Port of Tauranga Stella Passage Development

Assessment of Effects on Hydrodynamics and Sedimentation

8 April 2025

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1. Executive Summary

1.1 Scope of Assessment Undertaken

This report assesses the effects of the dredging and reclamation components of the Stella Passage Development (the proposal) on the generation of turbid plumes and sediment deposition (*sedimentation*), and on patterns of currents (*hydrodynamics*) within Te Awanui (Tauranga Harbour).

1.2 Environmental Effects Identified

Both stages of the proposal involve dredging and reclamation, so apart from the effects of scale, the potential environmental effects are the same for both.

During dredging and reclamation, the potential impacts include excavation of benthic biota, and the release of potential contaminants into the water column including suspended sediment (turbidity) and dissolved or absorbed materials such as heavy metals, hydrocarbons and pesticides.

During the post-dredging or recovery phase, the main potential impacts within Te Awanui are changes to the tidal circulation and sediment transport; changes to the behaviour of depth dependent phenomena, such as waves and storm surges; and changed patterns of erosion and accretion. These impacts tend to be long-term and may not manifest immediately after dredging and reclamation activities are completed.

1.3 Assessment of Environmental Effects

Sedimentation

Discharge of fines as a turbid plume from a trailing suction hopper dredge (TSHD) or a backhoe dredge (BHD) is the dominant potential environmental impact. The dredging plumes are largely confined to the deeper parts of channels downstream from the dredge due to their density and the use of controlled overflows from the dredge hopper. Most sediment within the plumes is deposited on the seafloor close behind the dredge.

Computer modelling, and observations during previous maintenance and capital dredging projects, shows that negligible sediment is transported into shallow subtidal and intertidal areas that could potentially be adversely affected. The available data indicates that the range of natural turbidity within Te Awanui exceeds TSHD turbidity levels outside the mixing zone.

On this basis, the proposal's effects on sediment deposition processes in Te Awanui are assessed as being very low outside the confines of the existing channels. With adherence to the mitigation measures recommended in this report, these effects would reduce to negligible.

Hydrodynamics

Numerical modelling and measurements taken before and after previous capital dredging campaigns shows that the effects of dredging on hydrodynamics are predominantly confined to the channels within the Port area of Te Awanui. Modelling specifically developed for the proposal shows a reduction in peak tidal velocities, and a small change in the durations of ebb and flood flows resulting from the dredging. The changes are at the limit of resolution of available instrumentation, and are less than the natural weather-induced variations.

On this basis, the proposal's effects on hydrodynamic processes in Te Awanui beyond the shipping channels are assessed as negligible. Within the shipping channels the proposal's effects are assessed as very low to low.

Contamination

The sediment being excavated predominantly consists of pristine Pleistocene terrestrial and marine sediments that contain no anthropic contaminants. Potential contamination is limited to the 0.2-0.5 m thickness of surficial sediments disturbed by sediment transport, bioturbation, and anthropic activities. This sediment will be diluted with deeper uncontaminated sediment, and largely completely confined to the dredge hopper for disposal.

With adherence to the mitigation measures recommended in this report, the effects of contamination will be negligible.

1.4 Recommendations and Mitigation Measures.

Sedimentation

The turbidity produced by dredging can be controlled by using the following management measures:

- overflow with constrictions to reduce plume buoyancy;
- limited overflow duration to control the total volume of sediment introduced into the plume; and,
- no overflow.

If necessary, with overflow the direction of plume movement can be controlled by restricting dredging to parts of the tidal cycle (e.g. ebb tide only).

Consent conditions (similar to those previously applied to dredging activities in Te Awanui) can require utilising an overflow approach and tidal state condition that minimises the amount of sediment potentially affecting areas of concern, combined with monitoring (observers and instrumentation) that can trigger appropriate avoidance approaches if necessary. These conditions would be appropriate to apply to the proposal, albeit with a requirement to review the trigger levels that prompt management measures to be initiated if new potential impacts of turbidity are identified.

Hydrodynamics

No mitigation measures are recommended in relation to effects on hydrodynamic processes, due to the proposal's negligible hydrodynamic effects beyond the shipping channels.

Contamination

No mitigation measures are recommended in relation to potential contamination, due to the proposal's negligible contamination impacts.

2. Introduction and Project Description

This report considers the potential effects of the proposal on the hydrodynamic and sedimentation processes within Te Awanui.

Figure 1 shows the components of the proposed development involving dredging or excavation, and reclamation, for the two stages proposed.

Stage 1 involves:

- Dredging a volume of ~850,000 m^3 from 6.10 ha on the western side of Stella Passage, including the area included in resource consent RC 62920 (Figure 2); and
- Extending Sulphur Point Wharf 285 m southwards and reclaiming 0.88 ha of coastal marine area landward of the wharf extension.

Stage 2 involves:

- Extending the Stage 1 dredged area southward towards the harbour bridge, and eastward towards Butters Landing, involving ~650,000 m^3 of dredging from an area of 4.45 ha;
- Extending Sulphur Point Wharf a further 100 m southwards and reclaiming 0.93 ha landwards of the extension.
- Extending Mount Maunganui Wharf 315 m southwards and reclaiming 1.59 ha landward of the extension; and
- Reclaiming 0.18 ha at Butters Landing in conjunction with development and occupation of the coastal marine area with minor structures (bunker barge jetty, mooring piles and similar).

The sediment to be used as fill in the construction of the reclamations is expected to be obtained from excavation of the batter slopes and adjacent dredging, with the sediment landed and dewatered within a bund as part of the reclamation area. The exception is the small 0.18 ha reclamation at Butters Landing where sediment may be trucked in from sediment stored and dewatered elsewhere.

The dredging required for Stage 1 of the proposal includes seabed located below and adjoining the areas previously authorised to be dredged under resource consent 62920 (Figure 2). Consent 62920 covers 5.9 ha of the 6.1 ha area that is proposed to be dredged for Stage 1, but only authorises dredging to a depth of 12.9 m. Stage 1 of this proposal will allow deepening the channel to a depth of 16 m. Previous assessments of the sediment characteristics for southern Stella Passage focussed on depths shallower than 14.5 m.[1] Hence, this assessment also considers any potential impacts involving sediment at depths between 14.5 m and 16 m.

The proposal may result in adverse impacts during three phases:[2]:

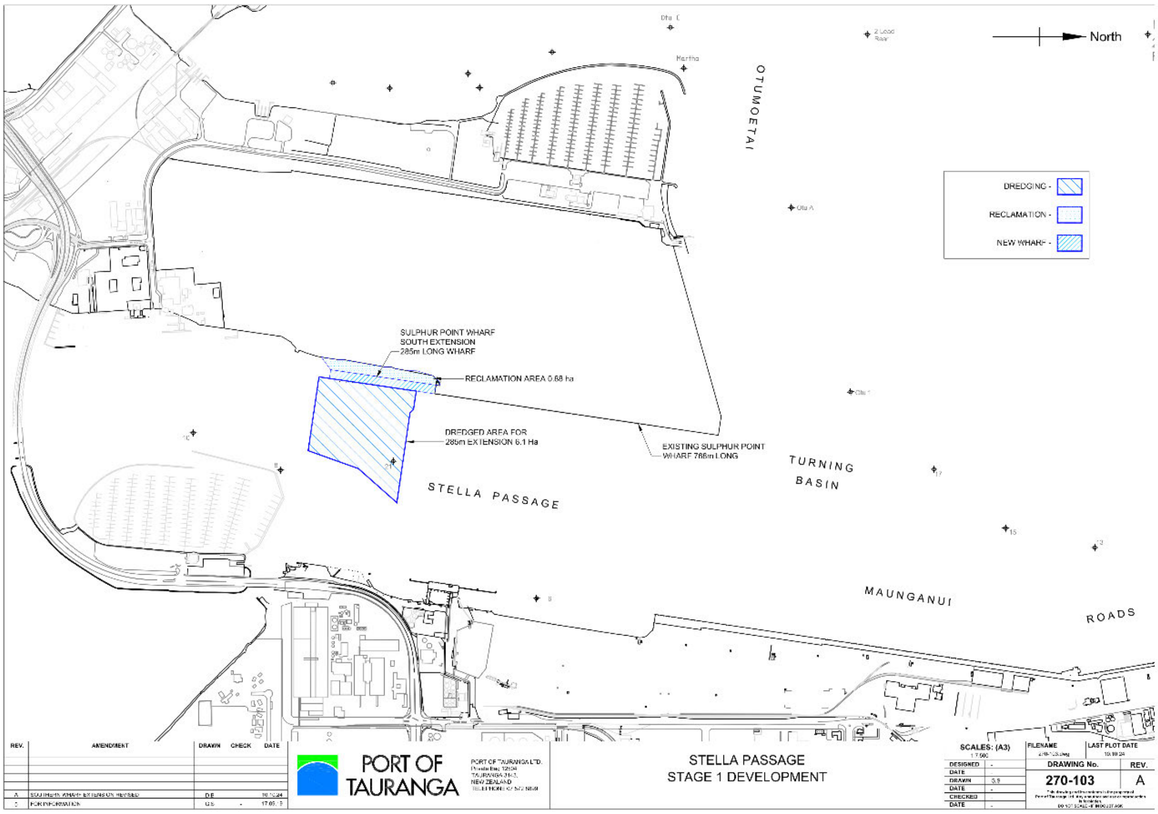
- during the excavation (dredging) of the seabed;
- during the construction of reclamations using dredged sediment; and;
- during the post-dredging or recovery period.

During the excavation phase, the main potential impacts are excavation of benthic biota, and the release of potential contaminants into the water column including suspended sediment (turbidity) and dissolved or absorbed materials such as heavy metals, hydrocarbons and pesticides.

During the construction of the reclamations, the main potential impacts are burial of benthic biota, and the release of potential contaminants into the water column including suspended sediment (turbidity) and dissolved or absorbed materials such as heavy metals, hydrocarbons and pesticides.

1 Moon, VG, & de Lange, WP. Characteristics of sub-surface sediments in southern Stella Passage, Tauranga Harbour. Environmental Research Institute Report 133, University of Waikato, Hamilton. 62 pp.

2 EPA (2016). Technical guidance: Environmental impact assessment of marine dredging proposals, Environmental Protection Agency, Western Australia: 23 pp.



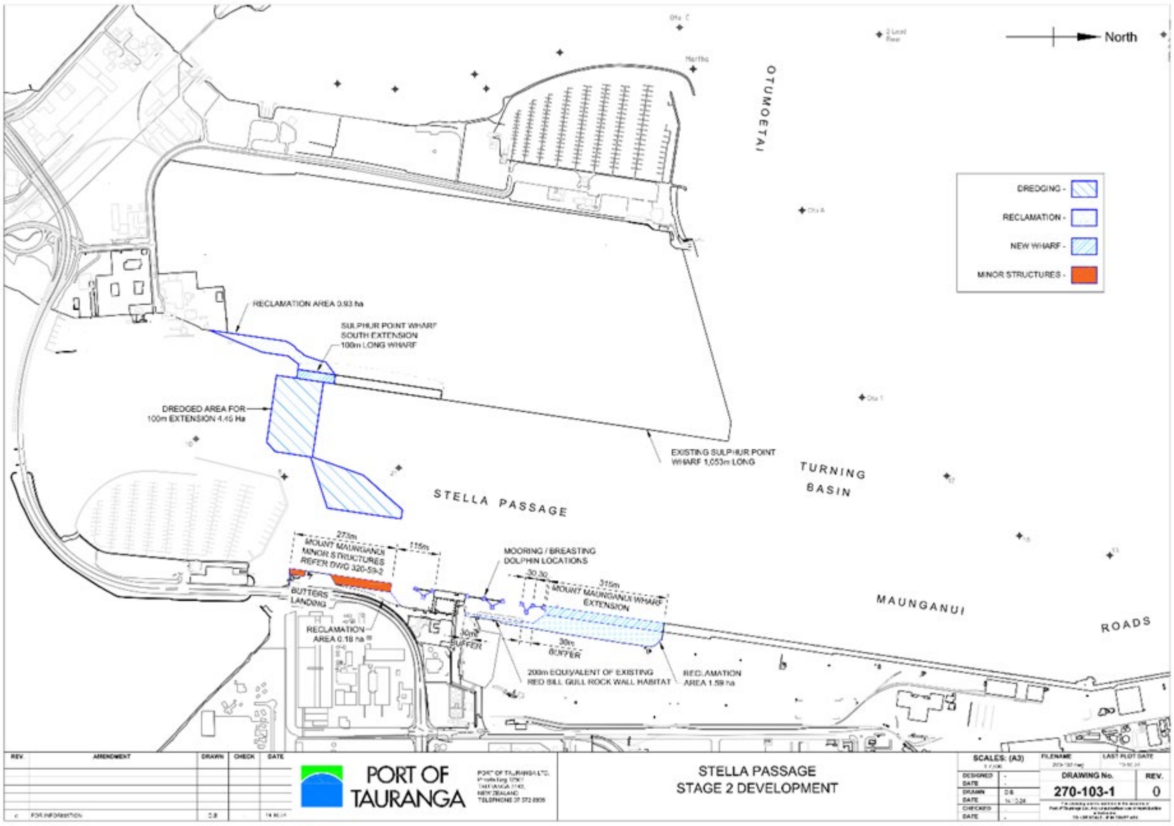


Figure 1: Proposed Stage 1 (upper) and Stage 2 (lower) development of Stella Passage showing the proposed dredging, and reclamations and structures associated with wharf extensions.

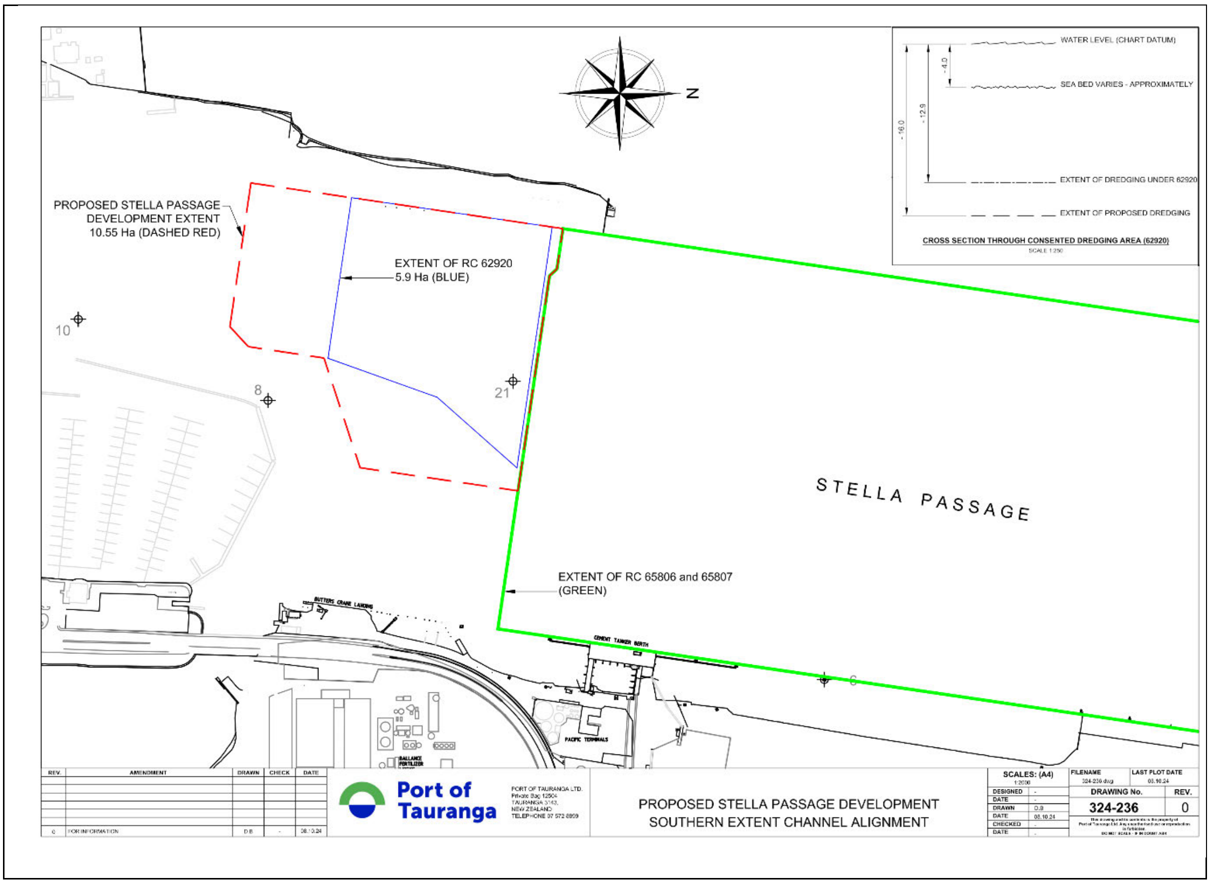


Figure 2: Relative extent of existing dredging resources vs this proposal

The effects at the excavation and reclamation construction phases are transient. The characteristics of the impacts for both phases are predominantly determined by the texture (size distribution) of sediment being dredged, the level of contamination, and the dredging technology and methodology used. This includes the size of the TSHD and BHD used. In general, smaller dredges have a smaller impact, assuming they have the same technology and follow the same procedures. This occurs because the amount of excavation and therefore disturbance per load is less due to the smaller capacity of the hopper. Therefore, the transient effects of dredging for Stages 1 and 2 will be reduced if a smaller TSHD or BHD is used.

The impacts during the excavation phase are also dependant on the characteristics of the sediments being dredged, although this can be mitigated by adjusting the dredging methodology. Although dredging technology and methodology is continually evolving (*viz*. Kirichek et al, 2021;[3] Hu et al, 2022;[4] Fuller et al, 2023[5]), this proposal is based on proven methodologies previously used by the Port of Tauranga. Section 3 will summarise the underlying geology of Stella Passage, the geomorphology, and past developments that have affected the hydrodynamics and sedimentation. Section 4 will assess the effects of the proposal on sedimentation.

Sediments not used to construct the reclamations will be disposed of at offshore sites. As this activity is authorised by existing consents, it is not considered in this assessment.

During the post-dredging or recovery phase, the main potential impacts are changes to the tidal circulation and sediment transport within and outside the harbour; changes to the behaviour of depth dependent phenomena, such as waves and storm surges; changed patterns of erosion and accretion; and dispersal of sediment from the

[3] Kirichek, A., Cronin, K., de Wit, L., & van Kessel, T. (2021). Advances in Maintenance of Ports and Waterways: Water Injection Dredging. In Sediment Transport-Recent Advances (pp. 1-20). IntechOpen.

[4] Hu, P., Deng, S., Zhao, Z., Cao, Z., & Liu, H. (2022). Dredging Volume Estimation and Dredging Timing for Waterway Maintenance: A Case Study Using a Depth-Averaged Hydrosediment–Morphodynamic Model with Transient Dredging Effects. Journal of Waterway, Port, Coastal, and Ocean Engineering, 148(5), 04022014.

[5] Fuller, W. P., Wagner, R. J., & Lewis, R. E. (2023). U.S. Hydrodynamic Dredging Challenges and Opportunities. Transportation Research Record, 2678(7), 487-500.

disposal site. Changes to tidal circulation primarily may occur within the harbour, but can affect the ebb-tidal delta, and manifest as changes to the shape of the tidal elevation curve (affecting tidal range, the timing of high and low tide, the duration of flood and ebb tidal flows, and tidal flushing). The post-dredging changes may be permanent, or persist for several years before returning to pre-dredging conditions.

The impacts during the post-dredging phase are predominantly determined by the changes made to the morphology (mostly the tidal channels), and the subsequent morphodynamics response, which involves an interactive system of changing currents and morphology. Usually, areas subject to dredging are naturally changing in response to processes such as weather events and variations in sediment supply. Depending on the scale of the changes produced by dredging, it can be difficult to identify the extent of adverse effects resulting from dredging as distinct from natural processes.

Section 5 will discuss the longer-term adjustments to the harbour morphology and hydrodynamics resulting from the proposed dredging.

3. Existing Environment

Te Awanui (Tauranga Harbour) is a geologically young feature in the Bay of Plenty, having formed within the last 7,500-8,500 years in response to sea level rise since the last ice age (de Lange et al, 2015).[6] It occupies two basins: the Katikati Basin in the northwest; and the Tauranga Basin in the southeast. These basins are located on the western margin of the Central Volcanic Zone (CVR) (Figure 3). Stella Passage, including the project footprint, is located within the Tauranga Basin.

Stella Passage and further south into and beyond Town Reach has been modified by progressive development of the Port of Tauranga and other infrastructure including the Tauranga Harbour Bridge and Marina, and causeways for road and rail.

