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Chapter 6 – Hydrodynamic Modelling

6. Hydrodynamic Modelling

6.1 Background

Hydrodynamic modelling of the entire Port Curtis region, encompassing the Western Basin Project Area, has been undertaken using the TuFlow –FV software. The purpose of this modelling is provide a tool to quantify key physical processes acting within the waters of the port, with the model capable of informing engineering design, and the assessment of environmental impacts. In particular, the model has been used to establish baseline conditions across the entire area of interest, and to then quantify the potential impacts of proposed dredging and reclamation works on key characteristics including:

- Tidal water levels;
- Currents (velocities) and bed shear stresses;
- Flushing characteristics (an indicator of potential impacts on water quality);
- Suspended sediment concentrations (arising from the proposed dredging process); and
- Sediment deposition.

The modelling therefore addresses tidal hydrodynamics and flushing characteristics, turbid dredge plume dispersion, wave conditions and sedimentation processes. Details of the modelling software, establishment, calibration and validation are provided in a separate model validation report (BMT WBM, 2009).

6.2 Purpose of Model

Hydrodynamic models, and linked models addressing waves, sediment and water quality, normally form one of the key components of any impact assessment in the ocean environment. Typically, models are developed over a wide regional extent, such that a much wider understanding can be obtained of processes (e.g. tidal characteristics) within that extent than could be provided through monitoring alone. Effectively, models allow two key advantages over monitoring:

- The ability to consider characteristics and impacts anywhere within the model extent; and
- The ability to predict how characteristics might change in response to actions within the extent. Such actions could include the dredging of a channel, the construction of a Reclamation Area, or the creation of a plume.

In order for models to be able to realise these advantages, a staged process must be adopted. This comprises:

- The collection of data to drive model boundaries (e.g. water levels, wave conditions, wind fields);
- The collection of data for calibration purposes (e.g. tidal currents and wave heights within the model extent, and typically within the general extent of one or more of the primary points of interest);
- The assembly of bathymetric and land boundary data, such that the physical characteristics of the seabed can be replicated;
- Creation of a model mesh;
- Model calibration;

- Model verification (i.e. to an additional dataset, where available);
- Determination of baseline conditions; and
- Assessment of proposed infrastructure or dredging activities through changes to the model mesh, boundaries, or bathymetry.

This chapter provides an overview of those items listed above relating to model creation, with results and impacts addressed in subsequent chapters.

6.3 Software

As indicated in Section 6.1, hydrodynamic modelling for the Project has been undertaken using the TuFlow–FV software. This was the same software as applied to the Fisherman's Landing Northern Expansion EIS. The TUFLOW-FV package contains hydrodynamic, advection-dispersion and sedimentation modules. The SWAN wave modelling package has been used for the wave assessments in Port Curtis and has been linked to TUFLOW-FV, as needed.

The TUFLOW-FV package includes standard 2 dimensional (2D) depth averaged hydrodynamic (HD) and advection-dispersion (AD) modules and also has the capacity to include meteorological forcing, wave related stresses and cohesive sediment transport modules, as outlined in subsequent sections. Wetting and drying is accurately incorporated, which is important in simulating the inter-tidal flats in Port Curtis, particularly in the vicinity of the proposed Reclamation Area.

6.4 Model Data

6.4.1 Bathymetric Data

The model bathymetry is based on a Digital Elevation Model (DEM) of the Port which has been derived from various survey components. This includes:

- Detailed pre and post-dredge hydrographic survey data (in digital spot-height format) of the dredged channels, swing basins and berths as provided by the Hydrographic Services section of Maritime Safety Queensland (MSQ) and GPC;
- Detailed hydrographic survey data (in digital spot-height format) of broad areas of the Port as provided by the Hydrographic Services section of MSQ and GPC; and
- Hydrographic survey data (in digital spot-height and contour format) and outlines of the edges of the shoreline, mangroves and saltpans used in producing Boating Safety Charts of the area as provided by the GIS and Cartography Section of MSQ.

Typical levels have been adopted for the edges of the mangroves and saltpan areas for interpolation in those upper inter-tidal zones where no specific survey level data is available. The various data components have been combined and prioritised with respect to date and detail where there is overlap in producing a base DEM.

As part of recent studies, the previously developed DEM has been updated with additional hydrographic survey data collected by MSQ in the Western Basin area. This includes:

- Clinton Swing Basin to South Passage Island Compiled Hydrographic Survey, June 2008 (MSQ Plan No: F500-014);

- South Passage Island Hydrographic Survey, 18-19 June 2008 (MSQ Plan No: F500-015); and
- South Passage Island to Grahams Creek Hydrographic Investigation, October 2008 – December 2008 (MSQ Plan No: F500-016).

Most survey data has been provided relative to LAT or Chart Datum which varies throughout the Port. For modelling purposes, all data has been adjusted to a constant datum (AHD) using information provided by MSQ at various sites. The DEM on which the model has been based is illustrated in Figure 6-1.

6.4.2 Tidal Water Levels

The tidal range within the port varies in accordance with location, with a range of 4.69 m at the “Standard Port” location of Auckland Point, increasing to between 5 and 6 metres through The Narrows. Details are provided in Table 6-1.

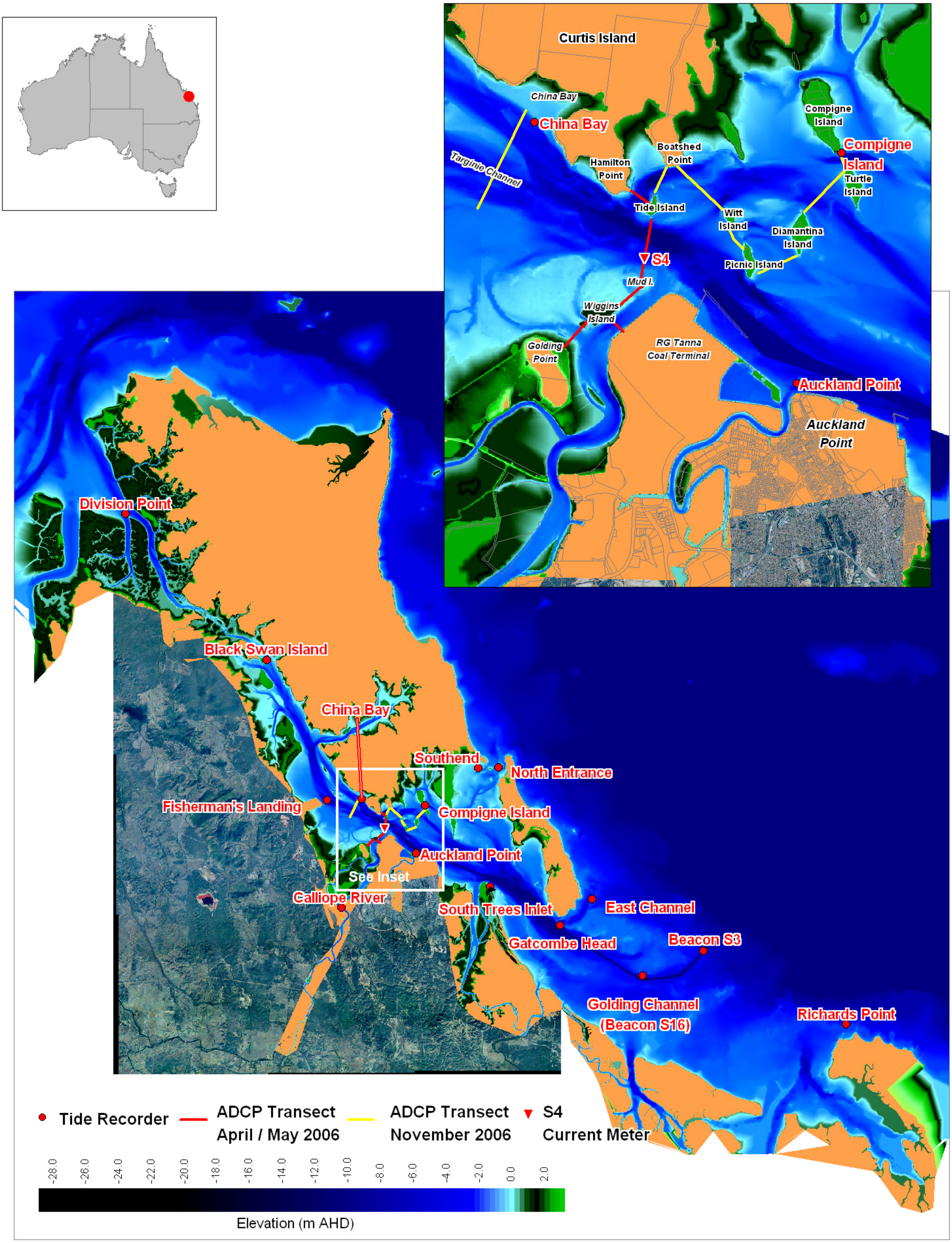

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Table 6-1 Gladstone Region Tidal Planes (m LAT)

