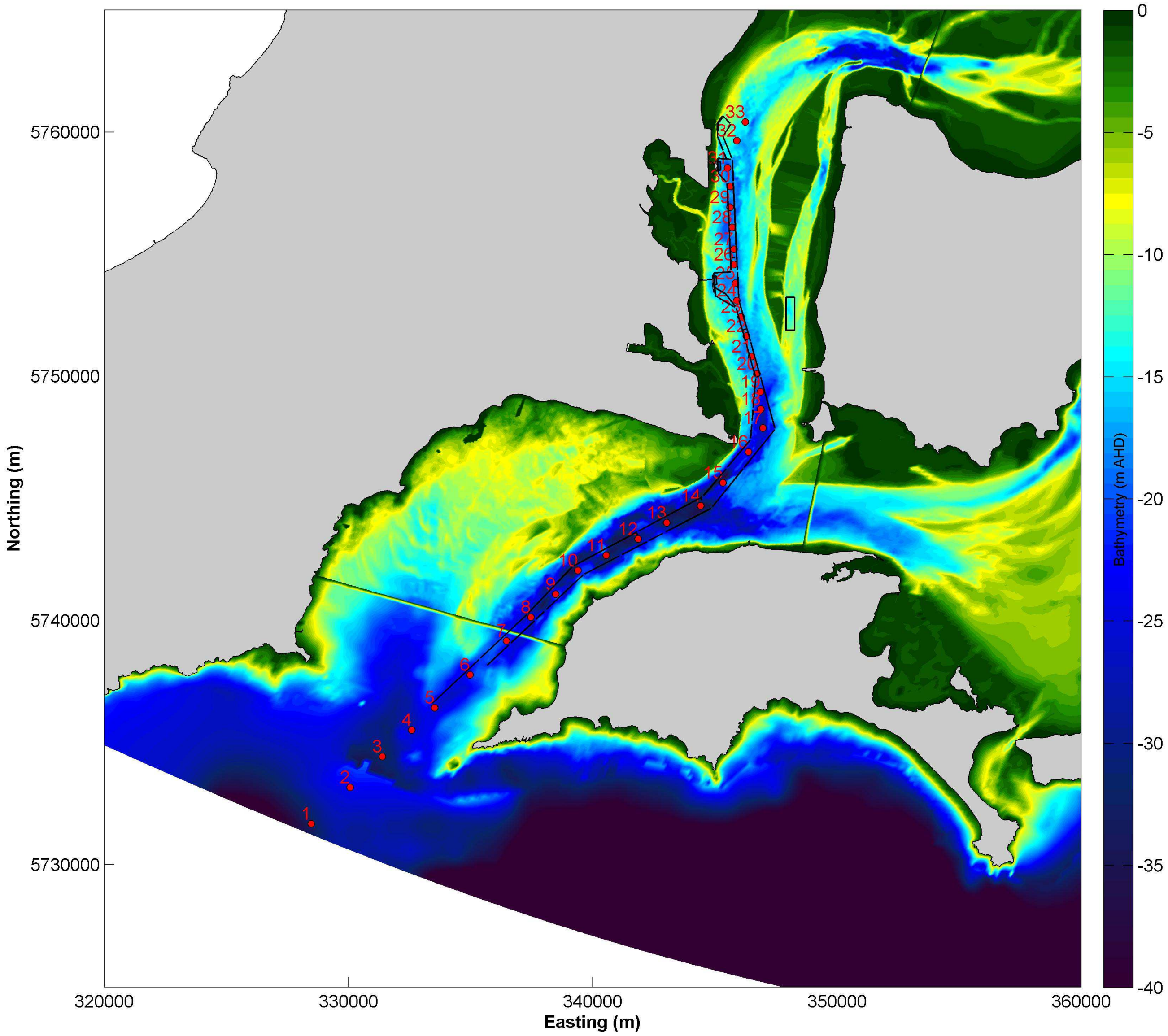

Figure 3: Location of Model Outputs and Model Bathymetry

Table 3: *Summary of Wave Statistics (Swell Only) at Model Output Points*

Output Point	Easting	Northing	Hs (m) 1% Exceedance	Tp (s) 1% Exceedance	Hs (m) 10% Exceedance	Tp (s) 10% Exceedance
MP01	328479	5731682	4.52	18.49	3.24	14.94
MP02	330069	5733176	4.69	18.56	3.37	15.00
MP03	331384	5734441	4.80	18.57	3.43	15.02
MP04	332587	5735527	4.96	18.76	3.48	15.24
MP05	333529	5736440	4.66	18.77	3.31	15.35
MP06	334974	5737781	3.29	18.73	2.33	15.36
MP07	336467	5739176	2.50	18.74	1.68	15.34
MP08	337467	5740135	2.61	18.75	1.59	15.31
MP09	338482	5741086	2.46	18.84	1.39	15.31
MP10	339390	5742047	2.00	18.80	1.13	15.16
MP11	340555	5742682	1.40	18.88	0.81	15.27
MP12	341849	5743349	1.21	18.89	0.71	15.27
MP13	343021	5744013	0.99	19.08	0.56	15.56
MP14	344416	5744707	0.76	18.96	0.44	15.30
MP15	345330	5745646	0.86	18.98	0.47	15.20
MP16	346378	5746911	0.46	18.71	0.27	14.64
MP17	346973	5747893	0.26	18.53	0.15	14.79
MP18	346872	5748659	0.20	18.76	0.12	14.95
MP19	346868	5749371	0.18	18.95	0.10	15.08
MP20	346724	5750110	0.17	18.79	0.09	14.93
MP21	346506	5750818	0.16	18.70	0.09	14.84
MP22	346291	5751653	0.17	18.65	0.09	14.73
MP23	346072	5752434	0.16	18.59	0.09	14.18
MP24	345889	5753096	0.16	18.48	0.09	6.48
MP25	345831	5753809	0.14	6.78	0.08	5.55
MP26	345784	5754578	0.14	16.60	0.08	5.62
MP27	345783	5755208	0.12	18.05	0.07	5.68
MP28	345713	5756096	0.12	16.52	0.07	5.47
MP29	345614	5756920	0.13	6.30	0.07	5.29
MP30	345635	5757774	0.13	5.74	0.07	5.15
MP31	345517	5758536	0.10	5.51	0.05	5.01
MP32	345900	5759644	0.09	17.05	0.05	4.79
MP33	346241	5760418	0.09	18.59	0.05	6.01

Summary & Discussion

This technical note presents a summary of the methodology and output used to provide the hydrodynamic input required to undertake 2D vessel simulations.

References

Haskoning Australia (2014*), Early Hydrodynamic Modelling for Port of Hastings Development Project,* prepared for Port of Hastings Development Authority, Final Draft for discussion purposes (Issue C), reference HAS-CEP0-HY-REP-0012-C, 19 December.