3.1 Geology, Geomorphology and Hydrodynamics of Te Awanui

The Tauranga Basin, including Stella Passage, mostly occupies a rift formed during the initial development of the Taupo Volcanic Zone (TVZ) based on regional gravity anomalies and geological data (Figure 4). It is separated from the Katikati Basin by a shallow interfluve between Matahui Point and Matakana Point that is only submerged around high tide. This interfluve represents the region between the caldera underlying the Katikati Basin and the rift forming the Tauranga Basin.

While the Tauranga Basin rift system appears to still be undergoing subsidence associated with active faults (ie. faults that have moved at least once in the last 125,000 years), the interfluves are rising. The Papamoa Hills are also rising based on continuous GPS (cGPS) data collected by GeoNet. It is considered that the distribution of warm to hot springs around Te Awanui is controlled by faults associated with the underlying caldera and rift system (Braithwaite and Christie, 1996).[7]

The sediment within the harbour is predominantly sourced from erosion of young volcanic deposits formed by eruptions in the Tauranga Volcanic Centre, primarily by fluvial transport (braided rivers) during glacial conditions when sea level was 100-120 m lower than at present (MacPherson *et al*, 2017).[8] These volcanic deposits naturally contain heavy metals including copper, lead, zinc, arsenic, vanadium, chromium and nickel (Hughes,

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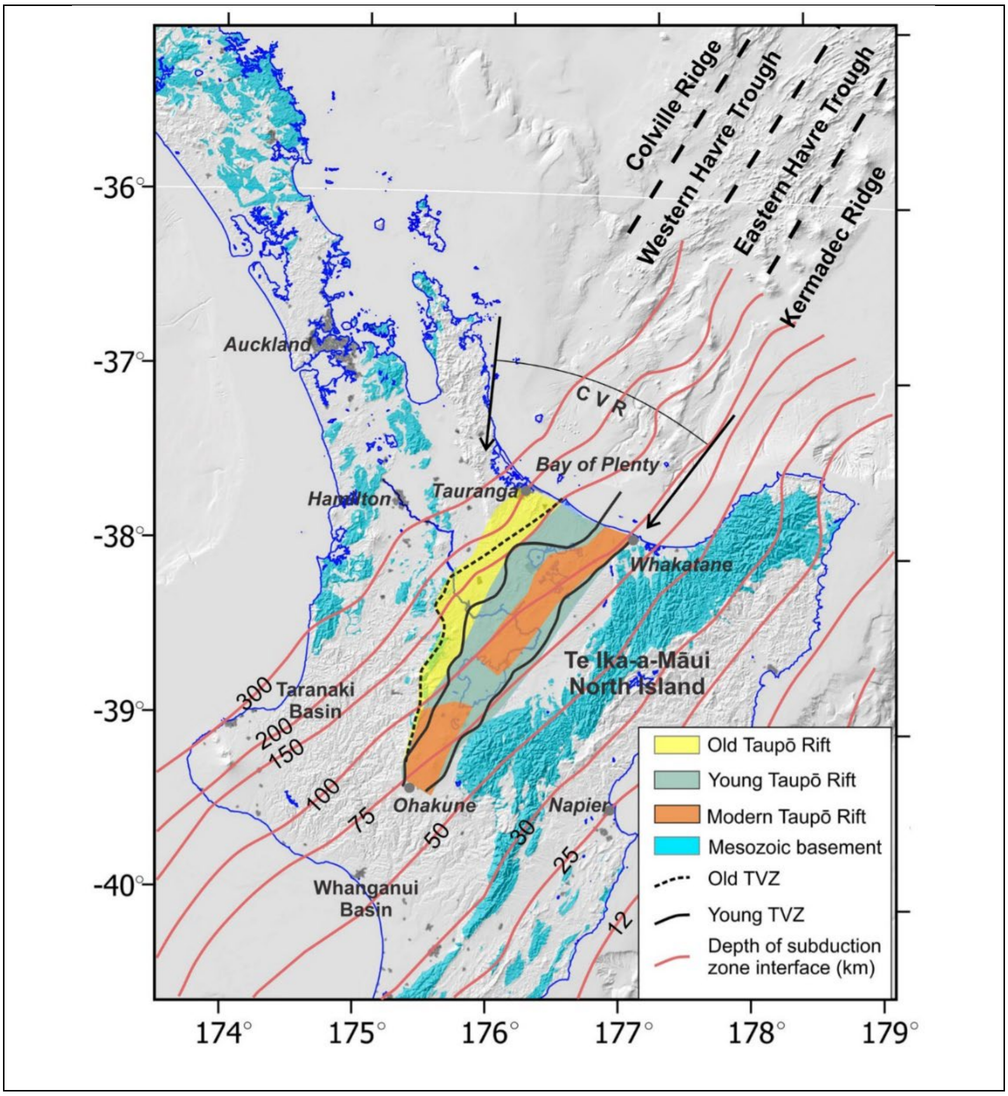
6 de Lange, W., Moon, V., & Johnstone, R. (2015). *Evolution of the Tauranga Harbour Entrance: Influences of tsunami, geology and dredging*. Proceedings of Australasian Coasts & Ports Conference 2015: 235-241.

7 Brathwaite RL, Christie AB. 1996. Geology of the Waihi area: part sheets T13 and U13 [map]. Lower Hutt (NZ): Institute of Geological & Nuclear Sciences. 1 folded map + 64 p., scale 1:50,000. (Institute of Geological & Nuclear Sciences geological map; 21)

8 MacPherson D, Fox BRS & de Lange WP, 2017: Holocene evolution of the southern Tauranga Harbour, *New Zealand Journal of Geology and Geophysics* 60: 392-409.

1993;[9] Whitbread-Edwards, 1994[10]); Hall, 1994;[11] Hopkins *et al,* 2021;[12] Cooper *et al*, 2012[13]). Hence, sediments within Te Awanui naturally have higher levels of heavy metals than other harbours in New Zealand that do not have significant volumes of young volcanic deposits in their catchments. The metals are incorporated within the sediment grains, and will not be released into the water column during dredging.



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9 Hughes G, 1993. *Volcanic geology of the Eastern Tauranga Basin and Papamoa Range*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

10 Whitbread-Edwards AN, 1994. *The volcanic geology of the Western Tauranga Basin*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

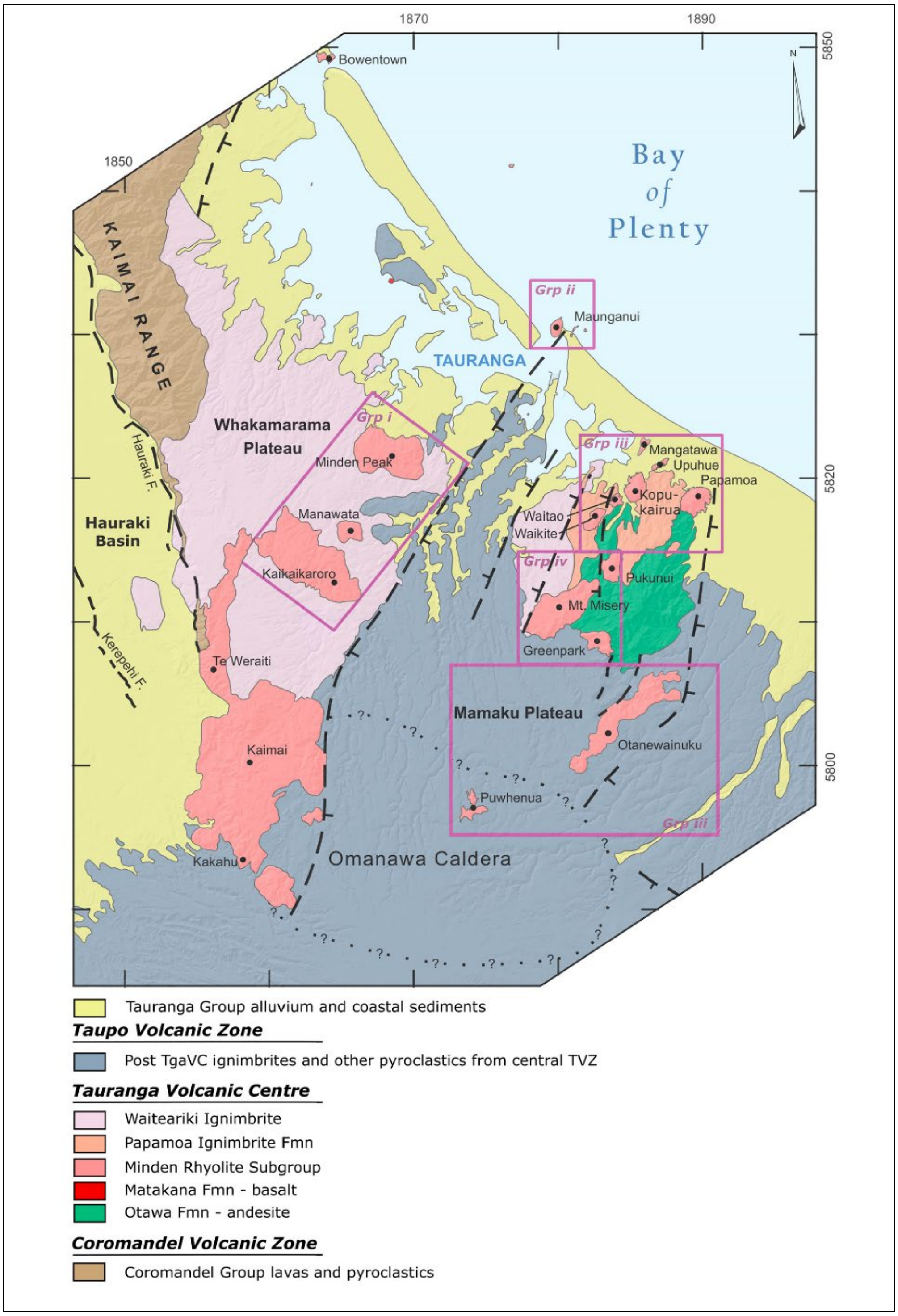
11 Hall GJ 1994. *Volcanic geology of the Southeastern Tauranga Basin*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

12 Hopkins JL, Bidmean JE, Lowe DJ, Wysoczanski RJ, Pillans BJ, Ashworth L, Rees ABH, & Tuckett F, 2021. TephraNZ: a major- and trace-element reference dataset for glass-shard analyses from prominent Quaternary rhyolitic tephras in New Zealand and implications for correlation. *Geochronology* 3: 465-504.

13 Cooper GF, Wilson CJN, Millet M-A, Baker JA, & Smith EGC, 2012. Systematic tapping of independent magma chambers during the 1 Ma Kidnappers supereruption. *Earth and Planetary Science Letters*, 313-314: 23-33.

Figure 3: Major tectonic features of the Central Volcanic Zone (CVR) and offshore Bay of Plenty. Contour lines represent the depth to top of the descending Pacific plate underlying the North Island. (Figure 1 from Stagpoole et al, 2021).[14]

The fluvial deposits have been overlain by a marine deposit of variable thickness formed by reworked volcaniclastic sediment that has been transported into the harbour from offshore. Some sediment is also supplied by fluvial transport from the surrounding catchments, and from erosion of volcanic deposits around the shoreline.



14 Stagpoole, V., et al. (2021). A two million-year history of rifting and caldera volcanism imprinted in new gravity anomaly compilation of the Taupō Volcanic Zone, New Zealand. New Zealand Journal of Geology and Geophysics 64(2-3): 358-371.

Figure 4: Simplified geological map of the Tauranga Volcanic Centre highlighting the structures and young pyroclastic deposits. The boxes identify groups of volcanic domes with comparable geochemical characteristics (Figure 2 from Pittari et al, 2021).[15]

The development of Te Awanui/Tauranga Harbour since sea level reached about the present level some 7,000 years ago, has followed the classic evolution from a juvenile to mature estuary. However, that the progression is quite slow compared to many other New Zealand estuaries due to a limited supply of sediment and rising relative sea level in the Tauranga Basin caused by subsidence. This means that there is a strong tidal influence (with minimal freshwater effects), and sufficiently deep water at high tide to allow moderate wave action. This results in the export of fine sediment from the intertidal and sub-tidal areas of Te Awanui. Fine sediment accumulation is restricted to the harbour margins, particularly in areas of locally high sediment supply, and/or very low wave activity (de Ruiter, 2022).[16]

Figure 5: Conceptual model of the main sediment transport pathways in Te Awanui, based on sediment connectivity analysis (de Ruiter, 2022).

15 Pittari, A., Prentice, M. L., McLeod, O. E., Yousef Zadeh, E., Kamp, P. J. J., Danišík, M., & Vincent, K. A. (2021). Inception of the modern North Island (New Zealand) volcanic setting: spatio-temporal patterns of volcanism between 3.0 and 0.9 Ma. New Zealand Journal of Geology and Geophysics, 64(2-3), 250-272.

16 de Ruiter, JP, 2022. Hypsometric and geometric controls on hydrodynamics, tidal asymmetry, and sediment connectivity in shallow estuarine systems. PhD Thesis, The University of Waikato, Hamilton, NZ. 116 p.

Siltation within Te Awanui tidal channels may occur in response to sediment supplied from one, or both, of two sources: marine sediment transported into Te Awanui by waves and tidal currents; and terrestrial sediment from freshwater catchments and shoreline erosion, reworked and transported by waves and tidal currents within the harbour. The boundary between marine-dominated and terrestrial-dominated is not static: it varies with the changing magnitude of tidal flows over spring-neap cycles, magnitude of freshwater inflows, and the influence of storms through storm surges and floods. In the long-term, as the harbour matures, the boundary moves seaward as the harbour naturally infills with sediment. The sediment source for the flood tidal delta (Te Paritaha or Centre Bank) and surrounding channels (Lower Western Channel, Otumoetai Channel, Maunganui Roads, Pilot Bay Channel, and Cutter Channel is predominantly marine and associated with the ebb and flood tidal delta system (MacPherson *et al*, 2017). Stella Passage is a transition zone from marine to terrestrial sediment dominated. Further from the harbour tidal inlets, the sediment sources are dominated by terrestrial inputs (Pritchard *et al*, 2009;[17] Hancock *et al*, 2009[18]).

de Ruiter (2022) utilised a numerical model of Te Awanui to undertake a sediment connectivity analysis to identify the main sediment pathways, sources and sinks. The results were used to develop the conceptual model in Figure 5.

Figure 5 replicates Figure 4.8 from de Ruiter, 2022. The arrows indicate the range of sediment grain sizes (colour) transported between the different estuary regions, and the relative strength of the connections (arrow size). Six divergent and convergent sub-basins are also highlighted (blue icons). Transport of coarse sediments (>300 µm) is mainly confined to the deep tidal channels, whereas sub-basins and upper estuary regions are characterised by transport of mainly finer sediment fractions (<200 µm).

The shallow interfluve between the two main basins only allows exchange of water and sediment at high tide. The movement is primarily driven by currents created by wind stress (typically at velocity <3% of the wind velocity, and sediment transport only involves locally sourced sediment (Figure 4). Overall, transport of coarse and medium sand (>300 µm, <1.75 phi) is predominantly confined to deeper tidal channels and the flood tidal delta, and finer sediment is moved in shallower areas

Moon and de Lange (2019) developed a 3D model of the sub-surface stratigraphy for the southern end of Stella Passage (Figure 6) by combining data from seismic surveys, cores and CPT profiles. This was used to generate cross-sections (Figures 7 and 8).

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17 Pritchard M, Gorman R, & Hume T, 2009a. Tauranga Harbour Sediment Study: Hydrodynamic and Sediment Transport Modelling. NIWA Client Report: HAM2009-032, February 2009.

18 Hancock N, Hume T, & Swales A, 2009. Tauranga Harbour Sediment Study: Harbour bed sediments. NIWA Client Report: HAM2008-123, March 2009.

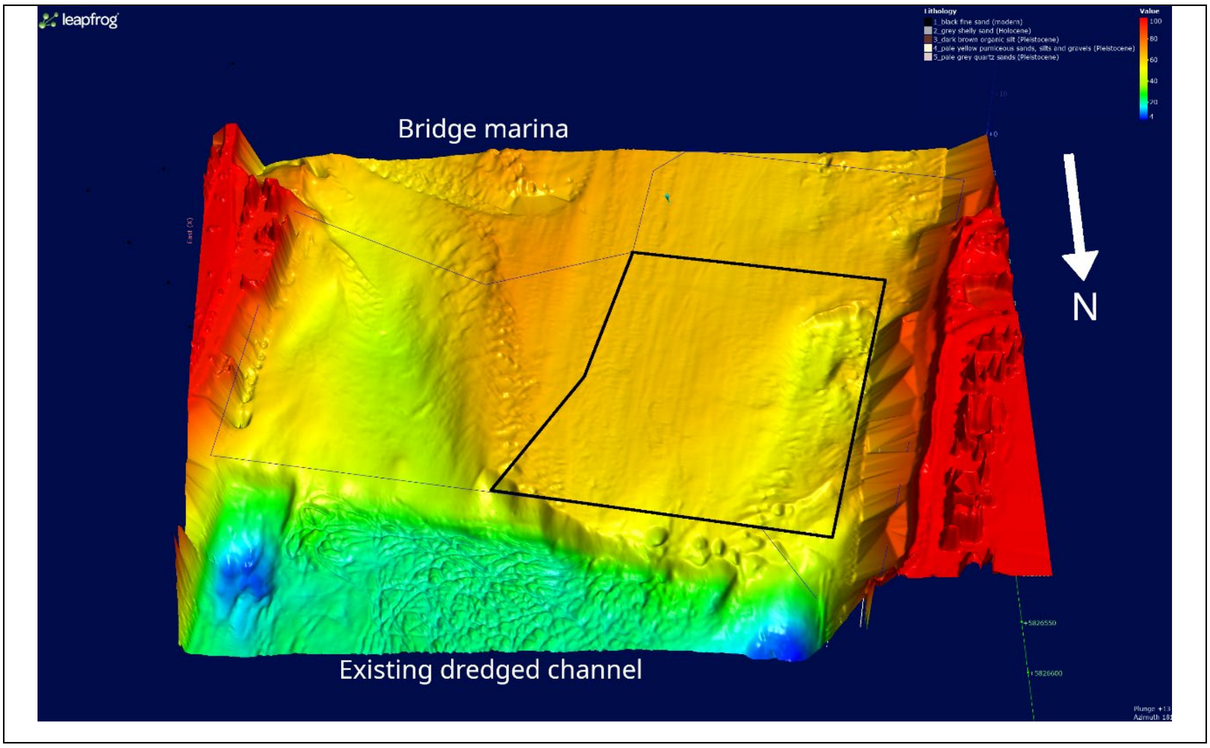

Figure 6: 3D subsurface stratigraphic model of southern Stella Passage looking south along the passage towards the Harbour Bridge. The Stage 1 excavation area is outlined by the black line. Note scoured tracks made by THSD drag heads within the existing dredged channel.

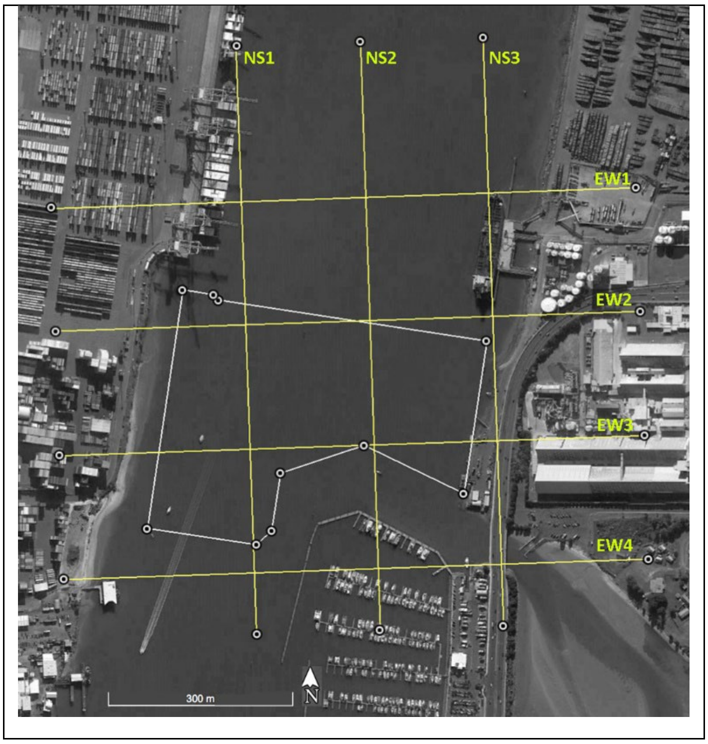

Figure 7: Locations of the cross-sections derived by Moon and de Lange (2019) from the Leapfrog model (Figure 6).

