Assessing the impact of sewage overflows on oyster harvest areas: Tweed River estuary technical summary

WRL TR 2023/18, May 2025

By Y Doherty, M Mason, A J Harrison and B M Miller

UNSW Water Research Laboratory

UNSW SYDNEY

UNSW Water Research Laboratory

UNSW SYDNEY

Assessing the impact of sewage overflows on oyster harvest areas: Tweed River estuary technical summary

WRL TR 2023/18, May 2025

By Y Doherty, M Mason, A J Harrison and B M Miller

Project details

Report title	Assessing the impact of sewage overflows on oyster harvest areas: Tweed River estuary technical summary
Authors(s)	Y Doherty, M Mason, A J Harrison and B M Miller
Report no.	2023/18
Report status	Final
Date of issue	May 2025
WRL project no.	2021101
Project manager	A J Harrison
Client	Department of Regional NSW
Funding acknowledgement	This study was funded through a Department of Regional NSW Storm and Flood Industry Recovery Program (SFIRP) – Sector Recovery and Resilience Grant with support from local councils and wastewater authorities

Document status

Version	Reviewed by	Approved by	Date issued
Draft	BMM	FF	12/03/25
Final	BMM	FF	26/05/25

This report should be cited as: Doherty, Y, Mason, M, Harrison, AJ and Miller, BM 2025, Assessing the impact of sewage overflows on oyster harvest areas: Tweed River estuary technical summary, WRL Technical Report 2023/18, UNSW Water Research Laboratory.

UNSW
Water Research Laboratory

www.wrl.unsw.edu.au
110 King St Manly Vale NSW 2093 Australia
Tel +61 (2) 8071 9800 ABN 57 195 873 179

This project has been funded under the Storm and Flood Industry Recovery program, jointly funded by the Australian and NSW governments. Although funding for this project has been provided by both Australian and NSW governments, the material contained herein does not necessarily represent the views of either government.

Australian Government

NSW GOVERNMENT

Contents

1 Introduction **1**
1.1 Project overview 1
1.2 Report context 1
1.3 Tweed River site description 2
1.4 About this report 3
2 Data collation **5**
2.1 Preamble 5
2.2 Water level and tidal flow gauging 5
2.3 Catchment inflows 8
2.4 Sewage overflow data 9
2.5 Bathymetry 10
2.6 Existing model 15
3 Model development **17**
3.1 Preamble 17
3.2 Model mesh development 17
3.3 Model bathymetry 18
3.4 Model boundaries 18
3.5 Hydrodynamic calibration and verification 22
3.5.1 February 1988 calibration period 22
3.5.2 February 2015 verification period 24
3.5.3 September 2019 verification period 25
3.5.4 Roughness coefficients 25
3.6 Water quality model development 26
3.6.1 Modelling of dispersion in RMA-11 26
3.6.2 Tidal straining and vertical velocity distribution 26
3.7 Limitations for future model uses 27
4 Scenario modelling **28**
4.1 Preamble 28
4.2 Overflow locations 28
4.3 Environmental variables 29
4.3.1 Stage of the tide 30
4.3.2 Catchment inflows 30
5 Conclusion **31**
6 References **32**
Appendix A Data collation **A-1**
A1 Bathymetric change A-1
Appendix B Model calibration **B-1**
B1 Hydrodynamic calibration and verification results B-1
B1.1 Tidal flow gauging calibration – 1988 B-2
B1.2 Water level calibration – 1988 B-4
B1.3 Water level verification – 2015 B-7
B1.4 Water level verification – 2019 B-11

List of tables

Table 1-1 Summary of project reference documents 1
Table 1-2 Summary of estuary specific reports 2
Table 2-1 Summary of data collated for this project 5
Table 2-2 Summary of water level gauges in Tweed River estuary and relevant ocean tide gauges 6
Table 2-3 Summary of tidal flow gauging locations in Tweed River estuary 6
Table 2-4 Summary of scaling factors for model catchment boundaries 8
Table 2-5 WaterNSW gauge flow percentiles 8
Table 3-1 Mannings n roughness coefficients of the final model 26
Table 4-1: Model stage of tide timing relative to the MHL water level gauges 30

List of figures

Figure 1-1 Oyster harvest areas in Tweed River estuary 4
Figure 2-1 Water level and tidal flow gauging locations 7
Figure 2-2 Catchment flow gauging stations* 9
Figure 2-3 Locations of reported sewage overflows on the Tweed River estuary 10
Figure 2-4 Coverage of 2018 LiDAR survey 12
Figure 2-5 Coverage of 2000 single beam survey 13
Figure 2-6 Bathymetry difference between 2000 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion 14
Figure 2-7 Tucker et al. (2023) RMA-2 model mesh geometry extent 16
Figure 3-1 Overview of modelling approach 17
Figure 3-2 RMA model mesh showing boundary condition locations 19
Figure 3-3 RMA model bathymetry (Barneys Point Bridge to Tweed Heads) 20
Figure 3-4 Full extent of RMA model bathymetry 21
Figure 3-5 1988 tidal flow calibration – Location A – Tweed Heads Entrance 22
Figure 3-6 1988 tidal flow calibration – Location B – Terranora Entrance 23
Figure 3-7 1988 tidal flow calibration – Location C – Letitia 23
Figure 3-8 1988 water level calibration – Location 1 – Tweed Heads 24
Figure 3-9 1988 water level calibration – Location 4 – Dry Dock 24
Figure 3-10 2015 water level calibration – Location 4 – Dry Dock 25
Figure 3-11 2019 water level calibration – Location 4 – Dry Dock 25
Figure 4-1 Modelled overflow locations in the Tweed River estuary 29

1 Introduction

1.1 Project overview

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Sydney was engaged to undertake an extensive study titled "Assessing the impact of sewage overflows on oyster harvest areas in NSW". This study was funded through a Department of Regional NSW Storm and Flood Industry Recovery Program (SFIRP) – Sector Recovery and Resilience grant with support from local councils and wastewater authorities.

The study seeks to understand the fate of contaminants and the potential exposure of oyster leases following overflow events under different environmental conditions including tides, wind and catchment runoff. The results of this study provide decision makers with quantitative data to assess exposure risk to specific harvest areas on an individual sewer overflow event basis. These outcomes allow for increased confidence in ensuring consumer safety, and more targeted harvest area closures to reduce the economic impact of widespread closures on local industry.

Sewage overflows into estuaries occur under a range of conditions, often due to malfunctioning or overwhelmed infrastructure. As a result, the environmental conditions in the estuary at the time of an overflow can vary. While experimental data (such as large scale dye release experiments) can be useful to understand contaminant transport in a single set of conditions (or a small number of conditions), it is impractical to collect such data for the broad range of conditions possible across multiple sewage overflow locations. Therefore, the approach of this study is to combine desktop numerical modelling and site-specific field investigations as a cost-effective means to gain sufficient understanding of contaminant transport.

For a detailed background to the study, refer to the User Guide (WRL TR2024/26).

1.2 Report context

This report is focussed on the Tweed River estuary. It provides technical details of the available data, data collection undertaken, model development and the capabilities of the predictive model.

This report provides specific details for the Tweed River estuary and should be read in parallel with User Guide WRL TR2024/26 and Technical Summary Report WRL TR2023/32 (Table 1-1). The other reports for each specific estuary are listed in Table 1-2.

Table 1-1 Summary of project reference documents

Report number	Intention
WRL TR2024/26	Project overview and user guide
WRL TR2023/32	Technical summary of fieldwork and modelling methods

Table 1-2 Summary of estuary specific reports

Estuary	Technical summary
Tweed River	WRL TR2023/18 (this report)
Nambucca River	WRL TR2023/19
Hastings River	WRL TR2025/05
Camden Haven River	WRL TR2023/20
Wallis Lake	WRL TR2023/21
Port Stephens	WRL TR2023/22
Clyde River	WRL TR2023/24
Shoalhaven/Crookhaven Rivers	WRL TR2023/23
Wagonga Inlet	WRL TR2023/25
Merimbula Lake	WRL TR2023/26
Pambula Lake	WRL TR2023/27

1.3 Tweed River site description

The Tweed River estuary is a large estuary in the Northern Rivers region of NSW, Australia. Adjacent to the Gold Coast and the Queensland border, the entrance to the Tweed River is 670 km north of Sydney. Towns in the catchment area of the Tweed River include Tweed Heads, Fingal, Chinderah, Condong, Murwillumbah and Tyalgum. The estuary system is comprised of two main branches which join 2 km upstream of the entrance at Ukerebagh Island: Terranora Creek and Tweed River. The Terranora Creek arm continues 8 km upstream into the shallow Cobaki and Terranora Broadwaters, while the Tweed River arm continues over 30 km upstream past Murwillumbah along the Rous and Tweed Rivers. The estuary waterway area is 22 km^2 and the tidal prism is approximately 13.5 x 10^6 m^3 (MHL, 2016).

The entrance channel to the estuary system is heavily modified and was first stabilised with rock armour units in the 1890s. Between 1962 and 1964, the entrance breakwaters were extended an additional 300 m offshore to their present position. The width between the breakwaters at the heads is approximately 150 m. Significant stabilisation works are present along the banks of the Tweed River and Terranora Creek. The estuary has one oyster harvest area: Tweed River which is located in the Terranora Broadwater. Key locations are shown in Figure 1-1.

1.4 About this report

This report includes the following sections:

- **Section 2: Data collation** – summarising the relevant existing data available to assist in calibration and verification of the numerical model of the estuary, including information on historical sewage overflow locations.
- **Section 3: Model development** – outlining the development of the numerical model of the estuary.
- **Section 4: Scenario modelling** – describing the suite of scenarios run for the estuary.

The following appendices are included which provide additional detail:

- **Appendix A: Data collation**
- **Appendix B: Model calibration**

Figure 1-1 Oyster harvest areas in Tweed River estuary

2 Data collation

2.1 Preamble

Table 2-1 summarises the preexisting available data relevant for development of the numerical hydrodynamic and water quality model.

Table 2-1 Summary of data collated for this project

Data type	Primary sources	Comments	Report section
Long term water level data	MHL (2023a) MHL (2023b)	Ten long term water level gauges in Tweed River estuary and an ocean tide gauge at Tweed Heads.	2.2
Tidal flow and water level	MHL (1988)	Tidal flow gauging at five locations and water level data at seven locations in February 1988.	2.2
Catchment discharge	WaterNSW (2023)	Four flow monitoring stations within the Tweed River estuary catchment.	2.3
Sewage overflows	NSW Food Authority	Data provided on overflows reported to EPA and NSW Food Authority including closure action pursued, spill duration and volume.	2.4
Bathymetry	DPIE (2018) OEH (1995); OEH (2000); OEH (2011); OEH (2014); OEH (2016) NSW Spatial Services (2012) NAVONICS (2023) NearMap (2024)	Bathymetry primarily sourced from 2018 marine LiDAR survey with supplementary data from OEH single beam surveys, 2012 Digital Elevation Model (DEM), NAVONICS SonarChart and NearMap aerials.	2.5

2.2 Water level and tidal flow gauging

Manly Hydraulics Laboratory (MHL) maintain ten permanent water level gauges on the Tweed River estuary, and one ocean tide gauge at the Tweed Entrance. Further water level and flow gauging has occurred during four MHL short-term data collection campaigns in 1975, 1980 and 1988. Additional MHL gauging of a flood event is also available from 1980. Due to ongoing hydrodynamic changes to the system associated with routine dredging of the Tweed Entrance, only the 1988 study was considered for model calibration purposes in this study. Flow gauging and water level sensor details used in this study are tabulated in Table 2-2 and Table 2-3. A map of MHL water level sensor and flow gauging locations is presented in Figure 2-1.

Table 2-2 Summary of water level gauges in Tweed River estuary and relevant ocean tide gauges

Water level gauge	Location label	Station number	Provider	Date range	MHL report number
Tweed Heads Offshore	-	201450	MHL	1982 – 2019	
Tweed Heads	1	201431	MHL	1987 – 2015	
Tweed Entrance South	2	201472	MHL	2014 – present	
Letitia	3	201429	MHL	1987 – present	-
Dry Dock	4	201428	MHL	1987 – present	-
Cobaki	5	201448	MHL	1987 – present	-
Terranora	6	201447	MHL	1987 – present	-
Barneys Point	7	201426	MHL	1987 – present	-
Tumbulgum	8	201432	MHL	1985 – present	-
North Murwillumbah	9	201420	MHL	1987 – present	-
Murwillumbah	10	201465	MHL	2002 – present	-
Bray Park Weir	11	201455	MHL	2002 – present	-
Kynnumboon	12	201422	MHL	1990 – present	-

Table 2-3 Summary of tidal flow gauging locations in Tweed River estuary

Tidal flow gauge	Location label	date	study
Tweed Heads Entrance	A	17/02/1988	MHL550*
Terranora Entrance	B	17/02/1988	MHL550*
Letitia	C	17/02/1988	MHL550*
Fingal Head	D	17/02/1988	MHL550*
Barneys Point Bridge	E	17/02/1988	MHL550*

* Report MHL550 is not available in pdf form and data is not available digitally. Flow values were manually digitised from the 2015 OEH Tidal Data Compilation report MHL2362.

Figure 2-1 Water level and tidal flow gauging locations

2.3 Catchment inflows

Gauged catchment inflows were available from WaterNSW. When these were not at the tidal limit (the model boundary), the flows were scaled up proportional to the additional catchment area using the method in WRL TR2023/32 Section 2.4. There are six model boundary inflows into the Tweed River estuary and continuous flow gauging of discharge and water levels are available from WaterNSW (2023) at four relevant locations: Rous River at Boat Harbour 3 (1957 to present), Tweed River at Uki (1937 to present), Oxley River at Eungella (1947 to present) and Cobaki Creek at Cobaki (1982 to present). Table 2-4 lists the model boundaries, the gauges used and the relevant scaling factor applied. Figure 2-2 shows the locations along with the catchment area flowing into each tidal boundary (solid line polygon) along with the associated portion of that catchment that is upstream of each gauge (hatched).

Table 2-4 Summary of scaling factors for model catchment boundaries

Model boundary	Base WaterNSW gauge	Scaling factor
Piggabeen Creek*	201012	1.28
Cobaki Creek	201012	1
Bilambi Creek*	201012	2.19
Duroby Creek*	201012	1.24
Tweed River	201001 & 201900	1.52 & 1.0
Rous River	201005	1.02

*This catchment was ungauged, so the gauge in the nearby Cobaki Creek catchment was scalled and used.

Flowrates exceeded at various percentiles for each WaterNSW gauge are shown in Table 2-5.

Table 2-5 WaterNSW gauge flow percentiles

Percentile	Cobaki Creek at Cobaki (201012) ML/d *(m^3/s)*	Rous River at Boat Harbour 3 (201005) ML/d *(m^3/s)*	Tweek River at Uki (201900) ML/d *(m^3/s)*	Oxley River at Eungella (201001) ML/d *(m^3/s)*
5th	0.26 *(0.0)*	5.6 *(0.06)*	12 *(0.14)*	9.0 *(0.10)*
20th	1.5 *(0.02)*	22 *(0.25)*	26 *(0.3)*	32 *(0.37)*
50th (median)	5.4 *(0.06)*	84 *(0.97)*	92 *(1.1)*	132 *(1.5)*
80th	22 *(0.26)*	335 *(3.9)*	502 *(5.8)*	628 *(7.3)*
95th	93 *(1.1)*	1889 *(22)*	3242 *(38)*	3476 *(40)*

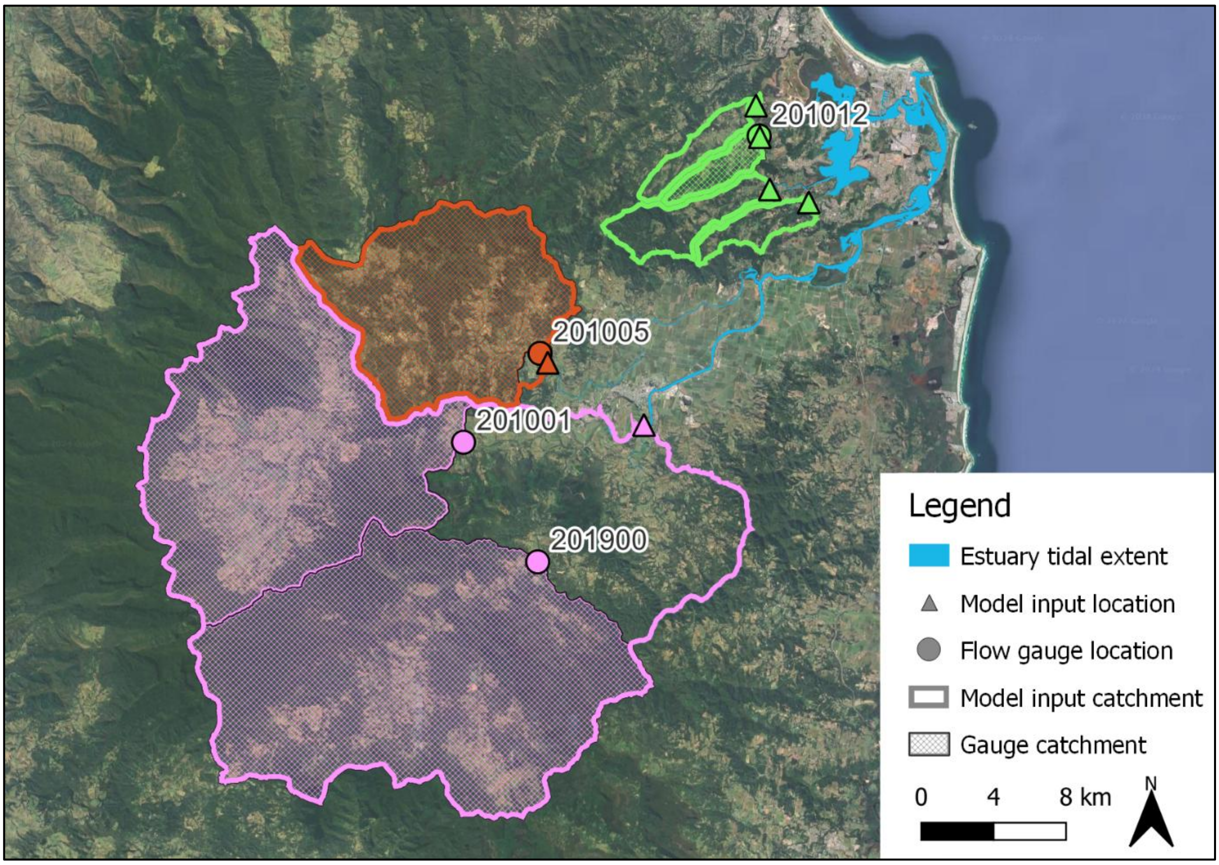

Figure 2-2 Catchment flow gauging stations*

*Hatched areas correspond to upstream catchments of WaterNSW gauges. Outline areas correspond to model input catchment areas. The colour of each outline corresponds to the WaterNSW gauge used for flow scaling.