Appendix A: Model Bathymetry of Scenarios

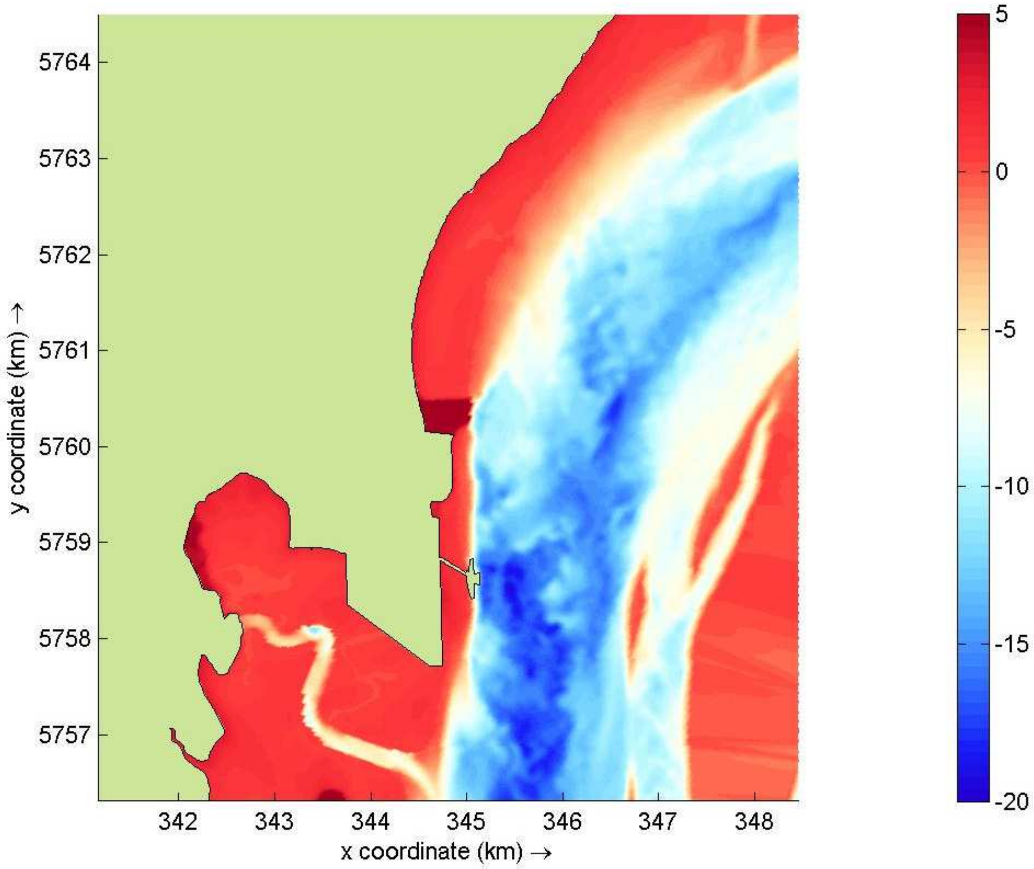

Figure A1: Bathymetry (m CD) Existing Scenario

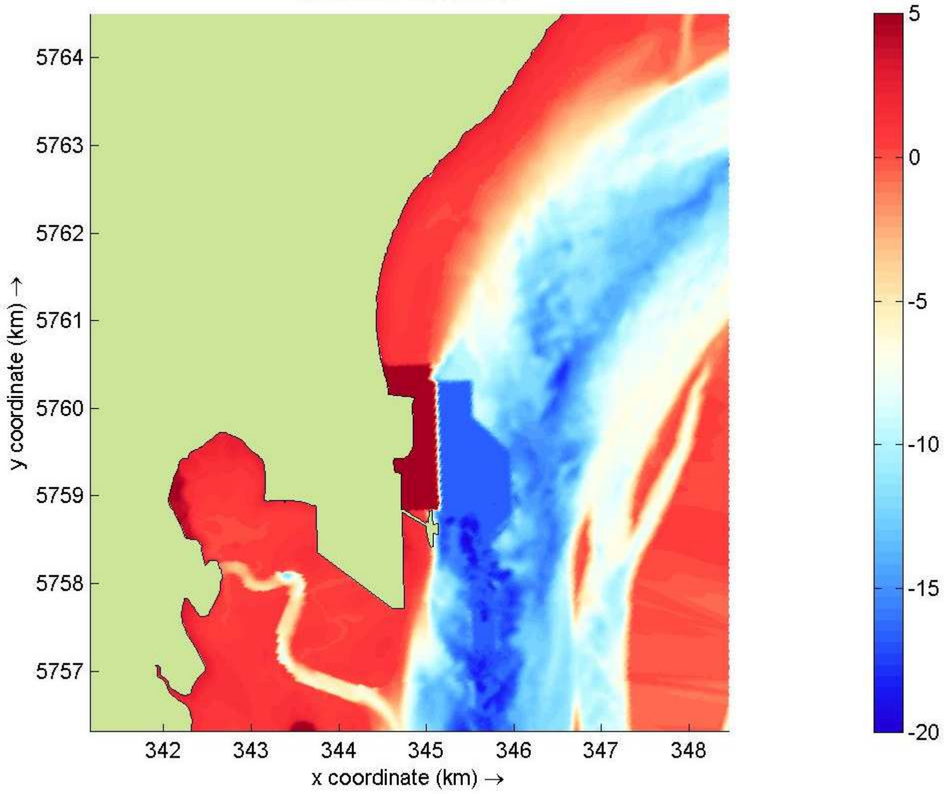

Figure A2: Bathymetry (m CD) Stage 1 Development Swing Basin adjacent to the southern-most berths

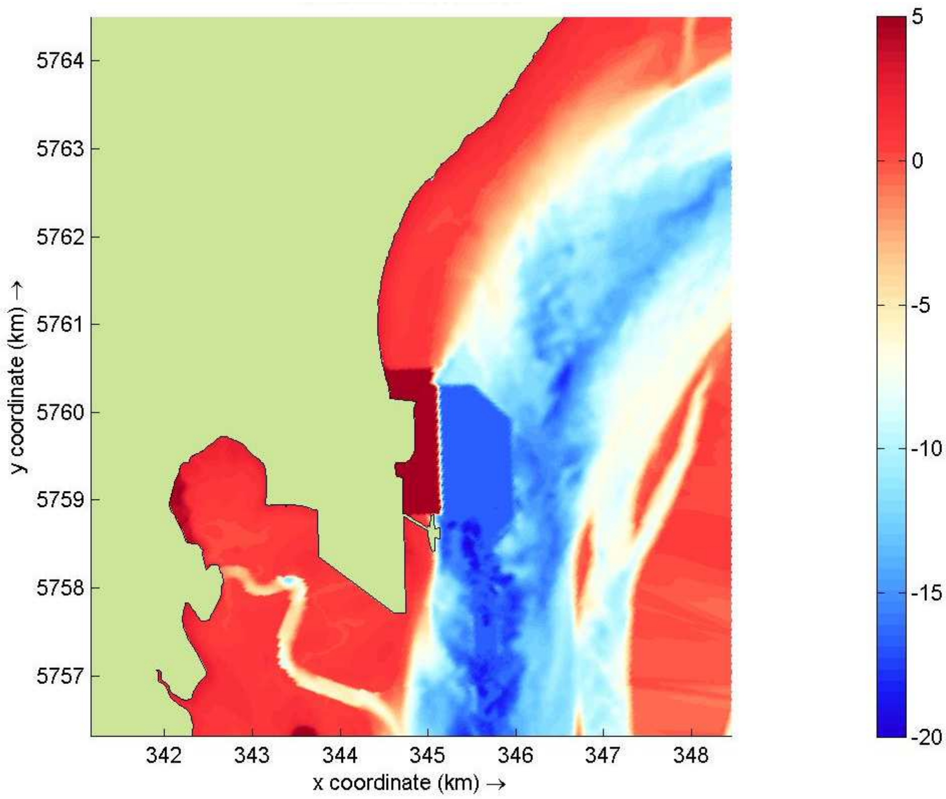

Figure A3: Bathymetry (m CD) Stage 1 Development Swing Basin extended further north