Moon and de Lange (2019) identified 5 main subsurface units within the area covered by the 3D model:

a) **Holocene black fine sands** – this facies only occurs as an ebb-tidal delta formed at the northern outlet from Waipu Bay at Whareroa Point on the eastern side of Stella Passage. It is a dark poorly-sorted to very-poorly-sorted very fine sand (30-40% fines), which is significantly finer than the other main facies. It does not occur in the area to be dredged for Stage 1, but may extend into the Stage 2 area (Figure 1);

b) **Holocene grey shelly sands** – this facies consists of grey, poorly to very-poorly sorted medium to very-fine sand, with 12-43% fines and shell fragments. With increasing depth the shell content decreases, the sediment becomes finer overall, and the fines content increases. The variations with depth are interpreted to represent changing depositional conditions as sea level rose during the Holocene marine transgression. The fines are predominantly silt-sized, with increasing clay with depth. However, the sampling for sediment texture from cores within this facies concentrated on lenses of organic rich fine matter, which had a higher fines content than the surrounding gravelly sands. Hence, the fines content is likely to be lower than reported. This facies represents over half the volume to be excavated;

c) **Pleistocene dark brown organic silt** – this facies occurs at the top of the alluvial fan sediments. It consists of organic-rich silts that probably represent salt marsh deposits analogous to the modern salt marshes on the margins of Te Awanui. This facies occurs predominantly along the western margin of the Stella Passage in the area to be reclaimed by the wharf extension, and in the southern area of Stella Passage towards the Harbour Bridge. It will mostly be untouched by dredging so it represents a small component of the sediment to be excavated. It may be useful to obtain samples of this unit to determine the fines content;

d) **Pleistocene pale-yellow pumiceous sands** – this facies represents an alluvial fan formed during the last glacial. It is a highly variable unit consisting of lensoidal or lenticular sub-units that have limited areal extent. These sub-units (in order of increasing fines content and decreasing volume) represent channel deposits, overbank flood deposits, lake sediments, swamp deposits and paleosols. The amount of weathering increases with depth (increasing age), which is associated with increasing clay content. The fines content varies from 18-97%, depending on the type of sub-unit, with no clear trend with depth. This facies is likely to contain iron pans associated with paleosols, and buried logs associated with over-bank flood and swamp deposits. This facies represents about a third of the volume to be excavated; and

e) **Pleistocene pale grey quartz sands** – this facies consists of moderately-sorted to very poorly-sorted medium to very fine sand, and represents an alluvial fan partially overlain by Eemian (previous interglacial) marine sediments deposited during the last glacial. There are some sub-units that consist of very poorly-sorted coarse to very fine silt. The fines content is lowest in medium sand sub-units (6%) and highest in the very fine silt sub-units (95%). This facies may be considered as an older version of the younger pale-yellow pumiceous sand facies in the overlying unit, with the main differences due to longer weathering (changed colours and increased fines), more consolidation (increased mass strength), and some marine sediments. This facies will only be encountered near the bottom of the excavation.

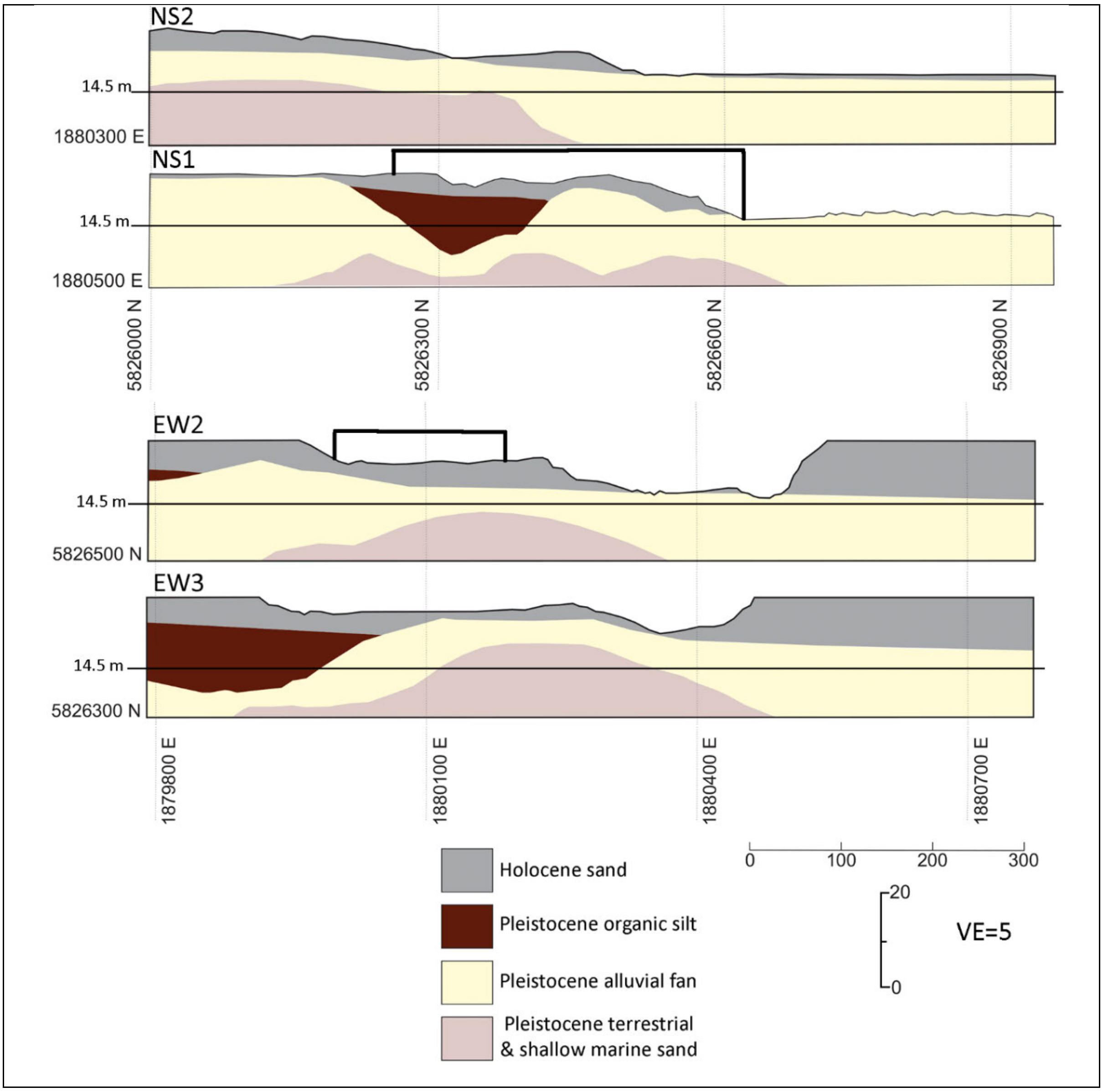

Figure 8: Cross-sections of the subsurface stratigraphy through Stella passage from Moon and de Lange (2019). The thick black lines indicate the area to be excavated to 16 m, 1.5 m below the 14.5 depth indicated.

This sequence of stratigraphic units indicates 3 main phases of deposition (MacPherson et al, 2017; Pittari et al, 2021; Prentice, 2023):[19]

- Deposition of marine sediments during the previous (Eemian) interglacial when sea levels were similar to the present day;
- Deposition of a complex sequence of terrestrial sediments during the last glacial period when sea level was up to 120 m lower than present. These sediments include primary pyroclastic deposits – airfall (tephra), and pyroclastic flow (ignimbrite) deposits – and fluvial deposits of volcaniclastic sediments derived from the volcanic centres in the TVZ, including the TVC. This sequence predominantly formed as an alluvial fan infilling the rift, and consists of braided river channels with coarser levees and fine overbank deposits including swamps (peats) and lake sediments;
- Deposition of predominantly marine sediments during the current (Holocene) interglacial. Initially deposition was rapid when sea level reached approximately present levels about 7,200-7,500 years ago.

[19] Prentice, ML (2023). Silicic volcanism of the Tauranga Volcanic Centre and the climactic Waitearki supereruption at the dawn of the Taupō Volcanic Zone. PhD Thesis, The University of Waikato, Hamilton, New Zealand.

Sedimentation rates decreased as development of the present-day day tombolo and barrier system restricted and then cut-off supplies of marine sediment from offshore. Eventually sediments were primarily derived from catchments further up the harbour. These sediments are significantly finer than the offshore marine sediments (e.g. the black fine sands facies derived from Waipu Bay).

Within Te Awanui, the presence of biogenic material, such as shells and wood, is a useful indicator of the age of sediment and the depositional environment (marine or terrestrial). During previous capital dredging programmes, biogenic material has included cemented sediments containing shells (beach rock), lumps of peat, and wood fragments to large portions of trees (Figure 9). Shells are associated with the marine sediments and are more common in the Holocene deposits, but can be found with the Eemian deposits where they are more likely to be associated with beach rock. Peat and portions of trees are most likely to be found within the interglacial alluvial fan deposits, and may be associated with iron pans (ferricrete) where iron leached out of surface sediments is precipitated to form a hard layer.

The lake (lacustrine) sediments and primary pyroclastic deposits may contain silt-sized silica (glass) sediments that produce highly visible plumes when dredged, even for low concentrations of suspended sediment (Coppede Cussioli, 2018[20]). These can occur as relatively small, localised deposits within the alluvial fan, which makes them difficult to locate before dredging.

Surficial and near-surface sediments potentially are affected by anthropic disturbance, including sedimentation, that can change the sediment texture (making it finer or coarser) and/or introduce contaminants. The proposed dredging areas (Figure 1) have been impacted by anthropic activities, primarily during the 20th and 21st centuries. The main potential impacts on the proposed dredged region are associated with port (including marinas) and urban development, such as historic reclamation, dredging, and ongoing storm-water discharges that may introduce contaminants adsorbed onto fine sediment (predominantly clays).

Anthropic impacts are mostly limited to the depth of sediment mixing due to sediment transport and bioturbation, which is of the order 0.2-0.5 m. However, there is a small area (borrow pit) where sediment was stored during dredging before being utilised elsewhere. Sediment cores for this area indicate that contaminants may have been mixed to a depth of several metres. The core sample contaminants observed only consisted of broken glass fragments and there was no evidence of introduced fine sediments. It is unlikely that dredging the surficial sediments and deeper sediments within the borrow pit site will release contaminants into the water column.

[20] Coppede Cussioli M, 2018. *Ecological effects of turbidity variations in and around dredging areas in the Port of Tauranga*. PhD Thesis, The University of Waikato, Hamilton, New Zealand.

Figure 9: Examples of the larger clasts encountered by the trailer suction dredge during the 1991/92 Capital Dredging Programme: top left – shells cemented in estuarine mud; top right – wood, pumice, peat, iron cemented sands (ferricrete or iron pan) and rhyolite cobbles; and bottom – tree stumps.

In summary, the area proposed to be dredged involves several different units with a variety of sediment types that will require a combination of THSD and BHD dredges and methodologies. The sediment units involved are predominantly:

- Holocene grey shelly sands comprising more than half of the excavated volume, which have not undergone subaerial weathering. Hence, they have low fines contents and limited weathering products such as clays and iron oxides.
- Pleistocene pale-yellow pumiceous sands comprising about a third of the excavated volume. These represent an interbedded mixture of sediment types that have been exposed to about 20-100,000 years of weathering. They contain variable amounts of fines and weathering products. Localised deposits within this unit have previously produced very visible sediment plumes at low suspended sediment concentrations. Others have required a BHD for excavation.
- The remaining sediment units discussed above make up the balance of material to be excavated. They either form localised deposits at the boundaries of the proposed dredging, or occur at the deepest levels to be excavated. These units have the highest fines contents.

Anthropic contaminants are potentially present in the surficial Holocene grey sands. However, previous assessments have found concentrations to be very low and it is unlikely that dredging will release detectable levels into the water column.

The management of the fines present within proposed dredged area will be address in Section 4.

3.2 Evolution of Stella Passage

Comparison of maps and hydrographic charts from 1852 to the present (viz. Brannigan, 2009)[21] identified changes to the bathymetry of Te Awanui associated with reclamation and dredging. The most significant changes were (Appendix - Figures A1-A7):

- Reclamation of land associated with wharves and railway lines starting with the Tauranga Railway Wharf in 1924 (the earlier Railway or D- Wharf, was constructed at Mt Maunganui in 1910 and demolished in 1936, without involving reclamation), and then along the Mt Maunganui shoreline starting in 1952;

[21] Brannigan AM, 2009. *Change in geomorphology, hydrodynamics and surficial sediment of the Tauranga Entrance tidal delta system.* MSc Thesis, The University of Waikato, Hamilton, New Zealand.

- Development of dredged channels for the port starting in 1968;
- Reclamation of inter-tidal flats at Sulphur Point starting in 1965 and continued during the 1970s leading to the construction of the Sulphur Point Wharf completed in 1992;
- Reclamation for the causeway of the Tauranga Harbour Crossing in the 1980s;
- Development of the Tauranga Bridge Marina in the 1990s; and
- Extension of the Sulphur Point Wharf to provide and additional berth and accommodate larger container vessels (ongoing).

In relation to hydrodynamics and sediment transport within Stella Passage, the main subaerial changes were the reclamations of Sulphur Point and the Tauranga Harbour Crossing (Figures 10). These changes reduced the width of the channel at high tide. In addition, Stella Passage has been progressively deepened by dredging starting in the 1960s. Initially the Bay of Plenty Harbour Board operated its' own dredge to remove sand from Stella Passage and reclaim Sulphur Point, with most capital dredging completed by 1978. Two further capital dredging campaigns deepening the channel occurred in 1991-1992, and 2015-16.

Figure 10: (Top row) Aerial photographs of Stella Passage taken on 9th February 1943 (left) before, and on 28th November 1994 after (right), most of the historical infrastructure development. (Bottom) Google Earth image of Stella Passage taken on 6th March 2016 showing additional development after 1994. This consisted of extensions to the Sulphur Point Wharf and development of the Tauranga Bridge Marina. Photographs from Retrolens.co.nz.

Overall, the cross-sectional area of the Stella Passage channel adjacent to the wharves has increased since the situation shown in the 1943 aerial photograph (Figure 10 top left). The effects of the developments producing this change were predicted before development occurred by combining observations with modelling: initially a physical model of the harbour (Hydraulics Research Station, 1963,[22] 1968[23]), followed by numerical models (*viz*. Barnett, 1985;[24] Black, 1985[25]; Bell, 1991;[26] Mullarney & de Lange, 2018,[27] 2019[28]). The effects were also

[22] Hydraulics Research Station, 1963. *Tauranga Harbour Investigation. Report on First Stage*. Report No. 201. Hydraulics Research Station, Wallingford, England. 69p.

[23] Hydraulics Research Station, 1968. Tauranga Harbour Investigation. Report on the second stage. Report No. EX 395. Hydraulics Research Station, Wallingford, England. 92p.

[24] Barnett AG, 1985. *Tauranga Harbour Study: A report for the Bay of Plenty Harbour Board. Part I Overview. Part III Hydrodynamics*. Ministry of Works and Development, Hamilton, New Zealand.

[25] Black KP, 1984. Tauranga Harbour Study: A report for the Bay of Plenty Harbour Board. Part IV Sediment transport: text, figures and tables. Ministry of Works and Development, Hamilton, New Zealand.

[26] Bell RG, 1991. Port of Tauranga Model Study (Deepened Shipping Channel Proposal, Consultancy Report No 6127/1, DSIR Water Quality Centre, Hamilton, New Zealand.

[27] Mullarney JC, & de Lange WP, 2018. *Hydrodynamic modelling of proposed expansion of the Port of Tauranga shipping channels and wharves*. Environmental Research Institute Report No 119. Client report prepared for Port of Tauranga. Environmental Research Institute, Faculty of Science and Engineering, The University of Waikato, Hamilton. 30 pp.

[28] Mullarney JC, & de Lange WP, 2019. Impacts on sediment transport of proposed expansion of the Port of Tauranga shipping channels and wharves. *Environmental Research Institute Report No 125*. Client report prepared for Port of Tauranga. Environmental Research Institute, Faculty of Science and Engineering, The University of Waikato, Hamilton. 10 pp.

assessed after development using a combination of observations and models (*viz*. Davies-Colley & Healy, 1978;[29] Dahm, 1983;[30] Mathew, 1997;[31] Ramli, 2016[32]).

Several studies have focussed specifically on Stella Passage: Boulay (2012)[33] provides the most comprehensive review of the conditions within Stella Passage prior to the 2015-2016 capital dredging. McKenzie (2014)[34] modelled the impacts of various scenarios for future dredging beyond the planned 2015-16 campaign, including the effects on infrastructure such as the Tauranga Bridge Marina. Watson (2016)[35] examined the impacts of the 2015-16 dredging on Stella Passage and areas further upstream within the harbour. The combination of observations and modelling in these studies and others they cite indicate that the infrastructural developments around Stella Passage have resulted in:

- A decrease in peak flood and ebb tidal velocities within the dredged areas of Stella Passage, resulting in enhanced deposition of fine sediment at the southern end of the deepened channel where an ebb jet decelerates rapidly as it transitions from shallow to deep water;
- Enhanced westward transport of sand along the shoreline fronting Whareroa Marae due to increased ebb flows through the channel exiting the northern area of Waipu Bay as a consequence of the Tauranga Harbour Crossing causeway;
- Formation of a persistent tidal eddy between the Cement Tanker Berth and No 11 Berth at the southern end of the Mt Maunganui Wharves, due to the embayment between the wharf alignment and original shoreline; and
- Flood flow acceleration as the tide transitions from deep water to shallow water at the southern end of the dredged channel formed an armoured seabed of imbricated shells.

The 2015-2016 Capital dredging moved the transition zone southwards, resulting in scouring of the shallower channel south of the dredged channel over several months until an armoured seabed was established at the new location. Modelling predicted negligible impacts (predominantly a small change in the timing of high and low tide of the order of a few minutes depending on wind direction) of capital dredging of Stella Passage beyond the boundaries of Stella Passage and the northern channel of Waipu Bay. These predictions were confirmed by observations following the completion of dredging (Trividic, 2017).[36] The distribution and volumes of maintenance dredging within Stella Passage after 2016 are also consistent with the predicted flows (Figure 13).

Figure 11 shows most sediment accumulates north of the drop-off into the shipping channel (area with TSHD draghead tracks in Figure 6). Some sediment accumulates along the margins of the shipping channel close to the wharves, mostly on the western side along Sulphur Pt Berth (SPT).

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29 Davies-Colley R, & Healy TR, 1978. Sediment and hydrodynamics of the Tauranga Entrance to Tauranga Harbour. *New Zealand Journal of Marine and Freshwater Research*, 12: 225 -236.

30 Dahm J, 1983. *The geomorphic development, bathymetric stability and sediment dynamics of Tauranga Harbour*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

31 Mathew J, 1997. *Morphologic changes of tidal deltas and an inner shelf dump ground from large scale dredging and dumping, Tauranga, New Zealand*. PhD Thesis, The University of Waikato, Hamilton, New Zealand.

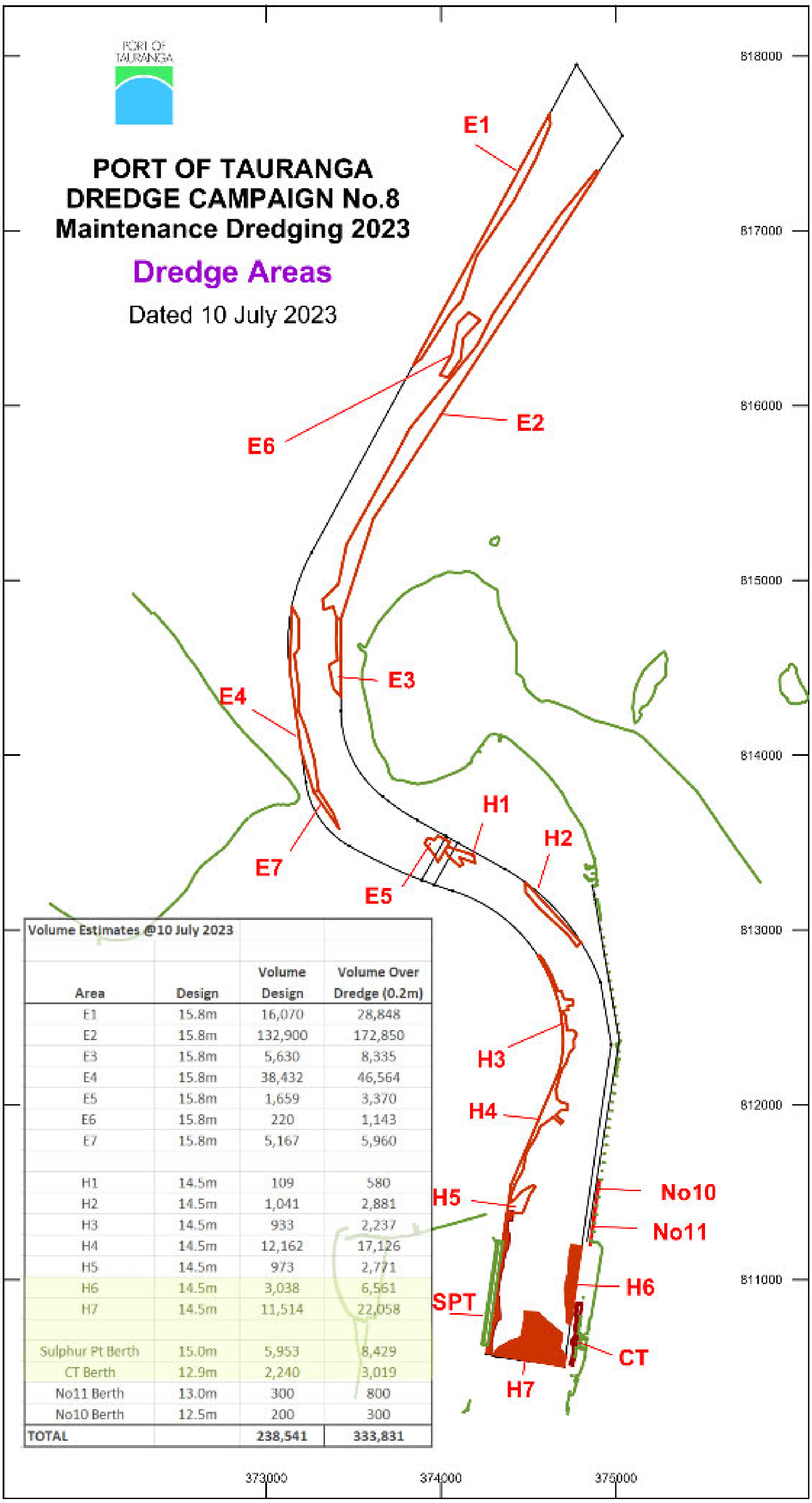
32 Ramli AY, 2016. *The Impact of Dredging on the Stability of Matakana Banks Ebb-Tidal Delta*. PhD Thesis, University of Waikato, Hamilton, New Zealand.

