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Manukau Harbour
Port Feasibility Study

Final Report

Prepared for
Te Manatū Waka | Ministry of Transport

Prepared by
Tonkin + Taylor Ltd and partners

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Table of contents

Executive summary

Purpose and scope

Te Manatū Waka / the New Zealand Ministry of Transport appointed Tonkin & Taylor Ltd and their subconsultants (Royal HaskoningDHV, MetOcean Solutions, Pacific Marine Management, the University of Auckland, Discovery Marine Limited, and RMA Science) to undertake a feasibility study to understand whether it would be technically feasible to establish reliable and safe marine access to a large-scale port in the Manukau Harbour.

This work follows on from the Port Future Study (2015) and the Sapere (2020) studies that both identified Manukau Harbour as a highly ranked option for future port development. Despite being a favoured location from a market proximity perspective, there remain unanswered questions around the technical feasibility given the complex and dynamic nature of the harbour entrance, weather conditions on the west coast of New Zealand, and operational risks associated with the spatial needs of a large greenfield port. The recommendation from the Sapere (2020) work was that further detailed engineering assessments covering geology, hydrodynamics, sediment transport and operational reliability were needed before technical viability of a Manukau Harbour port could be determined.

The Ministry has commissioned this foundational work before determining whether any further analysis should be undertaken. Previous studies explored environmental, social, and cultural factors from a consenting perspective concluding that there are 'significant, if not insurmountable, challenges in obtaining the necessary RMA approvals for new port development' and that special legislation would be required to override existing to enable a greenfield port to be developed. Overall port development costs were also evaluated for a Manukau Harbour port option. Therefore, the Ministry requested that the focus of this study was on engineering technical feasibility only, with the aim of answering the question of whether a port could technically be developed, not whether it should be developed. To do this the study focuses on filling the information gaps from the previous studies by undertaking the following scope of work:

- Defining a navigation channel that would allow safe navigation for the types of vessels servicing a large-scale hub port within the Manukau Harbour.
- Understanding whether there would be any operational constraints on navigation that would lead to downtime and affect operability.
- Understanding whether the spatial needs of a Manukau Harbour port could be met without interfering with the operations of other major facilities e.g. Auckland International Airport.
- Analysing the feasibility of opening (i.e. by capital dredging) the navigation channel to the required depth and width, including factors affecting this.
- Predicting the maintenance requirement for the navigation channel (i.e. by maintenance dredging) based on sediment infill rates, including understanding factors affecting this.
- Establishing volumes, work methods and cost estimates for the dredging works and putting these into context by comparing to other ports.
- Assessing risks affecting the engineering technical feasibility and exploring control measures to determine if there are critical or any residually high risks that could be a fatal flaw to port development in this location.
- Consulting with institutional knowledge holders, stakeholders, and mana whenua to provide inputs and feedback.