Tidal Plane	Gladstone (Standard Port)	Fisherman's Landing	The Narrows (Boat Creek)	The Narrows (Ramsay Crossing)
Highest Astronomical Tide (HAT)	4.69 (4.83)	4.97 (5.12)	5.44 (5.60)	6.00 (6.17)
Mean High Water Springs (MHWS)	3.91 (3.96)	4.14 (4.20)	4.52 (4.58)	5.02 (5.08)
Mean High Water Neaps (MHWN)	3.06 (3.11)	3.24 (3.30)	3.53 (3.59)	3.95 (4.01)
Mean Level (ML)	2.35 (2.34)	2.439 (2.41)	2.68 (2.68)	3.01 (3.01)
Australian Height Datum (AHD)	2.268 (2.268)	2.429 (2.43)	-	-
Mean Low Water Neaps (MLWN)	1.52 (1.57)	1.61 (1.66)	1.73 (1.79)	2.00 (2.07)
Mean Low Water Springs (MLWS)	0.67 (0.72)	0.71 (0.76)	0.73 (0.79)	0.93 (1.00)
Lowest Astronomical Tide (LAT)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

Note: Values sourced from Queensland Tide Tables 2009 (MSQ, 2008), apart from Fisherman's Landing, which were supplied independently by MSQ. Figures in brackets are new values published on the MSQ website (MSQ, 2009) including Fisherman's Landing.

It should be noted that there were no specific calculations reliant on tidal planes used in producing this report. All numerical model simulations referred to are based on measured data which are in fact compatible with the new tidal planes. These simulations include a tide close to the level of the new Highest Astronomical Tide (HAT). As such, the assessments of the effects of the development scenarios may be considered as up to date.

6.4.3 Additional Tidal Data

Tidal data collected for the study included:

- Tide water levels at the model boundaries and within Port Curtis over the period of data collection;
- Acoustic Doppler Current Profiler (ADCP) transects (i.e. boat mounted) of total flow and velocity distributions during spring and neap tides; and
- Continuous ADCP measurements from bottom-mounted instruments to provide longer term time series of currents and wave data.

Data applied to this EIS has been collected over several studies, as summarised in Table 6-2.

Table 6-2 Data Sources

Project	Dates of data collection	Data types
Wiggins Island Coal Terminal EIS	26th April 2006 to 8th May 2006	◗ Continuous water levels at 4 boundary locations # ◗ ADCP transects for spring and neap tides ◗ Bottom mounted S4 current meter
Boatshed Point / China Bay Investigations	2nd November to 9th November 2006	◗ Water levels at 9 locations # ◗ ADCP transects for spring tide at 7 locations
Fisherman's Landing area of Port Curtis	10th August to 25th August 2008	◗ Continuous water levels at 3 locations #
Western Basin Dredging and Disposal Project	15th April to 23rd April 2009 17th May to 30th June 2009	◗ Continuous water levels at 4 boundary locations # ◗ ADCP transects for spring and neap tides ◗ Bottom mounted ADCP for collection of continuous current (velocity) information.

Notes: For full details of all hydrodynamic data sets, reference should be made to the WBM Numerical Modelling Calibration and Validation Report (Appendix J).

Includes continuous water levels collected by MSQ at Auckland Point, South Trees and Fisherman's Landing.

6.4.4 Water Quality Data

The collection of water quality data was extensive, with much of this directly informing the ecological assessment, in additional to indirect linkages through the modelling process.

Data to allow the modelling of water quality comprised the following:

- Coincident physical water quality measurements of turbidity and laboratory analyses of total suspended sediment (TSS) concentrations as well as particle characteristics;
- Continuous ADCP measurements from bottom-mounted instruments to provide backscatter as an indication of suspended sediment concentrations;
- Continuous nephelometer measurements to provide longer term time series of turbidity in the Project Area; and
- Plume monitoring of turbidity and suspended sediment concentrations generated by dredging in the vicinity of Fisherman's Landing by the "Wombat" cutter suction dredger. This included physical water quality measurements of turbidity and laboratory analyses of TSS concentrations as well as particle characteristics.

Details as to the usage of this data may be found in the Wombat Monitoring Reports (GHD 2009c) and the WBM Numerical Modelling Calibration and Validation Report in Appendix J), and in the Water Quality Report in Appendix K.

6.4.5 Other Data

Meteorological data was collated in the form of wind speed/direction and atmospheric pressure from the Bureau of Meteorology for regional stations over the period of other data collection.

6.5 Types of Assessment

Models have been applied as listed below:

- **Hydrodynamic impact assessments** – Assessment of the impacts of specific dredging and reclamation scenarios on tide levels, velocities and flows.
- **Flushing impact assessment** – Assessment of the impacts of specific dredging and reclamation scenarios on the flushing characteristics of Port Curtis.
- **Plume dispersion assessments** – Simulation of the potential transport, dispersion and settling of turbid plumes of suspended sediment generated by dredging for specific scenarios of loadings and locations of dredgers including cutter suction dredgers (CSD), trailer suction hopper dredgers (TSHD) and tailwater discharge from Reclamation Areas.
- **Wave climate assessment** – Modelling of the day to day wave climate from the local wind climate and potential extreme wave conditions for specified wind speeds and water levels for design and impact assessment purposes of specific dredging and reclamation scenarios.
- **Sedimentation assessment** – Assessment of the implications of the specific dredging and reclamation scenarios on sediment transport processes within Port Curtis and the potential siltation of dredged areas.

6.6 Model Development

6.6.1 Model Extent

The model network extends over an area of some 635 km^2, incorporating Port Gladstone and the main inter-tidal areas between Curtis Island, Facing Island and the mainland. The modelled area represents a reach length of approximately 80 km extending from Richards Point in the southeast to Division Point at the northwest.

The model extent allows the incorporation and representation of all of the predominant tidal flows into the Port, being the main ocean entrance at the eastern model boundary, the North Channel between Curtis and Facing Islands and The Narrows.

There are a number of tributaries of the Port, including the Calliope River, Auckland Inlet, South Trees Inlet and the Boyne River, which are incorporated into the model. The normal (non-flood) fluvial component of flows within these river systems is insignificant in relation to the tidal flux. Thus, the primary purpose for the inclusion of these tributaries within the model relates to representation of tidal storage and exchange within the system.

6.6.2 Model Mesh

The model mesh showing the extent of the model coverage is illustrated in Figure 6-2. In developing the hydrodynamic model mesh, consideration was given to variations in the underlying bathymetry. For example, model resolution was enhanced at locations of rapidly varying bathymetry or expected high flow regions based on channel definition, as well as wherever the representation of dredged channels, swing basins and berth pockets was required.

Furthermore, the base model mesh was established to allow appropriate representation of the Reclamation Area and dredged channel / swing basins through changing of depths only, and not the mesh configuration, for each of the developed case scenarios. This eliminates any potential influence on model results arising through changes in the mesh.