33 Boulay SOC, 2012. *Analysis of multibeam sonar data for benthic habitat characterization of the Port of Tauranga, New Zealand*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

34 McKenzie JS, 2014. *Predicted hydrodynamic and sediment transport impacts of breakwater construction in Tauranga Harbour, New Zealand.* MSc Thesis, The University of Waikato, Hamilton, New Zealand.

35 Watson HM, 2016. *Potential impacts of wharf extensions on the hydrodynamics of Stella Passage and upstream regions of Tauranga Harbour, New Zealand*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

36 Trividic G, 2017. *Impact of dredging on Tauranga Harbour*. Master SML, Université de Bretagne Occidentale, France.



Area	Design	Volume Design	Volume Over Dredge (0.2m)
E1	15.8m	16,070	28,848
E2	15.8m	132,900	172,850
E3	15.8m	5,630	8,335
E4	15.8m	38,432	46,564
E5	15.8m	1,659	3,370
E6	15.8m	220	1,143
E7	15.8m	5,167	5,960
H1	14.5m	109	580
H2	14.5m	1,041	2,881
H3	14.5m	933	2,237
H4	14.5m	12,162	17,126
H5	14.5m	973	2,771
H6	14.5m	3,038	6,561
H7	14.5m	11,514	22,058
Sulphur Pt Berth	15.0m	5,953	8,429
CT Berth	12.9m	2,240	3,019
No11 Berth	13.0m	300	800
No10 Berth	12.5m	200	300
TOTAL		238,541	333,831

Figure 11: Estimated maintenance volumes in July 2023. The Stella Passage areas (H6, H7, SPT, and CT) are highlighted. Provided by Port of Tauranga Limited.

4. Assessment of Sedimentation Effects

4.1 Extraction

During the extraction phase a typical TSHD can generate turbid plumes in three distinct ways (Figure 12) (Mills & Kemp, 2016):[37]

- At the seafloor as the draghead disrupts the sediment to allow it to be pumped up into the dredge hopper;
- From the overflow discharge of water pumped into the hopper along with the sediment; and
- In shallow conditions, the propellor wash or jet can disturb sediment on the seafloor, and disrupt the settling process for the plumes produced by the other two sources.

Figure 12 distinguishes between the surface plume that results from mixing of the overflow sediment with the water around the dredge, and the dynamic plume that involves a density current transporting most of the overflow sediment. Plume generation and behaviour was measured during dredging operations at the Ports of Auckland in 1992 and 1993 (Priestley, 1995).[38] The observations showed that the increased density within the plume due to suspended sediment resulted in most discharged sediment being transported directly to the seabed, with the majority being rapidly redeposited as the plume collapsed and dispersed (as shown in Figure 12). This led to the conclusion by Priestley (1995) that the environmental effects were minimal.

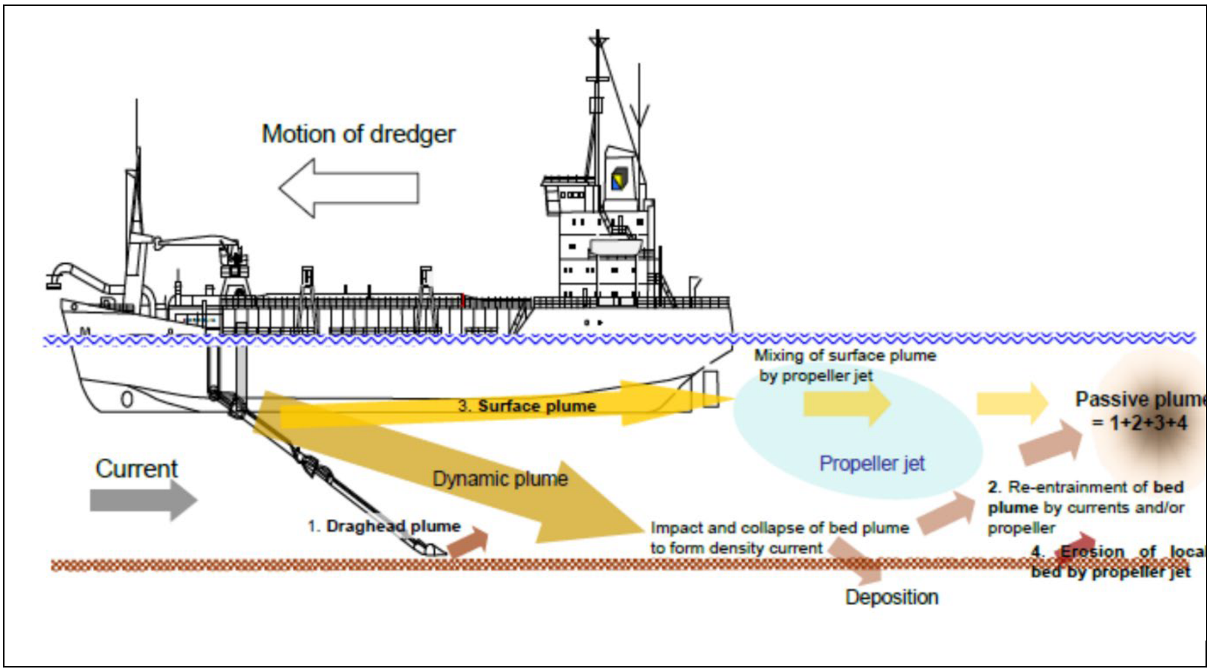


Figure 12: Release of sediment arising from dredging by a trailing suction hopper dredge and contributions to the suspended sediment (Figure 9 from Mills & Kemps, 2016).

As part of a series of studies assessing the impacts of dredging for the continental shelf and harbours of West Australia undertaken by the West Australian Marine Science Institution (WAMSI), Mills and Kemps (2016) undertook an extensive review of the international literature on the sources and sinks of sediments in dredging plumes for TSHDs and Cutter Suction Dredges (CSD). They concluded that the main source of sediment entering

[37] Mills, D., & Kemps, H. (2016). Generation and release of sediments by hydraulic dredging: a review. WAMSI Dredging Science Node, Report, Theme 2, Project 2.1. 77 pp.

[38] Priestley, S. (1995). Measured environmental impacts of dredging operations. WIT Transactions on The Built Environment, 8, 283-290.

the plumes was the hopper overflow, with Kemps and Masini (2017)[39] suggesting that overflow contributes >3 times the amount of sediment of the other sources combined. If the water was sufficiently shallow, then propellor wash disturbance of the sea floor was the second most important. Overall, the draghead plume was a minor source of sediment forming a plume. Hence, most methodological approaches to reducing turbidity associated with dredging focus on managing the overflow.

Kemps and Masini (2017) reviewed methods for estimating the proportions of sediment contributing to the dredge plumes, specifically the near-field plume where coarser sediment is rapidly being deposited, and the far-field plume where the finest sediment may remain in suspension for long periods (Figures 13 and 14). Figure 13 is a schematic diagram of the overflow and draghead plume sources, with density of the shading indicating the proportion contributed to the overall turbidity of the total near-field plume. The overflow plume consists of some spillage over the sides of the hopper, and the main discharge piped from the hopper.

As the plume moves away from the near-field, the concentration of suspended sediment within the plume declines rapidly as the plume disperses and, more importantly, the sediment settles to the seabed (Figure 14). For Stella Passage, dispersion is less important for the excavation phase than the disposal phase, as the flow is generally concentrated in deep channels, particularly during ebb tide. Settling of larger grain and clast sizes, typically fine sand and coarser, is rapid (order of seconds) so this material returns to the sea bed close to the dredge. The settling is enhanced if the sediment has aggregated into larger clasts, and if the concentration of sediment is sufficiently high for descending clasts to entrain finer sediments in their wakes.

Very fine sand to fine silt takes minutes to settle to the seabed (depending on water depth and level of turbulence), and the time/distance taken for this to occur defines the extent of the near-field plume. Previous consent conditions for the Port of Tauranga have defined a mixing zone relative to the dredge, which represents the maximum likely extent of the near-field plume. The remaining sediment (very fine silt and clay) tends to remain in suspension if there is any turbulence present, unless the grains form larger aggregates (flocculation, or incorporation into marine snow), and forms the far-field plume. Very fine material may take hours to days to settle, which means that it is generally exported from estuaries.

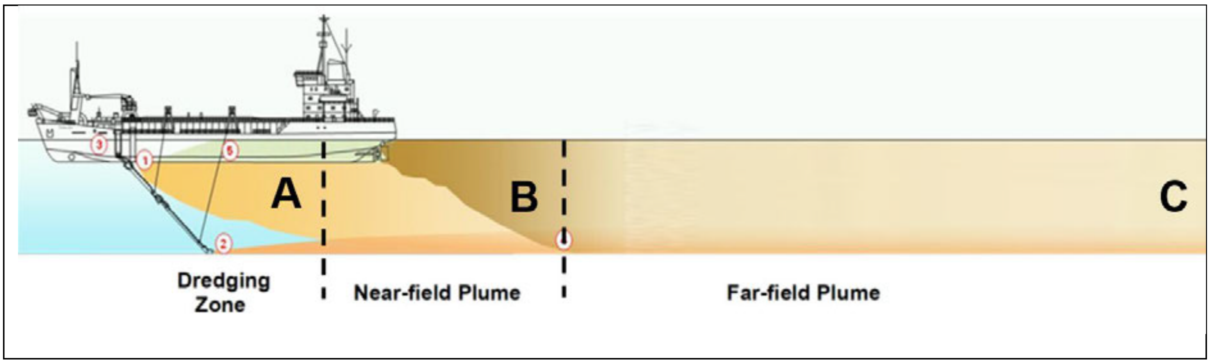


Figure 13: Schematic diagram of the turbid plumes for a trailing suction dredge produced by the sources and processes illustrated in Figure 12. The zones A, B, and C correspond to the zones in Figure 12 that shows the plume behaviour with time/distance from source.

The quantity of sediment discharged from the dredge hopper as overflow depends on the methodology being used. Figure 15 summarises three approaches to dredging available and their effects on turbidity. The TSHD used by the Port of Tauranga for the 1991/92 Capital Dredging Programme operated with a standard overflow. The TSHDs used for the 2015/16 Capital Dredging Programme used a low turbidity valve or choked overflow, which can restrict the piped overflow to reduce air bubbles that keep sediment in suspension, limit the amount of fine sediment entering the overflow, and strengthen the dynamic plume to enhance redeposition on the seabed. The low turbidity valve significantly reduced the extent of the near-field plume in 2015/16, and a far-field plume was not reported by observers. If necessary, overflow can cease completely so that only the near-bed draghead plume is generated.

[39] Kemps, H. & Masini, R. (2017). Estimating dredge source terms – a review of contemporary practice in the context of Environmental Impact Assessment in Western Australia. WAMSI Dredging Science Node, Report, Theme 2, Project 2.2. 23 pp.

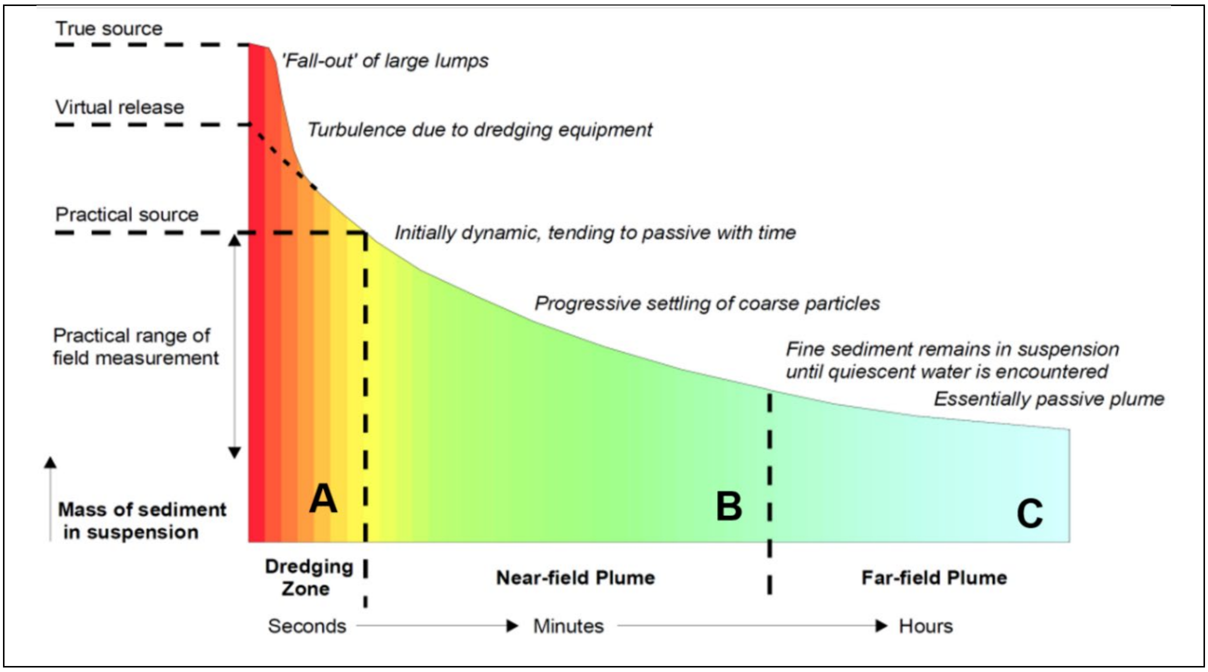


Figure 14: Schematic diagram of the sources of turbid plumes for a trailing suction dredge, where the overflow consists of two components: a concentrated discharge from a pipe at the stern of the dredge, and some discharge over the sides of the hopper. Propellor wash is not specifically shown. The zones A, B, and C correspond to the zones in Figure 12 that shows the plume behaviour with time/distance from source.

A review of the literature by Kemps and Masini (2017) indicated that ~85% of the fine sediments and all of the coarse sediment in the overflow plume was deposited within the extent of the near-field plume, with 15% contributing to the far-field plume. The use of choke valve technology (Figure 14) reduced the far-field fines contribution to 7-8%. Since most of the coarser sediment is retained within the hopper, the overflow tends to have a higher fines content than the sediment being dredged, so dredging will potentially increase the fines content of the surficial sediments.

This impact is probably more significant for frequent maintenance dredging, than capital dredging that is essentially a one-off event. There is not much literature that examines the effects of dredging on the seabed sediment texture during the extraction phase. The work published predominantly considers extraction from the inner continental shelf for renourishment or building materials (*viz*. Xu et al, 2014;[40] Crowe et al, 2016;[41] Mielck et al, 2018;[42] Gartelman, 2024[43]), where it is typically observed that extraction results in a fining of the surficial sediments. However, this is normally attributed to deposition of muds in the borrow pits sometime after dredging has finished. Xu et al (2014) noted that no previous studies had compared the sediment texture immediately before and after dredging. Most studies compare the sediment texture at the extraction site with "similar" sites elsewhere.

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40 Xu, K., Sanger, D., Riekerk, G., Crowe, S., Van Dolah, R. F., Wren, P. A., & Ma, Y. (2014). Seabed texture and composition changes offshore of Port Royal Sound, South Carolina before and after the dredging for beach nourishment. *Estuarine, Coastal and Shelf Science*, 149, 57-67.

41 Crowe, S. E., Bergquist, D. C., Sanger, D. M., & Van Dolah, R. F. (2016). Physical and Biological Alterations Following Dredging in Two Beach Nourishment Borrow Areas in South Carolina's Coastal Zone. Journal of Coastal Research, 32(4), 875-889.

42 Mielck, F., Hass, H. C., Michaelis, R., Sander, L., Papenmeier, S., & Wiltshire, K. H. (2019). Morphological changes due to marine aggregate extraction for beach nourishment in the German Bight (SE North Sea). Geo-Marine Letters, 39(1), 47-58.

43 Gartelman, A., Xu, K., Maiti, K., Liu, H., Moran, K., Wilson, C., Roberts, B. J., & Nelson, J. (2024). Sedimentation processes and morphological changes in a dredge pit and surrounding environment on Ship Shoal in the northern Gulf of Mexico. Marine Geology, 470, 107218.

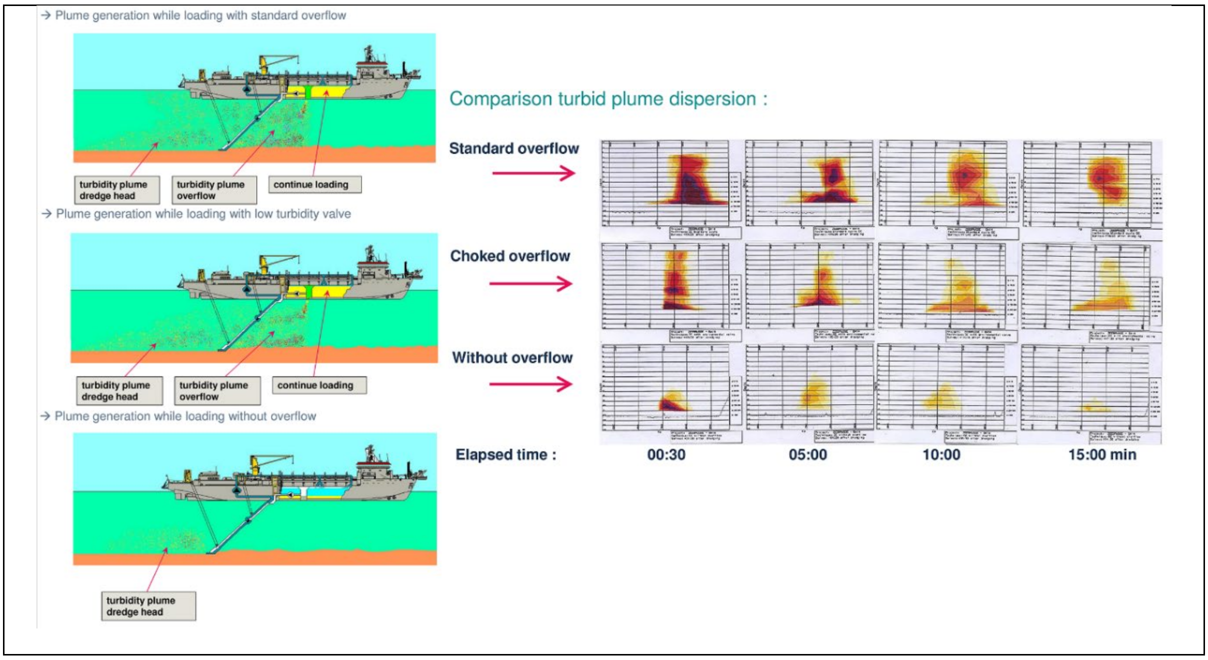

Figure 15: Schematic diagram of the sources of turbid plumes for a trailing suction dredge, where the overflow consists of two components: a concentrated discharge from a pipe at the stern of the dredge, and some discharge over the sides of the hopper. Propellor wash is not specifically shown. The zones A, B, and C correspond to the zones in Figures 15 and 16 that show the plume behaviour with time/distance from source.