Findings

- Safe marine access to the Manukau Harbour could only be achieved with extensive and ongoing dredging which is shown to be feasible with the range of dredging methods that are available today.
- To form a navigation channel and port area, large volumes (70 to 90 M m^3) of seabed material would need to be removed by capital dredging. This is estimated to take between 4 to 6 years to achieve and cost between $941 to $1,244 million with the configuration of the Manukau Bar at the start of the works dictating the equipment required, cost, time, and risk. Estimates are based on existing soil information and further ground investigation would be required to refine these.
- To maintain the navigation channel, very large volumes of accumulating sediment would need to be removed. This has been estimated to be in the order of 7.5 million m^3/year for the channel through the Manukau Bar and 0.7 million m^3/year for the inner harbour and port area. A dedicated maintenance dredger, capable of operating in the west coast wave climate, would need to be owned by the port and available 100% in winter and 50% in summer to achieve this. The cost of the dredger, a 10,000 m^3 capacity Trailing Suction Hopper Dredger, is estimated to be $176 million, and the ongoing maintenance cost to remove this material is estimated to be $37 million/year.
- Maintenance dredge volumes are very high when compared to New Zealand ports e.g. Port of Lyttelton removes ~0.5 million m^3/year and Port of Tauranga removes ~0.25 million m^3/year, as well as international examples which are considered to have high maintenance dredging regimes e.g. Columbia River Port removes ~3 million m^3/year. The large volumes combined with severe wave climate offshore of Manukau result in a much larger maintenance dredger being required compared to other ports e.g. ~2,000 m^3 capacity dredger used for existing New Zealand ports and 5,000 m^3 for Columbia River Port.
- Material dredged through the Manukau Bar would need to be placed back in the active coastal system to avoid destabilising the balance of sediment over time. To achieve this, the dredger would need to place material in relatively shallow depths and additional steps are likely required e.g. partial loading, multiple handling with smaller dredgers, or alternative placement methods, all of which increase the complexity and cost. There is therefore a low confidence in the ability to manage this without adverse effect which is a high risk for a port in this location.
- Suitable dredged material from the inner harbour would be expected to be used to form the port reclamation. Our estimates show that there would be surplus material and unsuitable material that would need to be disposed of. Whilst careful site selection, channel optimisation or beneficial reuse options may reduce these volumes there would be a need to dispose of material to an offshore disposal ground. The ability to gain approval for this is therefore a critical risk to a port in this location.
- It is usual practice for a Trailing Suction Hopper Dredger to operate an 'overflow system' during dredging to maximise the solids content in the hopper and achieve greatest dredging efficiency, therefore our dredge cost estimates have made this assumption. If this was not permitted from an environmental or social perspective, then there would be considerable cost increases for both capital (+60-70%) and maintenance (+30%) dredging. There are recent New Zealand examples where overflowing with a 'green valve' has been permitted e.g. Port of Lyttelton. The green valve reduces air entrapment and releases material at the bed to reduce sediment plume dispersion. Environmental effects are site specific and would therefore need to be evaluated for Manukau Harbour, therefore this remains a high commercial risk to a port in this location.

- Intermittent pilotage suspension is the most probable cause of ships being unable to enter or leave the Manukau Harbour. Overseas ships and high-risk domestic ships such as tankers and chemical carriers calling at a Manukau Harbour port would make use of a pilot to safely enter/exit the port through the navigation channel. This requires the transfer of an experienced mariner (the pilot) to ships offshore. The wave climate offshore of Manukau Harbour presents a challenge and, as with other ports in high energy environments such as Sydney and Melbourne, this operation would need suspending from time to time. The level of pilotage suspension will ultimately be a commercial decision; however, our analysis shows that the levels and durations of suspension expected for a Manukau Harbour port are not overly onerous when compared to other ports in high energy environments.
- Excessive ship motions, surf-riding and broaching when entering/exiting the harbour have been considered and do not pose a risk to medium or large ships. Smaller ships (less than 100 m in length) are shown to have restrictions in certain conditions; however, these are the size of vessels that can presently navigate the existing natural channels and the constraints would be less onerous within a defined channel.
- The Manukau Harbour has been shown to be able to provide the required spatial needs of a large-scale port. Port terminal site selection may, however, be restricted by the Auckland International Airport obstacle limitation surface (i.e. their reserved airspace) if intrusion is not permitted. We have shown that there are sites outside of this airspace, but the merits of port locations have not been evaluated. Should sites within the airspace be considered then an aeronautical study and Civil Aviation approval would be required. It is therefore not a fatal flaw to a port in this location but needs further consideration as part of the site selection process to determine the constraint.
- On review of other potential operational constraints, including anchorage, biosecurity processes, aids to navigation and channel sedimentation, the conclusions on navigational operability for a Manukau Harbour port are that the risks do not pose a fatal flaw and could be mitigated to acceptable levels.
- Manukau Harbour is of high interest to mana whenua as this body of water links to their rights under the Treaty of Waitangi, and there are a number of overlapping and active claims. The nature of these rights is still in consideration under Crown processes including claims under the Marine and Coastal Area Act (Takutai Moana) Act 2011 (MACA). There is a long history of settlement in this area as such the cultural landscapes, values and history are of deep significance. Mana whenua strongly articulated their whakapapa connection and kaitiaki status in relation to the Manukau Harbour. There is concern related to further pollution, the impact of dredging, and effects on the environment including wāhi tapu, urupā, māra kai sites and other sites of cultural significance. More broadly, mana whenua raised concerns about the effects of development within the harbour on their social, economic, and cultural interests as Treaty partners.