In developing the model mesh, particular focus was also given to a number of key areas to ensure a suitable model representation of flow conditions. For example:

- The model resolution was adapted to define the main channel alignment and low flow channels, particularly at low tides when the flows are restricted to narrow channels.
- There are numerous islands within the central Port area of interest, some of which have a significant influence on flow distribution. Local adjustment of the mesh resolution has been made to define the land boundaries, and the adjacent flow channels around the islands typically characterised by rapid changes in bathymetry.
- A significant proportion of the model area covers the mangrove and salt pan areas on the tidal fringes. Whilst generally not in critical regions, the influence of these areas on the tidal hydraulics within the system is important. The major objective in defining these intertidal areas is to represent the contribution to bulk tidal storage volume, which has an impact on the tidal exchange in the system.

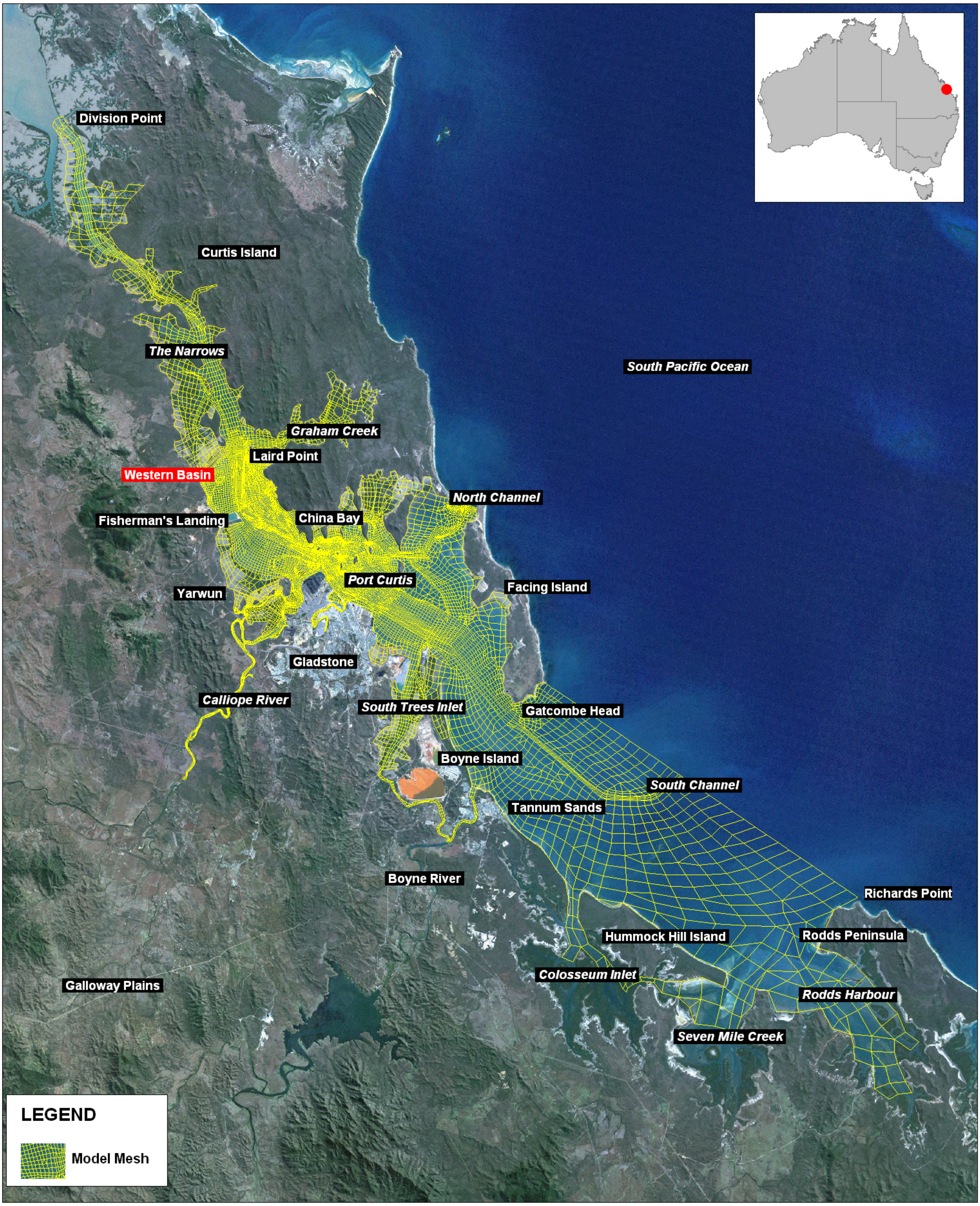
The Calliope River is a major tributary of the Port of Gladstone. The model has been extended for approximately 25 km upstream of the confluence with the main port channel. This provides the opportunity to adequately define the tidal storage within the river system and simulate the tidal flux.

6.6.3 Model Calibration

As part of previous studies, various water level and velocity/flow data have been collected to initially calibrate and subsequently, validate various hydrodynamic models of Port Curtis, inclusive of the Western Basin area. This data has typically targeted specific study areas within the Port.

Comprehensive data collection was undertaken in April-May 2006 for calibration of the hydrodynamic model produced for of the Wiggins Island Coal Terminal EIS project. Subsequently, data has been collected on a number of other occasions and in specific areas for further calibration and validation of upgraded models as part of other projects.

With the conversion of the model to TUFLOW-FV and further refinement of the mesh for the purposes of the Western Basin Dredging and Disposal Project EIS, the opportunity has been taken to re-run the latest model configuration with all key data sets from 2006 onwards to illustrate and confirm the model calibration and validation. Figures demonstrating the standard of calibration to each of these data sets are provided in the WBM Calibration and Validation Report in Appendix J, culminating in validation to the 2009 dataset.



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The simulation for the 2009 model of the Western Basin was undertaken without any further adjustment of model parameters and therefore, represents validation of the model with an independent data set. The main model boundaries also utilised measured water levels for the period. Figure 6-3 to Figure 6-13 provide evidence of the validation of the model to tidal water levels, tidal currents and total flows at specific areas of interest.

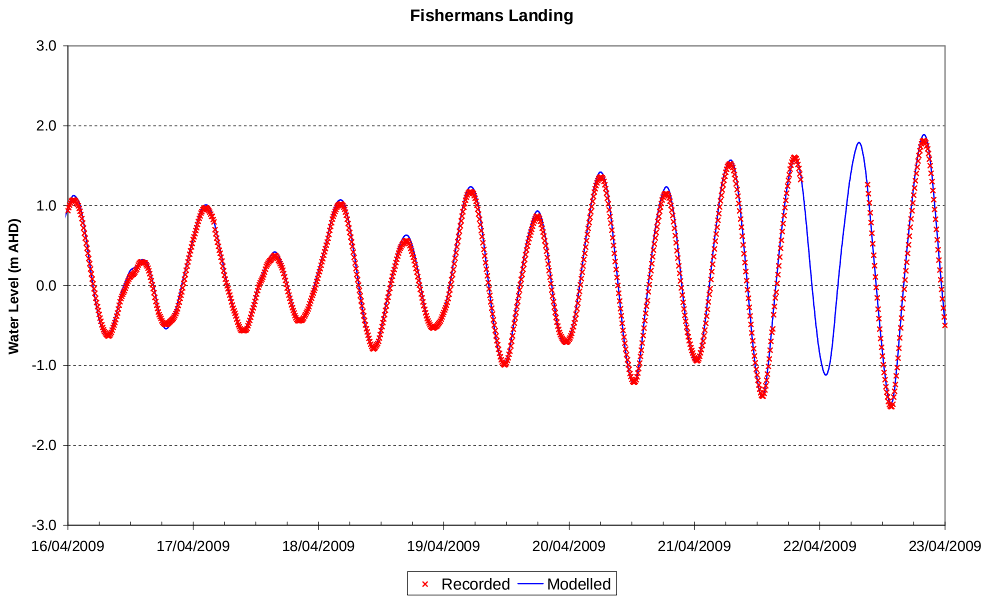

Figure 6-3 Water Level Validation – Fisherman's Landing, April 2009 (Neap Tide)