Studies that investigated the seabed changes caused by the extraction phase of dredging within estuaries have predominantly focused on changes to benthic biota, particularly macrobenthos. Some report changes to the physical characteristics. For example, Rehitha et al (2017)[44] reported sediment texture and density as well as water quality and assessed their correlation with changes in macrobenthos biomass. They found finer sediment and reduced biomass within dredged areas compared to non-dredged areas. However, they did not undertake sampling immediately before and after dredging, and also attributed changes and differences between sites to the impact of seasonal monsoons.

The overflow sediment discharge is normally expressed as a flux (e.g. $kg.s^{-1}$), whereas the plume sediment content is expressed in either concentrations such as Total Suspended Sediment (TSS), or an index of the effect of suspended material on light transmission, such as Nephelometric Turbidity Units (NTU). The rate of sediment deposition, particularly in the far-field, is generally very small (of the order $mg.cm^2.d^{-1}$) and cannot be measured reliably (Stark et al, 2017).[45] The relationships between the different parameters used to assess the potential impacts of plumes are non-linear and complex. They depend on many factors (Mills and Kemps, 2016; Fisher et al, 2017[46]; Kemps and Masini, 2017; Stark et al, 2017; Fearns et al, 2018:[47] Fearns et al, 2019[48]):

- Size and design of the dredge, which influences:
    - Hopper dimensions and the processes distributing and sorting sediment within the hopper. Generally, coarser sediments and clasts are preferentially trapped in the hopper;

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44 Rehitha, T. V., Ullas, N., Vineetha, G., Benny, P. Y., Madhu, N. V., & Revichandran, C. (2017). Impact of maintenance dredging on macrobenthic community structure of a tropical estuary. Ocean & Coastal Management, 144, 71-82.

45 Stark, C., Whinney, J., Ridd, P. & Jones, R. (2017). Estimating sediment deposition fields around dredging activities. WAMSI Dredging Science Node, Report, Theme 4, Project 4.3. 16 pp.

46 Fisher, C., Stark, C., Ridd, P. & Jones, R. (2017). Effects of dredging and dredging related activities on water quality: Spatial and temporal patterns. WAMSI Dredging Science Node, Report, Theme 4, Project 4.2. 94 pp.

47 Fearns, P., Dorji, P., Broomhall, M., Branson, P. & Mortimer, N. (2018). Plume Characterisation – Laboratory Studies. WAMSI Dredging Science Node, Report, Theme 3, Project 3.2.2. 47 pp.

48 Fearns, P., Dorji, P., Broomhall, M., Chedzey, H., Symonds, G., Branson, P., Contardo, S., Shimizu, K. & Sun, C. (2019). Plume Characterisation – Field Studies. WAMSI Dredging Science Node, Report, Theme 3, Project 3.2.1. 57 pp.

- Sediment discharge rate and duration, which determines the initial characteristics of the dynamic plume (e.g. density, momentum);
- Presence of “green” or choke valve technology, which controls the formation of air bubbles that can enhance transfer of sediment from the dynamic plume to the surface plume;
- Location of the overflow discharge, which determines the separation between the dynamic plume and surface plume behind the dredge (Figure 12); and
- Turbulence around and behind the dredge, caused by the passage of dredge and propellor wash.

- Currents, including:
  - Effective current due to the movement of the dredge, where higher dredge velocities result in more sediment being transferred from the dynamic plume to the surface plume;
  - Ambient currents and their orientation relative to the dredge motion. Within Te Awanui, and particularly Stella Passage, the currents and dredge tracks are predominantly aligned along the channels (the exceptions are at the junctions of channels, such as Stella Passage and Otumoetai Channel);
  - Wave-induced currents, which increase vertical turbulence.
- Sediment characteristics, including:
  - Sediment texture (particle size distribution), which is usually based on single grains, but for cohesive sediments should consider aggregates. The texture is an important factor determining the settling velocity, and hence the distance/duration that the sediment remains within plumes; and
  - Sediment grain shape and colour, which together with grain size determine the interaction between suspended sediment and light. These interactions determine the proportions of light scattered and transmitted, and changes to the quality of the light (spectral characteristics).
- Background suspended sediment, which is typically present and can naturally vary spatially and temporally.

Numerical modelling is normally used to estimate the plume movement and associated dispersion of suspended sediment. Models usually focus on the far-field plume, which is a simpler situation to model as most sediment is deposited within the near-field involving the interaction of multiple sources (Becker et al, 2015).[49]

BMT WBM (2015)[50] simulated the plumes generated by different options for maintenance dredging of Stella Passage using either a BHD or a TSHD. The TSHD modelled had a 18,000 m^3 capacity, compared to the 1,800 m^3 capacity of the *Albatros* TSHD normally used for maintenance dredging, and represents a worst-case scenario for capital dredging. It was assumed that 80% of the fine sediment entering the TSHD would be returned to the water column by overflow with choke valve technology, which reduces the sediment in the dispersing plume by 50-90% by limiting the quantity of air entrained in the overflow (Decrop, 2015).[51] The modelling suggested that worst case initial plume discharge rates would be:

- 3.3 $kg.s^{-1}$ for the BHD with a 0.14 $m^3.s^{-1}$ production rate.[52]
- 85.3 $kg.s^{-1}$ for the TSHD without overflow with a 5.33 $m^3.s^{-1}$ production rate.
- 486 $kg.s^{-1}$ for the TSHD with 10 minutes of overflow with a 1.28 $m^3.s^{-1}$ effective production rate.

These values are specific to the dredges and the sediment characteristics modelled. Settling from the near-field plume removed 85% of sediment, returning it to the dredged seabed, leaving 15% to disperse in the far-field

49 Becker, J., van Eekelen, E., van Wiechen, J., de Lange, W., Damsma, T., Smolders, T., & van Koningsveld, M. (2015). *Estimating source terms for far field dredge plume modelling*. Journal of Environmental Management, 149, 282-293.

50 BMT WBM, 2015. *Stella Passage Dredging – Scenario Modelling*. Memorandum to Port of Tauranga Ltd, BMT WBM Pty Ltd, Brisbane, Australia.

51 Decrop B 2015. *Numerical and Experimental Modelling of Near-Field Overflow Dredging Plumes*. PhD Thesis, Ghent University, Belgium.

52 Production rate is the rate at which sediment is extracted from the seabed. With overflow, an effective production rate is used to account for the volume of sediment lost via the overflow, which can involve assuming a slower rate of production or a larger volume extracted to fill the hopper (faster production).

plume (Figure 12). Their model results indicated that the sediment plumes would be largely confined to the Stella Passage and Maunganui Roads shipping channels, and no sediment would be deposited on Te Paritaha or in Waipu Bay (Whareroa Marae foreshore).

Montaño (2024)[53] presents the results of numerical modelling of plumes generated by a large TSHD and a BHD for the shipping channels in Te Awanui. They simulated a TSHD with a 15,000 m^3 maximum hopper capacity, compared to the *Balder R* with a 6,000 m^3 hopper capacity used for the 2015-2016 capital dredging and the *Albatros* with a 1,800 m^3 hopper capacity used for maintenance dredging. The BHD was assumed to excavate a maximum of 5,000 $m^3.d^{-1}$.

It was assumed that the sediment plumes were formed from a mixture of sediment grain sizes consisting of 53% medium sand, 5% fine sand and 40% silt. Coarse sands and gravels were assumed to be retained within the hopper, or settle immediately for the drag head plume. Clays were ignored due to the very low proportions of clay present in the sediment being excavated. The plume sources were taken as a proportion of the total volume excavated during a TSHD cycle, or per day for a BHD (Table 1).

Table 1: Summary of the source volume fluxes for the components of the excavation plumes (Figure 12) modelled by Montaño (2024).

	Proportion	TSHD Overflow	TSHD No overflow	BHD
Production rate		4.96 $m^3.s^{-1}$	7.22 $m^3.s^{-1}$	0.120 $m^3.s^{-1}$
TSHD drag head	3 %	0.15 $m^3.s^{-1}$	0.22 $m^3.s^{-1}$	
TSHD propellor wash	3 %	0.15 $m^3.s^{-1}$	0.22 $m^3.s^{-1}$	
TSHD overflow	20 %	0.99 $m^3.s^{-1}$	0.00 $m^3.s^{-1}$	
- Surface plume (20%)	4 %	0.15 $m^3.s^{-1}$	0.00 $m^3.s^{-1}$	
- Dynamic plume (80%)	16 %	0.79 $m^3.s^{-1}$	0.00 $m^3.s^{-1}$	
BHD bucket losses	4 %			0.005 $m^3.s^{-1}$
BHD surface losses	1 %			0.001 $m^3.s^{-1}$
Total surface plume	4 %	0.15 $m^3.s^{-1}$	0.00 $m^3.s^{-1}$	0.001 $m^3.s^{-1}$
Total seafloor plume	26 %	1.09 $m^3.s^{-1}$	0.44 $m^3.s^{-1}$	0.005 $m^3.s^{-1}$
Total plume	30%	1.24 $m^3.s^{-1}$	0.44 $m^3.s^{-1}$	0.006 $m^3.s^{-1}$

Figure 16 shows the TSHD and BHD surface and near bed (seafloor) plumes for La Niña Summer conditions. Montaño (2024). also presents results for La Niña Winter conditions to assess if seasonal changes in weather affect plume generation and dispersal. However, no seasonal effects were evident. The plumes are confined to the channels, and do not extend over Te Paritaha or into Waipu Bay through any of the channels draining the Bay.

53 Montaño, M., 2024. *Dredge plume modelling: Dredging plume dispersion over existing and proposed port configurations*. Report prepared for the Port of Tauranga. MetOcean Solutions, December 2024.

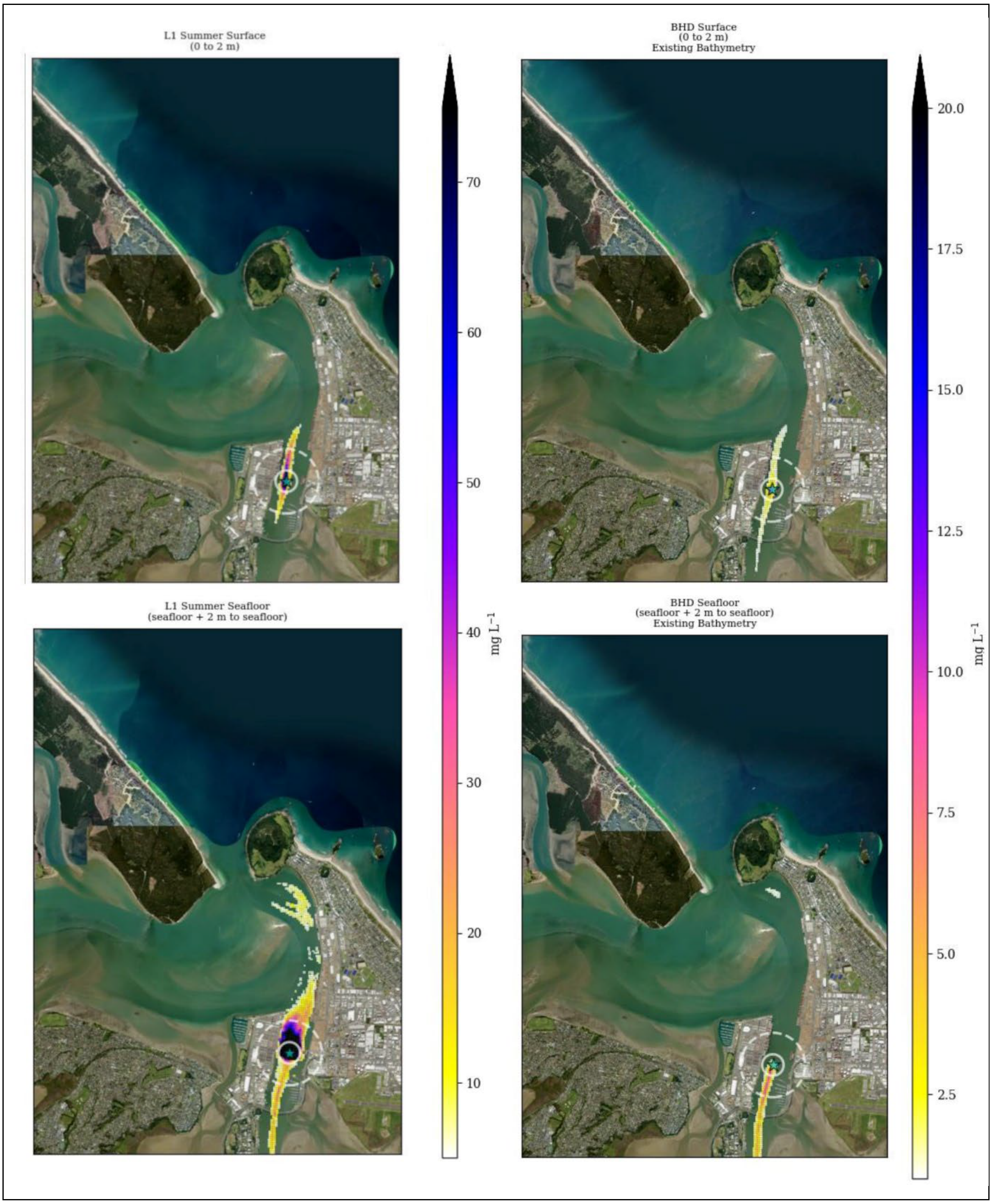

Figure 16: Modelled sediment plumes (mean TSS in mg.l^{-1}) for a large TSHD (left column) and a BHD (right column) excavating sediment from the southern Stella Passage. The surface plume represents the surface 2 m of the flow, and the seafloor plume represents the deepest 2 m. The point of release is marked by a star, and surrounding circles represent a 200 m (solid line) and a 600 m (dashed line) circumference to identify the mixing zone. (Figures 3.11 and 3.16 from Montaño, 2024).

Figure 17 summarises the total number of days that the TSS exceeds a threshold of 75 mg.l^{-1} during a 65 day dredging simulation[54]. The time series data presented by Montaño (2024) shows that the extent of the surface and seabed plumes beyond the 600 m mixing zone (dashed line) is dependent on the tidal range. Spring tides

[54] A TSS of 75 mg.l^{-1} was determined by Boffa Miskell as the threshold associated with adverse effects on pipi (Paphies australis) after 13 days continuous exceedance within Te Awanui (Montaño, 2014).

are associated with stronger flows, and so suspended sediment is transported further before it settles to the seabed. During the total of 130 days of dredging modelled, there was one occasion where TSS reached 0.2 $mg.l^{-1}$ over Te Paritaha close to Cutter Channel during the largest spring tide modelled.

Figure 17: Number of days that peak TSS exceeded 75 $mg.l^{-1}$ for a large TSHD excavating sediment from the southern Stella Passage for a 65 day period. The surface plume represents the surface 2 m of the flow, and the seafloor plume represents the deepest 2 m. The point of release is marked by a star, and surrounding circles represent a 200 m (solid line) and a 600 m (dashed line) circumference to identify the mixing zone. (Figure 3.5 from Montaño, 2024).

Numerical models and monitoring of previous capital and maintenance dredging demonstrate that the proposed dredging of southern Stella Passage with appropriate management approaches will produce plumes that are transient and restricted to the shipping channels. Therefore, sediment deposition is concentrated within the shipping channels, and there will be no detectable deposition of suspended sediment in areas of concern, including Te Paritaha and Waipu Bay (including Whareroa Marae foreshore). However, the potential impacts of the sediment plumes are not solely due to the concentration of sediment (Coppede Cussioli, 2018). In particular, the size, shape and colour of the suspended sediment can affect the transmission of Photosynthetically Active Radiation (PAR) impacting on photosynthesis (Coppede Cussioli *et al,* 2019).[55] These potential impacts are normally considered in terms of turbidity, and this is assessed in the next section.

4.2 Turbidity

Due to the uncertainties involved in modelling sediment plumes, it is usually necessary to undertake real-time monitoring of the sediment plumes, which can involve a range of techniques such as sediment traps/sensors, water sampling and profiling, static PAR and/or Nephelometric Turbidity Units (NTU) sensors, acoustic profiling,

55 Coppede Cussioli M, Bryan KR, Pilditch CA, de Lange WP, & Bischof K, 2019. Light penetration in a temperate meso-tidal lagoon: Implications for seagrass growth and dredging in Tauranga Harbour, New Zealand. *Ocean and Coastal Management* 174: 25-37.

and aerial/satellite remote sensing (e.g. Mills and Kemps, 2016; Fearns et al, 2017;[56] Whinney et al, 2017[57]). The monitoring can be used to validate the model predictions and be incorporated in consent conditions to trigger responses if the plumes do not behave as expected, or if predicted plumes can exceed thresholds under some circumstances.

Bryan et al (2013)[58] reviewed data from an array of turbidity sensors within the port area to determine the "natural" variation in turbidity (Figure 18), which included contributions of suspended material from storm-water discharges into Te Awanui. This study found the highest average natural turbidity levels at 5 NTU within Stella Passage, compared to 3.5 NTU in the Otumoetai Channel, <2 NTU in the Entrance, and 3-4 NTU elsewhere. There is significant temporal variability, and high turbidity events (>5 NTU) occurred within Stella Passage ~10% of the time and typically lasted for 20-30 hours.

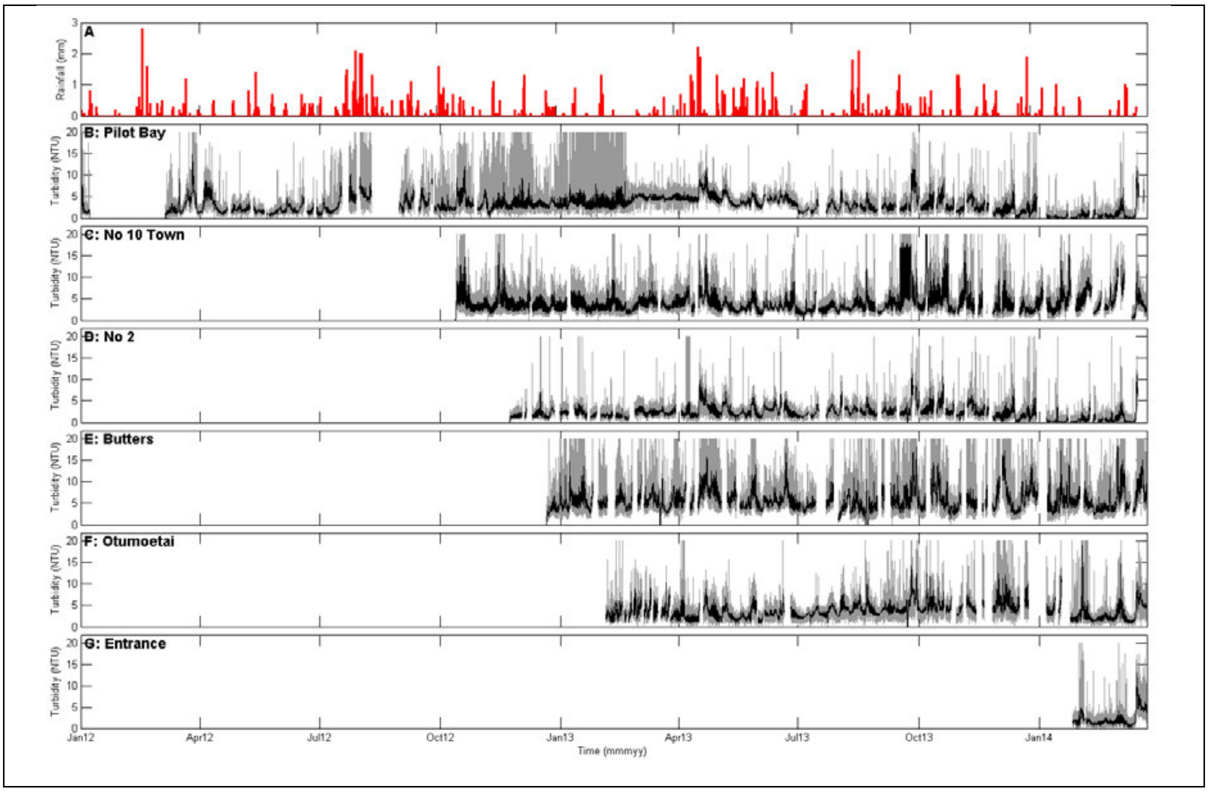

Figure 18: Time series of (A) rainfall and (B-F) turbidity (NTU) data collected by the Port of Tauranga. The grey line represents the raw turbidity data with biofouled sections removed, and the black line represents the 6-hour moving average. Sensors C (No 10 Town) and E (Butters) are located at the southern end of Stella Passage close to the proposed dredging. (Figure 7 from Bryan et al, 2013).