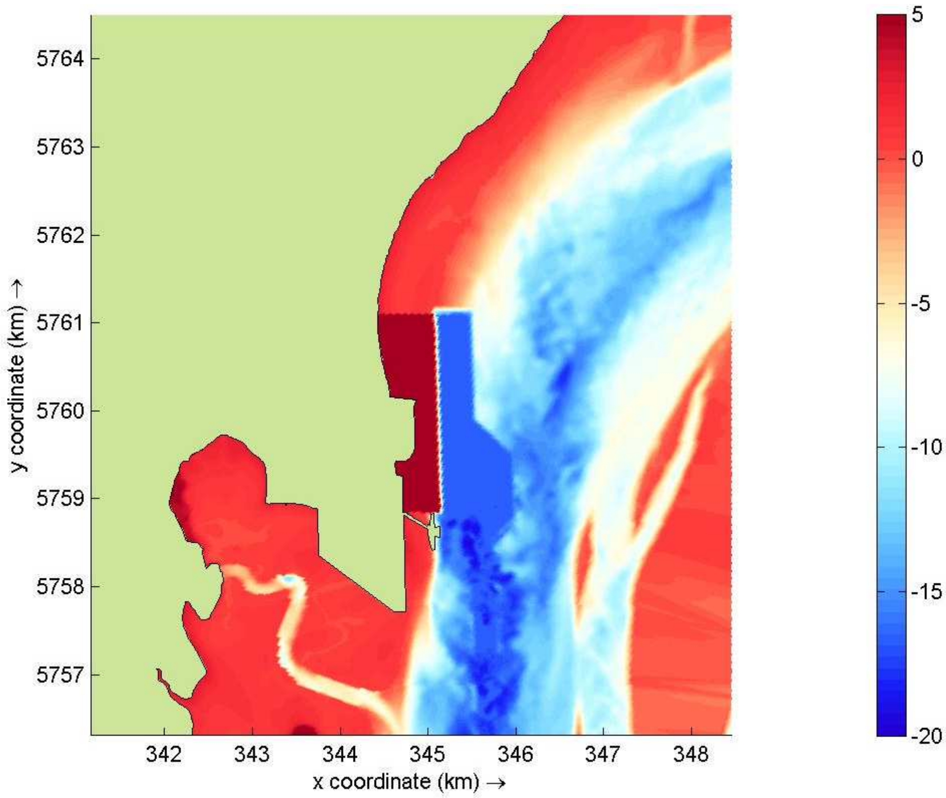

Figure A4: Bathymetry (m CD) Extended Stage 1 with swing basin at southern berths

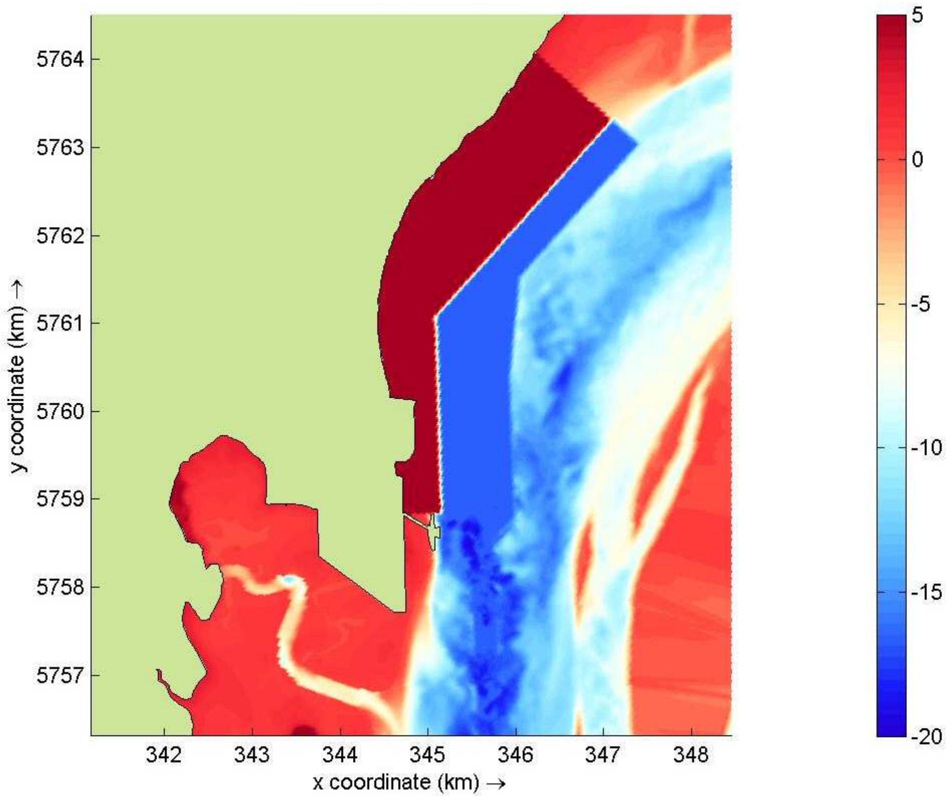

Figure A5: Bathymetry (m CD) Full Development 'Along the Shore Option'