2.4 Sewage overflow data

Tweed Shire Council (TSC) is the agency responsible for wastewater treatment and sewage management in the catchment surrounding the Tweed River estuary. The sewerage system is comprised of a reticulation network of pipes and sewage pumping stations (SPS), in addition to wastewater treatment plants (WWTPs) at Tyalgum, Uki, Murwillumbah, Tumbulgum, Kingscliff and Banora Point. When sewage overflows occur, TSC is required to notify NSW Food Authority so that appropriate decisions can be made on whether harvest area closures are necessary. Information on sewage overflows between 2016 and 2023 has been provided by the NSW Food Authority and reported overflow locations are shown in Figure 2-3. More information on sewage overflows and why they occur is provided in WRL TR2023/32 Section 2.5.

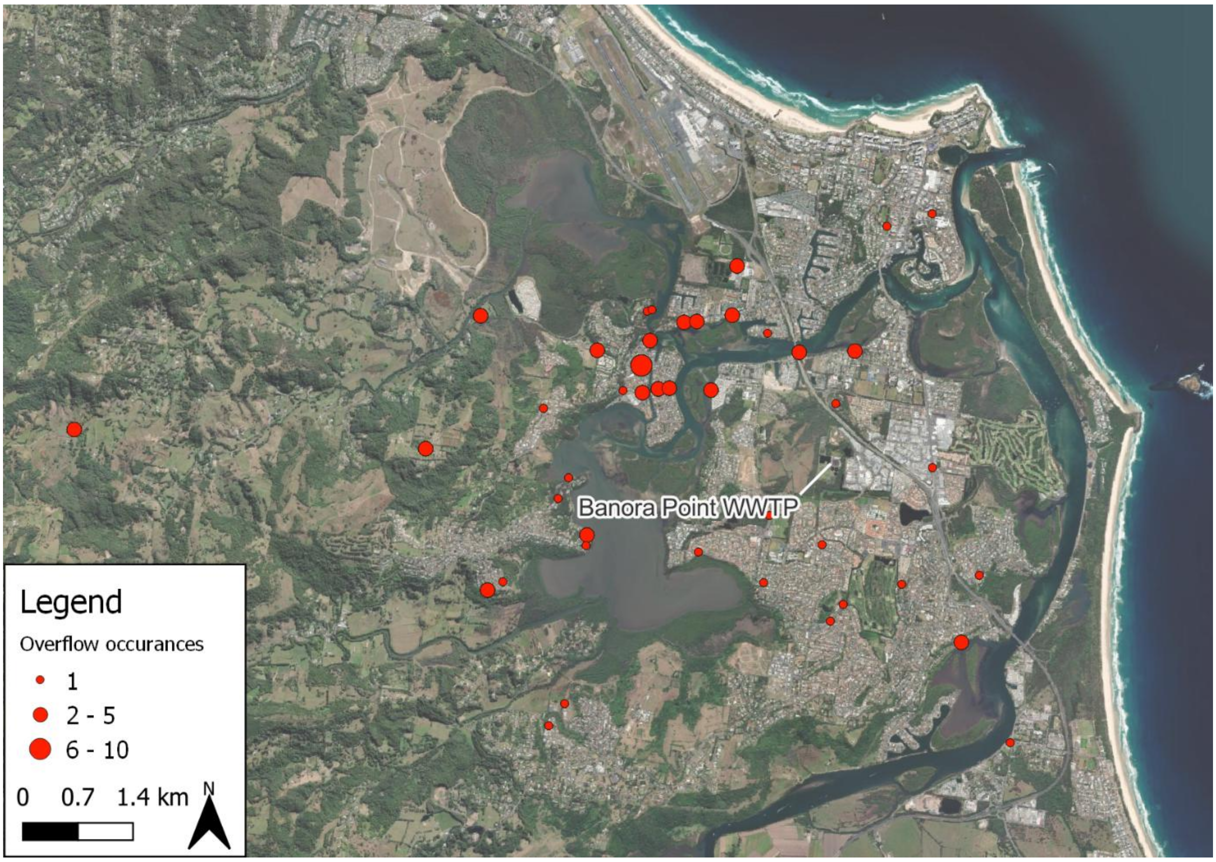

Figure 2-3 Locations of reported sewage overflows on the Tweed River estuary

2.5 Bathymetry

Two existing bathymetry datasets were sourced for this project:

- Coastal marine LiDAR collected by the former NSW Department of Planning, Industry and Environment (now DCCEEW) in 2018. In the Tweed River estuary region, this survey covers areas up to 3 km from of the coast at a resolution of 5 m and corresponds to all regions seaward of the Pacific Highway (shown in Figure 2-4). This is the most recent and detailed survey and was used as the preferred bathymetry source for all regions of the mesh covered by the survey extent.
- Single beam bathymetry data collected in 1995, 2000, 2011, 2014 and 2016. These datasets were collated and provided by the NSW Office of Environment and Heritage (OEH, now DCCEEW) and is available on the Australian Ocean Data Network (AODN) portal. The 2000 survey is the most extensive and was primarily utilised for this project. This 2000 data was collected as a series of transects which cover the estuary with 20 m spacing (refer to Figure 2-5). In Terranora Creek, this survey extends between the confluence with the Tweed River, to the confluence with Cobaki Creek. In the Tweed River, the survey extends from the entrance to 2 km downstream of Tumbulgum. This dataset was used in regions not covered by the marine LiDAR. The OEH surveys completed in 1995, 2011, 2014 and 2016, only cover regions already covered by the 2018 LiDAR survey.

For areas where the 2000 single beam survey overlapped with the 2018 marine LiDAR extent, the difference in depth was investigated (refer to Figure 2-6). Covering all regions inland of the Pacific Highway, 51% of the sampled readings had a difference of < 50 cm, while the remaining 49% mostly varied by 0.5 to 3.5 m. The mean change was a deepening of 0.25 m, with a standard deviation of 0.9 m. By comparing NearMap (2024) imagery through time and for the years' corresponding to the bathymetric surveys, it is evident that the sand shoals within the Tweed River and Terranora Creek are mobile and constantly fluctuate. These variations depend on driving factors including entrance depth, oceanic tide, river inflows, flood events and dredging activity.

Although a net deepening was observed between 2000 and 2018, it may be that the sand bars and shoals are in a state of dynamic equilibrium with long-term trends. Yearly tidal analyses performed by MHL since 2017 to assess the effects of the Tweed sand bypass state that no significant morphological changes leading to changes in tidal response have occurred since 2017 (MHL, 2018; MHL, 2019; MHL, 2020; MHL, 2021). For figures of bathymetric change between the 2018 LiDAR and OEH surveys from 1995, 2011, 2014 and 2016, refer to Appendix A1.

Additional bathymetric, topographic, and aerial data utilised include:

- 1 x 1 m DEM LiDAR data, collected in 2012 and available from NSW Spatial Services, was used for shallow areas inland of the extent of the 2018 LiDAR survey, provided they were above water level during the 2012 survey.
- NAVONICS SonarChart™ was utilised for qualitative verification of model bathymetry. This was primarily used to assess whether model bathymetry was capturing the location and geometry of complex features not fully captured by single depth soundings such as shallow reefs, abrupt drop-offs, and river confluences.
- High resolution NearMap imagery was used to qualitatively provide information on important bathymetric features.

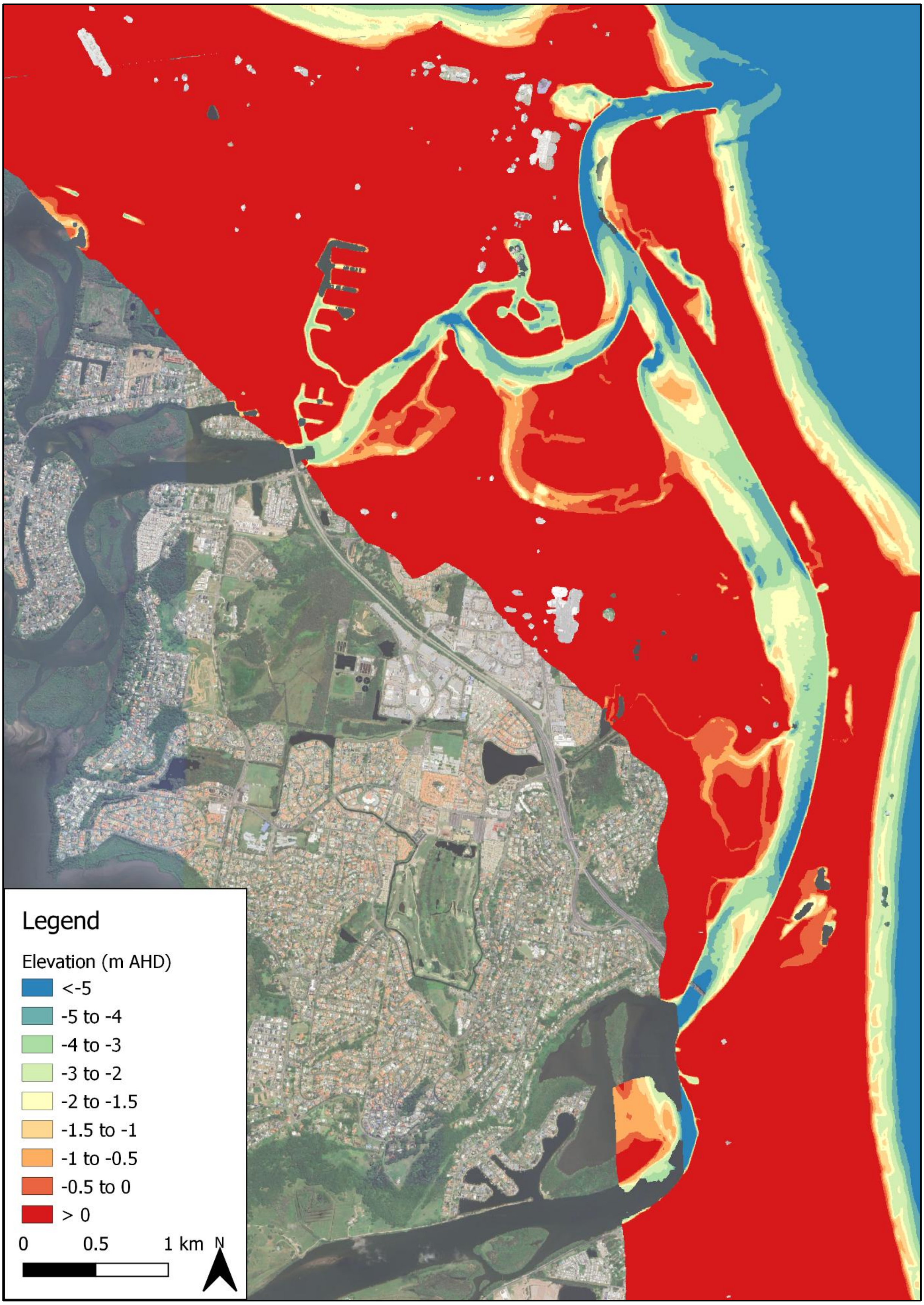

Figure 2-4 Coverage of 2018 LiDAR survey

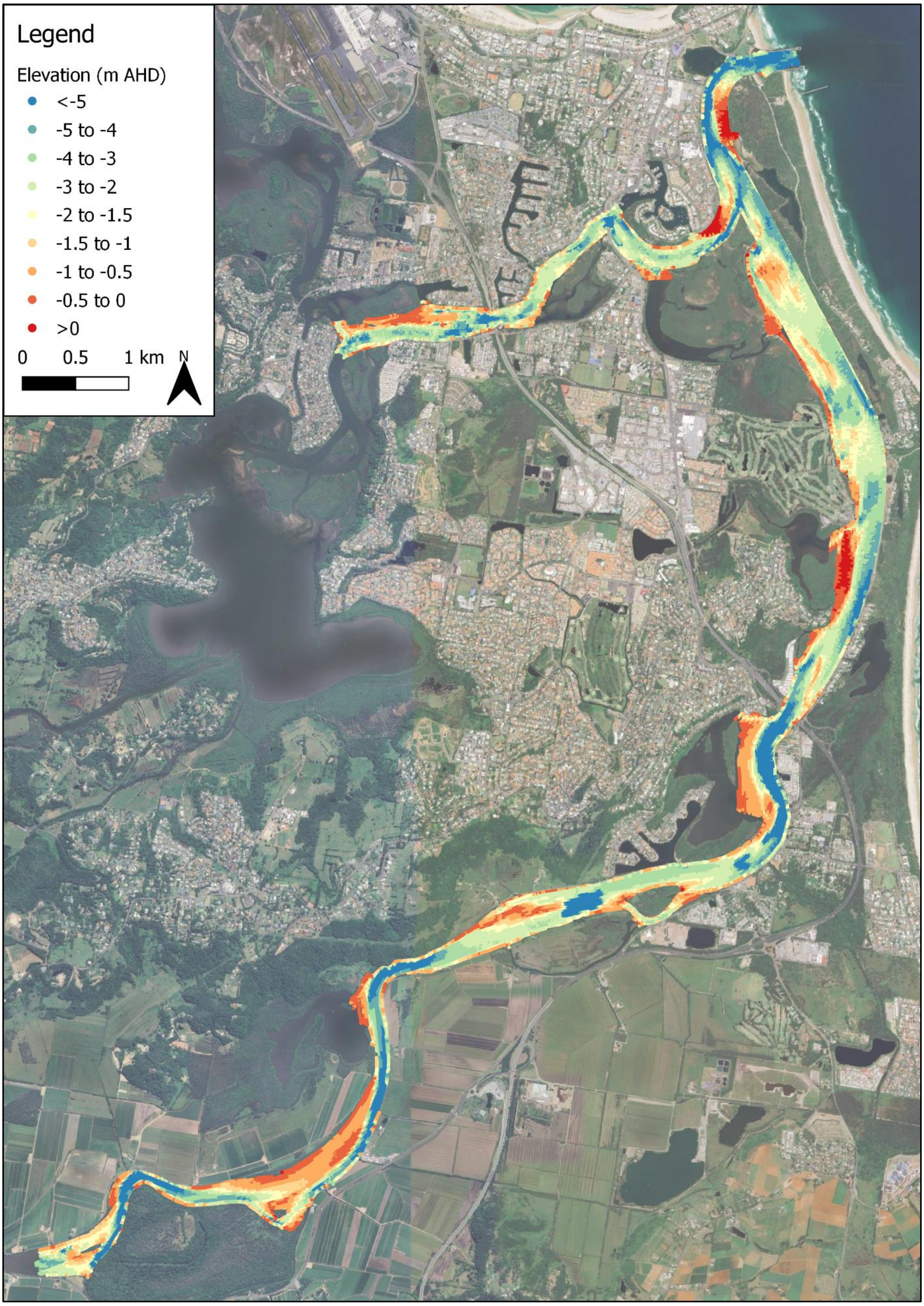

Figure 2-5 Coverage of 2000 single beam survey

Figure 2-6 Bathymetry difference between 2000 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion

2.6 Existing model

The Tucker et al. (2023) produced an RMA-2 hydrodynamic model of the Tweed River estuary for the NSW Department of Primary Industries (DPI) as part of a Tweed River floodplain prioritisation study, for understanding the impact of sea level rise on floodplain drainage. This model mesh was used in the initial model development, however additional model area was added to the Cobaki and Terranora Broadwater regions adjacent to the Tweed River oyster harvest area. Further refinements were made to model resolution and bathymetry to increase model stability for water quality modelling of sewage overflow events. A map showing the extent of the existing Tweed River RMA model is shown in Figure 2-7.

The oyster industry in the Tweed River is substantially smaller than in other systems considered in this project, and is located in an isolated location which was already considered high risk from overflows due to the proximity to a large urban population. For this reason, as well as the pre-existence of a calibrated hydrodynamic model of the Tweed River estuary, no additional field data was collected for this location, as it was anticipated to be relatively well understood that most overflows would have a significant impact on the area.

Figure 2-7 Tucker et al. (2023) RMA-2 model mesh geometry extent

3 Model development

3.1 Preamble

The model used for this project consists of both a hydrodynamic and a water quality model. After initial refinement to the preexisting model, the model was iteratively refined through calibration based on the MHL data collection campaign from 1988. Model water level verification was performed for 2015 and 2019 using the permanent MHL water level gauge data. The hydrodynamic model was then used as an input for the water quality model. This model was informed by dye release experiments and was then used to run sewage overflow scenarios. A schematic of this process can be seen in Figure 3-1. For a detailed overview of the model development used for the broader project, refer to WRL TR2023/32 Sections 6 and 7.