Bay of Plenty Regional Council water quality standards for bathing use water clarity instead of turbidity as their threshold criteria. Clarity is roughly the inverse of turbidity and relationships between clarity, turbidity measured by NTU, and TSS have been published (viz. Davies-Colley & Smith, 2001;[59] West & Scott, 2016[60]). Water clarity measurements are more reliable than turbidity measurements and are considered the more useful parameter

56 Fearns, P., Broomhall, M. & Dorji, P. (2017). Optical remote sensing for dredge plume monitoring: a review. WAMSI Dredging Science Node, Report, Theme 3, Project 3.1.1. 38 pp.

57 Whinney, J., Jones, R., Duckworth, A. & Ridd, P. (2017). Continuous *in situ* monitoring of sediment deposition in shallow benthic environments. WAMSI Dredging Science Node, Report, Theme 4, Project 4.4. 25 pp.

58 Bryan KR, Douglas E, Pilditch CA, & Cussioli MC, 2014. *Setting water quality limits and monitoring turbidity for the Port of Tauranga. Part A: Preliminary Investigation*. ERI report 25. Environmental Research Institute, Hamilton, New Zealand. 22 pp + appendix.

59 Davies-Colley RJ, & Smith DG, 2001. Turbidity, suspended sediment, and water clarity: A review. *Journal of the American Water Resources Association* 37: 1085-1101.

60 West AO, & Scott JD, 2016. Black disk visibility, turbidity, and total suspended solids in rivers: A comparative evaluation. *Limnology and Oceanography: Methods* 14: 658-667.

for assessing aesthetics, contact recreation and fish habitat. However, it has primarily been used for measurements within freshwater environments, although Gall et al (2019)[61] present data consisting of 12 sites along the lower Wairoa River and into Te Awanui.

Gall et al (2019) found that the Wairoa River had the highest median water clarity (y_{BD}=2.47 m) of the 6 upper North Island estuaries they had data for (10 years of monthly measurements from 2006-2015 inclusive). More importantly they determined that for east coast estuaries, including Te Awanui, water clarity is dependent on both TSS and coloured dissolved organic matter (CDOM). At times, CDOM accounted for 40-50% of the light attenuation in Te Awanui/Tauranga Harbour. Further, they found small, but significant, differences between all the estuaries, leading them to recommend that local verification and 'tuning' is desirable for relationships involving water clarity, turbidity and TSS.

The southern area of Stella Passage was identified as representing the greatest potential impact due to the generation of turbid plumes. There are proven management approaches previously utilised by POTL in accordance with resource consent conditions that can prevent adverse impacts by minimising the generation of turbid plumes, including:

- Dredging with no overflow, which does not produce a surface plume (Table 1).
- Manage the overflow (e.g. choked overflow) to reduce entrainment of air bubbles that reduce the settling velocities of fine sediment (Figure 15) (de Wit et al, 2020)[62].
- Operating overflow only during ebb flows, so that plumes are constrained within the shipping channels and transport suspended sediment towards the harbour entrance.
- Use a BHD in areas that may generate high levels of suspended sediment, as the much smaller production rate creates lower TSS levels.
- Use real-time monitoring of turbidity between the dredging area and locations of concern, with trigger points for different management approaches. This will also provide data on background levels of turbidity.

Table 1 indicates that the largest sources of sediment for the plumes occur near the seabed, so that the seafloor plume has the highest initial TSS (Figure 16). The seafloor plume TSS decreases faster than the surface plume (Figure 15), due to the larger grain sizes in suspension, and proximity to the bed. The seafloor plumes are also trapped within the channel due to their density, unless there is a significant increase in turbulence. The main source of increased turbulence is prop-wash. The effect of prop-wash decreases with increasing water depth below the dredge keel: at keel clearances <2 m the amount of sediment entrained into the plumes is generally higher than assumed by models; and at keel clearances >9 m, the effect of prop-wash is minimal (Stewart and Lehman, 2013[63]; Willemsen, 2022[64]).The Bay of Plenty Regional Council undertake water clarity and turbidity monitoring at various sites within the catchment of Te Awanui/Tauranga Harbour, with data available from Land Air Water Aotearoa (LAWA)[65]. Table 2 summarises the 2016-2020 median data for water clarity and turbidity for catchments potentially contributing to clarity and turbidity within Stella Passage.

Table 2: Median water turbidity and clarity for catchments potentially contributing to turbidity at the Port of Tauranga. Data are for 2016-2020 and obtained from the LAWA website.

Location	Turbidity (NTU)	Clarity (m)
Rocky Stream	6.8	1.02
Waitoa Stream	2.9	1.96
Waimapu Stream	3.3	1.64

[61] Gall M, Swales A, Davies-Colley R, & Bremner D, 2019. Predicting visual clarity and light penetration from water quality measures in New Zealand estuaries. *Estuarine, Coastal and Shelf Science* 219: 429-443.

[62] de Wit L, Bliek B, & van Rhee C, 2020. Can surface turbidity plume generation near a trailer be predicted? *Terra et aqua* 160, 15 pp.

[63] Stewart, J. P., & Leaman, C. K. (2013). Validation of dredge plume modelling inputs. Australasian Port and Harbour Conference (14th: 2013: Sydney, NSW),

[64] Willemsen, M.P.J. (2022). An Analysis of Trailing Suction Hopper Dredger Dredge Plume Development and the Use of Suspended Sediment Source Terms Delft University of Technology]. Delft.

[65] https://www.lawa.org.nz/

Kopurererua Stream	6.6	0.97
Wairoa River (SH2 bridge)	3.6	1.44
Omanawa River (SH29 bridge)	3	1.95
Wairoa River (Powerstation)	1.4	2.39

The data in Table 2 show that the results of Bryan et al (2013) are consistent with predominantly freshwater input of suspended solids coupled with dispersion and resuspension within the harbour. The available data also indicates that the relationship between clarity and turbidity varies between different catchments.

Coppede Cussioli (2018) obtained a larger dataset than Bryan et al (2013) combining turbidity and PAR sensors for 2012-2016, although not all sensors operated for the full period. This included data obtained during the 2015-2016 Capital Dredging campaign. Since her thesis focused primarily on the impacts of turbidity on seagrass (nana, eelgrass, *Zostera mulleri*), her data are presented as the light attenuation coefficient, K_d(PAR). She presents a standard relationship relating this with NTU, and also developed an empirical relationship specifically for Te Awanui/ Tauranga Harbour. She also derived relationships between TSS and NTU for different sediment colours, which were:

$$Grey\ sediment \quad NTU = \frac{TSS - 9.637}{1.412}$$

$$White\ sediment \quad NTU = \frac{TSS - 2.594}{3.012}$$

Coppede Cussioli et al (2019) identified the main constituents of the material causing turbidity at each site using multiple regression. Overall the average composition was 4.96±2.04 mg.l^{-1} of suspended particulate material (SPM) which contributed 50% of K_d(PAR); 1.04±0.47 µg.l^{-1} of Chlorophyll-a contributed 25% of K_d(PAR); 0.19±0.08 µg.l^{-1} of coloured dissolved organic matter (CDOM) contributed 10% of K_d(PAR); with the remaining 15% being random noise in the model. The CDOM contribution is much lower than that determined by Gall et al (2019) for the Wairoa River (10% *cf* 40-50%), while the Chlorophyll-a contribution is higher (25% *cf* <10%).

Coppede Cussioli et al (2019) show that K_d(PAR) is lowest at the harbour entrance, and increases upstream within the harbour, with the highest values at the mouth of the Wairoa River. Excluding the Wairoa River site (which was the only site that had sea bed light levels at 61% of surface radiation, despite the highest attenuation due to shallow water depth), the highest K_d(PAR) levels occurred near the entrance to the Tauranga Bridge Marina in Stella Passage.

The average K_d(PAR) for the port area was 0.39±0.15 m^{-1}, with little seasonal variation: spring 0.39±0.14 m^{-1}; summer 0.39±0.08 m^{-1}; autumn 0.38±0.10 m^{-1}; and there was insufficient winter data to get statistically meaningful results for some sites. The small seasonal variability is consistent with the seasonal variation in rainfall for Tauranga (Chappell, 2013),[66] suggesting freshwater discharges into the harbour may be a significant source of natural turbidity. This is also suggested by the variation in turbidity with the tidal cycle: at low to moderate turbidity levels, turbidity is highest at low tide and decreases to a minimum at high tide with an average increase in K_d(PAR) of 0.12±0.07 m^{-1}.

Depending on the location and tidal elevation, rainfall was associated with large increases in turbidity, particularly at low tide. The largest increases occurred in the Cutter Channel/Pilot Bay area (by up to 0.5 m^{-1}); while Te Paritaha/Centre Bank showed no obvious response. This may reflect the storm-water discharges into the main tidal channels, particularly along Town Reach, Stella Passage and Maunganui Roads.

Coppede Cussioli et al (2019) suggested that vessel movements in the channels could also contribute to turbidity due to propeller wash disturbing sediment. Clave (2019)[67] monitored turbidity and PAR under Mt Maunganui Wharf to assess the effects of propeller wash. She found that near-bed turbidity levels were typically around 1 NTU (~11 mg.l^{-1}, ~0.35 m^{-1}), but did increase to 10 NTU (~24 mg.l^{-1}, ~0.5 m^{-1}) in response to both vessel movements and rainfall. Clave's data indicated that vessel-induced turbidity dissipated rapidly (10-15 minutes), while turbidity associated with rainfall took longer (1-48 hours).

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66 Chappell PR, 2013. *The climate and weather of the Bay of Plenty 3rd Edition*. NIWA Science and Technology Series, No. 62.

67 Clave A, 2019. Study of different environmental factors in order to determine If the washing of vessel propellers causes the proliferation of *Atrina zelandica* underneath the wharves of Tauranga Harbour. Internship Report, Le Cnam Intechmer, France.

Dredging contributes extra SPM above the background turbidity. Coppede Cussioli (2018) obtained data from the array of turbidity and PAR sensors operated by the Port of Tauranga, and profiling measurements, during maintenance dredging and the 2015-2016 Capital Dredging campaign. She found that the highest turbidity (70 $mg.l^{-1}$, 33 NTU, Kd(PAR)=0.8 m^{-1}) occurred close to the seabed within the dynamic sediment plume produced by the TSHD *Pelican* during maintenance dredging. The TSHD *Pelican* was not operating with a choke valve. At the sensor array, the influence of dredging was up to 0.1 m^{-1}, which is a little lower than the average natural variation between high and low tide, and is lower than turbidity associated with freshwater inflows into Te Awanui during heavy rain events.

Measurements within the plumes produced by the TSHDs and BHD were not made during the 2015-2016 Capital Dredging campaign. However, the TSHDs employed choke valve technology to reduce the suspended sediment concentrations in the plume (de Wit et al, 2020). Observers on board the dredges reported that the plumes were significantly less obvious than those produced by the smaller Pelican dredge previously. Due to the background variability in the data obtained by the turbidity sensor array it is not possible to confirm if this resulted in a quantifiable decrease at the sensor sites.

Acoustic monitoring of the sediment plumes generated by maintenance dredging by the TSHD *Pelican* (Cussioli et al, 2015)[68] showed that they were contained within the channel, and rapidly lost the coarser sediments and clasts due to settling close to the dredge. The far-field plumes were not able to be distinguished from the pre-dredging (ambient) backscatter conditions after an hour of tracking. The backscatter intensities recorded indicated that maximum sediment concentrations initially reached up to 1.4 times the ambient levels, which corresponded to a point sample from the dynamic plume near the seabed of 70 $mg.l^{-1}$ of suspended solids before the sediment transitioned to the seafloor plume and TSS decreased rapidly.

The sediment plumes were constrained to the channels, and the acoustic data did not detect the plumes moving into the shallower areas adjacent to the channels. Since acoustic methods cannot distinguish between the plume and background suspended sediment, this can only be used as evidence that if a plume was present, it was comparable to the pre-dredging background turbidity. Average TSS values within the channels being dredged during sampling were 7-9 $mg.l^{-1}$ at the surface, 7-9.5 $mg.l^{-1}$ in mid-depths, and 8-13 $mg.l^{-1}$ near the bed (Coppede Cussioli, 2018).

The sediment plumes during the Capital Dredging campaign of 2015-2016 were not tracked acoustically. They were monitored by observers on the dredge, and an array of turbidity sensors around the margins of the dredged channels. No issues associated with dredge plumes were reported.

The available data on turbidity levels associated with previous dredging in Te Awanui, and natural levels of turbidity show that the dredge plumes are associated with peak turbidity levels that are within the range of natural variability and well below the peak natural turbidities reported. The sediment plume modelling discussed in the previous section indicates that the peak turbidities will occur in the immediate vicinity of the dredge (where the dynamic plume reaches the seabed, Figure 12). The modelling also shows that the dredge plume TSS for areas of concern would be in the range 0-5 $mg.l^{-1}$ (< 1 NTU), which is less than ambient levels, in the unlikely event that some of the plume did reach these areas. Hence, the impact of dredging plumes beyond the shipping channels in the immediate area of the dredging is considered negligible. The impact in the immediate area can be minimised by the use of appropriate dredging management measures, such as those described earlier in this section.

4.3 Reclamation

No drilling within Stella Passage is proposed for the development of wharves and dolphins, with offshore work for wharf/dolphin supports involving driven piles. Observations of previous pile-driving for construction of wharves, Tauranga Harbour Crossing, and Tauranga Bridge Marina indicate very localised sediment disturbance, and no significant plume generation. Jetting has previously been used, which reduces noise but creates more disturbance of sediment around the pile. Hence, driven steel tubes will be used. These are then filled with reinforced concrete to create the final wharf support pile.

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68 Cussioli MC, Bryan KR, Pilditch CA, & de Lange WP, 2015. *Dispersal of dredging plumes in Tauranga Harbour, New Zealand: A field study*. In Australasian Coasts and Ports 2015. Wellington, New Zealand: IPENZ. 7 pp.

Reclamation for the wharf extensions will involve creating an offshore barrier or bund, and then backfilling. The proposal involves a concrete revetment, with rock armouring the batter slope at the base of the revetment. A combination of fine rock sizes and geotextiles will be used to control movement of sand through the rock batter.

Backfilling will involve one or more of:

- Fill from offsite land sources
- Suitable (low fines) dredged sediment pumped ashore from a TSHD
- Suitable sediment (low fines) excavated while forming the batter slopes

It is intended that the primary source of marine fill will be sediment excavated to form the batter slopes. This material will be excavated by a long-arm excavator or crane mounted grab, and will be landed behind the construction site to drain before being moved and stockpiled. This type of excavation involves low water contents and requires minimal containment pond volume. Experience with previous construction at the port indicates a short-term containment volume matching the rate of extraction is sufficient to control runoff.

If extra fill is required, then suitable dredge spoil will be pumped ashore, as currently occurs to maintain a sand stockpile at Sulphur Point under existing consent conditions. Sand is pumped ashore from a TSHD into a containment area surrounded by a bund. Observations during a pumping transfer from the TSHD *Albatros* in 2019 indicated that a 100 x 30 m containment area is sufficient for an 1,800 m^3 capacity hopper, and generated about 900 m^3 of water runoff that was contained by the bund. This water can evaporate, or be removed after any suspended sediment has settled. Filter screens and floating booms will be deployed if necessary to confine or restrict turbidity. The turbidity levels will be monitored in the vicinity of the pile driving and reclamation when marine sediment is being transferred ashore and dewatered.

4.4 Summary of Sedimentation Effects

Overall modelling, observations and measurements of dredge plumes associated with the development of the Port of Tauranga demonstrate that, within a mixing zone of up to 200 m upstream and 600 m downstream of the dredge, the plumes are of short duration (typically <15 minutes), with medium to low turbidity compared to natural turbidity within Te Awanui/Tauranga Harbour. The width of the plume is typically <50% of the channel width, but this depends on the path of the dredge (TSHD) with a wider plume when dredging across the channel. Peak turbidity very close to the dredge, near the seabed within the dynamic plume may be comparable to the highest turbidity levels observed during rare extreme rainfall events. However, due to rapid settling of sediment from the dynamic plume, peak turbidity levels decay rapidly within the mixing zone.

From observations of previous capital and maintenance dredging, the far-field plume is largely confined to the channels depending on the state of the tide. At slack water, the far-field plume tends to disperse radially and can impinge on shallow areas flanking the channels. However, once the tidal velocities increase the far-field plume advects along the streamlines of the tidal flow, which restricts the width of the plume and tends to constrain it to the channel. This effect is strongest during ebb tide, when water drains from the intertidal and shallow subtidal areas flanking the channels (e.g. from Te Paritaha). The flow of water into the channels prevents the plume from moving into the shallows.

The Stage 1 excavation area (Figure 1 upper) is not subject to tidal flows that could directly transport the far-field plume into northern Waipu Bay (Whareroa Marae foreshore), which was confirmed by Mantaño (2024). During a flood tide, the far-field plume could be transported into southern Waipu Bay via tidal channels between the Tauranga Harbour Bridge and the Railway Bridge causeway. The 10 Town Reach (Figure 2) NTU turbidity sensor would provide a warning of this potentially occurring, or it can be avoided by not dredging during flood tide or without overflow. As the excavation proceeds, the near-field plume will increasingly be trapped within Stella Passage on flood tides by the deepening channel.

The Stage 2 excavation (Figure 1 lower) involves an extension eastward towards Butters Landing. This does not extend far enough to encounter the fine sediment delta formed by discharge from Waipu Bay, and the modelling reported by Mantaño (2024) shows that it does not extend into the flood flow that enters Waipu Bay via the northern channel through the causeway. Therefore, it is very unlikely that sediment plumes from the TSHD will impact Waipu. The potential risk can be minimised by appropriate dredging management.

5. Assessment of Hydrodynamic Effects

5.1 Research Summary

Starting with the Tauranga Harbour Study (1982-1985), a series of numerical models of Te Awanui have been developed by the University of Waikato, and by the University of Bremen (during the collaborative Intercoast postgraduate programme 2010-2019), utilising different modelling packages including 3DD, DHI Mike systems, ELCOM-CAEDYM, and Delft 3D. The most recent modelling undertaken by MetOcean Solutions utilised the SCHISM hydrodynamic model (Watson & Berthot, in prep.)[69],[70] for 2015 and 2023 bathymetric conditions (before the last capital dredging and 'present day').

For assessing the impacts of the proposed Stage 1 dredging, two overall models of the Tauranga basin of Te Awanui/Tauranga Harbour were used. Tay (2011)[71] developed a hydrodynamic-biogeochemical model using ELCOM-CAEDYM to simulate dispersal of terrestrial nitrogen within the harbour. This model used the bathymetry before the 2015-16 capital dredging and was also used to simulate the hydrodynamic responses to tides, storm winds, and freshwater inflows (Tay *et al*, 2013).[72] Stewart (2020)[73] presents the calibration, validation and verification of a Delft-3D hydrodynamic model covering the entire harbour and offshore region initially developed in conjunction with the University of Bremen (Kwoll, 2010).[74] The model bathymetry was updated with new survey data from the Port of Tauranga as it became available, and represents conditions after the 2015-2016 capital dredging. This model was further developed by de Ruiter (2022) to assess the exchange of sediment between sub-estuaries and the main basins of Te Awanui.

Comparison of the models presented by Tay (2011), Stewart (2020), de Ruiter (2022) and Watson and Berthot (in prep.) indicated that the hydrodynamic effects of the 2015-2016 capital dredging were negligible beyond the immediate area of the port and dredged channels.

McKenzie (2014) used the DHI Mike system of numerical models in conjunction with Tonkin & Taylor Ltd to create a high-resolution model for Stella Passage, Town Reach and Waipu Bay to assess the impacts of proposed breakwaters and dredging on the Tauranga Bridge Marina, and on sedimentation within Waipu Bay. This model used the bathymetry existing before the 2015-16 capital dredging, and also simulated several different hypothetical post-dredging conditions.

Brunschwiler (2015)[75] investigated the behaviour of freshwater plumes associated with stormwater discharges into Stella Passage and the Maunganui Roads channels. This involved both moored instruments and boat-mounted instrument profiling. The moored instrument deployments included a variety of profiling acoustic current meters deployed along the channels from 10th April to 17th May 2014 before the capital dredging occurred. Plumes during rain events were tracked using moored and boat-mounted CT and CTD (Conductivity, Temperature and Depth) sensors.

Watson (2016) reviewed all previous investigations and modelling for Stella Passage and the upstream areas of Te Awanui/Tauranga Harbour, before undertaking data collection from 3rd September to 2nd October 2015. This occurred during the 2015-2016 capital dredging and included re-occupying deployment locations used prior to dredging (particularly the Stella Passage location used by McKenzie (2014) between 26th October and 30th November 2011). Additional upstream sites near the Railway, Maungatapu and Hairini Bridges were included to assess far-field impacts of dredging on currents and water elevations. Current velocity data was not recorded at these additional sites before the 2015-2016 dredging, but water level data had been collected at Hairini Bridge and Oruamatua (upstream from the Maungatapu Bridge) by the Bay of Plenty Regional Council. Since the Delft

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69 Watson, H., Berthot, A, in prep. *Hydrodynamic and Wave Modelling*, Report prepared for Port of Tauranga Ltd, MetOcean Solutions.