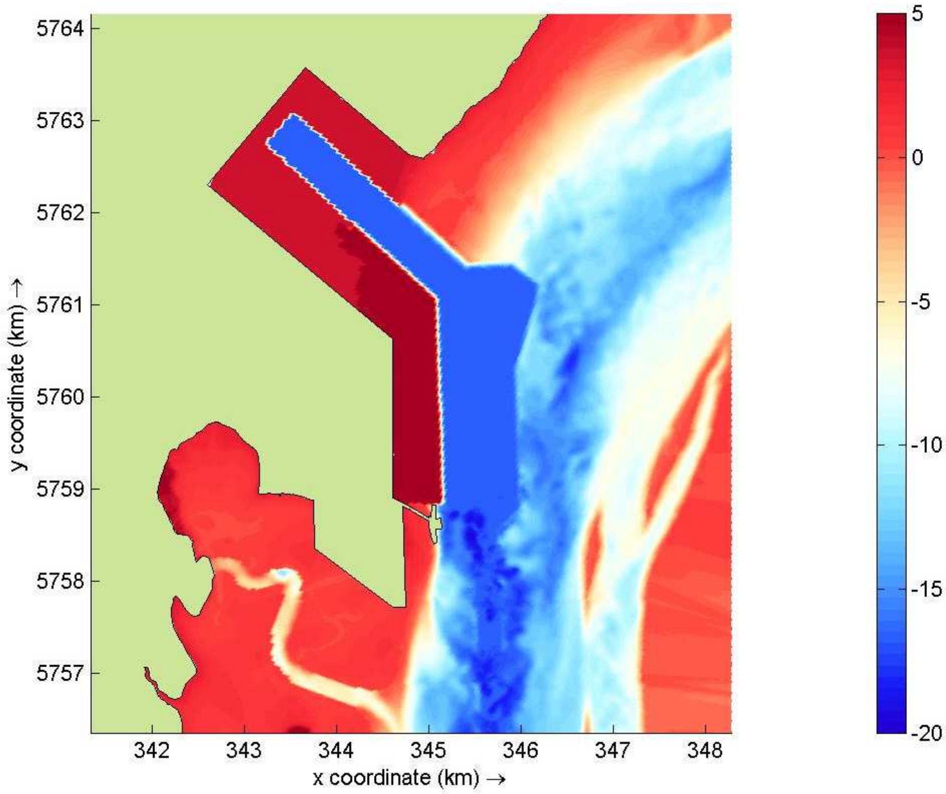

Figure A6: Bathymetry (m CD) Basin Option with a short training wall

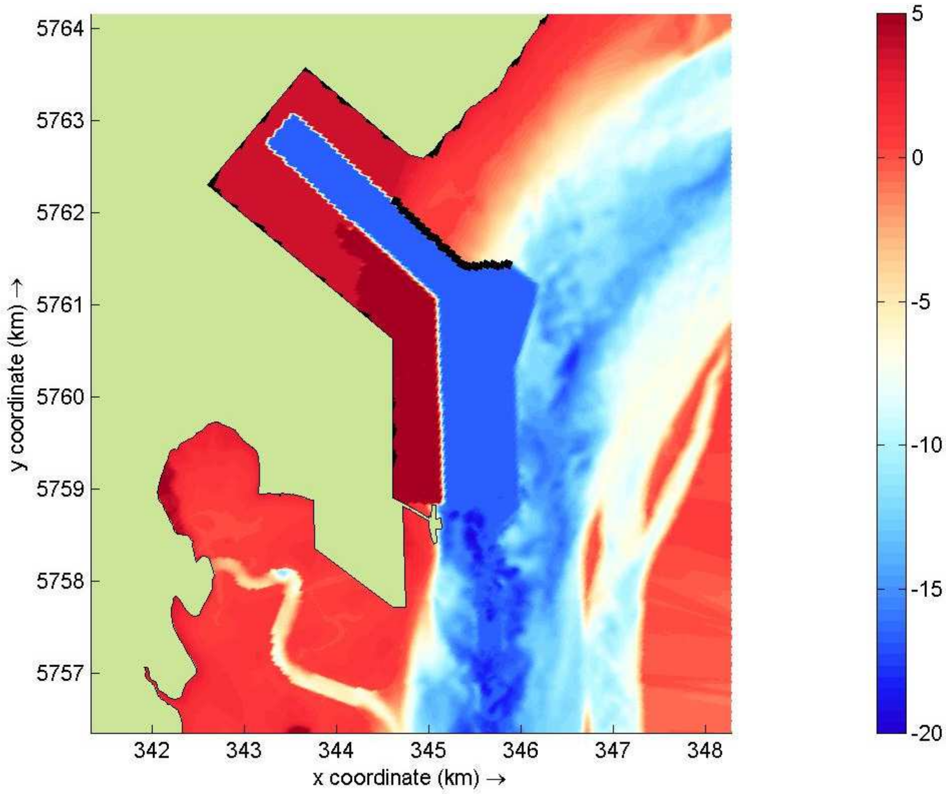

Figure A7: Bathymetry (m CD) Basin Option with a long training wall (black line indicates emergent training wall)

Appendix B - Technical Note

To	:	Christian Taylor (PoHDA)
From	:	Evan Watterson, Alex Le Royer, Heiko Loehr, Rohan Hudson
Cc	:	Greg Britton, Nick Lewis
Date	:	1/04/2015 (Final Draft)
Subject	**:**	**Non-tidal Currents at Proposed Port Site**

Introduction

This Technical Note presents the results of an analysis of recently collected current and water level data to assess the importance of non-tidal effects on current speeds observed in the navigation channel.

The current data reviewed covers a Doppler Profiler type instrument deployed at a site near-by to the proposed port development area (see Figure 1). This data was collected by Royal HaskoningDHV for the Port of Hasting Development Authority.

A sensitivity check (using a hydrodynamic model) on the influence of non-tidal (i.e. storm surge) conditions on current speeds in the channel and swing basin is also presented.

Data Reviewed

Table 1 provides a summary of the data used in this Technical Note. Figure 1 shows the locations of the respective monitoring sites.

Table 1 *Overview of the monitoring sites and collected data*

Site Name/Location	Deployment Capture Period	Instrument/Sensor Type	Parameter
LNA 05 – Proposed Port Site (RHDHV)	Deployment 1: (**36 days**): 30 June 2014 to 5 August 2014 Deployment 2: (**80 days**): 24 August 2014 to 12 November 2014	Deployment 1: TRDI Workhorse Monitor (1200kHz) Deployment 2: Nortek AWAC (1MHz)	Currents and Waves

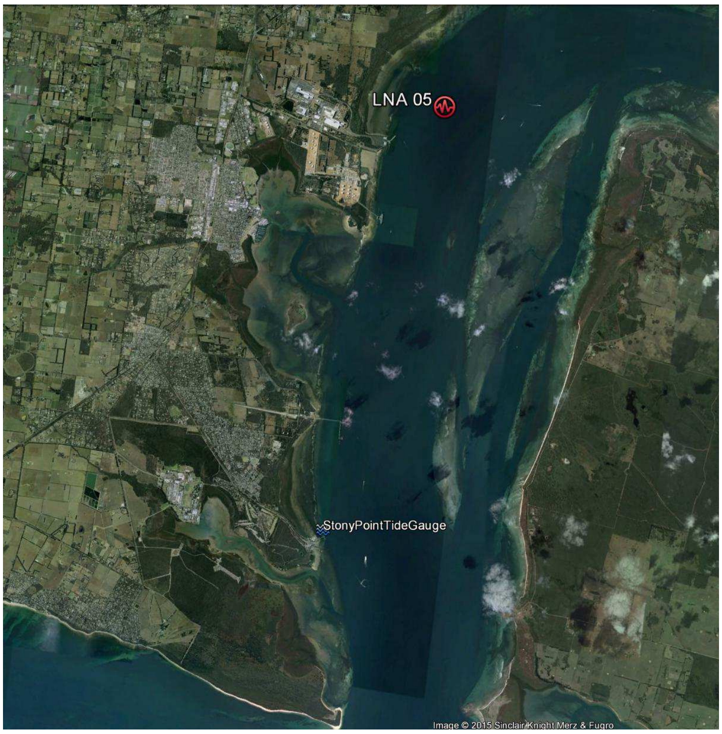

Figure 1: Locations of the current monitoring site (LNA 05) and the Stony Point Tide Gauge.

Analysis Methodology

The analysis methodology involves the deconstruction of the total measured current into tidal and non-tidal components. The tidal component of the total current results from the predictable astronomical forcing (i.e. the periodic rise and fall of the sea surface). The forcing of the non-tidal current component can be derived from storm surge, wind driven currents or wave driven currents.

Tidal water levels, in much the same way, can be predicted for any time in the past or future as can tidal currents. This would typically involve an analysis which takes into account the regular cyclic nature of solar and lunar motions. The deconstruction of total current measurements into components was achieved using UTide, a harmonic analysis package implemented in Matlab (Codiga, 2011). The UTide Matlab script performs a harmonic analysis of the signal and determines tidal constituents to estimate. This then allows the tidal currents to be predicted and the non-tidal components to be estimated.

The data recorded by Current Doppler Profiler type instruments consists of current speed and direction measurements over the full water column. Currents are measured across the depth profile by using a number of vertical cells (or depth bins).