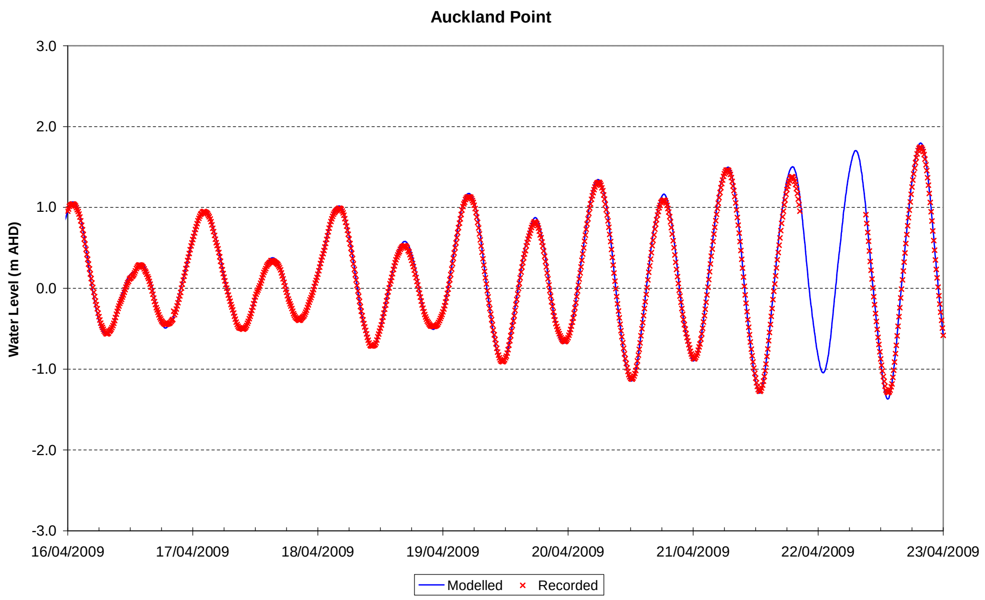

Figure 6-4 Water Level Validation – Auckland Point, April 2009 (Neap Tide)

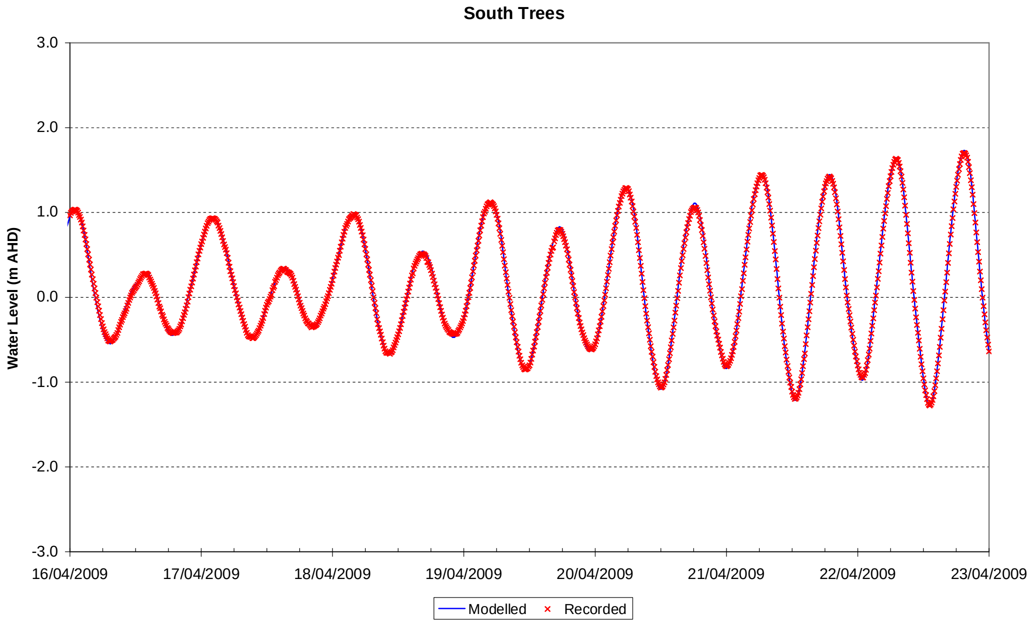

Figure 6-5 Water Level Validation – South Trees, April 2009 (Neap Tide)

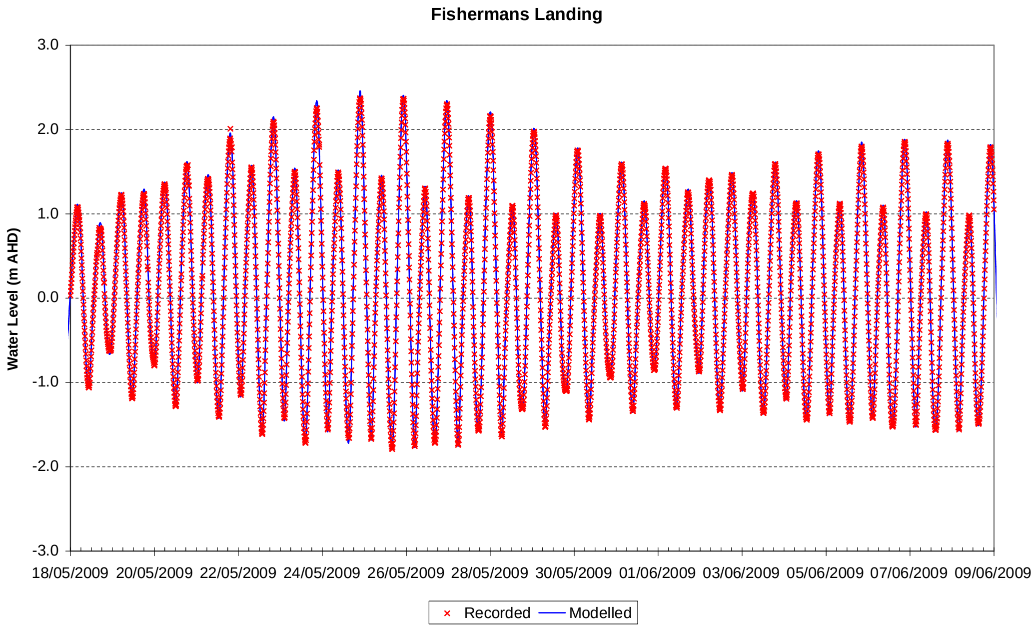

Figure 6-6 Water Level Validation – Fisherman's Landing, May 2009 (Neap and Spring Tides)

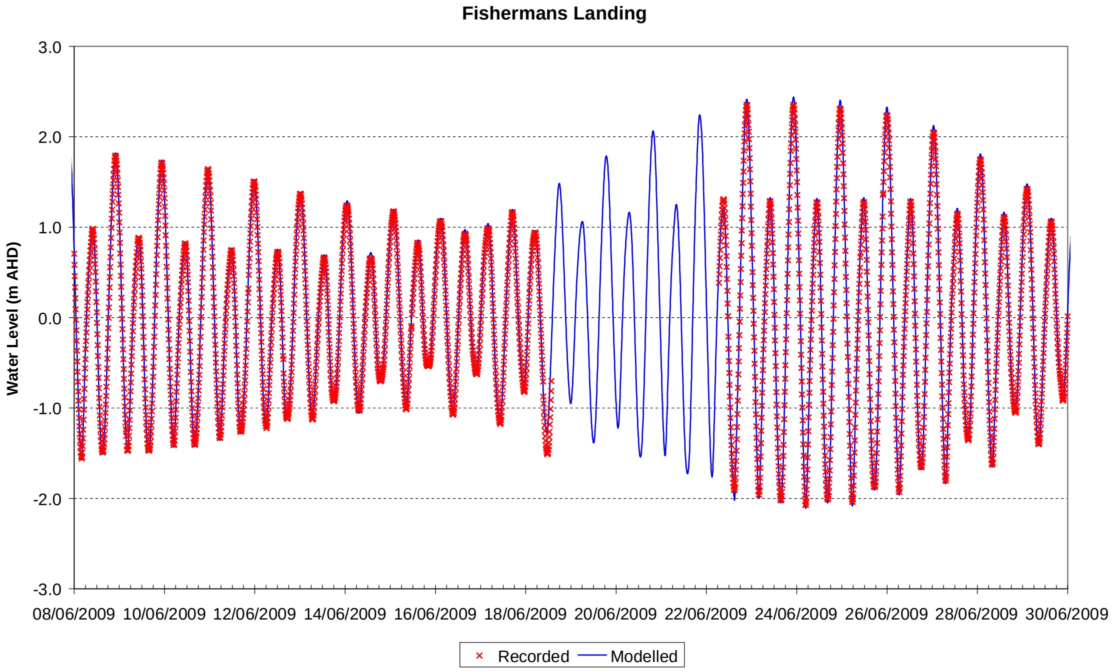

Figure 6-7 Water Level Validation – Fisherman's Landing, June 2009 (Neap and Spring Tides)