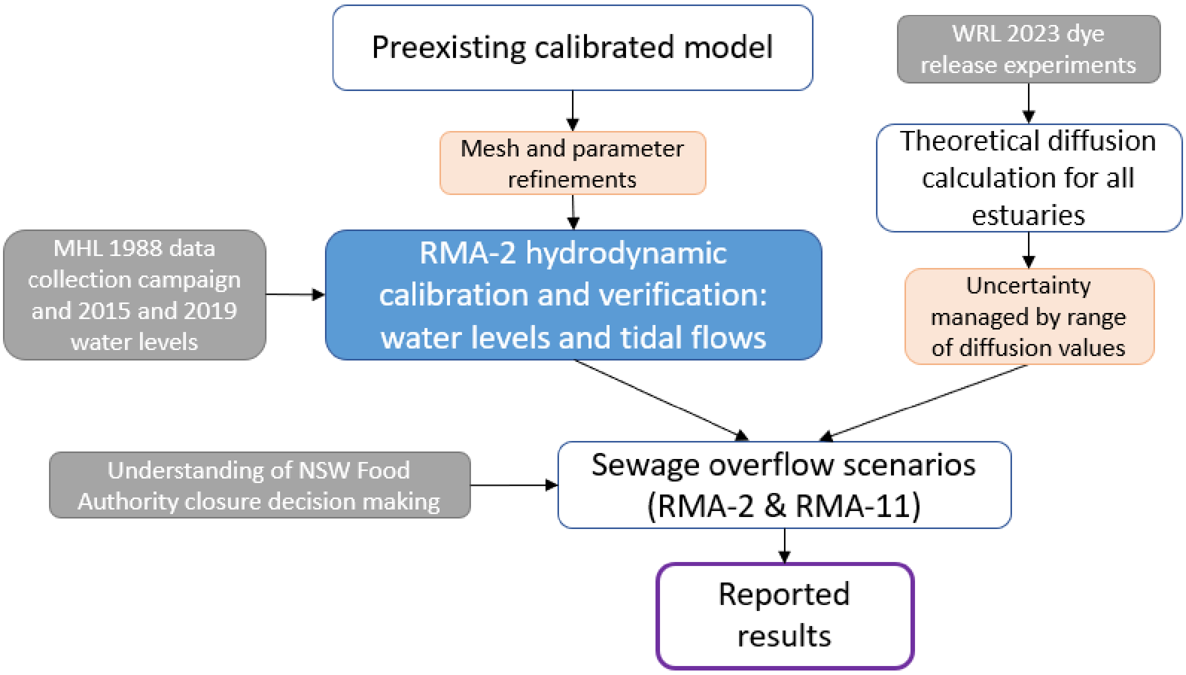

Figure 3-1 Overview of modelling approach

3.2 Model mesh development

The model domain extends from approximately 500 m offshore of the Tweed Entrance breakwater, to the tidal limits of the estuary and its major tributaries (refer to Figure 3-2). The model mesh consists of over 12,100 nodes and 4,800 elements varying in size from 25 m^2 to over 45,000 m^2. A two-dimensional, depth averaged model mesh was chosen for the Tweed River, where advective transport is largely driven by tidal and riverine flow (not wind). A discussion on the impact of model dimensionality is provided in WRL TR2023/32 Section 6.2.2.

Mesh resolution is highest near the entrance and on sharp bends in the lower estuary, with lower resolution and one-dimensional elements in the upper reaches of both the Terranora Creek and Tweed River arms. Refer to WRL TR2023/32 Section 6.2.3 for a discussion of model resolution.

3.3 Model bathymetry

Model bathymetry was based on the sources discussed in Section 2.5 and primarily utilised the 2018 DPIE (now DCCEEW) coastal marine LiDAR topo-bathy survey for the lower estuary. For regions outside of the LiDAR extent, the OEH 2000 single beam survey was used. The bathymetry from the existing model mesh was used for locations upstream of the extent of the OEH survey. NAVONICS (2023) SonarChart™ and NearMap imagery were used to inform sand bar bathymetry and channel edge locations in areas where no additional data was available. The NSW Spatial Services 1 m resolution DEM (2012) was used for shallow intertidal regions. Although the channel at Tweed Entrance and scour regions on sharp bends and constrictions are up to 12 m deep, the main channels of Terranora Creek and Tweed River generally vary from 3 to 6 m. The model bathymetry and nodal bed elevations for the lower estuary are shown in Figure 3-3 and Figure 3-4.

Estuaries are dynamic systems and bathymetric changes through time will alter water levels, velocities, and tidal flows for the same set of boundary conditions. The Tweed River estuary has a trained river entrance, which prevents significant short-term changes in the entrance conditions. However, the sand bars and shoals within the lower estuary are mobile and fluctuate depending on driving conditions (refer to Section 2.5). Despite this, a single bathymetry was developed for this model, and used for all model runs. This was shown to result in reasonable model calibration and verification for water levels and flow across the main channel, discussed further in Section 3.5.

3.4 Model boundaries

The model includes six upstream catchment flow boundaries, shown in Figure 3-2 and discussed in Section 2.3. A tidal elevation boundary was included in the model offshore of the Tweed heads (refer to Figure 3-2). This modelled water level boundary was based on observed tidal elevation data collected by MHL at Tweed Entrance South (station number 201472). The Tweed Heads (station number 201431) gauge was used as a boundary condition for models run before the installation of the Tweed Entrance South gauge in 2014. This data was smoothed to remove signal noise and increase model stability. For modelling water quality scenarios, all boundaries (upstream and ocean) were set to a constant constituent concentration of zero (e.g. no pollutant inflows from these boundaries).

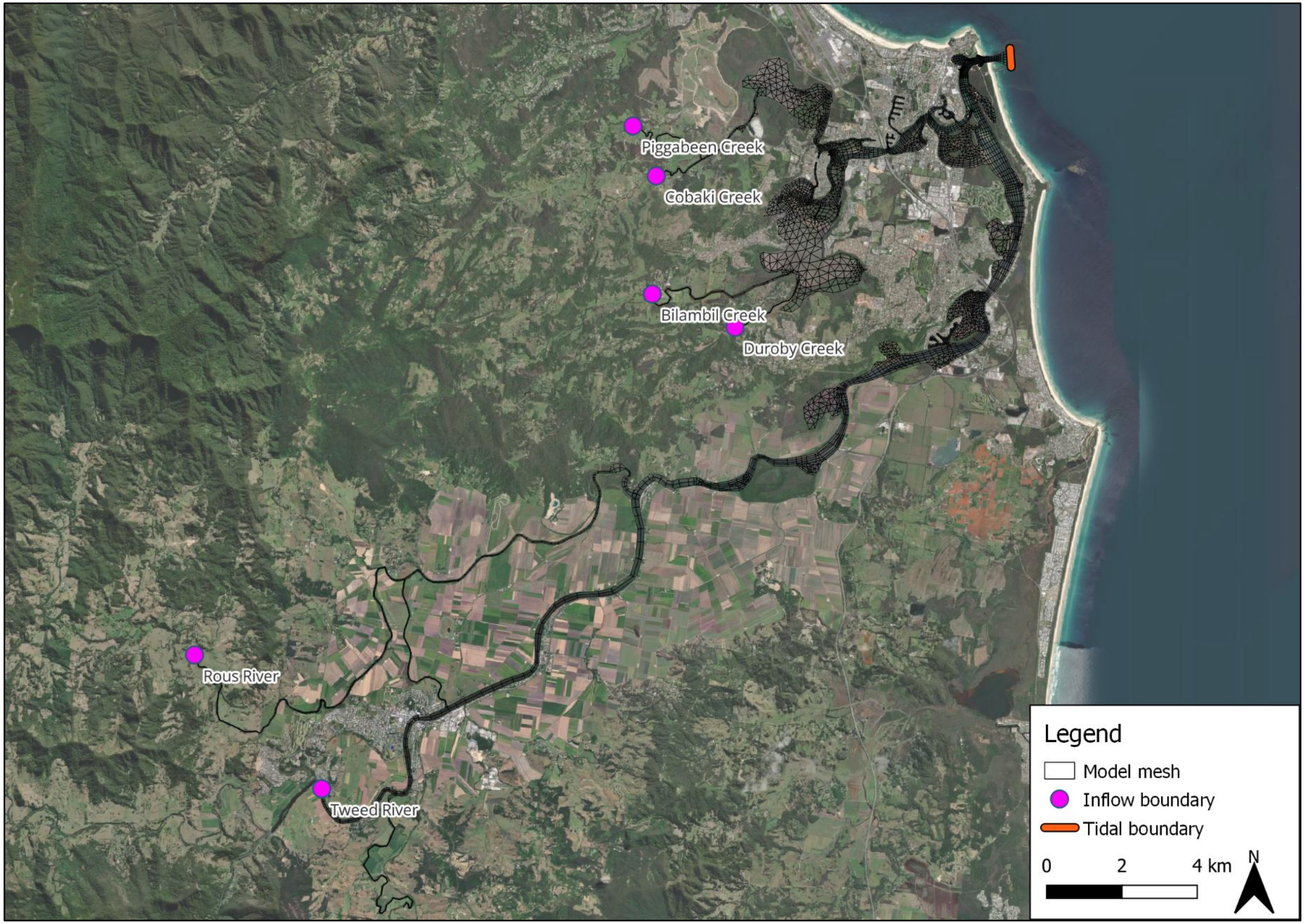

Figure 3-2 RMA model mesh showing boundary condition locations

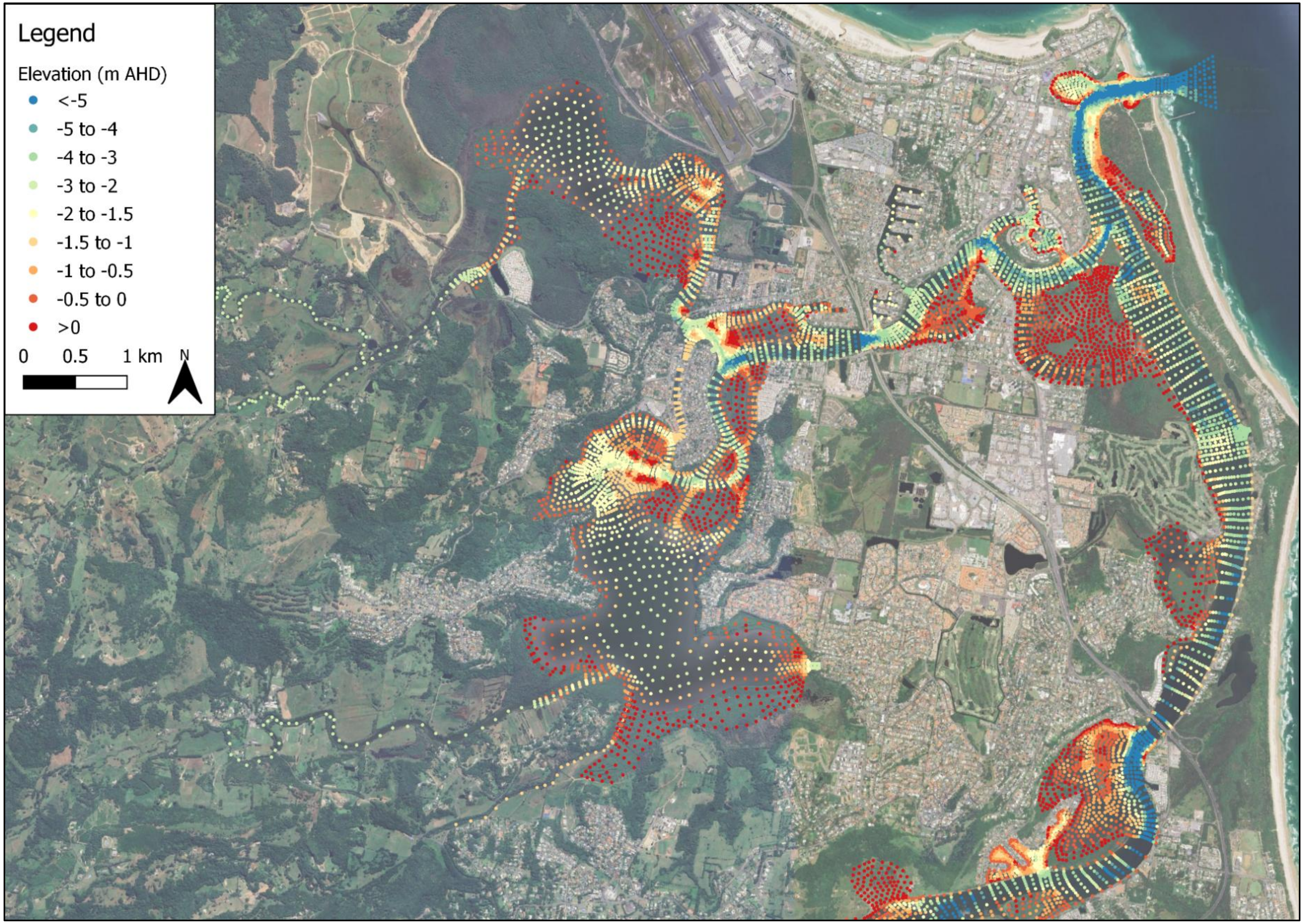

Figure 3-3 RMA model bathymetry (Barneys Point Bridge to Tweed Heads)

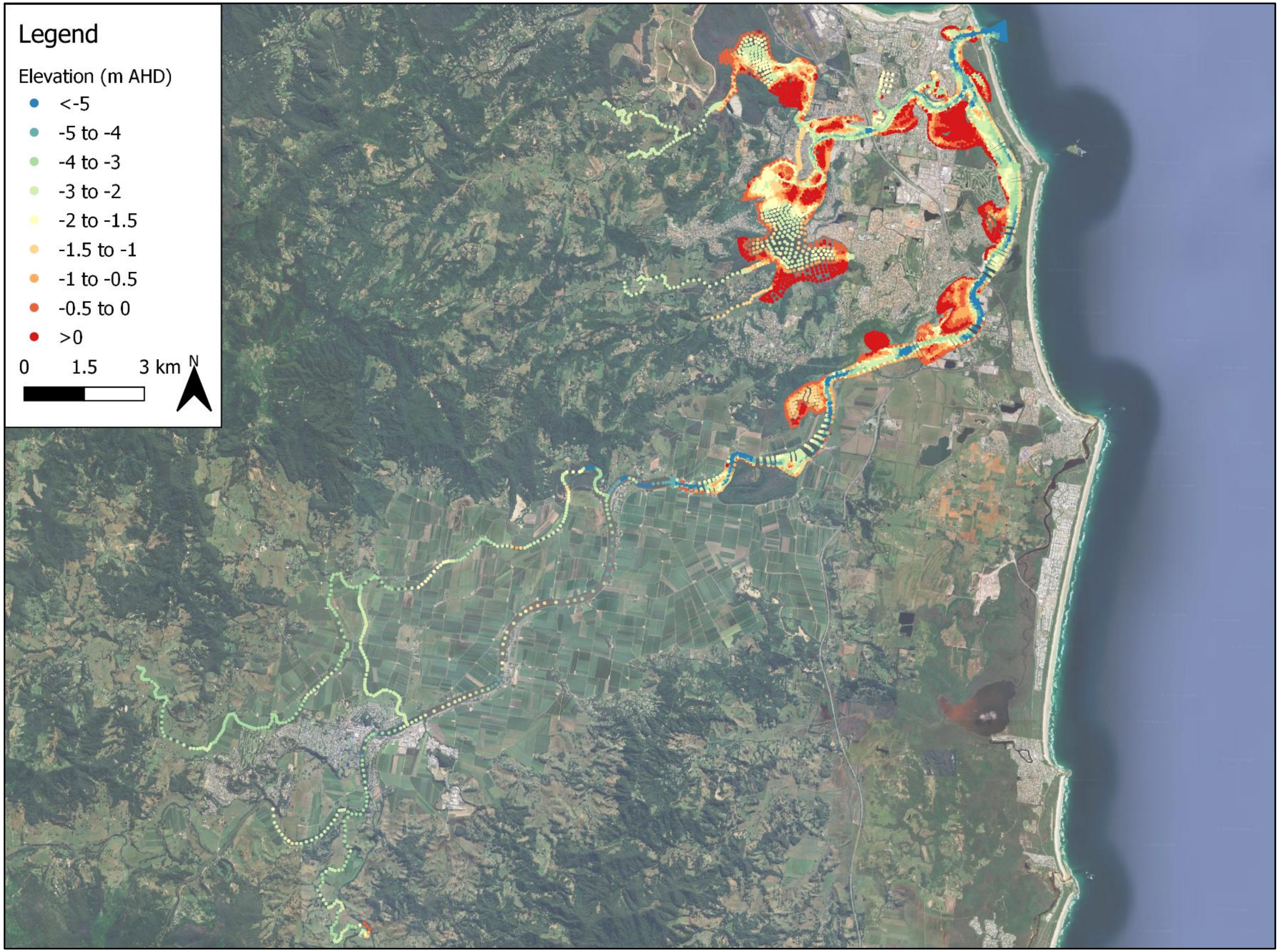

Figure 3-4 Full extent of RMA model bathymetry

3.5 Hydrodynamic calibration and verification

Hydrodynamic calibration should be based on flow, velocities and water levels at several locations throughout the estuary. For more details on calibration and how models were determined to be fit for purpose refer to WRL TR2023/32 Section 6.4. One suitable set of hydrodynamic data was available for calibration purposes. This was collected by MHL in 1988 and is described in Section 2.2. Verification was then performed using the MHL long term water level gauges available at 11 locations in the Tweed River estuary (see Section 2.2). For each period, a minimum 3 day model warmup period was run.

3.5.1 February 1988 calibration period

During the 1988 MHL data collection campaign in the Tweed River estuary, tidal flow data was collected at five transects and water level data at seven locations (refer to Section 2.2). The model parameters were calibrated to this period. Measured tide levels were applied at the ocean boundary and scaled catchment inflows were applied at the six upstream model inflow boundaries. Plots of all observed water levels and flow compared with model results are shown in Appendix B1.1 and B1.2, while select results are shown below.

A reasonable flow curve shape was achieved for model tidal flows into the system at Tweed Heads (Figure 3-5). Peak inflow, outflow and slack timing were well matched, however the modelled peak magnitude of outgoing flow was above measured flow and the peak magnitude of incoming flow slightly larger than the measured flow. Flow into Terranora (Figure 3-6) followed a similar pattern with the shape of the flow matched, but peak flows overestimated on the outgoing and incoming tides. Measured flows in the Tweed River at Letitia were noisy, however a good match was observed for timing, and peak flows (Figure 3-7). While the increase in flows may be associated with erosion in the channel reflected in the model bathymetry (resulting in it being more efficient), it is noted that the measured peak ebb and flood flows do not follow a simple mass balance check. Peak measured ebb flow at the heads is 805 m^3/s while the sum of Terranora Creek and Letitia is 935 m^3/s. Peak measured flood flow at the heads is - 625m^3/s while the sum of Terranora Creek and Letitia is -730 m^3/s. This suggests that there may be errors in the flow measurements particularly at the entrance (where the calibration was worst fit), which led to more reliance on alternate data locations.