The steps taken in the analysis of the measured current data during each of the deployment periods were:

- Data QQA/QC checks and screening of raw data from the instrument.
- Import of data into Matlab.
- Harmonic analysis of each vertical bin applied to each deployment period.
- Plotting and inspection of resulting tidal and non-tidal currents.

The single largest ‘residual event’ was further analysed and provided an understanding of the likely effect of non-tidal currents on currents that occur within the Navigation Channel of Western Port.

Results

During data QA/QC pre-processing checks on the Deployment Period 2 it was identified that the instrument at LNA 05 had moved. This movement was identified via a change in the instruments heading, pitch, roll and average depth. This movement occurred on the 22 September 2014. While, the instrument recorded good data for the entire deployment period, harmonic analysis results for the period from the 24 August 2014 to the 20 September 2014 were not consistent with the other periods. This is likely to have been a result of the shorter duration of this period. Therefore this period has been discarded for the purposes of this Technical Note. Further work will be done to correctly interpret harmonic analysis for this period at a later stage.

As a result the useable data period for harmonic analysis period covered a total of 87-day, comprising of the 36 days of Deployment Period 1 and the last 51 days (from 21 September 2014 and 12 November 2014) of Deployment Period 2.

Table 2 provide a summary of some of the basic statistics on the total measured current and the calculated tidal and non-tidal current for the 87-days of data used for harmonic analysis. Resulting statistics are presented for three representative depth layers: surface currents, mid-depth currents and bottom currents.

Table 2: Summary of current statistics and percentage of total energy (PoE) of the tidal and residual currents at three depth layers at LNA 05

Depth layer	Total current		Tidal current			Residual current		
	Mean (m/s)	Max (m/s)	Mean (m/s)	Max (m/s)	PoE (%)	Mean (m/s)	Max (m/s)	PoE (%)
Surface	0.44	0.89	0.43	0.87	98.82	0.05	0.43	1.18
Mid	0.40	0.82	0.39	0.80	98.92	0.04	0.39	1.08
Bottom	0.33	0.69	0.32	0.68	98.53	0.04	0.34	1.47

Figure 2 and Figure 3 below present plots of the following information for the each of the Deployment Periods:

- The top panel shows the recorded water levels, predicted tide and residual water level at the location of the instrument (as based on the raw pressure signal).
- The middle 3 panels show the results of the UTide analysis presented as: total (measured) velocity V, the predicted tidal velocity component (Vt) and the residual velocity component (Vr) for three different heights in the water column.
- The bottom two panels shows (1) the residual currents for the near surface, mid-water and near bottom layers and (2) the tidal currents at the three different depth layers. It is clearly visible that the residual current velocities tend to gradually decrease from the surface to the bottom.

It is noted in Figure 2 that there is a significant ‘residual event’ between the 30 July and 1 August 2014. This event is believed to be a result of a moderate storm surge that occurred in the Bass Strait at this time. Figure 4 provides a detailed view of this event including plots of:

- Top panel - water levels, predicted tide and residual water level.
- Middle panel – total current, tidal current and residual current.
- Bottom panel – residual current shown as positive when it increases total current speeds and negative when it reduces total current speed.

Discussion

A summary of the preliminary observations relevant to the assessment of non-tidal currents at the proposed port site is as follows:

- The operational (i.e. the day-to-day) effect of non-tidal effects on total current magnitude were not particularly significant generally resulting in a change in speed of the dominant tidal current of around 0.05 m/s or 10-12%.
- During ‘residual events’ non-tidal effects can be significant causing change to the observed current magnitudes of 50-60%.

Based on the one observed larger residual events (see Figure 4) the behaviour of the non-tidal effects are further detailed as:

- Observed non-tidal effect caused increases in current speed of up to 0.4 m/s or 60%. The larger observed increases occurred on the flood tide but where not in phase with peak flood currents. The peak in non-tidal current occur after the peak in the flood tide current. At the peak of the flood tide observed non-tidal increases in current speed where in the order of 0.2 m/s or 30%. This was observed as a pronounced effect on a single flood tide at the onset of the storm surge event.
- Non-tidal effects caused small phase shifts in tidal currents, generally observed as a later than predicted high water slack (i.e. a longer flood tide delaying the onset of ebb flows).
- After the residual event peaked and ocean residual began to subside, non-tidal effects reflected as a reduction in peak flood currents.

Analysis of a single current monitoring location is insufficient to determine the overall circulation of storm surge flows in Western Port and on other locations within Navigation Channel. Based on the analysis done for this Technical Note further investigations should consider:

- The effect of the tidal /or storm surge storage volumes in the upper embayment on the behaviour of non-tidal currents.
- Differential channel friction effects during flood and ebb tides including the impact of waves on ebb currents in the Western Entrance.
- The possibility that storm surge flows that enter the upper embayment via the North Arm may be preferentially discharged to the ocean via the East Arm and both Western Entrance and Eastern Entrances.
- Differential effect of shoaling between tidal wave frequencies (diurnal/semi-diurnal) and storm surge frequencies (2-5 day periods).