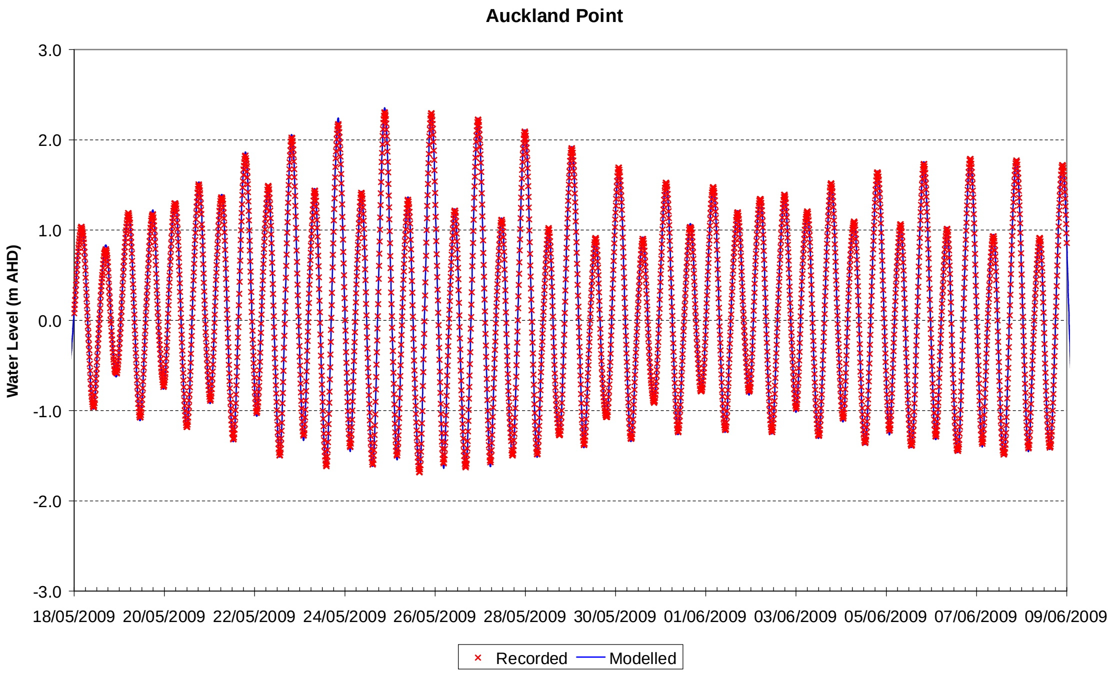

Figure 6-8 Water Level Validation – Auckland Point, May 2009 (Neap and Spring Tides)

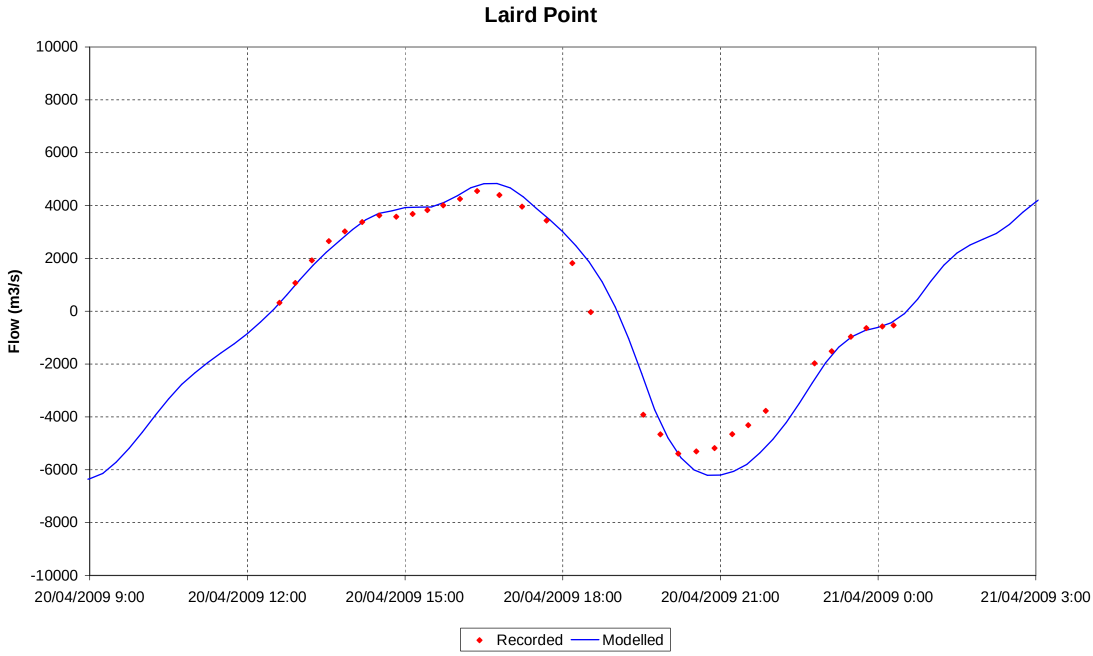

Figure 6-9 Flow Validation – Laird Point, April 2009 (Neap Tide)

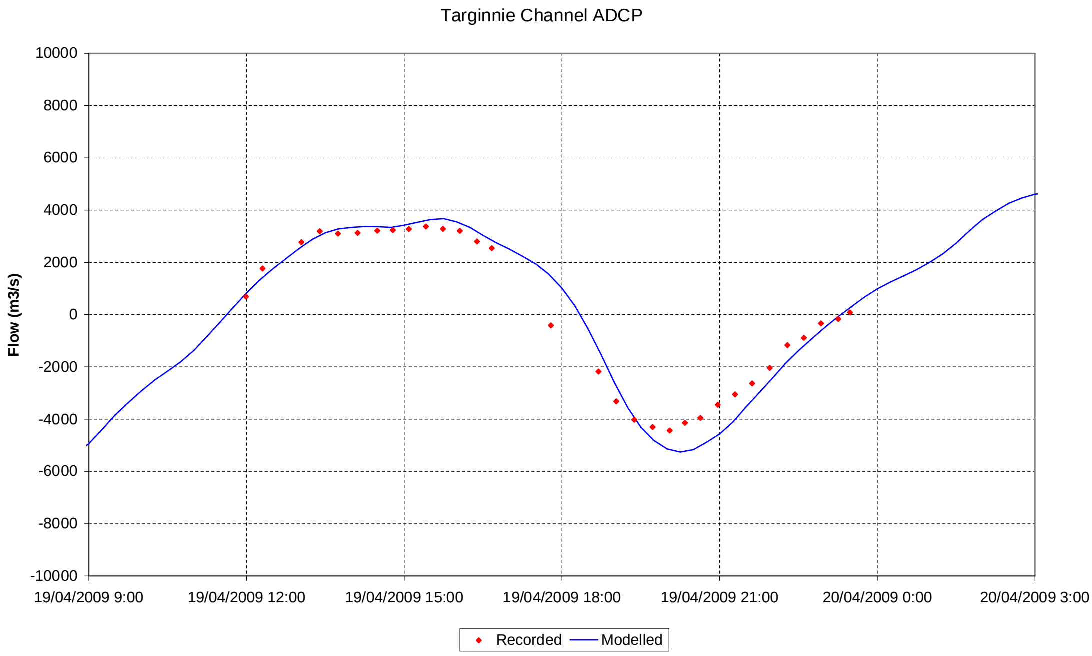

Figure 6-10 Flow Validation – Targinie Channel, April 2009 (Neap Tide)