70 Watson, H., Berthot, A, in prep. *Tauranga Harbour Historical Configurations: Modelling*, Report prepared for Port of Tauranga Ltd, MetOcean Solutions.

71 Tay HW, 2011. *Nutrient dynamics in shallow tidally dominated estuaries*. PhD Thesis, The University of Waikato, Hamilton, New Zealand.

72 Tay HW, Bryan LR, de Lange WP & Pilditch CA, 2013. *The hydrodynamics of the southern basin of Tauranga Harbour*. New Zealand Journal of Marine and Freshwater Research, 47: 249-274.

73 Stewart BT, 2020. *Investigating groundwater derived nutrient fluxes within Tauranga Harbour, New Zealand.* PhD Thesis, The University of Waikato, Hamilton, New Zealand.

74 Kwoll E, 2010. *Evaluation of the Tauranga Harbour numerical model*. MSc Thesis, University of Bremen, Germany

75 Brunschwiler NR, 2015. *Dispersal and mixing of stormwater run-off plumes in the Port of Tauranga, New Zealand*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

3D model calibration, validation and verification is primarily driven by water elevation observations, the water level data collected before, during and after dredging is adequate to assess dredging impacts. In this case, the current velocity data collected before, during and post-dredging for the 2015-2016 capital dredging at locations expected to have the largest impacts, provide additional confidence in modelled impact assessments.

Mullarney & de Lange (2018) created a higher resolution nested grid for the Stella Passage, Town Reach and Waipu Bay area to simulate the near-field impacts of the final proposal for the Stella Passage Development. This model used data collected after the 2015-2016 dredging for an abandoned PhD study on the dredging impacts within Te Awanui/Tauranga Harbour. Some of the data was analysed and presented by Trividic (2017) as part of a MSc internship at the University of Waikato. The PhD project focussed on the tidal delta system and shipping channels downstream of Stella Passage, primarily on the sedimentological changes within the shipping channels. However, the study did include post-dredging data from the Railway Bridge location used by Watson (2016).

Finally, Clave (2019) measured currents and suspended sediment underneath the Mt Maunganui Wharves in response to tidal flows, storm water discharges, and propeller wash. The numerical models used for modelling dredging impacts treat the wharves as a solid face at the outer edge of the wharf, which is not the case for most of the wharves. Generally, there is a breakwater beneath the wharf, with the wharf extending seaward on piles. Hence, there can be a significant volume of water beneath the wharf.

While it is recognised that the piles may create a high resistance to flow, resulting in low velocities under the wharves, this had not been measured for Tauranga. It was also considered possible that propeller wash associated with large vessels manoeuvring near the wharves may cause strong currents affecting biota (particularly benthic shellfish on soft substrates such as Horse Mussel, *Atrina zealandica*) and structures. The results from Clave (2019) show that tidal velocities within the wharf structure are significantly reduced: dropping from a peak of 0.6-0.7 $m.s^{-1}$ near the surface in the channel to 0.2 $m.s^{-1}$ near the surface between the first two seaward rows of piles. The near-bed velocities under the wharf dropped to 0.05-0.08 $m.s^{-1}$. Current velocities throughout the water column under the wharf increased while ships were berthing and departing, with the peak measured velocity being 0.7 $m.s^{-1}$ when the propeller(s) of the *Rivertec* were operating close to the current meter. The increased velocities were of short duration (5-10 minutes). While the vessel was moored next to the wharf, tidal velocities decreased (0.1 $m.s^{-1}$ peak near surface when the *Berge Phan XI* was berthed next to the current meter).

These observed velocities are consistent with the observed small accumulation of medium to fine sediment under the wharf reported by Clave (2019) and justify the assumption of a vertical wall along the face of the wharves made by Mullarney & de Lange (2018) for their modelling.

5.2 Research Conclusions

Over the approximately 6 decades of physical and numerical modelling of the impacts of development on the hydrodynamics of Te Awanui/Tauranga Harbour, the following consistent findings have resulted from simulations of dredging activities:

- The largest changes in velocities occur in the immediate area dredged, with three main effects:
    - Velocities are reduced where the channel cross-sectional area is increased by deepening, or widening, or both. This is expected as the tidal discharge remains the same, and the tidal discharge is the product of area and velocity;
    - Abrupt velocity changes occur at the margins of the area dredged due to the increased gradient between the dredged channel and the adjacent sea bed. In particular, there is a zone of rapid flow acceleration where there is a large depth change. This tends to create a jet that causes scouring of the sea bed in the shallowest section of channel (typically during flood tide, and a narrow zone of high near surface velocity in the deepest section of the channel (typically during ebb tide). The modelling by McKenzie (2014) specifically considered the impact of the peak ebb tidal jet on large vessels manoeuvring within Stella Passage, and found that it would cause a significant lateral force on the vessels if the flow was confined by the construction of a solid breakwater around the Tauranga Bridge Marina.
    - The reduction in flow velocities within dredged channels results in a reduction in the flow competence (maximum size of suspended sediment that can be transported) and the flow capacity (maximum

quantity of suspended sediment that can be transported). This causes sediment to drop out of suspension and be deposited, requiring maintenance dredging.

- Deepening of channels affects the velocity at which tidal waves propagate within the Harbour, with two main effects:
  - The timing of high water tends to be advanced as the crest of the tidal wave arrives earlier. This occurs because the velocity of the tidal wave (known as celerity), is a function of the square root of the depth. The timing change also depends on the length of dredged channel. For Tauranga, the largest change resulted from the first capital dredging that created the Entrance Channel, Cutter Channel and Maunganui Roads: resulting in both a significant depth change and longest new channels. Subsequent dredging has involved a smaller effective depth change and increased channel length. The Stella Passage Development involves a large depth change, but a small channel length increase. The models indicate that the expected change in the time of high water upstream from Stella Passage is smaller than the observed variation due to weather conditions and the calibration errors in the models (Mathew, 1997; Watson, 2016): in the order of <5-10 minutes earlier depending on distance from Stella Passage.
  - Tidal asymmetry increases as the flood duration decreases and ebb duration increases. This tends to shift the tidal behaviour to more hypersynchronous conditions where convergence increasingly dominates over friction. This effect is enhanced if the channel width is decreased while the depth is increased (as for the Stella Passage development). As a consequence, the tidal range increases landward from the harbour entrance. Analysis of tidal constituents from various tide gauges prior to the 2015-2016 capital dredging showed that tidal range decreased as the tide entered the harbour, increased landward along the main dredged shipping channels (hypersynchronous), and decreased landward along the main tidal channels (hyposynchronous) upstream from the port (McKenzie, 2014; Christophers, 2015).[76] The maximum increase/decrease in measured tidal amplitude was 2-5 cm). Tyler (2018)[77] analysed tidal characteristics at Moturiki (1974-2018), Tug Berth (1989-2018), Omokoroa (2014-2018), Hairini (2002-2018) and Oruamatua (2001-2018) and found no change to tidal range due to the 2015-2016 capital dredging, consistent with the numerical model predictions. He did not analyse the Sulphur Point gauge, where the largest potential increase in tidal range could have occurred due to the deepening of the main shipping channels.

McKenzie (2014) simulated two dredging scenarios while assessing the impacts of different breakwater options for the Tauranga Bridge Marina, which broadly match Stages 1 and 2 of this proposal. Watson (2016) and Mullarney and de Lange (2018, 2019) specifically modelled Stage 1 with a 16 m deep Shipping Channel.

All the model results for the equivalent of Stage 1 of the current proposal with a 16 m deep Shipping Channel showed the same pattern of peak flow changes (Figure 19), with almost identical magnitudes. McKenzie (2014) modelled the southern end of Stella Passage at the high resolution (4x4 m) due to his focus on the Marina and Waipu Bay, while Watson (2016) and Mullarney and de Lange (2018, 2019) were modelling a larger area of Te Awanui and had nested grids with a minimum grid size of 20x20 m. Hence, the model results of McKenzie are the basis for assessing the changes in Stella Passage and the other model studies are used for more distant areas of the harbour. de Ruiter (2022) modelled the entire harbour to assess sediment transport, although his modelling did not include dredging scenarios. His results are useful for identifying sediment pathways and sources/sinks.

Stage 1 will not affect the tidal prism for Te Awanui: i.e. the volume of water that enters or leaves the harbour during the flood or ebb tide. Hence, the volumetric flows through Stella Passage before and after the Stage 1 dredging and reclamation works are completed will remain the same (ignoring the variations caused by tidal range, freshwater inputs, and wind stress). This means that if the cross-sectional area of parts of Stella Passage change, there will be compensating changes in the water velocities in those parts. This means that increasing the area by dredging will reduce velocities, and vice versa for reduced area due to reclamation. Since the area increase due to dredging is larger than the area reduction due to reclamation, the velocities should decrease overall.

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[76] Christophers A, 2015. *Paleogeomorphic reconstruction of the Omokoroa Domain, Bay of Plenty, New Zealand*. MSc thesis, The University of Waikato, Hamilton, New Zealand.

[77] Tyler MJ, 2018. *Storm surges in Tauranga Harbour*. MSc Thesis, The University of Waikato, Hamilton, New Zealand.

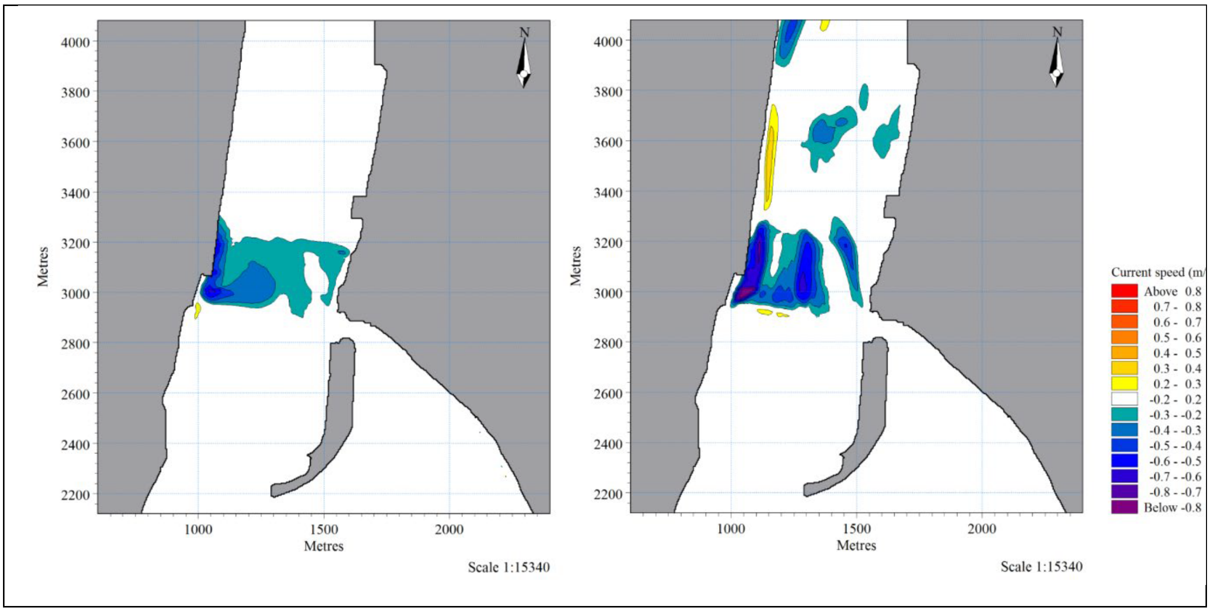

Figure 19: Difference in current speed at peak spring flood (left) and peak spring ebb (right) between simulations of existing bathymetry and Stage One with deepened shipping channel. Yellow to red colours indicate an increase in peak current speed, while green to purple colours indicate a decrease in peak current speed. Figure 5.44 from McKenzie (2014).

The modelling by McKenzie (2014), and subsequent studies, show the same response to dredging and reclamation for Stella Passage. The largest change occurs in the region covered by RC 62920 (Figure 1), as this is where the largest increase in area occurs. There are some small deviations from the expected general reduction in flow velocities resulting from changes in the flow directions (Figure 20). Excavation of part of the channel (Stage 1) causes the strengthening and reorientation of a downstream tidal jet during ebb flows (Figure 19 right), which causes a slight increase in modelled velocities close to the Sulphur Point Wharves (Figure 18 right). It is possible that this increase will be a little larger if the channel is not deepened to 16 m as there is no compensation due to an increase in channel cross-sectional area. The jet also affects an eddy that forms near the Tanker Berth, causing it increase in size and rotate more slowly.

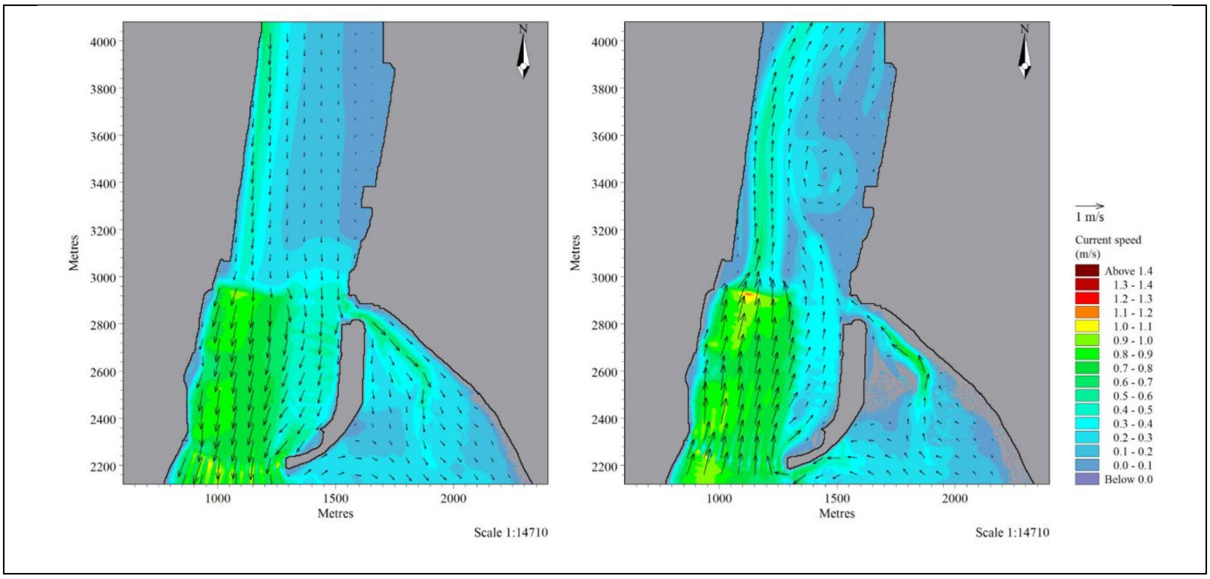

Figure 20: Current speed and velocity vector plots for spring tide conditions from the Stage One with deepened shipping channel simulation. Peak flood tide is displayed left and peak ebb tide is displayed right. Figure 5.40 from McKenzie (2014).

The flow patterns shown in Figure 19 are a slight enhancement of the current flow patterns due to increased convergence of the flood flow into the deepened southern extension of the shipping channel, and the strengthening of the ebb jet from the shallow channel into the deeper shipping channel. This will increase the accumulation of sediment exported from Town Reach along the Sulphur Point Berths and eastern side of Stella Passage (SPT, CT & H6 areas in Figure 11).

All of the modelling studies show that the impacts of the dredging on the hydrodynamics of Te Awanui occur within the region shown in Figures 19 and 20. There are no potential impacts on Te Paritaha, Waipu Bay and other locations beyond Stella Passage due to changed hydrodynamics.

6. Conclusions

Overall, the effects of Stages 1 and 2 on sedimentation and hydrodynamic processes within Te Awanui are very similar. While the effects potentially differ slightly in magnitude, the effects of each stage, and the combined effects of both stages, are less than minor, subject to the adoption of the appropriate mitigation measures (Table 3).

- For the excavation phase, the effects on sedimentation and turbidity are dependent on the characteristics of the TSHD used and the specific geological units encountered. Based on previous capital dredging programmes and numerical modelling, any effects due to these factors will be less than minor.
- For the reclamations, there will be slight differences depending on the scale of the reclamation and the sources of the sediment used for each reclamation. Since the reclamation sediment plumes are smaller scale than the TSHD plumes, the differences are expected to be less than minor.
- For the post-dredging recovery phase, beyond the immediate environs of Stella Passage, the impacts are negligible to undetectable. Within Stella Passage, Stage 1 will predominantly affect flows along the western side of the southern end of the channel, while Stage 2 will affect flows across the whole width of the southern end. In the central section of the channel, Stage 1 is likely to have the largest impact on flows through the modification of the ebb tide eddy. This will be modified further by the Mount Maunganui Wharf extension. Modelling demonstrates no impact on flows at the northern end of Stella Passage, except for a slight reduction in peak velocities when the channel is deepened to 16 m. Overall, the predicted hydrodynamic changes are not significant.
- Some areas within Te Awanui have previously been identified as specific areas of concern, and these were assessed individually:
    - Te Paritaha – the proposed dredging in southern Stella Passage will have no detectable effect on tidal currents over the ebb shield, and, hence will not affect the available tidal window for harvesting kai moana. Sedimentation and turbidity from dredging plumes will also not be detectable on Te Paritaha.
    - Panepane – the proposed dredging in southern Stella Passage will have no effect on tidal currents or wave action in the vicinity of Panepane and, therefore, will no contribute to the dynamic changes of the point.
    - Tauranga Bridge Marina entrance – none of the numerical models show a detectable change in tidal velocities near the entrance to the Bridge Marina. One model indicates a slight increase in peak velocities in a narrow zone along the southern side of the bridge. This model utilised different bathymetric grids to the remaining models, and simulated all possible future port developments. Models that only simulated the Stella Passage dredging showed no changes in tidal velocities around the Harbour Bridge.
    - Whareroa Marae – the proposed dredging in southern Stella Passage will have no detectable effect on tidal currents, sedimentation or turbidity for the Whareroa Marae foreshore. Therefore, there will not be an effect on the erosion of the shoreline, which has been identified as linked to the causeway for the Harbour Bridge. The dredging will not change existing or future mean and extreme sea levels at Whareroa Marae.
    - Katikati Basin – the proposed dredging in southern Stella Passage will have no effect on the Katikati Basin and locations within it, as it is too far away and is effectively a separate water body in terms of tidal propagation.

- Opopoti Marae, Maungatapu Peninsula, Motuhoa Island, and Matakana Point - the proposed dredging in southern Stella Passage will have no effect on tidal currents, sedimentation, shoreline erosion, and mean or extreme sea levels at these locations. Te Awanui is a dynamic system that responds to weather events and their interaction with the local geology and geomorphology. Historic and recent changes for these locations (and any other location distant from Stella Passage) reflect local conditions including sediment supplied by floods from local catchments, and the effects of locally wind-generated waves and currents.

Table 3 summarises the impacts of the proposed dredging discussed above, and includes responses to iwi/hapū suggestions for mitigation measures.

Table 3: Summary of the impacts of the proposed dredging, mitigation measures incorporated in the project, iwi/hapū recommendations for additional mitigation, and comments including assessment of iwi/hapū recommendations.

Location	Impacts	Project mitigation	Iwi/hapū recommendation	Comments
		Excavation phase (dredging)		
		Hydrodynamics		
		CVA concerns that hydrodynamic changes can lead to increased sedimentation and tidal changes at locations of cultural value, and affect local ecosystems		
Stella Passage	The ebb tidal jet entering the dredged channel will move southwards due to the extension of the channel. Hence, there will be a localised increase in ebb tidal velocities immediately south of the excavated channel. Due to the increased cross-sectional area of the dredged extension, there will be a decrease in tidal velocities within the new dredged channel. The effects further north in Stella Passage are minor. There will be a slight change in the timing of high and low water at the southern end of the extended shipping channel (smaller than the normal variation due to weather and tidal range).	No mitigation required.	Monitor tide and current changes post-channel deepening.	Hydrodynamic impacts are confined to Stella Passage, predominantly within the area of channel extension. Section 5.2 of Assessment Report. Monitoring of tides and currents has been ongoing since the before the initial capital dredging, and is expected to continue into the future as it is also necessary for port operations. No additional monitoring is required.
Otumoetai Channel, Maunganui Roads, Cutter Channel, Pilot Bay	No impact.			
Te Paritaha (flood tidal delta)	No impact.			
Waipu Bay, and Whareroa Marae foreshore	No impact. in the northern tidal channels and along shoreline near Whareroa Marae.			Changes in tidal flows at Whareroa Marae are due to the harbour crossing, which concentrates outflow from northern Waipu Bay into the channel by Whareroa Marae. Proposed dredged channel design avoids changing flows through harbour crossing causeway bridge at Whareroa Point.
Town Reach	No impact.			
Waimapu Estuary	No impact.			