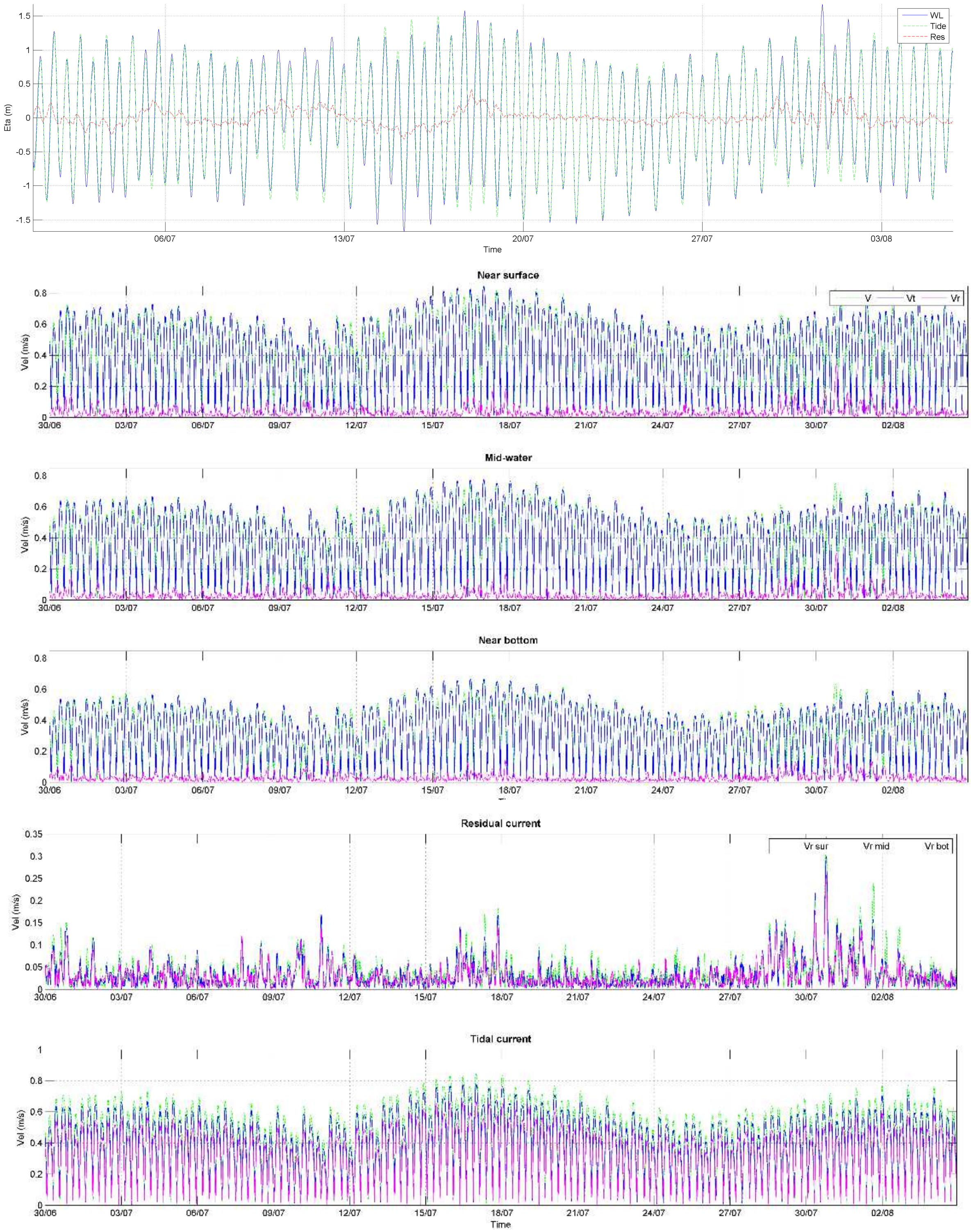

Figure 2: Plots of water level (top), currents (total, tidal and residual) for here depths (middle panels) and residual and tidal current magnitude (bottom) for site LNA05 during Deployment Period 1.

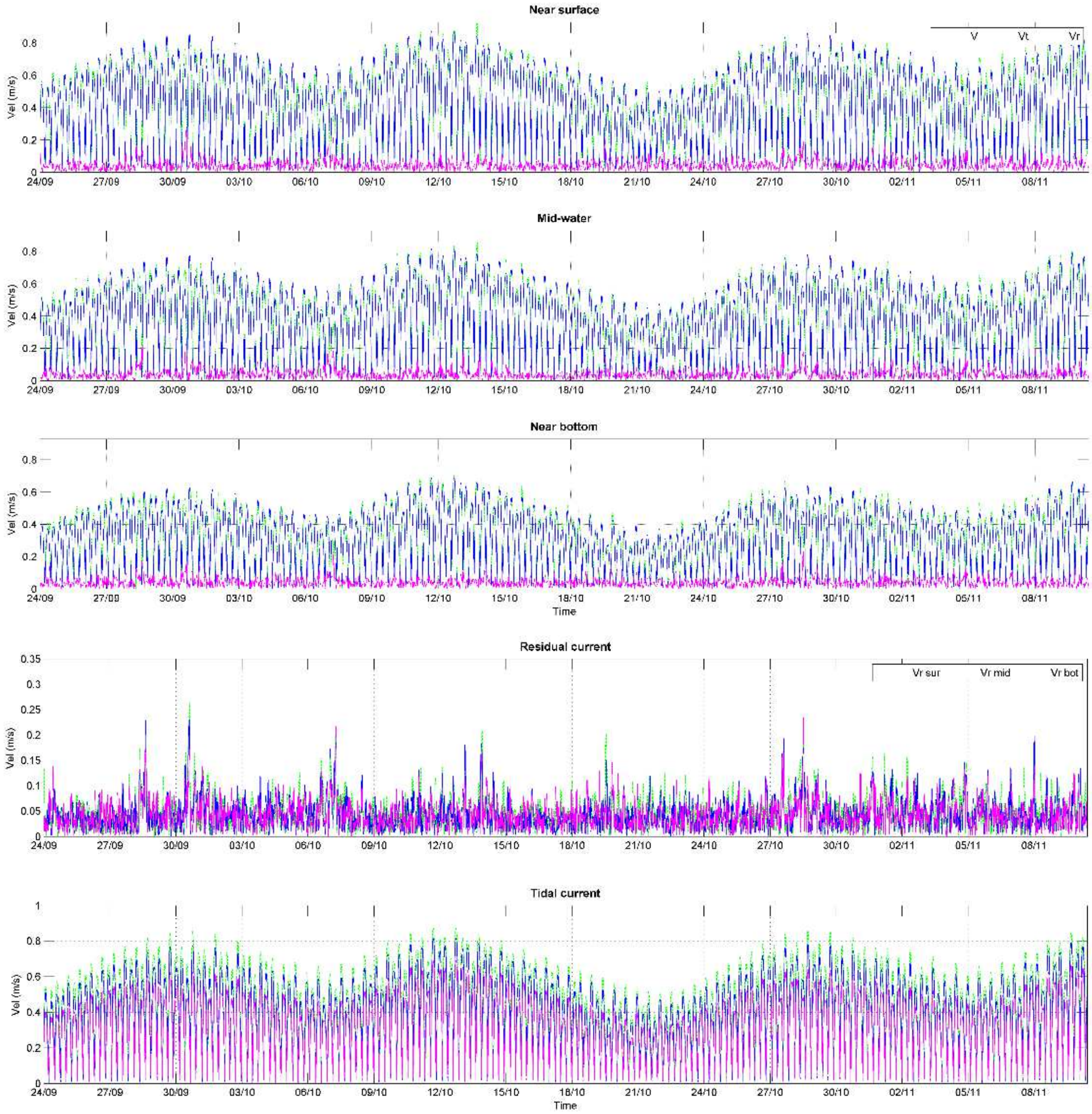

Figure 3: Plots of water level (top), currents (total, tidal and residual) for here depths (middle panels) and residual and tidal current magnitude (bottom) for site LNA05 during Deployment Period 1.

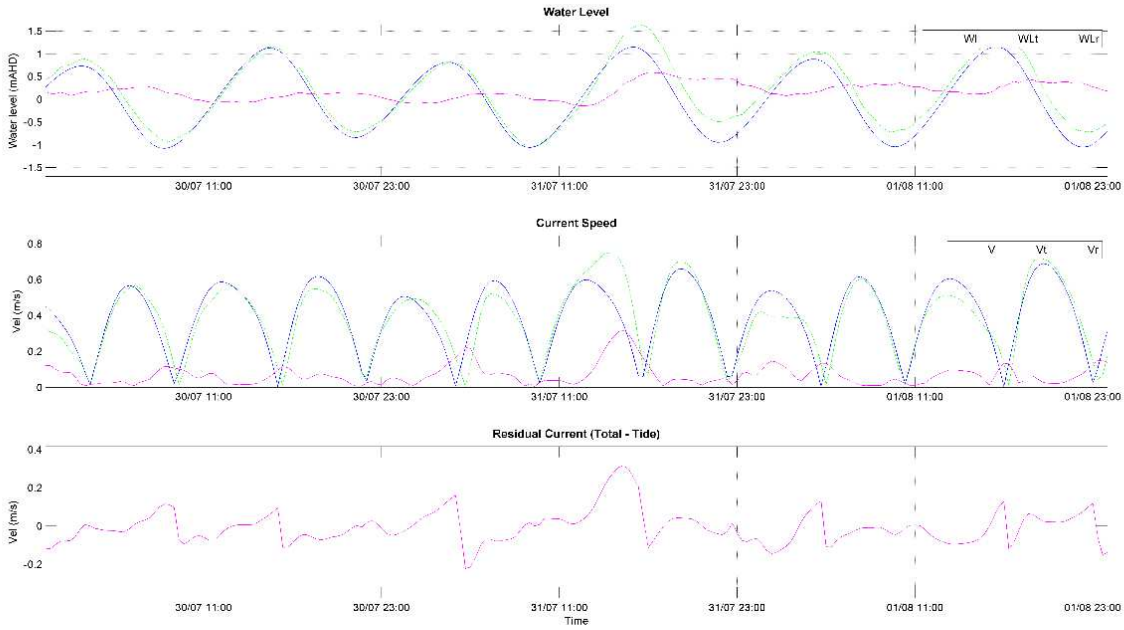

Figure 4: Detailed comparison of water level (top), current speed (centre) and residual currents at LNA 05 during a high-residual event between 30/07/2014 and 01/02/2014