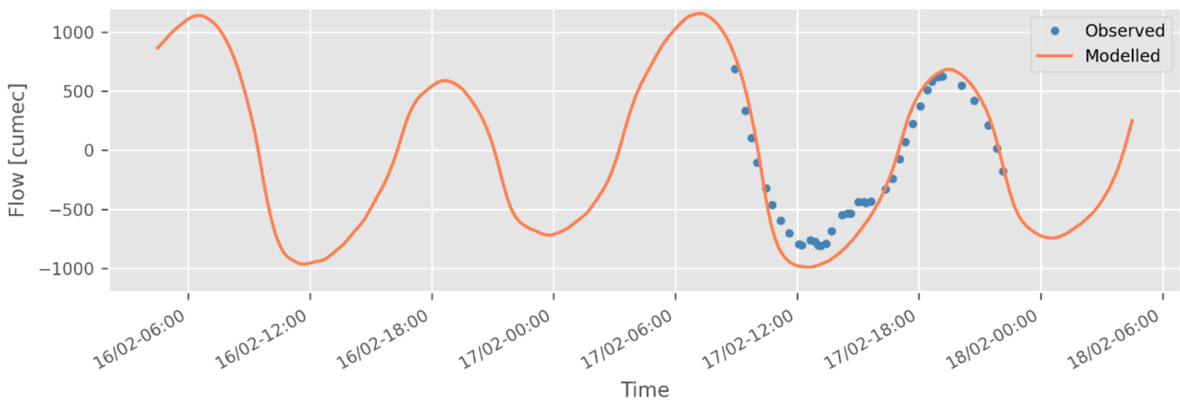

Figure 3-5 1988 tidal flow calibration – Location A – Tweed Heads Entrance

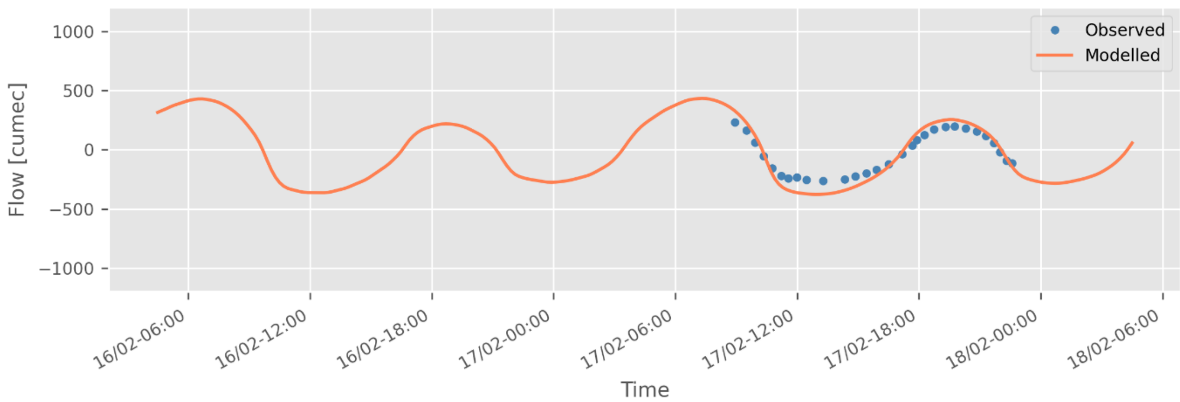

Figure 3-6 1988 tidal flow calibration – Location B – Terranora Entrance

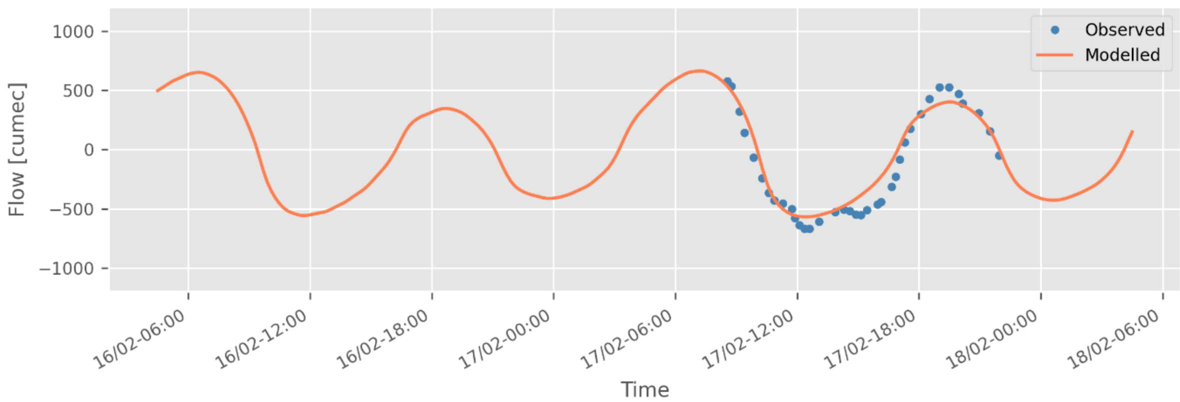

Figure 3-7 1988 tidal flow calibration – Location C – Letitia

Modelled water levels near the entrance show delayed and reduced high tide peaks when compared to observed flows (see Figure 3-8 for an example). This is due to the use of the Tweed Entrance gauge as the driving tides, meaning that losses through the entrance are captured twice (once by using internal tides and once by the model). Nevertheless, tidal range is satisfactorily approximated in the Tweed River farther upstream. Water levels at Letitia, Cobaki and Dry Dock (see Figure 3-9 for an example) show lower and earlier lows than the observed data, however this is not true in the 2015 verification period, and is thus likely caused by bathymetry changes. Although these results indicate the model may be overestimating system flows, the model was deemed fit for purpose given the uncertainty in the measured data.

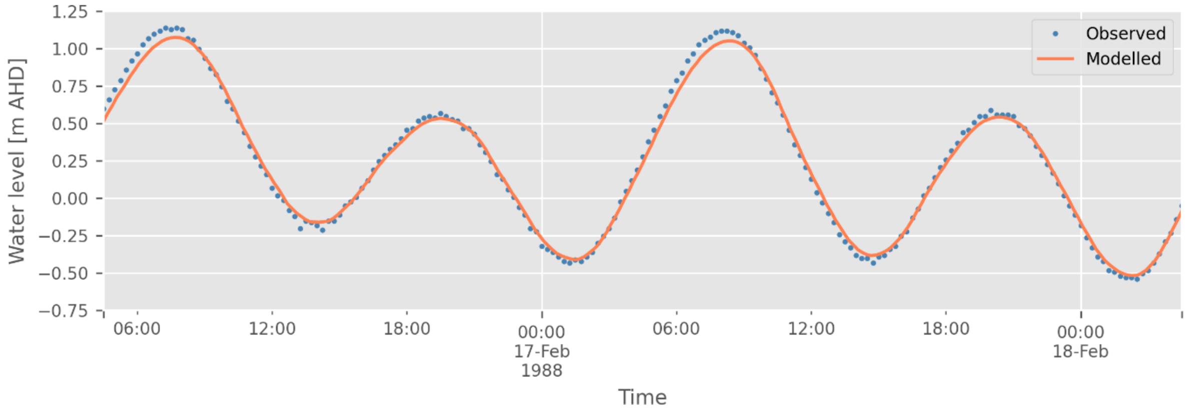

Figure 3-8 1988 water level calibration – Location 1 – Tweed Heads

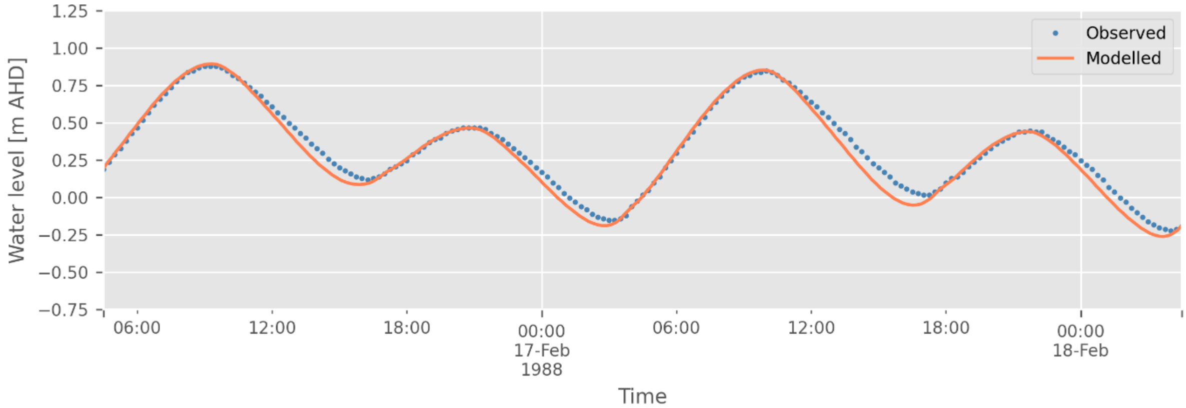

Figure 3-9 1988 water level calibration – Location 4 – Dry Dock

3.5.2 February 2015 verification period

To verify the model under more recent conditions, model water levels were compared against 2015 data from the ten permanent MHL water level gauges (refer to Section 2.2). Measured tide levels were applied at the ocean boundary and scaled catchment inflows were applied at the six upstream model boundaries. Model results were then compared with the observed data, using the same model parameters used for the 1988 model run. Plots of all observed water levels compared with model results are shown in Appendix B1.3, while select results are shown below.

A good model match was achieved for all water levels east of the Pacific Highway. It is noted that the fit of water levels in the Terranora Broadwater and Terranora Creek (see Figure 3-10 for an example) are improved relative to the 1988 period, likely reflecting a better approximation of the 2015 bathymetry from the 2018 bathymetry survey. Worse water level matches were observed upstream from Tumbulgum with model high water levels 10 cm below recorded water levels, however this is not located near the oyster harvest areas in this system.

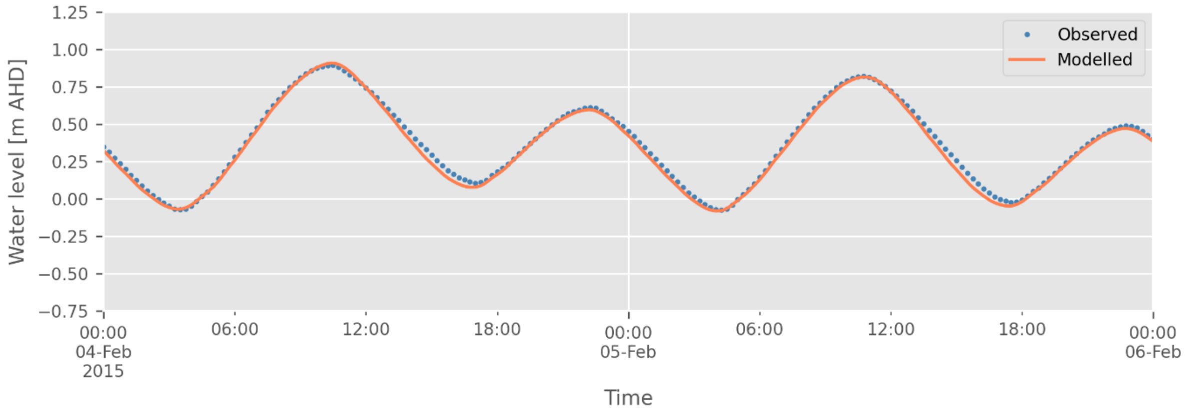

Figure 3-10 2015 water level calibration – Location 4 – Dry Dock

3.5.3 September 2019 verification period

A longer period of approximately 1 month was simulated in 2019 to further verify the model. Model water levels were compared against the 2019 data from the nine permanent MHL water level gauges (refer to Section 2.2). Measured tide levels were applied at the ocean boundary and scaled catchment inflows were applied at the six upstream model boundaries. Model results were then compared with the observed data, using the same model parameters used for the 1988 model run. Plots of all of the observed water levels compared with model results are shown in Appendix B1.4, while select results are shown below.

Similar results were achieved to the 2015 verification period (see Figure 3-11 for an example). Based on satisfactory fit to the 1988, 2015 and 2019 periods, despite some uncertainties and potential bathymetry change, the model was deemed fit for purpose.

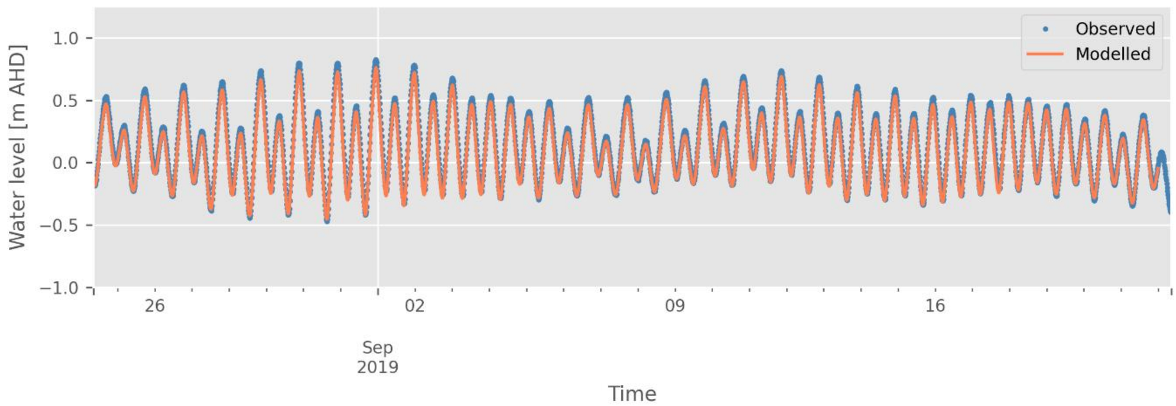

Figure 3-11 2019 water level calibration – Location 4 – Dry Dock

3.5.4 Roughness coefficients

Table 3-1 lists the roughness coefficients (Manning's n) which control the frictional losses in the final calibrated model. Most areas have a coefficient between 0.02 and 0.03, which is typical for large sandy channels.

Table 3-1 Mannings n roughness coefficients of the final model

Location	Manning's n roughness coefficient
Entrance to Ukerebagh Island	0.021
Tweed River from Ukerebagh Island to Pacific Highway	0.030
Tweed River upstream of Pacific Highway	0.020
Terranora Creek	0.026
1D channels	0.025
Broadwaters	0.020
Intertidal areas	0.040

3.6 Water quality model development

3.6.1 Modelling of dispersion in RMA-11

Dye dispersion experiments provided valuable information on dispersion and its simulation in modelling. In particular, they provided evidence for a sensible range of dispersion coefficients to use in the modelling. However, it was concluded that they could not be used to produce estuary specific values for dispersion. Hence, a range of dispersion values, derived from the field experiments, was used across all the estuaries. Models were run with two dispersion coefficients, 0.5 and 1.5 m^2/s in the channels, and the scenario results presented are a combination of the two to manage the uncertainty in dispersion. For further details on how these dispersion values were determined, sensitivity testing, and how model results were combined refer to WRL TR2023/32 Section 7.3, 7.4 and 8.2.3.

A single dispersion coefficient of 4 m^2/s was used in the two Broadwaters to capture potential dispersion from wind driven mixing. The RMA-11 model utilised a 3 minute timestep, with results output every 6 minutes. High temporal resolution was required in this system due to the high velocities which result in rapid plume movement through the channels.

3.6.2 Tidal straining and vertical velocity distribution

As outlined in WRL TR2023/32 Section 7.5, tidal straining is a process leading to asymmetrical vertical velocity distributions in some estuaries. In instances of tidal straining, much higher velocities are observed at the surface than at the bed on the ebb tide, with much less velocity difference observed on the flood tide. As no fieldwork was completed on the Tweed River, vertical velocity distributions could not be quantified in this estuary as it was on others using GPS drifter drogues. However, as it is a riverine system, it is likely that tidal straining occurs on this system.

However, as all overflows are located in the lower estuary, where water is likely to be consistently saline (as confirmed by MHL (1983)), tidal straining was not considered important for most of the area of interest in this study. The one exception to this is overflows on Fingal Head at slack low tide. Under some circumstances, the modelled plume does not reach Terranora Creek for several tidal cycles and has a minimal impact on the harvest area. However, in the case of tidal straining, or with tides of differing sizes, the plume may reach the junction sooner. Thus, the results at this location have increased downstream flows (to replicate the impact of tidal straining) to ensure this is appropriately accounted for when used for decision making.

3.7 Limitations for future model uses

This model has been constructed and calibrated to be fit for the purpose of modelling sewage overflow transport from the modelled locations to oyster harvest areas. The model may be adapted for other uses, however the limitations must be considered. A general discussion on the limitations of applying these models to other use cases can be found in WRL TR2023/32 Section 6.6.

Limitations specific to the Tweed model include:

- Limited calibration and verification data was available on this estuary. No additional field data was collected, as this estuary only has a single harvest that is already accepted to be at high risk from overflows. This may not be true of other use cases, especially ones regarding the entire estuary.
- The model does not simulate density driven processes, which are likely to result in tidal straining in some situations in the Tweed River. As is discussed in Section 3.6.2, this was not considered as a potential impact on most results from this model, however, could be important for other model use cases.
- There is known to be bathymetry change in the system, including possible long-term trends. The single bathymetry used for this model provided an adequate fit in the area of interest over the 1988, 2015 and 2019 model run periods, but model performance was much worse in the upper Tweed, likely due to bathymetry change. Updated or variable bathymetry may be required for other model use cases.

4 Scenario modelling

4.1 Preamble

A detailed description for the methods of scenario modelling for this project can be found in WRL TR2023/32 Section 8. For the Tweed River, a total of 108 model scenario simulations were completed, including permutations of:

- Four overflow locations
- Four stages of the tide
- Three catchment inflow conditions
- Three overflow volumes and duration

Reporting focused on the minimum dilution observed in each harvest area (during the 21 day scenario) and the time taken for the plume to reach each harvest area at 5,000,000 times dilution. Refer to WRL TR2023/32 Section 8.3 for more information. In situations where multiple scenarios gave very similar results, these scenarios were grouped for ease of use, and the worst case results (minimum dilution and shortest travel time) were reported, as detailed in WRL TR2023/32 Section 8.3.6.

The results of all modelled scenarios have been compiled into a user-friendly HTML tool. A description of the tool and its use can be found in the User Guide (WRL TR2024/26).

4.2 Overflow locations

Four locations were used to simulate overflow locations into the Tweed River estuary. These locations were based on historical overflow events (Section 2.4) and input from NSW Food Authority. These locations typically correspond to creek lines or infrastructure where sewage may be directed to following an overflow. The model only considers overflows from the moment they enter the estuary surface water system. Containment prior to reaching the estuary may still be effective. A judgement of whether the overflow reached the estuary should be made in consultation with local authorities to determine if the modelled scenarios need to be considered. Moreover, in situations where there is a delay between the overflow occurrence and the time it reaches the estuary, this delay and related uncertainty needs to be considered when determining which stage of the tide scenario to use. If it is uncertain which scenario timing should be used, use the possible timing which results in the worst case scenario. Modelled overflow locations are shown in Figure 4-1.