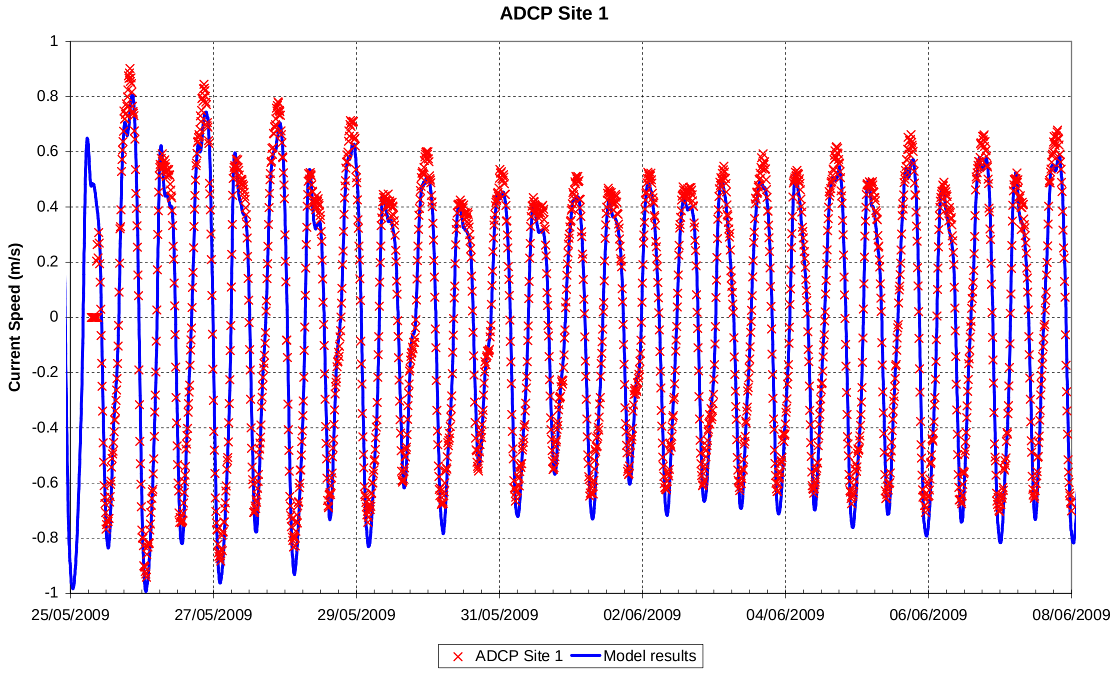

Figure 6-11 Current Speed – GHD ADCP Site 1, May 2009

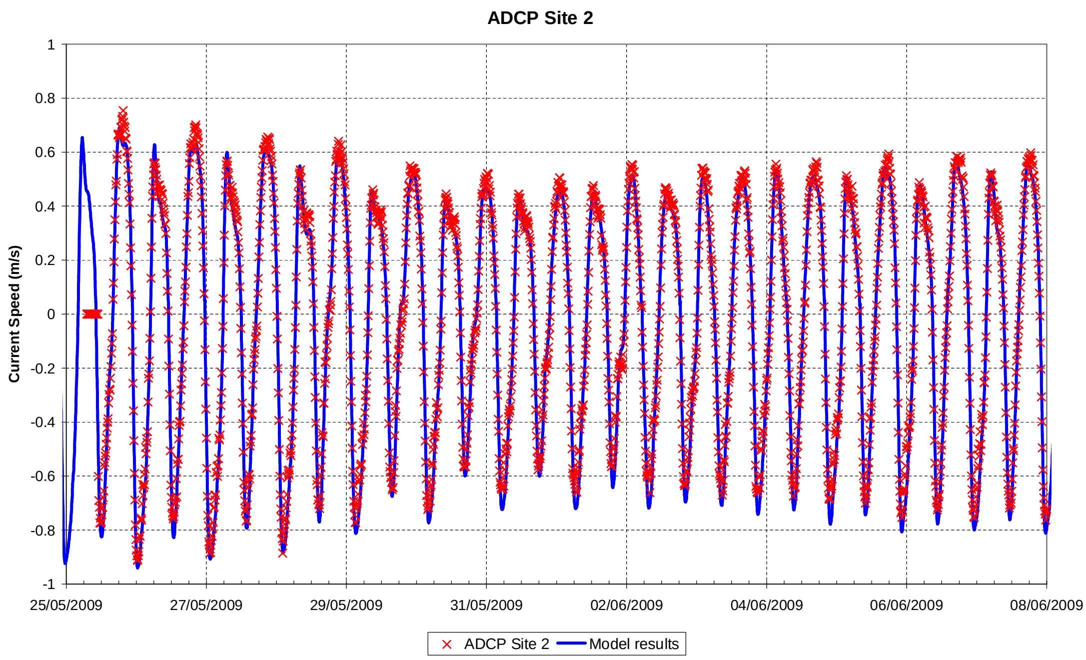

Figure 6-12 Current Speed – GHD ADCP Site 2, May 2009

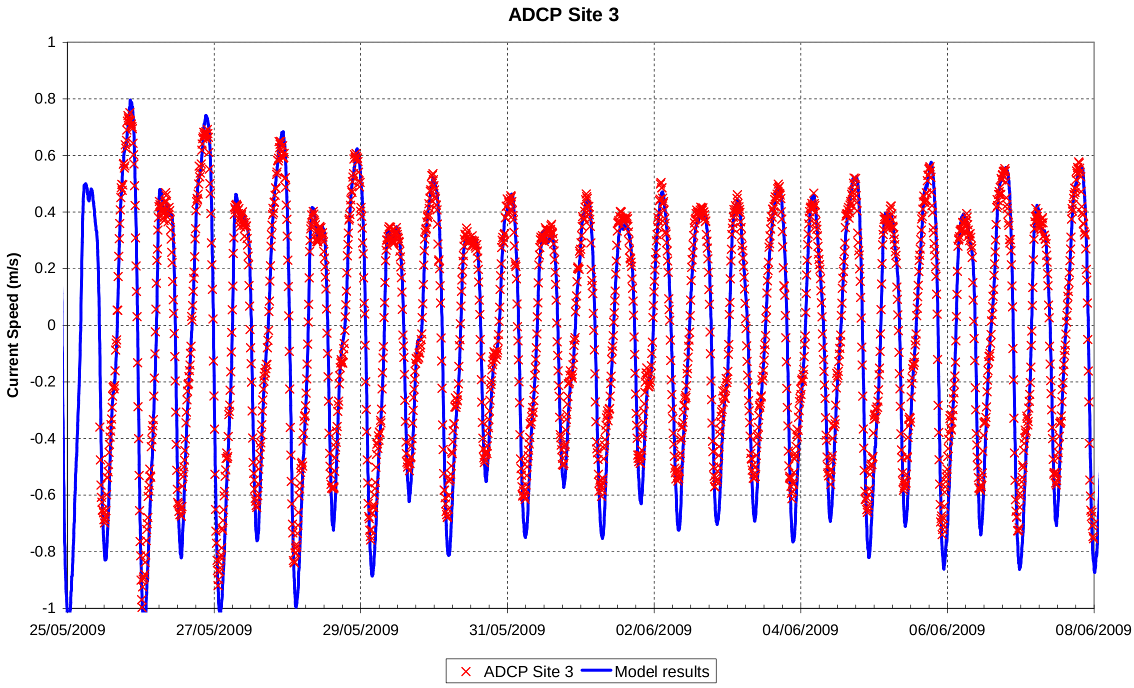

Figure 6-13 Current Speed – GHD ADCP Site 3, May 2009

6.7 Assumptions

6.7.1 Simulation Duration

All simulations were carried out for a two month period using tidal boundaries derived from data recorded in February and March 2009. The two month simulation period was chosen from a longer six month data set of recorded tides to include large spring tides and small neap tides which are likely to maximise potential impacts. The water levels at Auckland Point for this period are illustrated in Figure 6-14. It can be seen that this period includes large spring tides with ranges up to 4.55m at Auckland Point.