Hydrodynamic influence of Non-Tidal Currents

A sensitivity check on the influence of non-tidal currents on current speeds in the channel and swing basin has also been undertaken using the hydrodynamic model produced by Cardno. An idealised storm surge with a 0.5 m magnitude and a 36 hour period was added to the observed tides to simulate a period that included non-tidal currents. The peak of the storm surge was adjusted to coincide with the high tide that occurred on the morning of the 19th December, 2012 as presented in Figure 5. The storm surge was applied to the Along the Shore scenario. It should be noted that increased winds that would be typically associated with such a storm surge were not included in the storm surge scenario. While no detailed local long term analysis was undertaken for this investigation, based on previous experience in South East Australia, typical storm surge durations range from 0.5 to 5 days and a 0.5 m magnitude storm surge is likely to occur a number of times a year in Western Port.

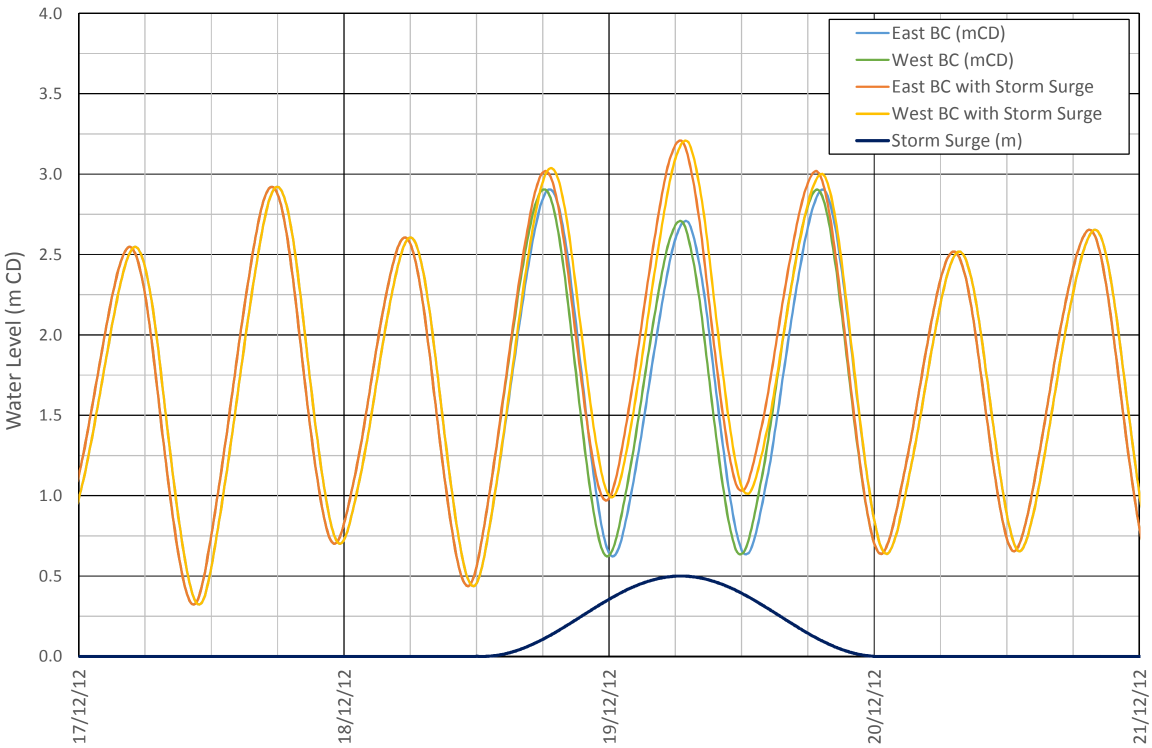

Figure 5: Model Tidal Boundary with 0.5 m, 36 Hour Storm Surge

A plot of modelled water levels at Stony Point Figure 6 indicates that the 0.5 m surge offshore increases water levels at Stony Point by slightly over 0.5 m. A plot of modelled current speeds at ADCP south (located in the swing basin along the first facet of the berth, see Figure 8) is presented in Figure 7 and shows that currents speeds increase by slightly over 0.1 m/s during the flood tide preceding the first high water on the 19thDecember. This represents an increase in current speeds of over 16% (from a peak of 0.6 m/s to 0.7 m/s). A map showing the spatial distribution of changes to current speeds (peak flood) due to the storm surge is presented in Figure 8.

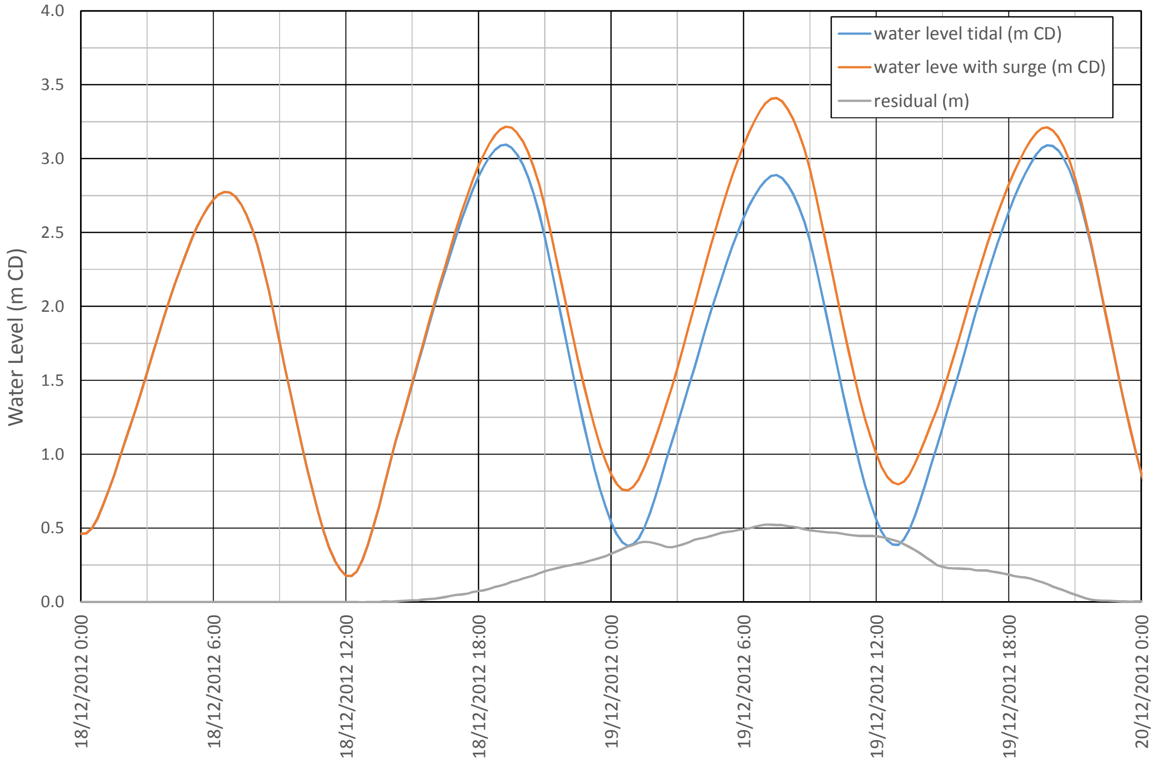

Figure 6: Stony Point Modelled Water Levels (tide only and tide with surge) and Residual