Conclusion

The study concludes that, from an engineering perspective:

1. It is technically feasible to open and maintain a navigation channel to the Manukau Harbour suitable for the size of ship serving a large-scale port.
2. The spatial needs of a large-scale port could be met, and navigational operability risks could be managed.

While the Manukau Harbour is technically feasible, there are a number of significant risks relating to capital and operational costs, consenting and potential adverse effects to physical coastal processes. These risks may be possible to overcome and/or manage, but will likely present challenges in progressing. Further work could be undertaken to fully understand these from an economic, social, environmental, and cultural perspective. We note that this study has focused on the Manukau Harbour as a distinct option and has not compared the findings in the context of the other port development options, which would require further evaluation.

Future matters to address

Should the Manukau Harbour progress as an option then:

- Port terminal site selection would be required. The Auckland International Airport airspace restriction (obstacle limitation surface) may affect this and needs to be investigated further. A holistic options assessment, considering environmental, social, and cultural opportunities and constraints would be required.
- Locating a port in the Manukau Harbour would raise significant concerns for mana whenua. The impacts on the taiao (environment) and the kaitiakitanga of tangata whenua will need to be adequately assessed as a key determination on the viability of this project. Feedback through this study has been that mana whenua groups should be engaged early in future decisions and included in a decision-making governance structure. To understand the full extent of the impacts and identify if avoidance or mitigation of these impacts is possible, mana whenua have made it clear that there is an expectation for a co-design process (or similar) between Treaty partners, the Crown and mana whenua.
- Identification, assessment, and appropriate management of effects (cultural, social, environmental) will be a key step at future stages to build on previous work. Targeted studies into the ability to manage placement of dredged material back into the active coastal zone to avoid adverse effects e.g. erosion to adjacent shorelines, has been identified as a high risk to a port in this location and would need to be resolved.
- There are high risks associated with the dredging works that may have a significant bearing on the capital and operational costs which would need commercial appraisal taking account of the updated costs from this study.

1 Introduction

Te Manatū Waka / the New Zealand Ministry of Transport appointed Tonkin & Taylor Ltd and their subconsultants (Royal HaskoningDHV, MetOcean Solutions, Pacific Marine Management, the University of Auckland, Discovery Marine Limited, and RMA Science) to undertake the Manukau Harbour Port Feasibility Study, which aims to understand whether it would be technically feasible to establish reliable and safe marine access to a large-scale port in the Manukau Harbour.

The Manukau Harbour Port Feasibility Study will support ongoing work by the Ministry on the National Freight and Supply Chain Strategy, which is examining New Zealand's freight system for the next 30 years.

1.1 Background

The Manukau Harbour (location shown in Figure 1.1) was identified in the Port Future Study (2015) as one of two potential new locations to replace the current Port of Auckland site. It was also the highest ranked option in the Sapere (2020) studies.

Despite being a favoured location, there remain unanswered questions around the technical feasibility given the complex and dynamic nature of the harbour entrance, weather conditions on the west coast of New Zealand, and operational risks associated with the spatial needs of a large greenfield port.

Sapere (2020) recommended that these safety issues be investigated further, and that more detailed engineering assessments covering geology, hydrodynamics, sediment transport and operational reliability were needed before the technical viability of a Manukau Harbour port could be determined. The Ministry of Transport has therefore commissioned this foundational work to determine whether the Manukau Harbour should be considered further for port development in the future.