At each overflow location, three different overflow conditions were considered:

1. 10 kL overflow over 1 hour (10 kL/hr)
2. 30 kL overflow over 3 hours (10 kL/hr)
3. 100 kL overflow over 10 hours (10 kL/hr)

The rate of discharge (10 kL/hr) was kept constant between each condition. This is equivalent to a rate of approximately 3 L/s. Intermediate results can be inferred for overflows of the same duration, but a different volume. See WRL TR2023/32 Section 8.3.3 for details on how to do this.

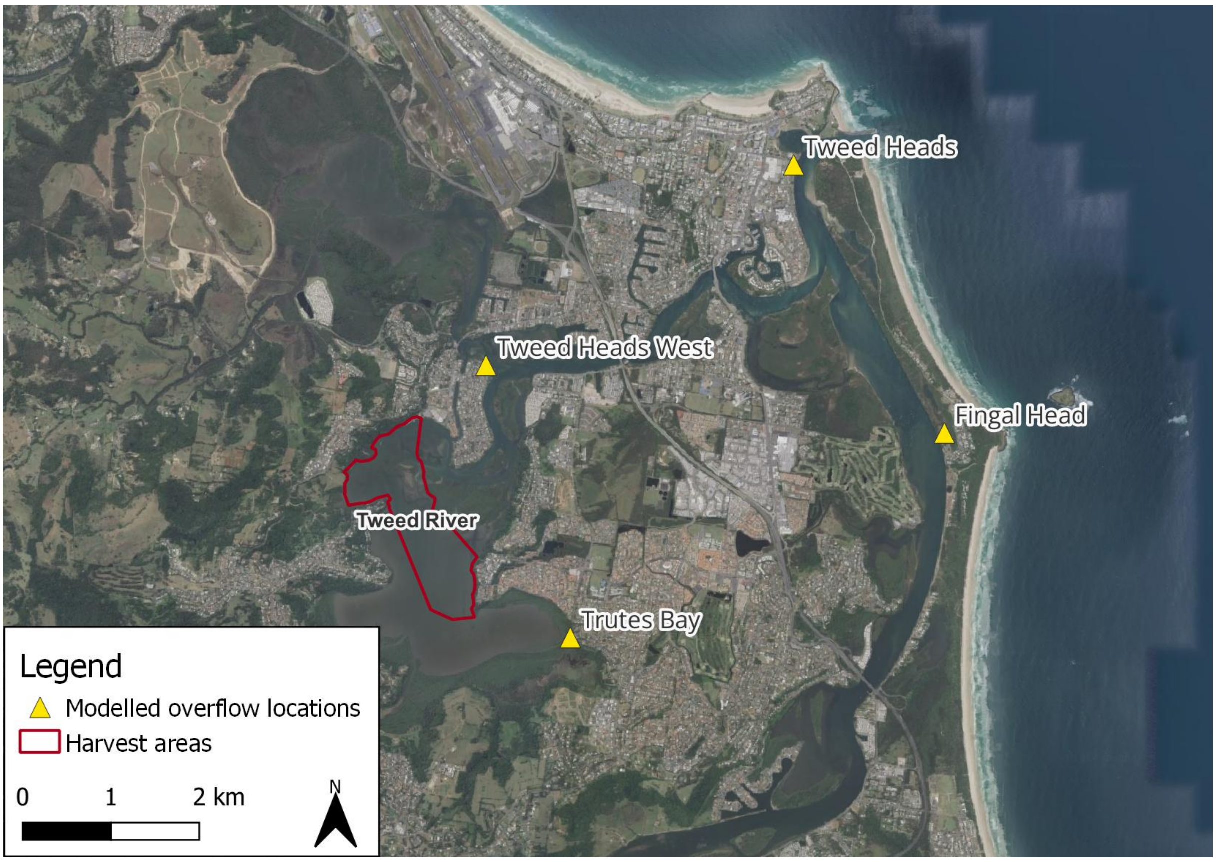

Figure 4-1 Modelled overflow locations in the Tweed River estuary

4.3 Environmental variables

Two environmental variables were tested for the Tweed River:

1. Stage of the tide (slack low tide, slack high tide, mid ebb tide and mid flood tide)
2. Magnitude of catchment inflows (median, 80th percentile and 95th percentile)

4.3.1 Stage of the tide

Stage of the tide for all locations is indexed to the MHL water level gauge, via the relationship described in Table 4-1.

Table 4-1: Model stage of tide timing relative to the MHL water level gauges

Overflow location	Results scenario	MHL water level gauge	Water level at start of spill
Tweed Heads West and Trutes Bay	Slack low tide	Dry Dock (201428)	Low tide
Tweed Heads West and Trutes Bay	Mid flood tide	Dry Dock (201428)	Halfway between low and high tide
Tweed Heads West and Trutes Bay	Slack high tide	Dry Dock (201428)	High tide
Tweed Heads West and Trutes Bay	Mid ebb tide	Dry Dock (201428)	Halfway between high and low tide
Tweed Heads and Fingal Heads	Slack low tide	Letitia (201429)	Low tide
Tweed Heads and Fingal Heads	Mid flood tide	Letitia (201429)	Halfway between low and high tide
Tweed Heads and Fingal Heads	Slack high tide	Letitia (201429)	High tide
Tweed Heads and Fingal Heads	Mid ebb tide	Letitia (201429)	Halfway between high and low tide

The stage of the tide is important at all overflow locations other than Trutes Bay (and of duration less than 10 hours). Overflows at slack high tide at the other three overflow locations will largely leave the estuary in a single tidal cycle, limiting the potential impact on the harvest area. This highlights the need for accurate reporting of the timing and duration of overflows from these locations.

4.3.2 Catchment inflows

While catchment inflow did influence plume behaviour in the broader estuary, it did not significantly influence the minimum dilution (maximum concentration) that was observed in the harvest area in most cases. The exception to this is at Fingal Heads, where under some circumstances, catchment inflows affected the impacts to the harvest area. However, the range of these impacts was not within the uncertainty created by the impact of tidal straining at this location (refer to Section 3.6.2). Therefore, results for different catchment inflows have been combined for all locations. See WRL TR2023/32 Section 8.3.4 for more details on scenario grouping.

5 Conclusion

This report is focussed on the Tweed River estuary produced for the study “Assessing the impact of sewage overflows on oyster harvest areas in NSW”. The purpose of this report was to provide technical and estuary specific information on the process and data sources used to create the Tweed River estuary model. Key information included in the report relates to the integration of existing data sources, the May 2023 field data collection campaign, data processing, model development, and model verification.

This report should be read in conjunction with WRL TR2023/32 which provides details on the technical methods used across each of the 11 study estuaries (including the Tweed River) and discussions on modelling limitations including model parameter sensitivity and pollutant dispersion. Results of the scenario modelling is available in the accompanying tool, which is documented in the User Guide (WRL TR2024/26).

6 References

DPIE 2018. NSW Marine LiDAR Topo-Bathy 2018 Geotif. Department of Planning, Industry and the Environment.

MHL 1983. Tweed River Tidal Data, MHL312.

MHL 1988. Tweed River Tidal Investigations 1971-1988. MHL550 ed.: Manly Hydraulics Laboratory.

MHL 2016. OEH Tidal Data Compilation. MHL2363 ed.: Manly Hydraulics Laboratory.

MHL 2018. Tweed Sand Bypass Tidal Analysis 17-18, MHL2650.

MHL 2019. Tweed Sand Bypass Tidal Analysis 18-19, MHL2677.

MHL 2020. Tweed Sand Bypass Tidal Analysis 19-20, MHL2761.

MHL 2021. Tweed Sand Bypass Tidal Analysis 20-21, MHL2822.

MHL. 2023a. *NSW Ocean Tide Data Collection Program* [Online]. Manly Hydraulics Laboratory. Available: https://www.mhl.nsw.gov.au/Data-OceanTide [Accessed 2023].

MHL. 2023b. *NSW Water Level Data Collection Program* [Online]. Manly Hydraulics Laboratory. Available: https://www.mhl.nsw.gov.au/Data-Level [Accessed 2023].

NAVONICS. 2023. *NAVONICS Chart Viewer SonarChart* [Online]. Available: https://webapp.navionics.com/ [Accessed 2023].

NearMap. 2024. *NearMap MapBrowser* [Online]. Available: https://apps.nearmap.com/maps/ [Accessed 2024].

NSW Spatial Services 2012. 2km x 2km Grid 1 metre Resolution Digital Elevation Model. Department of Finance, Services and Innovation.

OEH 1995. NSW Office of Environment and Heritage (OEH) Single-beam Bathymetry and Coastal Topography Surveys.

OEH 2000. NSW Office of Environment and Heritage (OEH) Single-beam Bathymetry and Coastal Topography Surveys. NSW Public Works Department.

OEH 2011. NSW Office of Environment and Heritage (OEH) Single-beam Bathymetry and Coastal Topography Surveys.

OEH 2014. NSW Office of Environment and Heritage (OEH) Single-beam Bathymetry and Coastal Topography Surveys.

OEH 2016. NSW Office of Environment and Heritage (OEH) Single-beam Bathymetry and Coastal Topography Surveys.

Tucker, T. A., Rayner, D. S., Harrison, A. J., Lumiatti, G., Rahman, P. F., Gilbert, D. M. & Glamore, W. C. 2023. Tweed River Floodplain Prioritisation Study. WRL.

WaterNSW. 2023. *Continuous water monitoring network* [Online]. Available: https://realtimedata.waternsw.com.au/water.stm [Accessed 2023].

Appendix A Data collation

A1 Bathymetric change

The below figures summarise the bathymetric change between OEH singlebeam surveys (1995, 2000, 2011, 2014, 2016) and the 2018 LiDAR topo-bathy survey.

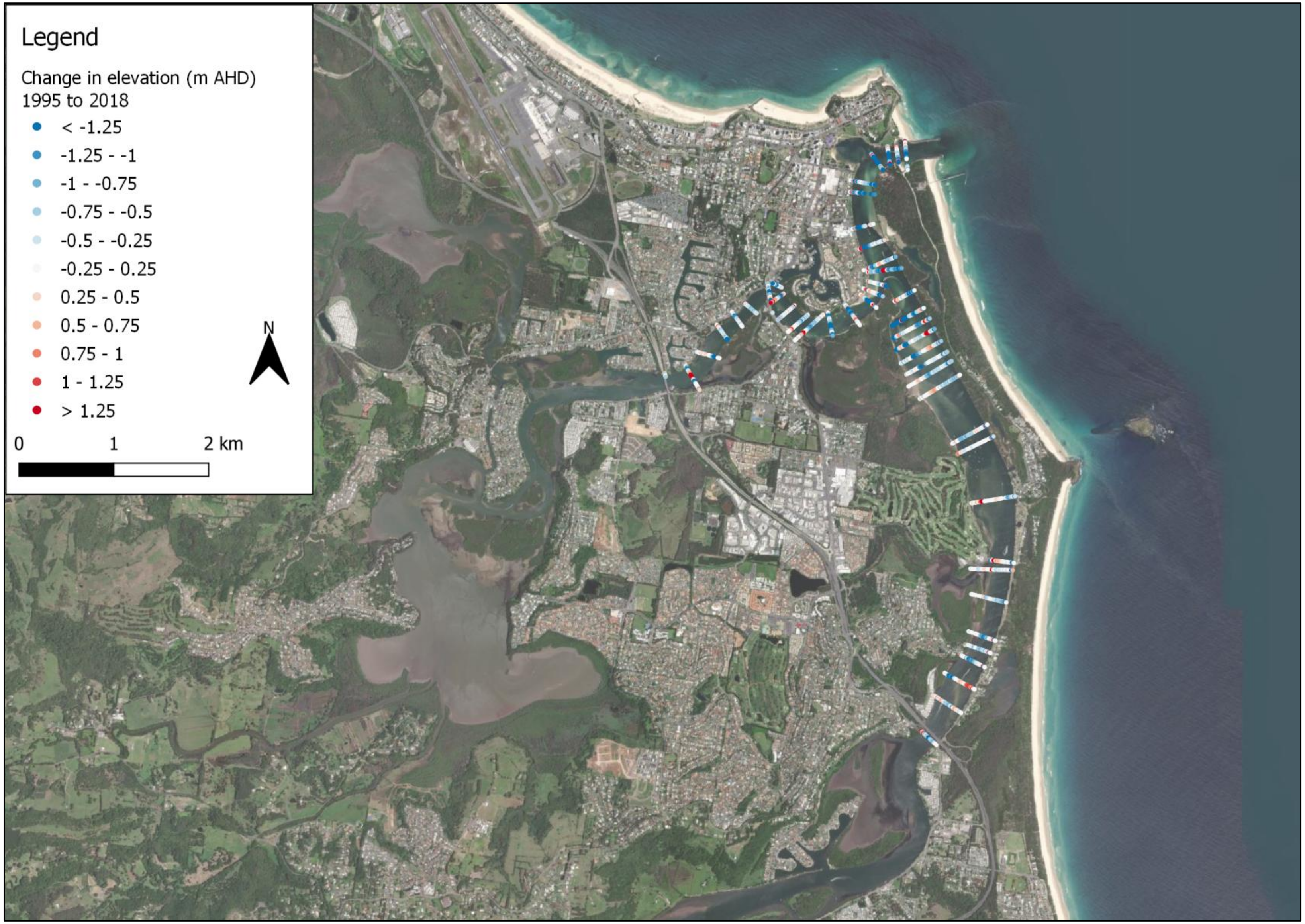

Figure A-1 Bathymetry difference between 1995 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion

Figure A-2 Bathymetry difference between 2000 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion

Figure A-3 Bathymetry difference between 2011 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion

Figure A-4 Bathymetry difference between 2014 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion

Figure A-5 Bathymetry difference between 2016 survey and 2018 marine LiDAR. Red represents accretion and blue represents erosion

Appendix B Model calibration

B1 Hydrodynamic calibration and verification results

The below figures summarise results from the Tweed River estuary hydrodynamic calibration and verification process. For more information, refer to Section 3.5.