An analysis of longer term tide and wind data was also carried out to illustrate that the selected two month simulation period was representative for assessment purposes. Figure 6-15 illustrates the high tides and low tides and the associated tidal ranges for one year of data (1/07/2008 – 30/06/2009) recorded at the standard port gauge at Auckland Point (data source MSQ) which includes the selected two month simulation period (4/02/2009 – 3/4/2009) as indicated.

The tidal ranges have also been analysed for percentage occurrence and cumulative percentage occurrence for the whole year and the two month simulation period as presented in Figure 6-16.

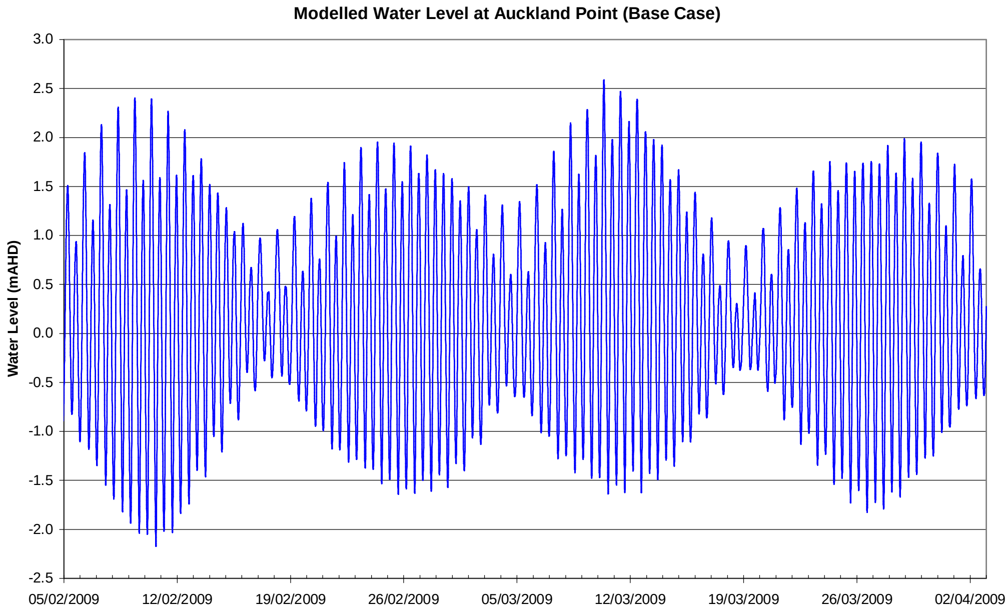

Figure 6-14 Simulation Period Water Levels – Auckland Point

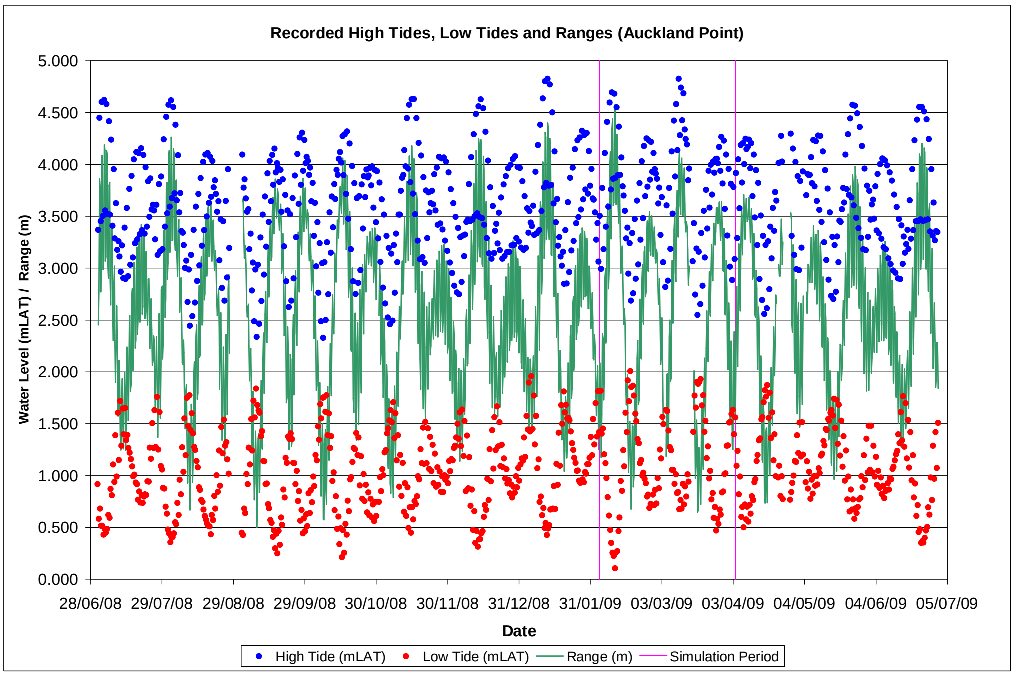

Figure 6-15 Annual Tidal Variations – Auckland Point (Data Source MSQ)

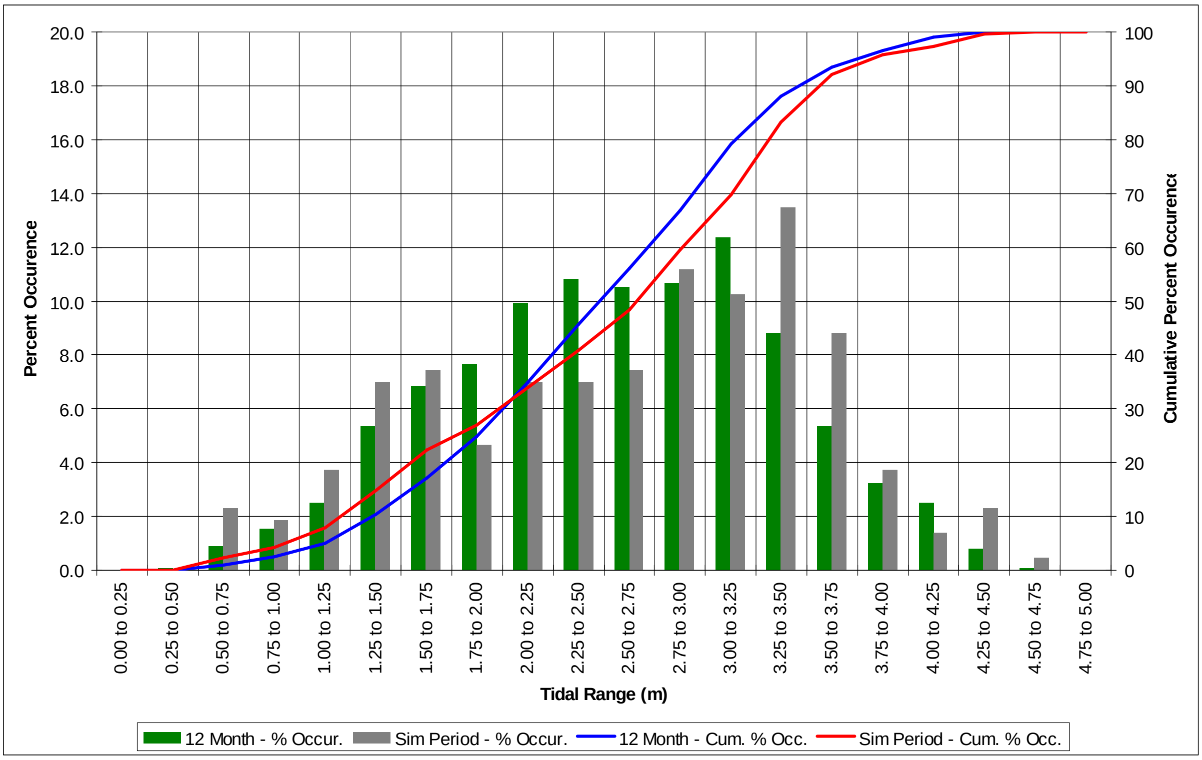

Figure 6-16 Tidal Range Occurrence Comparison - Auckland Point (Data Source MSQ)

It is noted that the two month simulation period includes:

- The largest range of the year;
- The lowest low tide of the year;
- The equal highest high tide of the year;
- Generally, a higher percentage of larger ranges (> 3.25m) than the 12 month period;
- A higher percentage of smaller ranges (< 1.75m) than the 12 month period; and
- A lower percentage of mid ranges (> 1.75m < 3.25m) than the 12 month period.