Location	Impacts	Project mitigation	Iwi/hapū recommendation	Comments
Rangatataua Estuary	No impact.			
Remainder of Te Awanui	No impact.			
Sedimentation and erosion *CVA concerns that increased sedimentation will impact kai moana*				
Stella Passage	Localised erosion is expected south of the excavated area as the ebb jet migrates southward during dredging. This will continue post-dredging as summarised below. Sedimentation from settling of sediment from plumes, mostly within the mixing zone (hence predominantly in southern Stella Passage). Sediment decreases rapidly northwards from the dredged extension.	Relocation and re-establishment of existing patterns of tidal flow and seabed characteristics. No mitigation required apart from maintenance dredging.	Include sedimentation monitoring and habitat restoration planning. Develop a response framework for increased sedimentation.	Sedimentation within shipping channels is monitored routinely in order schedule maintenance dredging to maintain the design depth. Sedimentation within the areas adjacent to the shipping channels is monitored relatively frequently to provide depth information for hydrographic charts. Since the shipping channels are subject to relatively frequent disturbance by maintenance dredging and other port operations, they are not suitable for habitat restoration. The existing response is to undertake maintenance dredging.
Otumoetai Channel, Maunganui Roads, Cutter Channel, Pilot Bay	Very minor sedimentation (too small to measure) due to settling of fine sediment from low concentration turbid plumes in southern Maunganui Roads during large spring tides. No impact elsewhere.			
Te Paritaha (flood tidal delta)	No impact.			
Waipu Bay, and Whareroa Marae foreshore	No impact.	Various restoration funds offered as conditions of consent to SPDAG and Whareroa Marea		Local processes dominate in Waipu Bay, so no impact from dredging. Beach renourishment used to mitigate erosion at Whareroa Marae due to structures along Waipu shoreline east of the marae, and modifications to tidal flows in Waipu Bay caused by harbour crossing.
Town Reach	No impact.			

Location	Impacts	Project mitigation	Iwi/hapū recommendation	Comments
Waimapu Estuary	No impact.			Local processes dominate in these areas, so no impact from dredging can be identified.
Rangatataua Estuary	No impact.			
Remainder of Tauranga Basin	No impact.			
	Water quality (turbidity) *CVA concerns that turbidity associated with dredging will adversely affect a clear and pristine wai, kai moana and other marine taonga*			
Stella Passage	Within the mixing zone, there may be conspicuous changes to colour and visual clarity. This can be avoided or minimised by adjusting dredging/excavation procedures when thresholds are reached. The highest levels of turbidity are confined to the mixing zone, and are transient.	Alternative dredging methodologies and turbidity control triggers offered in the Dredge Management Plan.	Develop targeted monitoring for dredging to manage turbidity. Monitor silt pocket potential.	Sections 4.2 and 4.3 of Assessment Report. Turbidity is monitored and trigger levels are based on total turbidity (ambient turbidity + dredge plume turbidity) to account for other sources of turbidity in Te Awanui (rain, wind, discharge from catchments and storm water, etc). Additional monitoring beyond that already allowed for the in the project is not required.
Otumoetai Channel, Maunganui Roads, Cutter Channel, Pilot Bay	No impact.			
Te Paritaha (flood tidal delta)	No impact.			
Waipu Bay, and Whareroa Marae foreshore	No impact.	Alternative dredging methodologies and turbidity control triggers offered in the Dredge Management Plan.		Sections 4.2 and 4.3 of Assessment Report show that no impact is likely. Dredging methodology, monitoring and trigger levels included in the project are sufficient to manage turbidity in this area if something unexpected occurs.
Town Reach	No impact.			
Waimapu Estuary	No impact.			Local processes dominate in these areas.
Rangatataua Estuary	No impact.			
Remainder of Tauranga Basin	No impact.			
	Contamination			

Location	Impacts	Project mitigation	Iwi/hapū recommendation	Comments
CVA concerns that contaminants released by dredging will adversely affect a clear and pristine wai, kai moana and other marine taonga				
Stella Passage	No impact. Contaminants are confined to the surface layer (up to 20-30 cm thick) and are predominantly found close to source (freshwater catchments, stormwater discharge points, and marina berths). Dredging is not occurring in areas close to source, and the dredging process dilutes contaminants by mixing the surface layer with deeper, older, uncontaminated sediments.		Repeat contamination assessment using Australian Government (2009) standards. Establish consistent monitoring for contamination before and after dredging. All discharges to water must be treated or contained. Regular water quality monitoring should be carried out with results shared with iwi/hapū.	Testing with sentinel oysters by Regional Council showed contamination was predominantly associated with freshwater runoff from catchments, and leaching of antifoulants and sacrificial anodes (predominantly from marinas). The Regional Council monitors contaminant levels in sources contributing contaminants to Te Awanui. Repeat testing of surface sediment contaminants is not necessary for capital dredging - a one-off event. Treatment or containment of all potential discharges to water is beyond the scope of this assessment.
Disposal sites	No impact.			Any contaminated surficial sediments that may be dredged are greatly diluted by mixing with uncontaminated sediment within the dredge hoppers before disposal.
Reclamation fill	No impact.			Any contaminated surficial sediments that may be excavated will be mixed with uncontaminated sediment within bunds confining the excavated material on site.
Recovery phase (post dredging)				
Hydrodynamics				
CVA concerns that hydrodynamic changes can lead to increased sedimentation and tidal changes at locations of cultural value, and affect local ecosystems				
Stella Passage	Medium-term changes to flow patterns at the abrupt depth change occurring at the southern end of the dredged channel in response to scouring of the shallow seabed on the southern side. This will cease when an armoured bed is established by the concentration of shells on the seabed.	Monitoring of tides and currents has been ongoing since the before the initial capital dredging, and is expected to continue into the future as it is also necessary for port operations.	Monitor tide and current changes post-channel deepening.	Additional monitoring is not required.

Location	Impacts	Project mitigation	Iwi/hapū recommendation	Comments
Otumoetai Channel, Maunganui Roads, Cutter Channel, Pilot Bay	No impact.			Hydrodynamic impacts for the proposed dredging are confined to the Stella Passage, predominantly the southern end. The changes to tidal wave propagation resulting from the extension of the deep shipping channel are too small to affect Town Reach, and cannot affect other regions. The Regional Council monitors water levels at various sites around Te Awanui outside the Port Area. These are sufficient to identify changes to tidal behaviour. Tidal currents are sensitive to local sedimentation/erosion, so that monitoring tidal currents will not identify any consequences of dredging.
Te Paritaha (flood tidal delta)	No impact.			
Waipu Bay, and Whareroa Marae foreshore	No impact.			
Town Reach	No impact.			
Waimapu Estuary	No impact.			
Rangatataua Estuary	No impact.			
Remainder of Tauranga Basin	No impact.			
Sedimentation and erosion *CVA concerns that increased sedimentation will impact kai moana*				
Stella Passage	Medium-term scour of the shallow seabed immediately south of the end of the dredged channel. This will remove the sand and finer components, and concentrate the coarser sediment (winnowing) to eventually form a surface resistant to further erosion (armouring). The winnowed sediment will be deposited in the southern end of the dredged channel. Deposition of order of 5,000-10,000 m3.y-1 depending on contributions from storm water and organic detritus. Expected to decline over time as sea bed becomes armoured.	Maintenance dredging (predominantly of terrestrial sediment discharged into the harbour upstream from Stella Passage).	Include sedimentation monitoring and habitat restoration planning. Develop a response framework for increased sedimentation.	Sedimentation within shipping channels is monitored routinely in order schedule maintenance dredging to maintain the design depth. Sedimentation within the areas adjacent to the shipping channels is monitored relatively frequently to provide depth information for hydrographic charts. Since the shipping channels are subject to relatively frequent disturbance by maintenance dredging and other port operations, they are not suitable for habitat restoration. The existing response is to undertake maintenance dredging.
Otumoetai Channel, Maunganui Roads, Cutter Channel, Pilot Bay	No impact.			There are no hydrodynamic changes associated with the Stella Passage dredging, so there will not be any

Location	Impacts	Project mitigation	Iwi/hapū recommendation	Comments
Te Paritaha (flood tidal delta)	No impact.			changes to sedimentation patterns as a result
Waipu Bay, and Whareroa Marae foreshore	No impact.			
Town Reach	No impact.			Local processes dominate in these areas.
Waimapu Estuary	No impact.			
Rangatataua Estuary	No impact.			
Remainder of Tauranga Basin	No impact.			

7. Appendix – Historic hydrographic charts

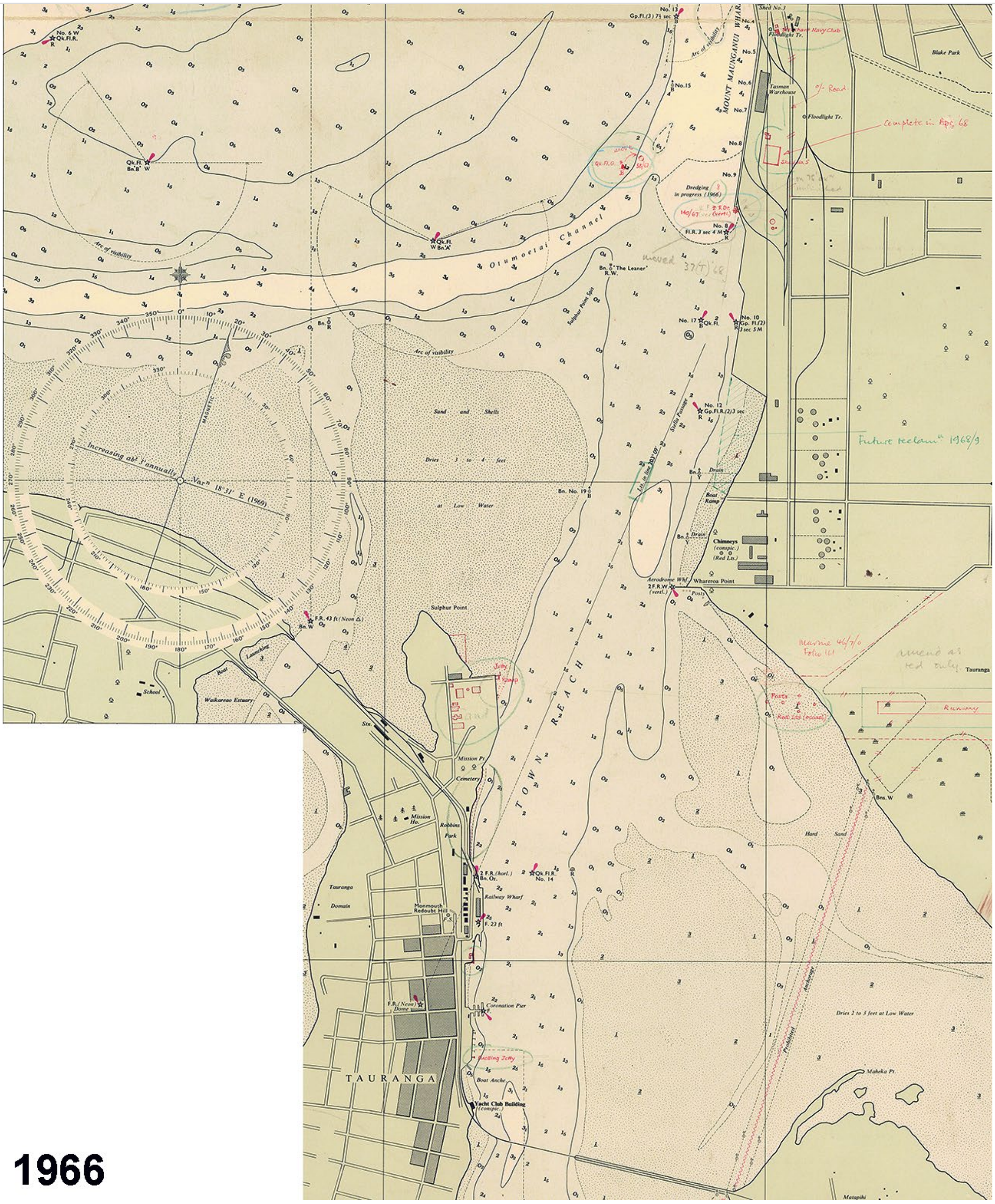

Figure A1 – Section of hydrographic chart 5412 for the Stella Passage area in 1966 showing shipping channels, port infrastructure and surrounding harbour bathymetry.

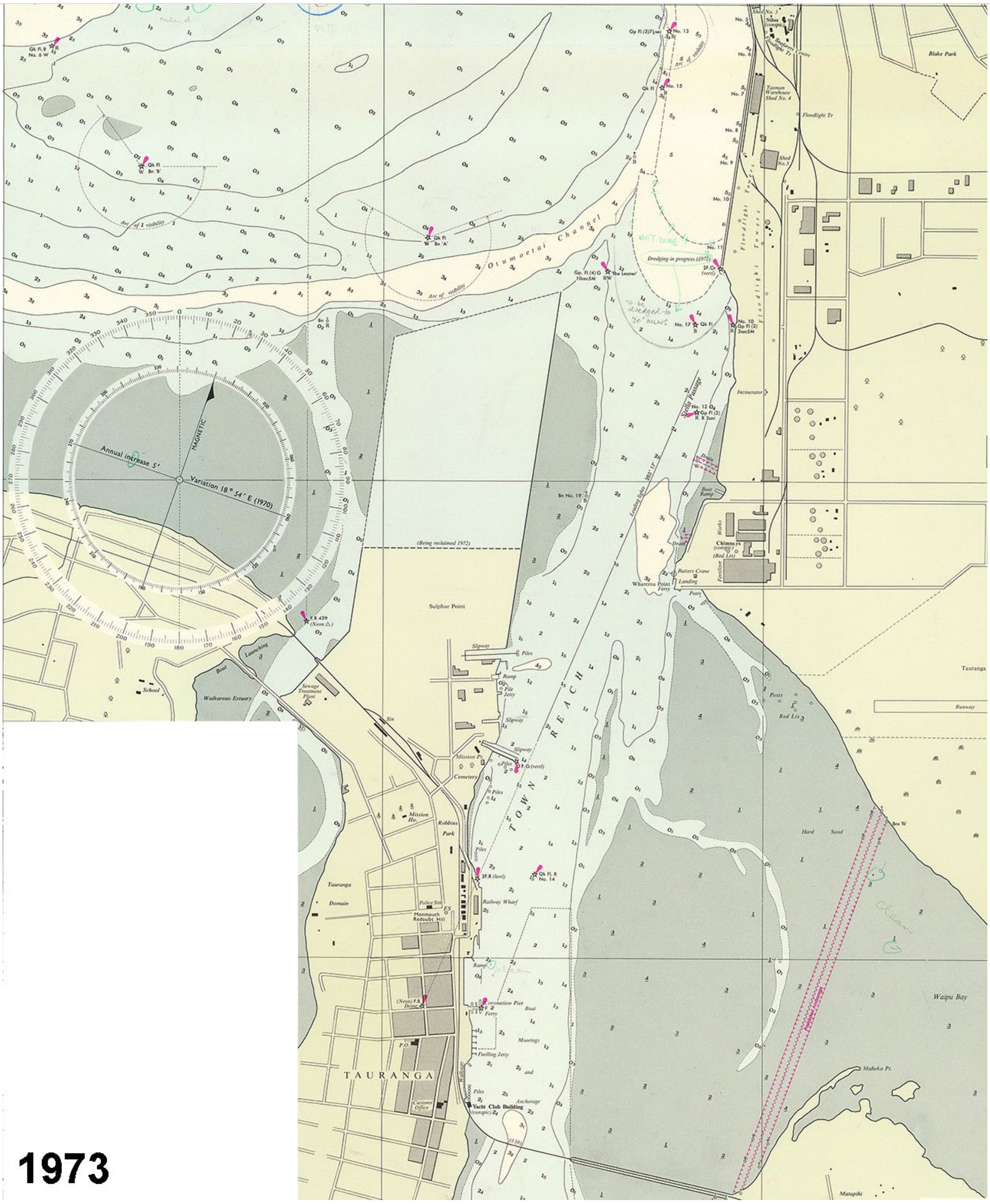

Figure A2 – Section of hydrographic chart 5412 for the Stella Passage area in 1973 showing shipping channels, port infrastructure and surrounding harbour bathymetry.

Figure A3 – Section of hydrographic chart 5412 for the Stella Passage area in 1983 showing shipping channels, port infrastructure and surrounding harbour bathymetry.

Figure A4 – Section of hydrographic chart 5412 for the Stella Passage area in 1992 showing shipping channels, port infrastructure and surrounding harbour bathymetry.

Figure A5 – Section of hydrographic chart 5412 for the Stella Passage area in 1995 showing shipping channels, port infrastructure and surrounding harbour bathymetry.

Figure A6 – Section of hydrographic chart 5412 for the Stella Passage area in 1998 showing shipping channels, port infrastructure and surrounding harbour bathymetry.

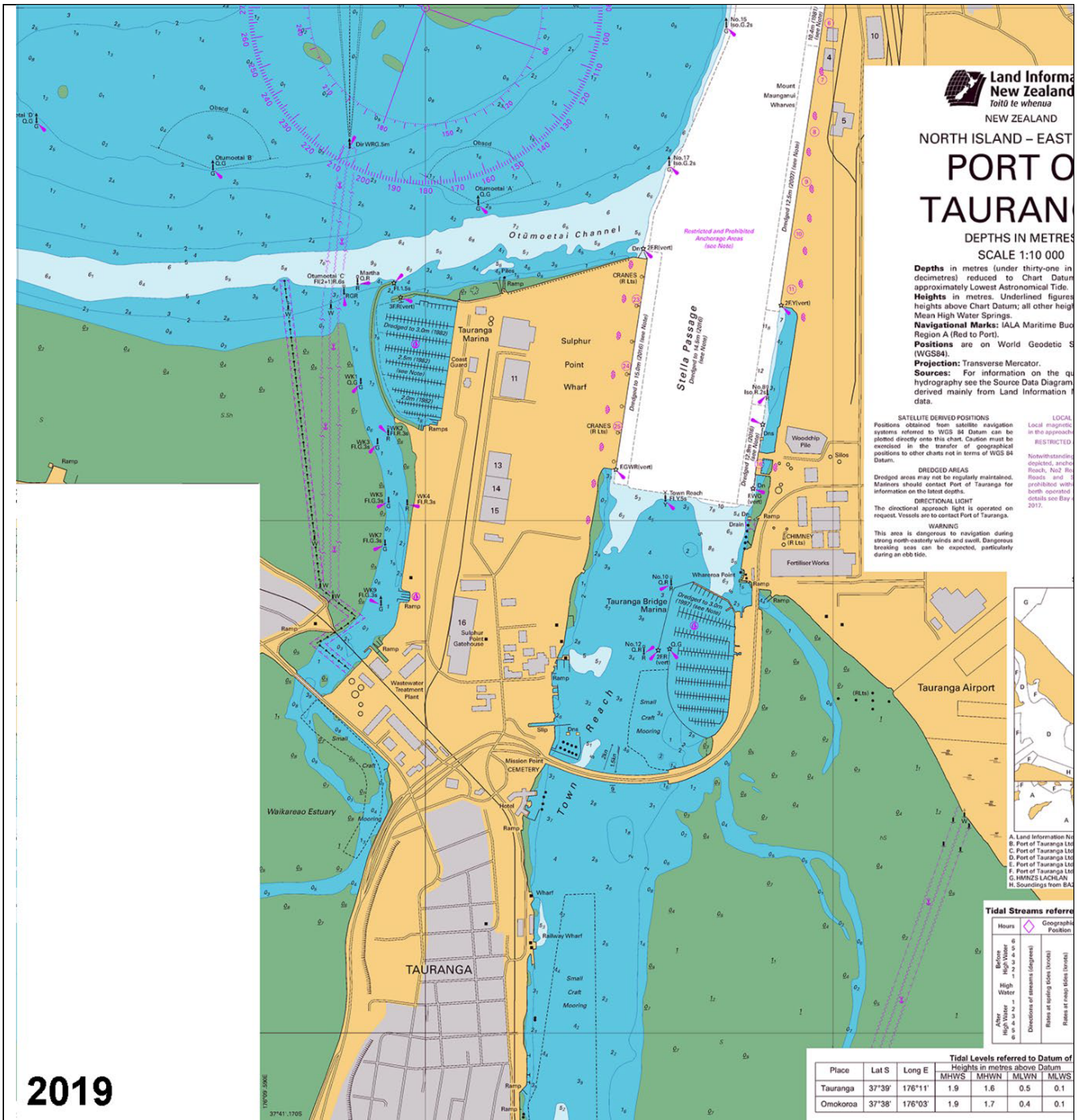

Figure A7 – Section of hydrographic chart 5412 for the Stella Passage area in 2019 showing shipping channels, port infrastructure and surrounding harbour bathymetry.