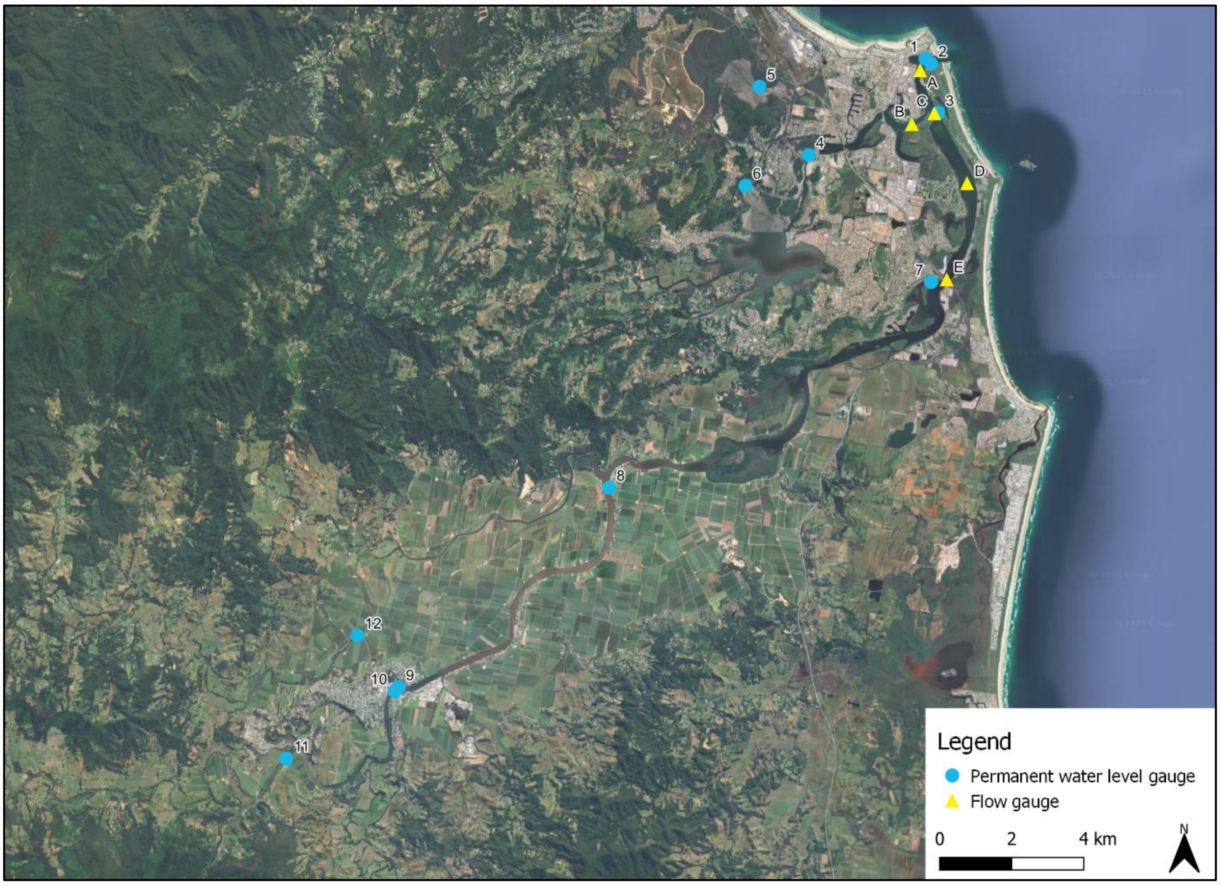

Figure B-1 Water level and tidal flow gauging locations

B1.1 Tidal flow gauging calibration – 1988

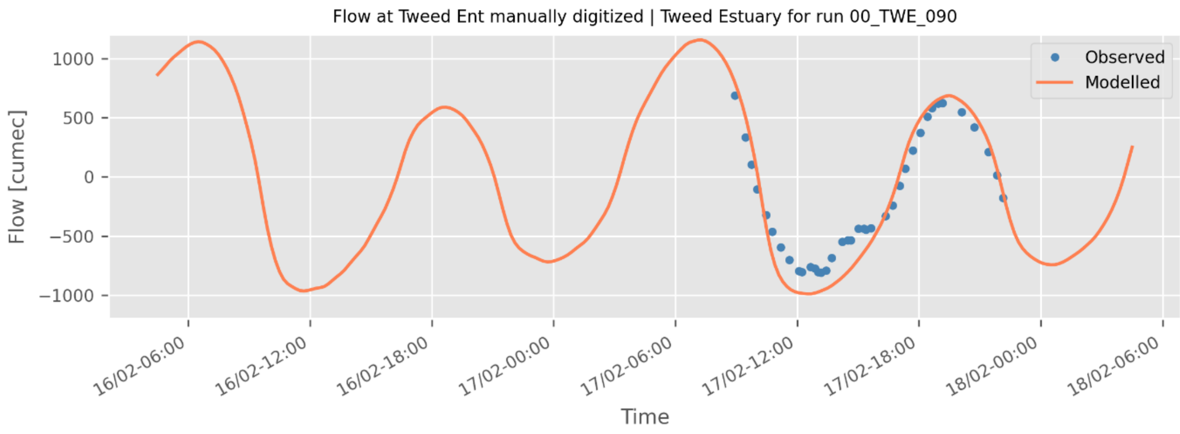

Figure B-2 1988 tidal flow calibration – Location A – Tweed Heads Entrance

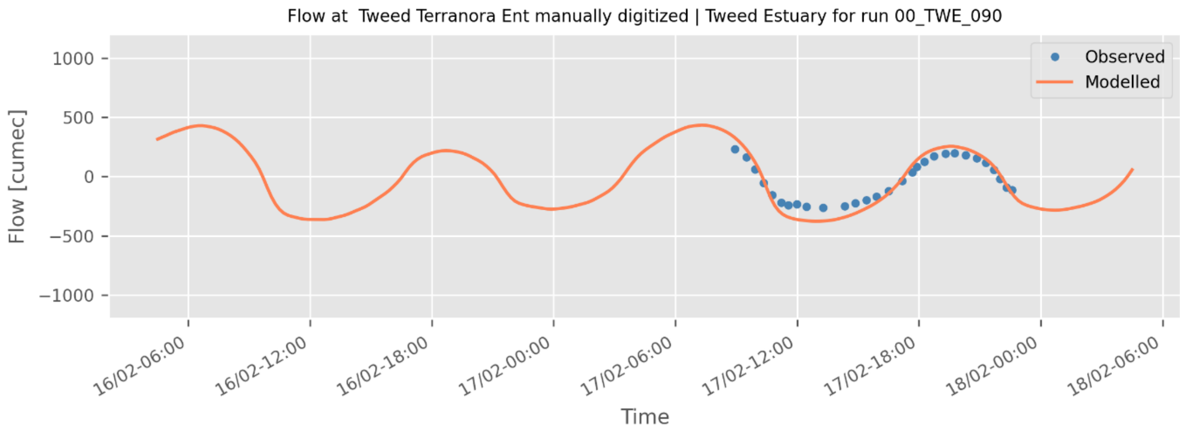

Figure B-3 1988 tidal flow calibration – Location B – Terranora Entrance

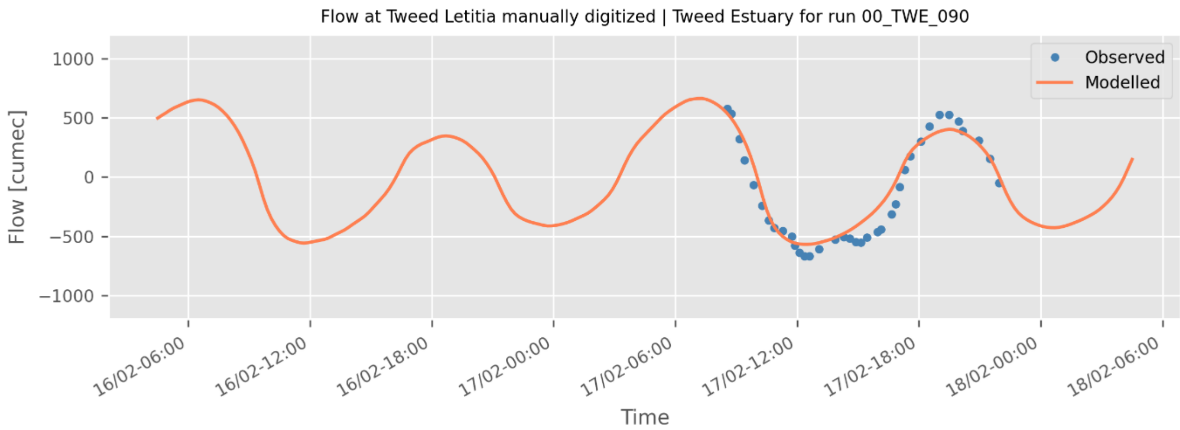

Figure B-4 1988 tidal flow calibration – Location C – Letitia

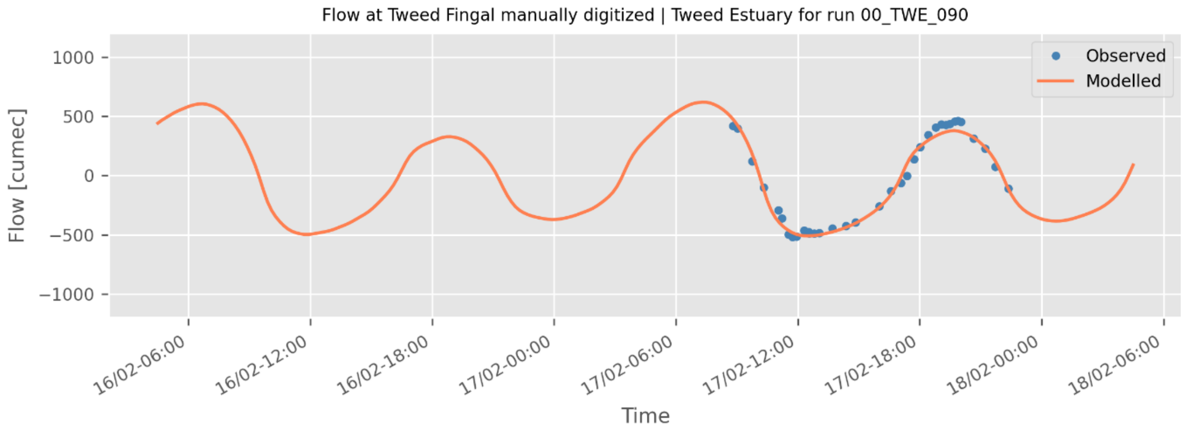

Figure B-5 1988 tidal flow calibration – Location D – Fingal Head

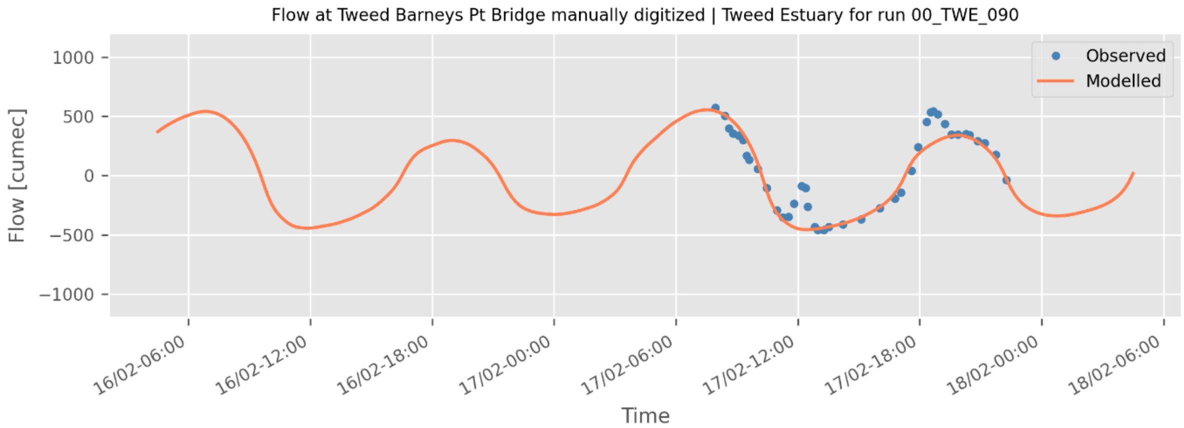

Figure B-6 1988 tidal flow calibration – Location E – Barneys Point Bridge

B1.2 Water level calibration – 1988

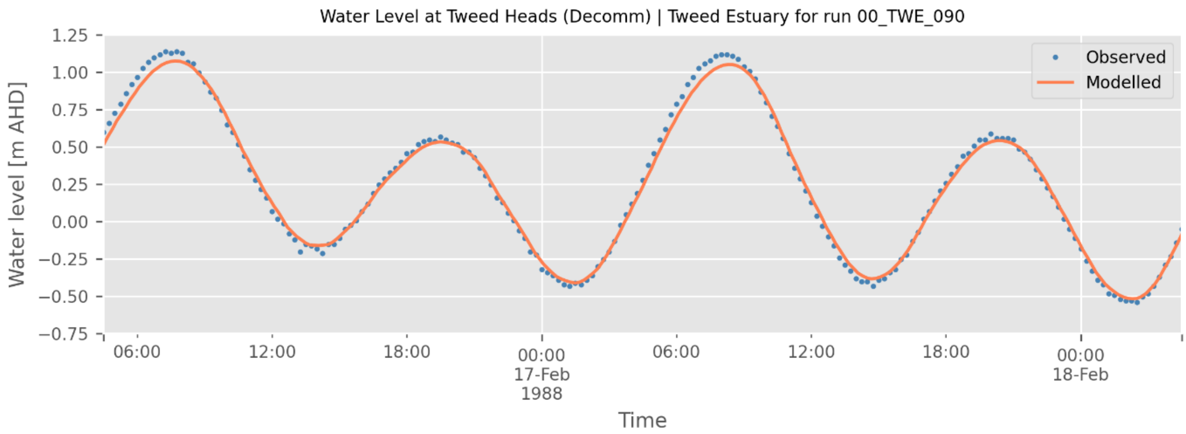

Figure B-7 1988 water level calibration – Location 1 – Tweed Heads

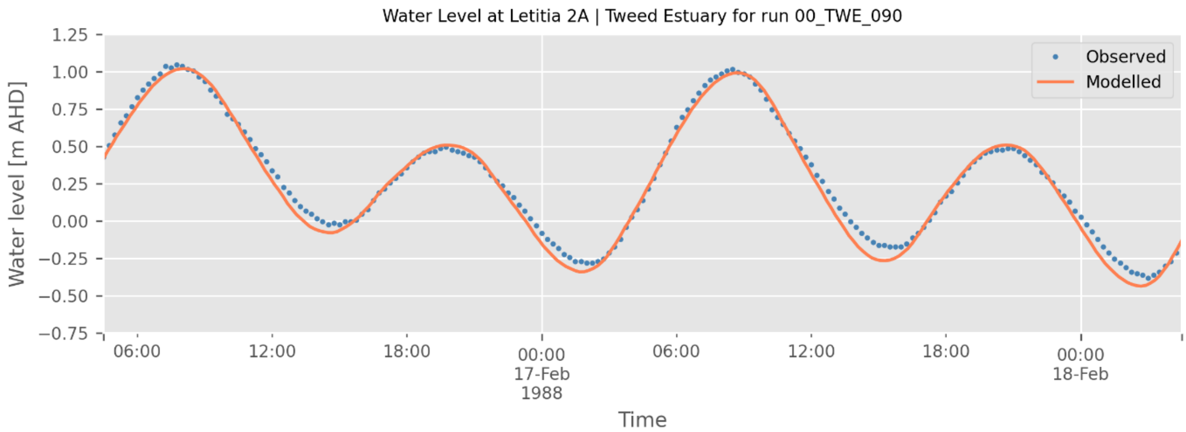

Figure B-8 1988 water level calibration – Location 3 – Letitia

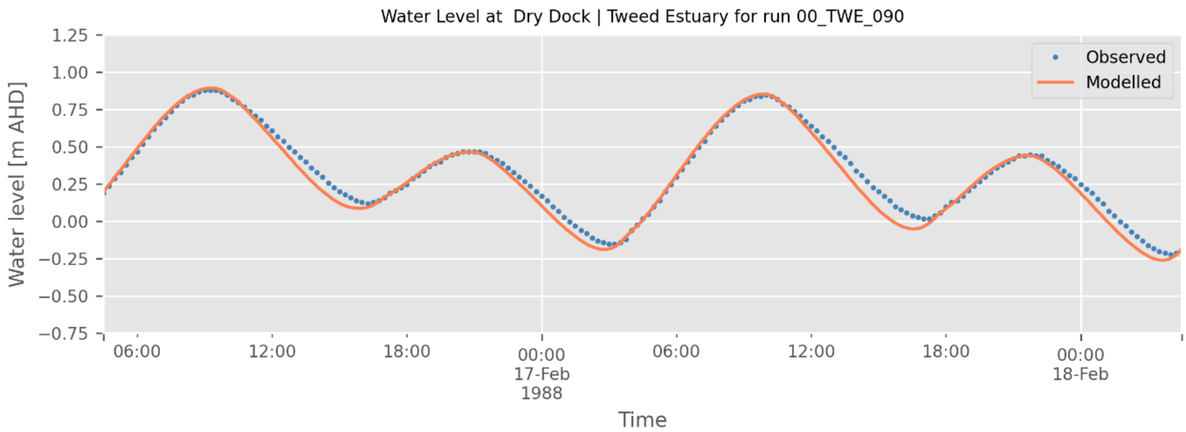

Figure B-9 1988 water level calibration – Location 4 – Dry Dock

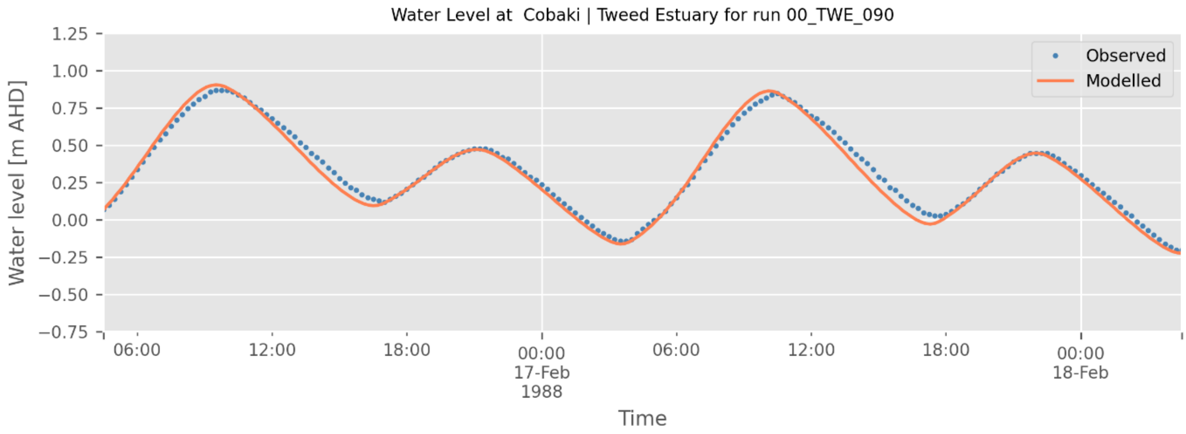

Figure B-10 1988 water level calibration – Location 5 – Cobaki

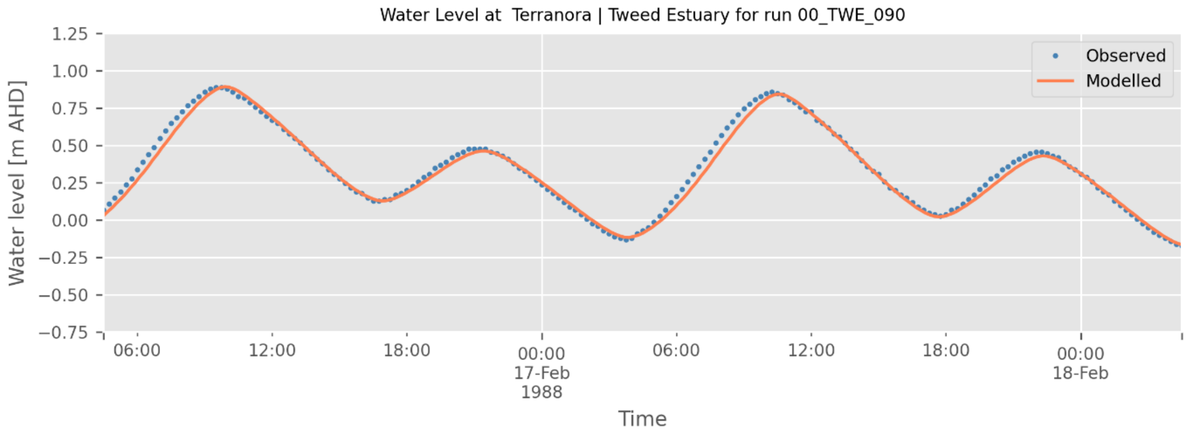

Figure B-11 1988 water level calibration – Location 6 – Terranora