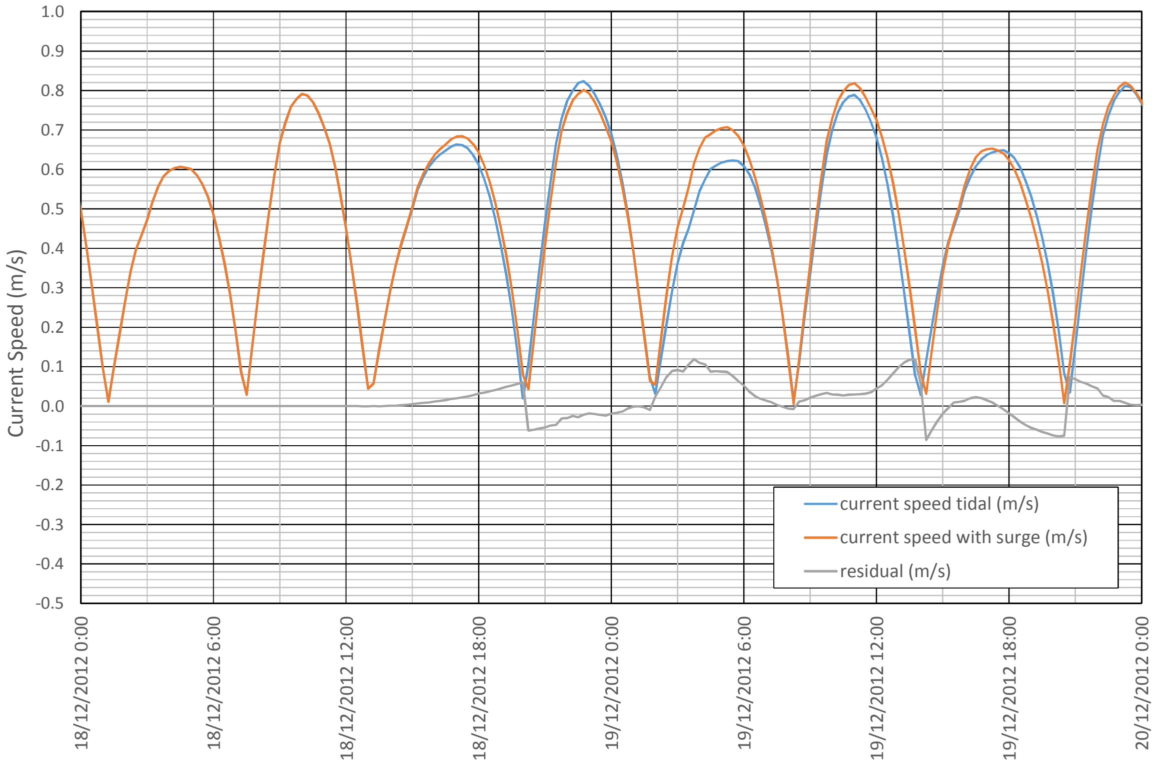

Figure 7: ADCP South Modelled Current Speeds (tide only and tide with surge) and Residual

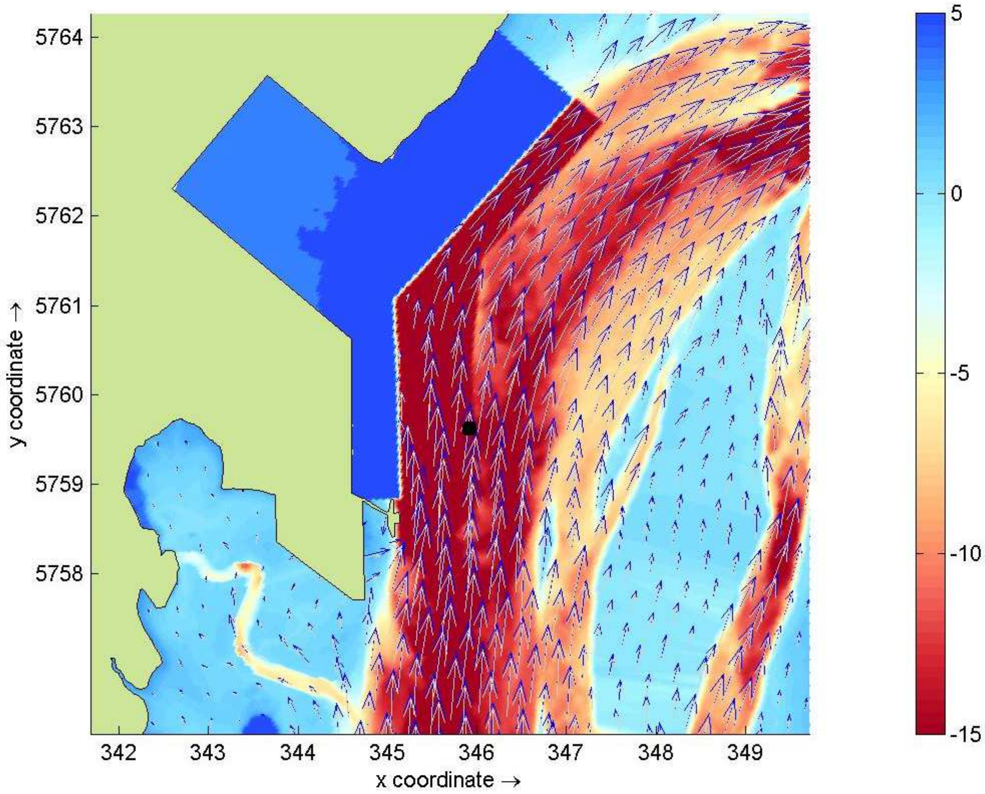

Figure 8: Tidal (Grey) and Tide with Surge (Blue) Currents at Peak Flood Tide for the Along the Shore Scenario.
Bathymetry (m CD) and South ADCP (Black Dot) location are also mapped

Summary & Discussion of Residual Current Modelling

A hydrodynamic model sensitivity check on the influence of non-tidal forces (i.e. storm surge) on current speeds in the channel and swing basin indicate that current speeds may increase by approximately 20% if a 0.5 m, 36 hour duration storm surge occurred. It is important to note that the modelled residual current speeds presented in this document cannot be directly compared to the observed residual (i.e. non-tidal) currents discussed above, as the modelled residual current speeds are depth averaged and used an idealised storm surge.

Royal HaskoningDHV
Enhancing Society Together

References

Haskoning Australia (2014*), Early Hydrodynamic Modelling for Port of Hastings Development Project,* prepared for Port of Hastings Development Authority, Final Draft for discussion purposes (Issue C), reference HAS-CEP0-HY-REP-0012-C, 19 December.