In general, it is considered that the two month simulation period chosen is representative for the purposes of impact assessment.

6.7.2 Additional Sensitivity Analysis

Additional model runs were performed using Scenario 3 (refer Section 6.8 for definition) in order to assess the sensitivity of the plume exceedance results to the two-month duration of the simulation and the six-week period of results used in the percentile calculation of results.

A six-month simulation corresponding to Scenario 3 was performed in order to address the former concern, with 10% exceedance levels calculated from all but the first two weeks of the simulation. The corresponding six-month simulation results are shown in Figure 4-18 of the Numerical Modelling Report (Appendix J) along with the sensitivity analysis difference. In this report, it can be seen that the two-month and six-month plume simulation results are almost identical, indicating that the percentile exceedance results are not being unduly biased by the simulation duration.

6.7.3 2D vs. 3D

The potential impacts of the proposed works on tidal hydraulics have been assessed with the calibrated and validated TUFLOW-FV model of Port Curtis. The base hydrodynamic model is two dimensional (2D) depth averaged, which is appropriate for the high-energy macro-tidal regime and predominantly well-mixed conditions of Port Curtis, as determined from analysis of field measurements and review of the characteristics of Port Curtis.

Support for the validity of the 2D modelling approach is offered in the form of:

- Evidence of thorough mixing through high tidal current speeds in the channels;
- Extensive wetting and drying of inter-tidal areas;
- An absence of stratification from temperature and salinity profiles collected in June 2009;
- Review of data from the bottom mounted ADCPs, which indicated general uniformity of current directions across the full depth, and current magnitudes fitting the logarithmic profile that would be expected in a fully-mixed boundary layer.

Further descriptions and discussion of this issue provided in the Numerical Model Validation and Calibration Report in Appendix J.

6.7.4 Influence of Wind and Waves

Currents within coastal waters can be driven by a combination of tide, wind and waves. In undertaking modelling of these waters, it is necessary to understand whether all three contribute in a meaningful manner, or whether only one or two of the driving forces are dominating.

Simulations were conducted with and without wind forcing, demonstrating that the overall hydrodynamic and flushing characteristics of the main channel areas are dominated by tide, with wind only having a small influence.

In addition, a no-wind (2-month) simulation corresponding to Scenario 3 (refer Section 6.8 for definition) was performed in order to assess the sensitivity of the dredge plume results to wind-induced circulations (Section 4.5 of the WBM modelling report, Appendix J). The sensitivity analysis presented in Appendix J suggests that in the absence of wind, a slight increase by up to 2mg/L (total suspended solids) is observed in the vicinity of the Fisherman’s Landing north source. There is also a slight increase in the vicinity of Boatshed Point.

The wave climate in the inner harbour area is dominated by locally generated wind waves, with there being negligible ocean swell penetration (Connell Hatch, 2006). Wave conditions are generally mild with significant wave heights being less than 0.5m for about 96% of the time and less than 0.3m for about 80% of time (BMT WBM, 2009). Even during extreme wave conditions, wave periods are typically less than 5s. Such short period waves would not be expected to significantly contribute to the forcing of currents within the inner harbour. Accordingly, coupling of the wave and hydrodynamic models has not been undertaken.

6.8 Scenarios Assessed

This section provides a summary of how scenarios have been defined in terms of (a) geographic locations, and (b) the type of work proposed at each location. Project stages are first defined, followed by the definition of dredging scenarios for the purposes of modelling. Dredging scenarios refer to which project stages will have been completed as part of the scenario.

Project stages are defined below, with “stage” being used to denote location rather than timing.

6.8.1 Base Case

The base case includes the following features:

- All existing channels, swing basins and berths;
- Dredging presently being undertaken for Fisherman’s Landing Berth 1 assumed as complete;
- Completion of the proposed ultimate dredging for the Wiggins Island Coal Terminal (WICT) project; and
- The existing Fisherman’s Landing reclamation.

6.8.2 Stage 1A Dredging

At the commencement of the dredging Project, it has been assumed that the Western Basin Reclamation bund is fully constructed. In addition, dredging will commence in the Clinton Bypass Channel and China Bay. Hence, Stage 1A may be defined as follows:

Base case plus:

- Western Basin Reclamation bund fully constructed;
- Clinton Bypass Channel dredged to 200 m wide at -13 m LAT;
- Spur Channel to China Bay dredged to 200 m wide at -13 m LAT; and
- China Bay Swing Basins (2) dredged to 600 m wide at -13 m LAT.

6.8.3 Stage 1B Dredging (Stage 1)

For the early part of Stage 1B, the following works are planned.

Stage 1A plus:

- Targinie Channel 180 m wide at -10.6 m LAT;
- Fisherman’s Landing Bulk Liquids Wharf Swing Basin 550 m wide at -10.6 m LAT; and
- Fisherman’s Landing Bulk Liquids Wharf Swing Berth to 430 m long at -12.5 m LAT.

6.8.4 Stage 1B Dredging (Fully Developed)

Stage 1B will be completed through dredging of the following:

- Targinie Channel 180 m wide at -13.0 m LAT;
- Fisherman’s Landing Swing Basin 650 m wide at -13.0m LAT; and
- Fisherman’s Landing Bulk Liquids Wharf Swing Berth to 430 m long at -13.0 m LAT.

6.8.5 Stage 2 Dredging

- Channel extension to Laird Point 200 m wide at -13m LAT;
- Laird Point Swing Basin approx 600 m wide at -13m LAT; and
- Western Basin reclamation bund fully constructed.

6.8.6 Stage 3 Dredging

- Berth and Swing Basins to Laird Point 400 m wide (total 600 m) at -13m LAT; and
- Western Basin reclamation bund fully constructed.

6.8.7 Stage 4 Dredging

- China Bay and Hamilton Point additional Swing Basins and Departure Areas at -13 m LAT; and
- Western Basin reclamation bund fully constructed.

6.8.8 Modelling Scenarios

Model scenarios have been created using a combination of the above stages. Hence, there are only four modelling scenarios for which the potential impacts to water levels, velocities, flushing, sediment and plumes have been assessed. These are summarised in Table 6-3.

Table 6-3 Modelling Scenarios

Scenario	Dredging
Base Case	Existing Channels Present Fisherman's Landing Berth 1 Ultimate Wiggins Island Coal Terminal Existing Fisherman's Landing reclamation
Scenario 1 (Base +)	Stage 1A Stage 1B (Stage 1) Western Basin reclamation fully constructed
Scenario 2 (Base +)	Stage 1A Stage 1B (fully developed) Stage 2 Western Basin reclamation fully constructed
Scenario 3 (Base +)	Stage 1A Stage 1B (fully developed) Stage 2 Stage 3 Stage 4 Western Basin reclamation fully constructed

The scenarios defined above are each based on application of the calibrated hydrodynamic model, with the only changes to each scenario comprising bathymetric changes to represent the proposed dredging activity associated with each scenario.

Discussion of the results of modelling are presented initially in the Numerical Modelling report (Appendix J), and then further in terms of implications in the Coastal Processes assessment (Chapter 7 and Appendix M) and the Water Quality Report (Chapter 9 and Appendix K).