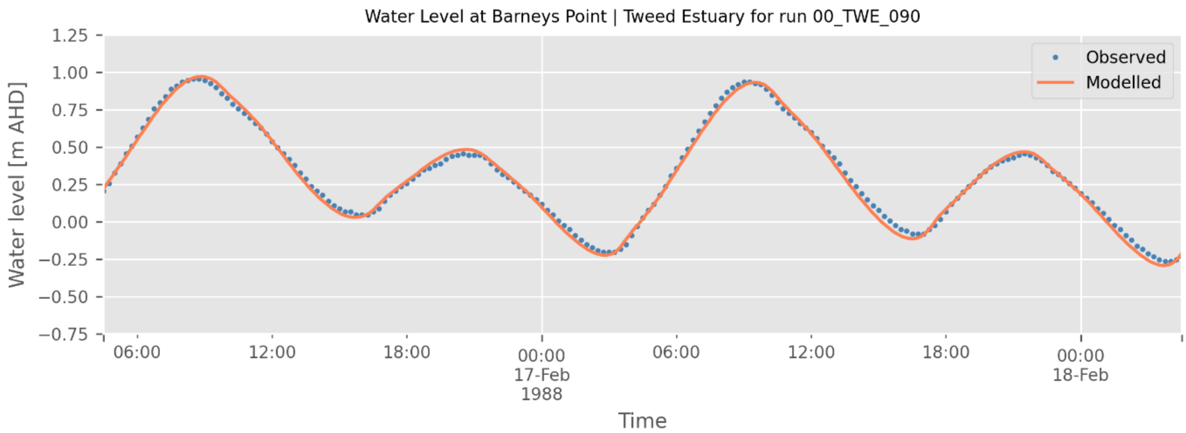

Figure B-12 1988 water level calibration – Location 7 – Barneys Point

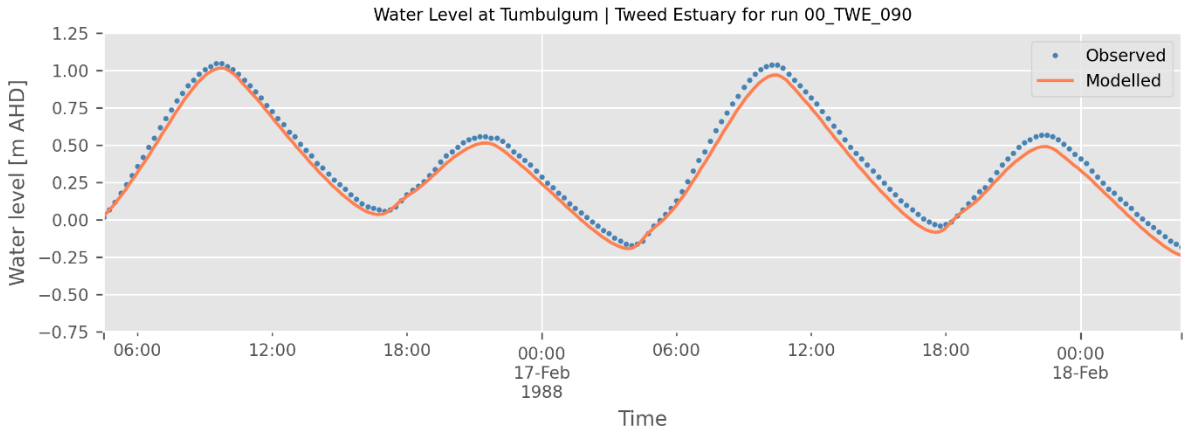

Figure B-13 1988 water level calibration – Location 8 – Tumbulgum

B1.3 Water level verification – 2015

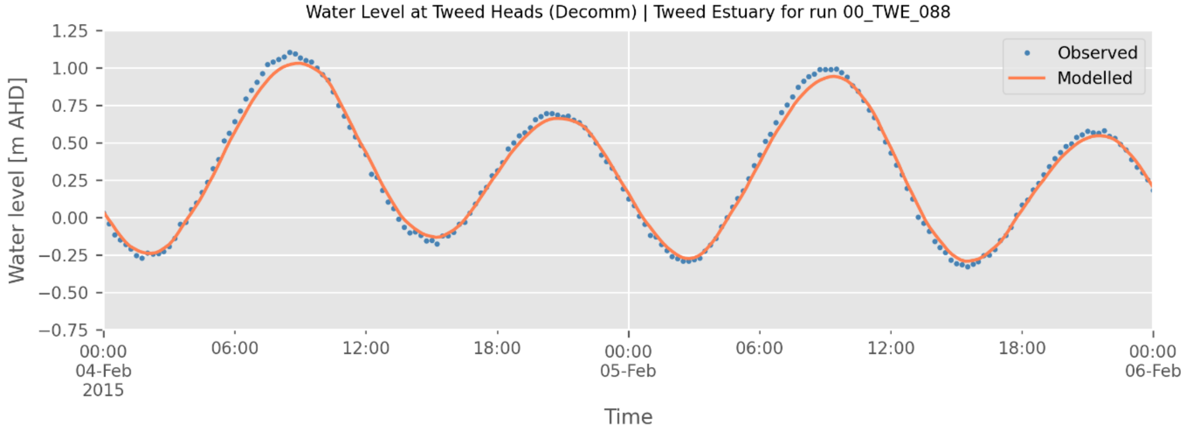

Figure B-14 2015 water level verification – Location 1 – Tweed Heads

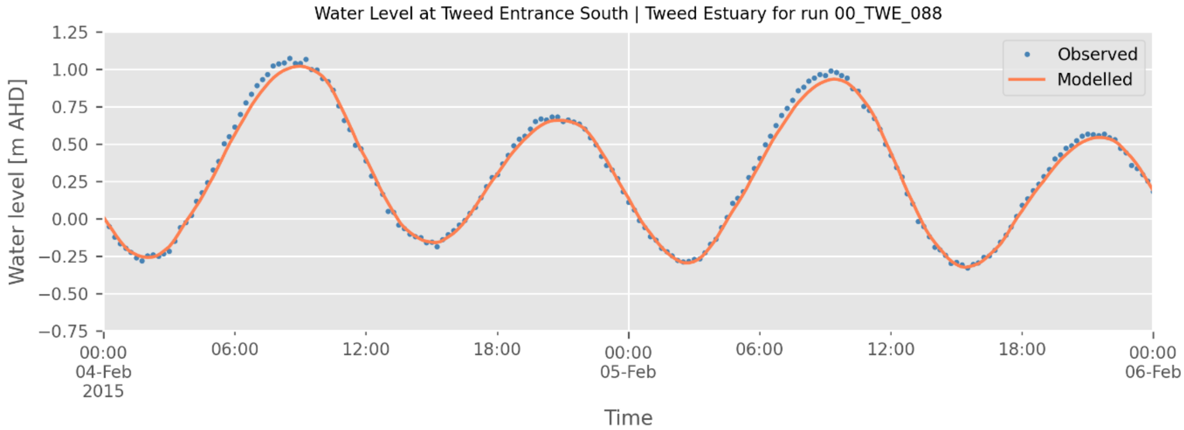

Figure B-15 2015 water level verification – Location 2 – Tweed Entrance South

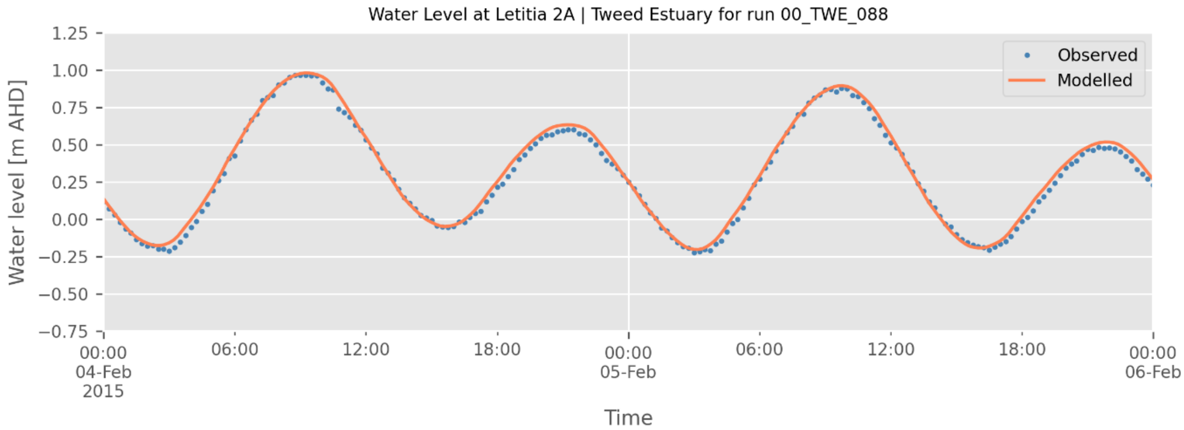

Figure B-16 2015 water level calibration – Location 3 – Letitia

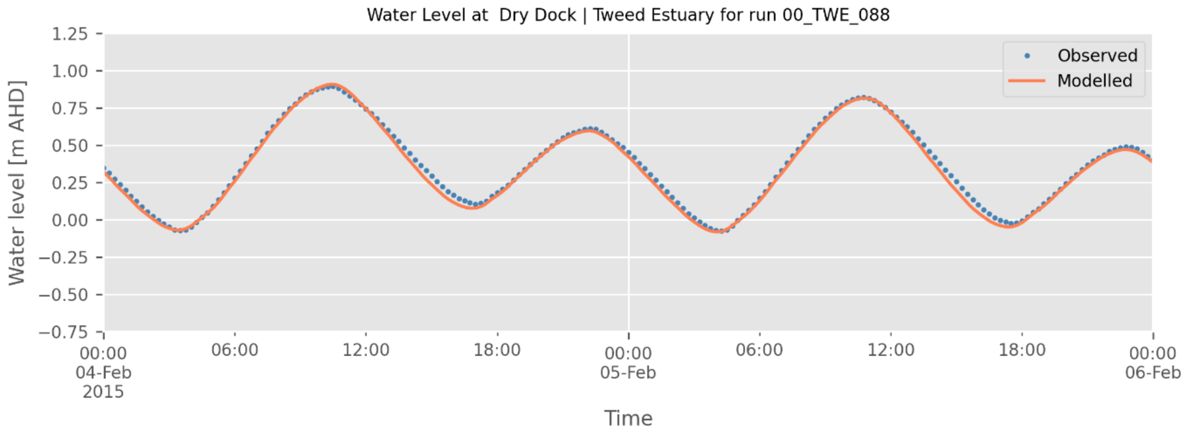

Figure B-17 2015 water level calibration – Location 4 – Dry Dock

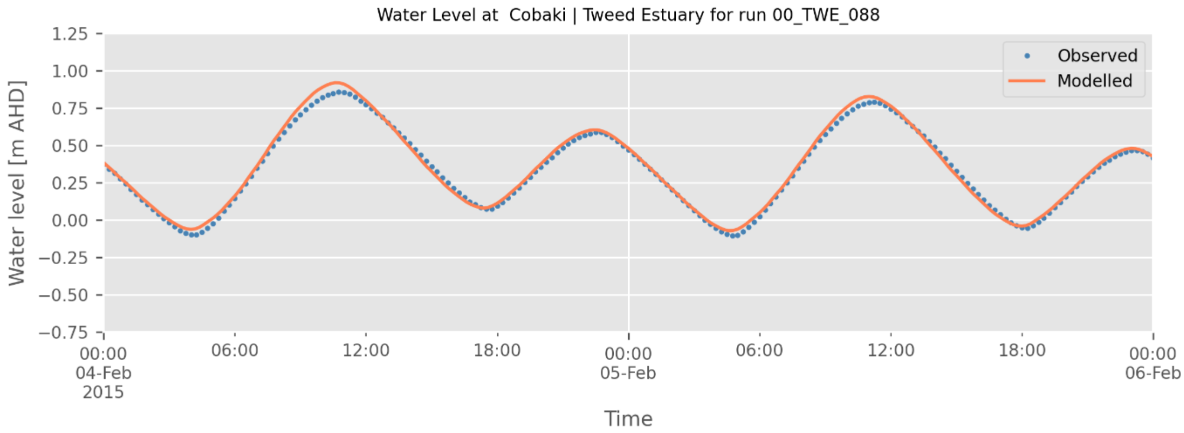

Figure B-18 2015 water level calibration – Location 5 – Cobaki

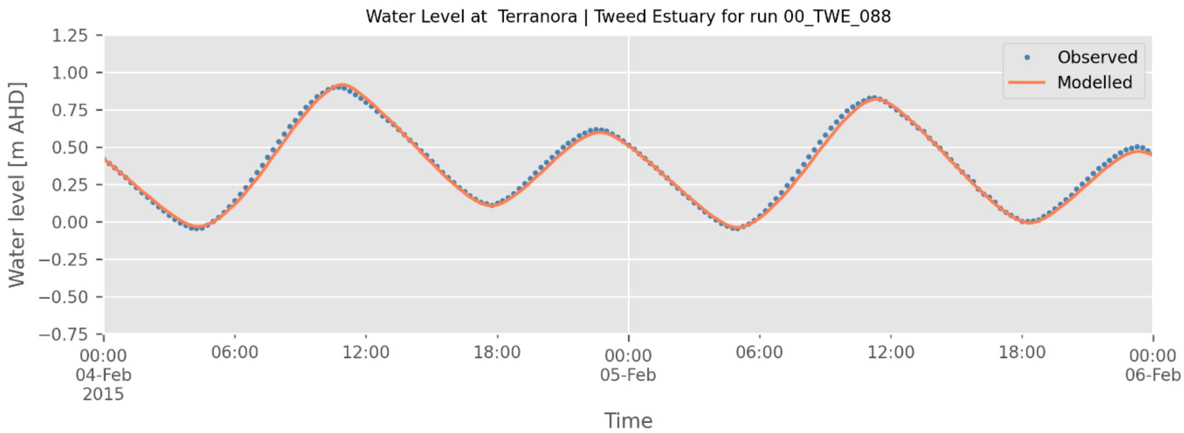

Figure B-19 2015 water level calibration – Location 6 – Terranora

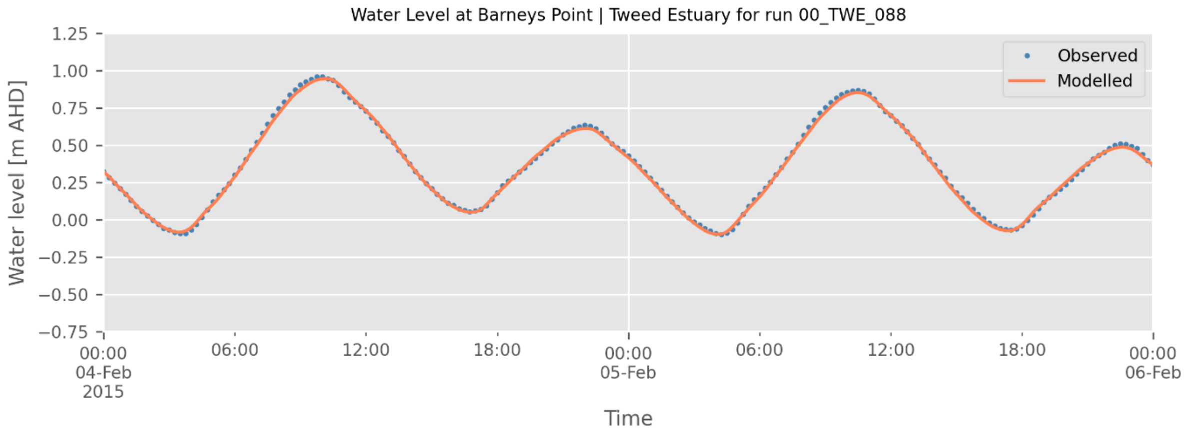

Figure B-20 2015 water level calibration – Location 7 – Barneys Point

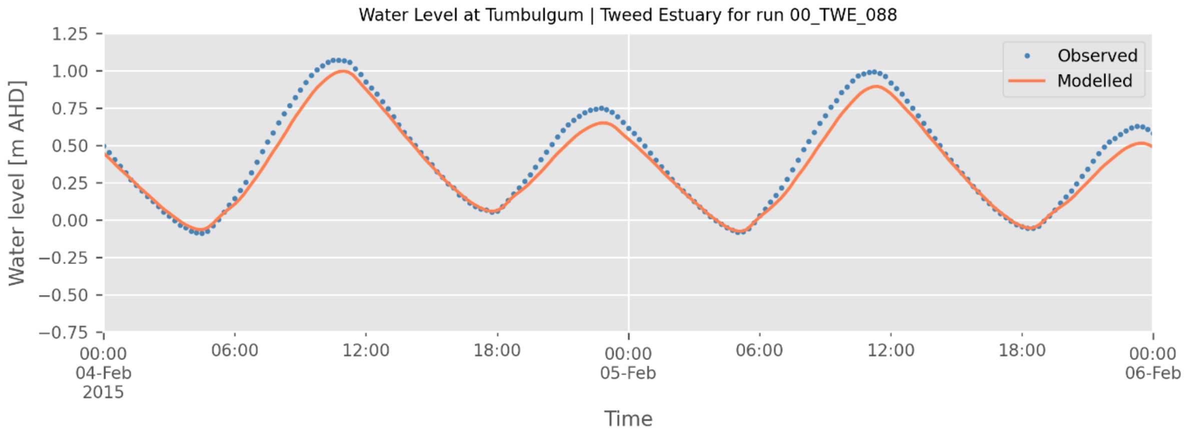

Figure B-21 2015 water level calibration – Location 8 – Tumbulgum

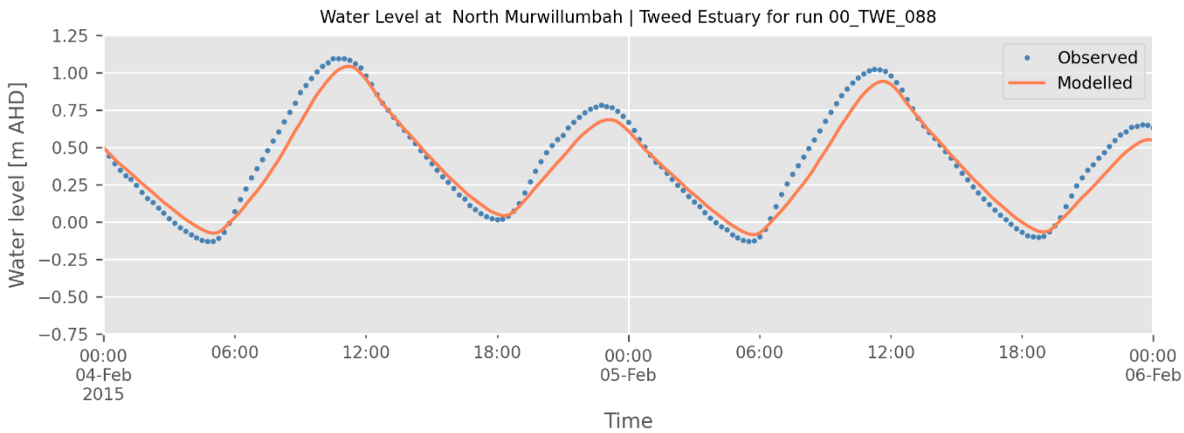

Figure B-22 2015 water level verification – Location 9 – North Murwillumbah

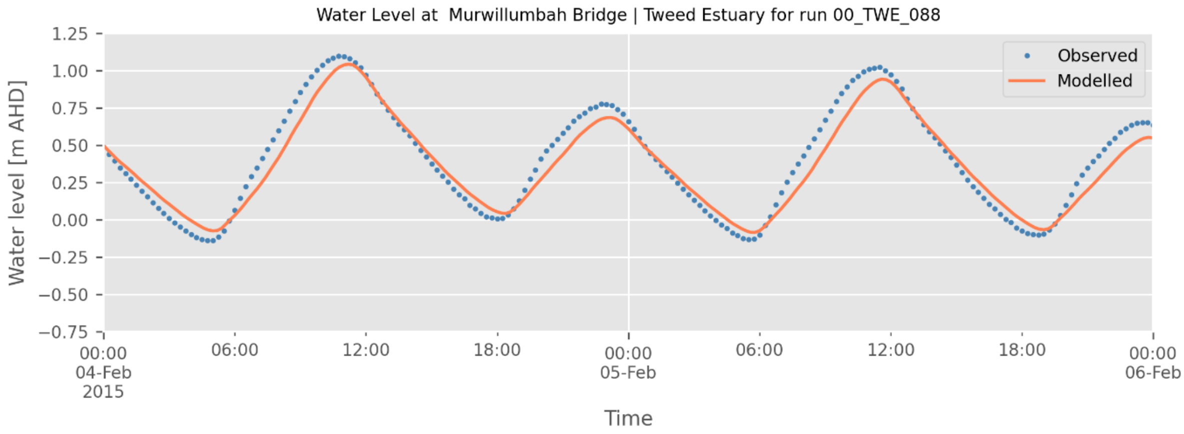

Figure B-23 2015 water level verification – Location 10 – Murwillumbah

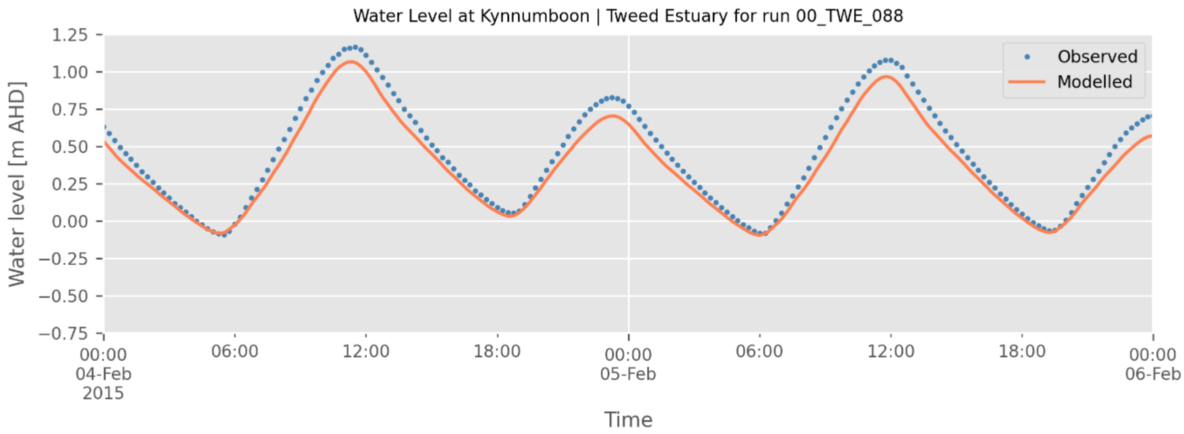

Figure B-24 2015 water level verification – Location 12 – Kynnumboon

B1.4 Water level verification – 2019

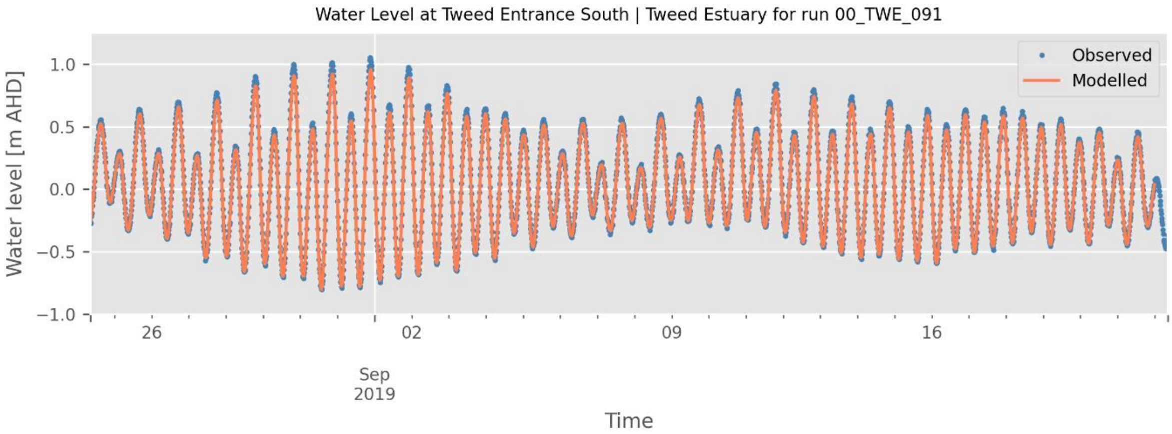

Figure B-25 2019 water level verification – Location 2 – Tweed Entrance South

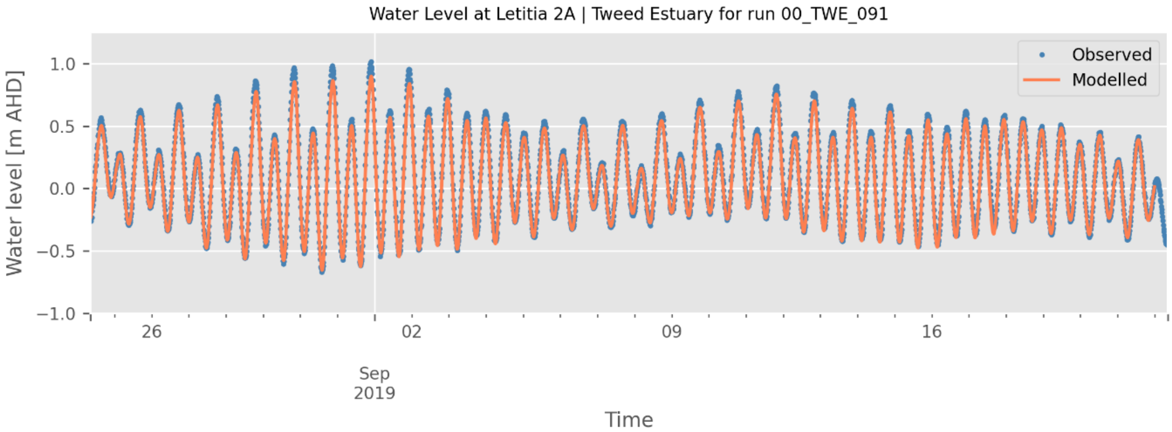

Figure B-26 2019 water level calibration – Location 3 – Letitia

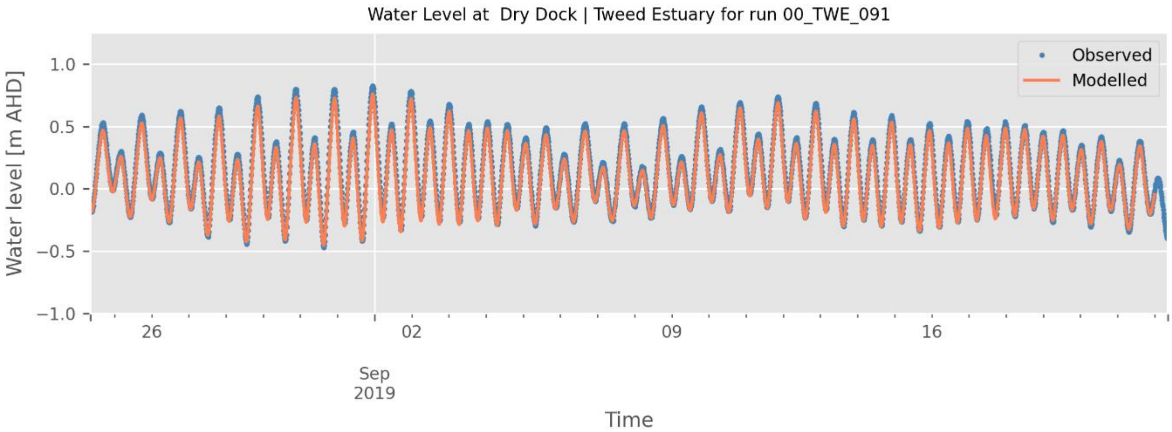

Figure B-27 2019 water level calibration – Location 4 – Dry Dock

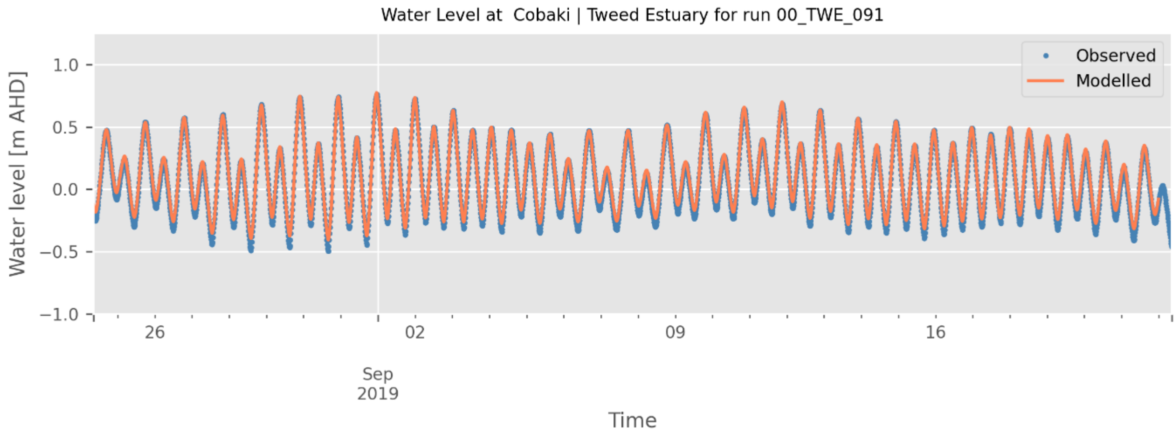

Figure B-28 2019 water level calibration – Location 5 – Cobaki

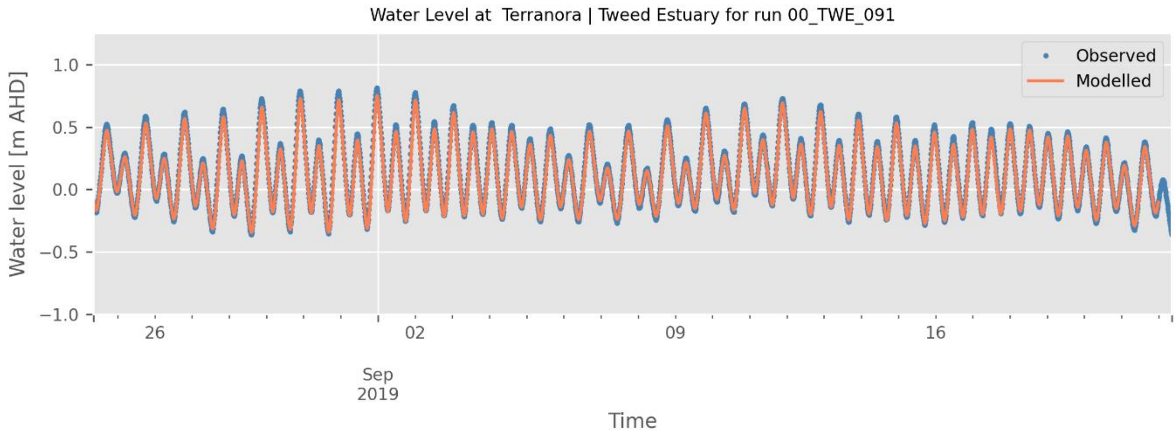

Figure B-29 2019 water level calibration – Location 6 – Terranora

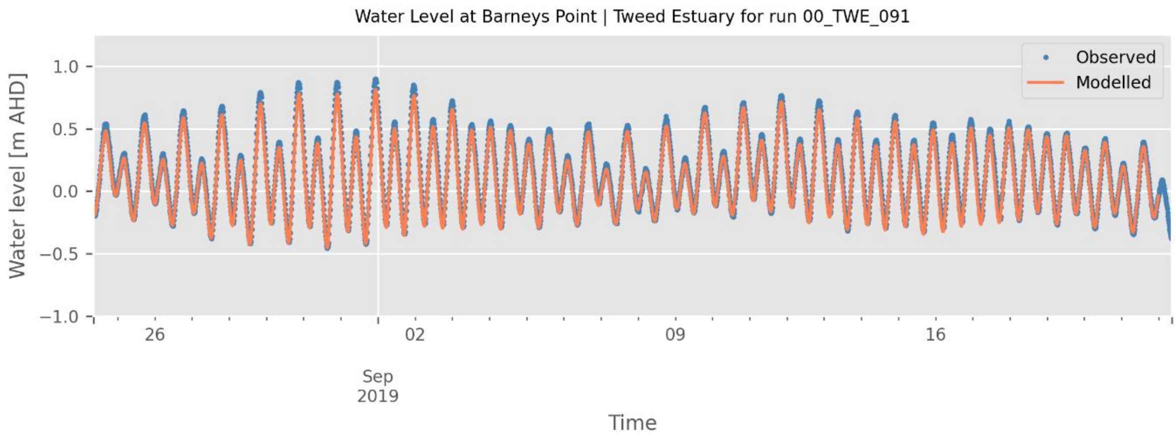

Figure B-30 2019 water level calibration – Location 7 – Barneys Point

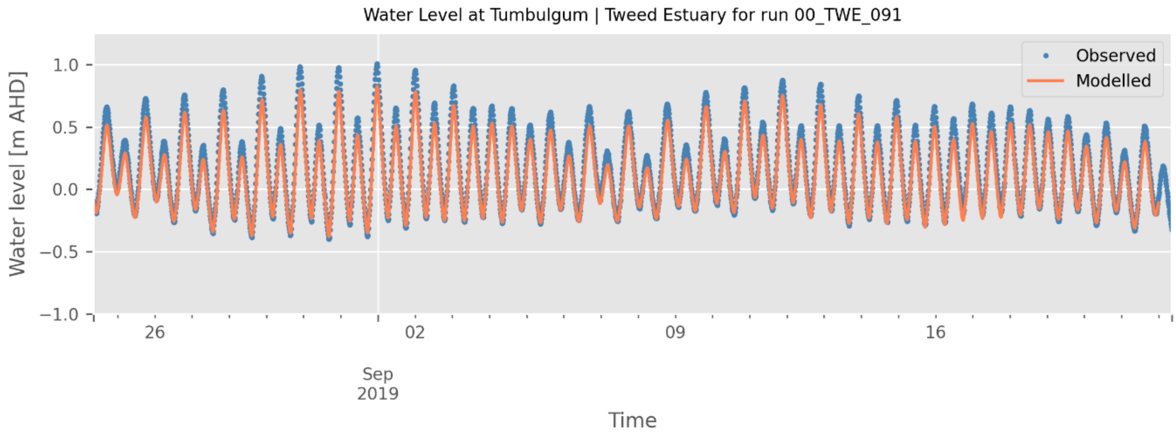

Figure B-31 2019 water level calibration – Location 8 – Tumbulgum

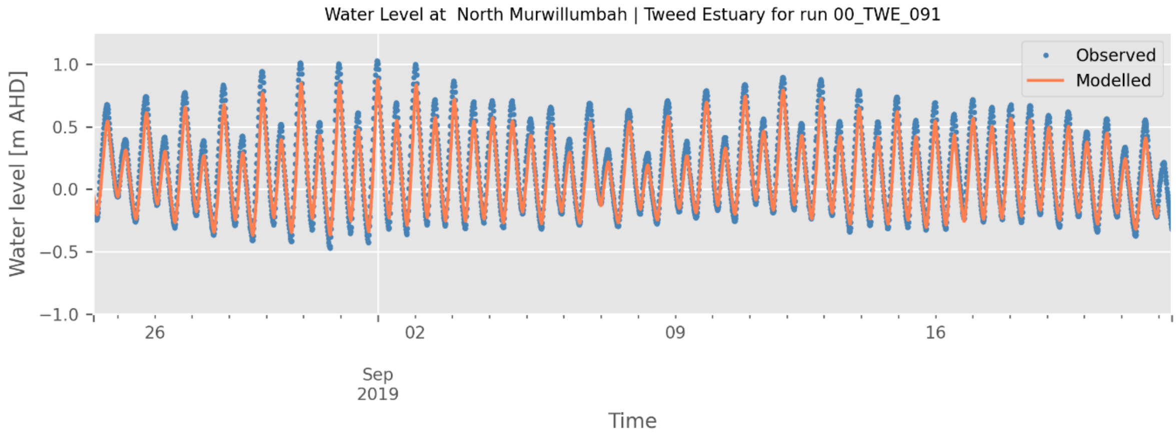

Figure B-32 2019 water level verification – Location 9 – North Murwillumbah

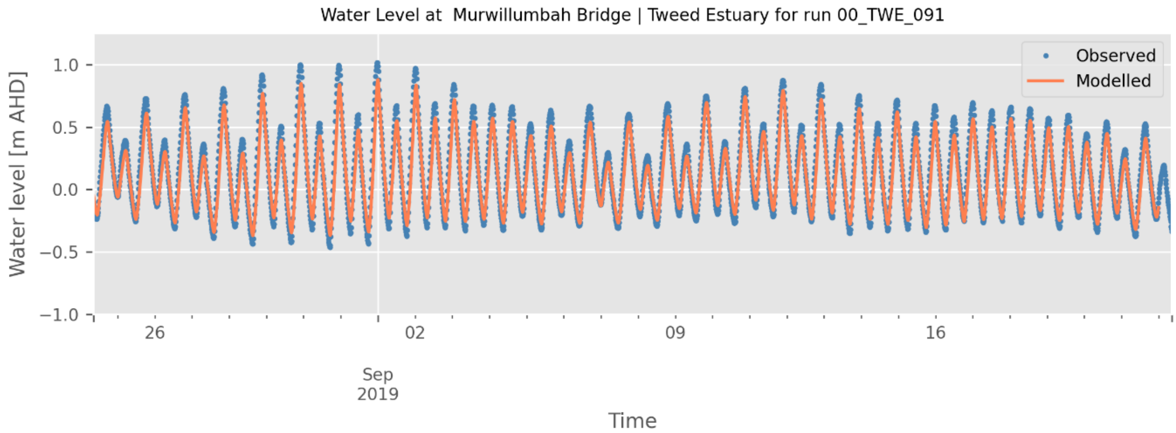

Figure B-33 2019 water level verification – Location 10 – Murwillumbah