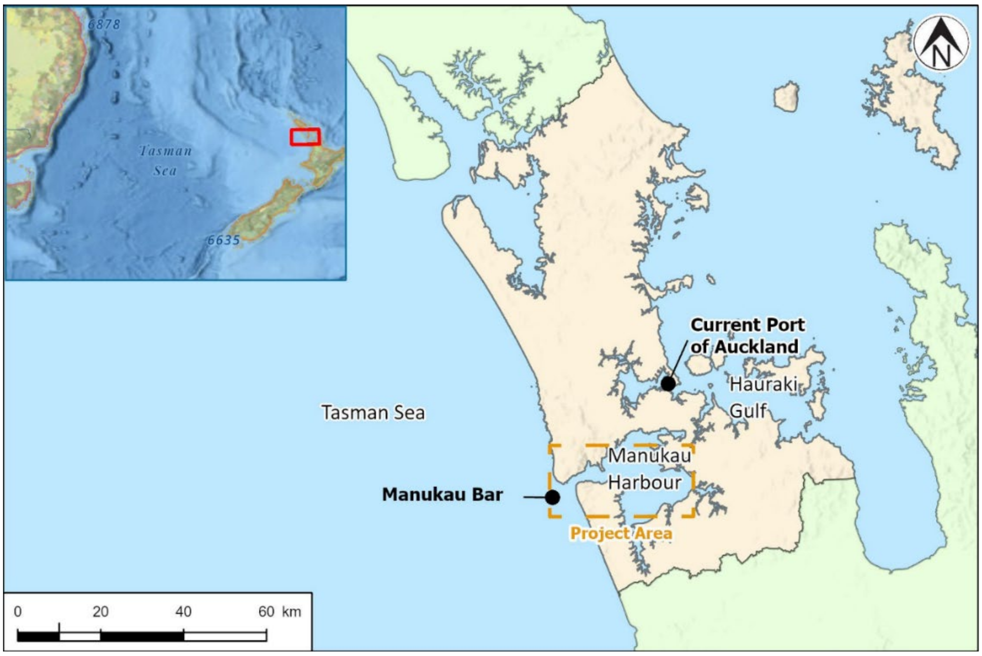

Figure 1.1: Location of Manukau Harbour within the Tasman Sea in relation to the existing Port of Auckland location and the Auckland Region.

1.2 Study purpose and scope

The Manukau Harbour Port Feasibility Study aims to answer the question of whether a port could technically be developed, not whether it should be developed. To do this, the study focuses on filling the information gaps from the previous studies regarding:

- Safe navigation for vessels servicing a large-scale port.
- Opening and maintaining a dredged navigation channel, with focus on the dynamic harbour entrance i.e. the Manukau Bar.
- Other risk factors affecting technical feasibility.

Previous studies have explored planning, environmental, social, and economic factors regarding a Manukau Harbour port option. Therefore, the Ministry has requested that the focus of the study is on engineering technical feasibility only. For completeness we have reviewed the findings of previous studies, particularly relating to planning risks, and assessed any additional risks that may affect this. This has included engagement with mana whenua and key stakeholders who hold information related to the scope of this study.

Our scope included:

- Defining a navigation channel that would allow safe navigation for the types of vessels servicing a large-scale hub port within the Manukau Harbour.
- Understanding whether there would be any operational constraints on navigation that would lead to downtime and affect operability.
- Understanding whether the spatial needs of a Manukau Harbour port could be met without interfering with the operations of other major facilities e.g. Auckland International Airport.
- Analysing the feasibility of opening (i.e. by capital dredging) the navigation channel to the required depth and width, including factors affecting this.
- Predicting the maintenance requirement for the navigation channel (i.e. by maintenance dredging) based on sediment infill rates, including understanding factors affecting this.
- Establishing volumes, work methods and cost estimates for the dredging works and putting these into context by comparing to other ports.
- Assessing risks affecting the engineering technical feasibility and exploring control measures to determine if there are any critical or residually high risks that could be a fatal flaw to port development in this location.

1.3 Stage of port development

It is important to recognise that the planning and implementation of a major greenfield port can take years to decades to realise. A typical process for this is provided by PIANC (2019), which we reproduce in Figure 1.2 for context. Given the uncertainties around the viability of a Manukau Harbour port, this study precedes Step 1 (development of a port vision and strategic plan) and Step 2 (setting of functional and performance requirements), although it is acknowledged that the Port Future Study (2015) and Sapere (2020) work started these steps. This study therefore sits within Step 3 (outlining the spatial needs) and Step 4 (identification and characterisation of potential sites), focusing on safe navigation, dredging requirements and operational constraints. The study will therefore provide feedback into Steps 1 and 2, which will need to be developed further in conjunction with the other steps in later studies and levels of design to realise a port in this location.

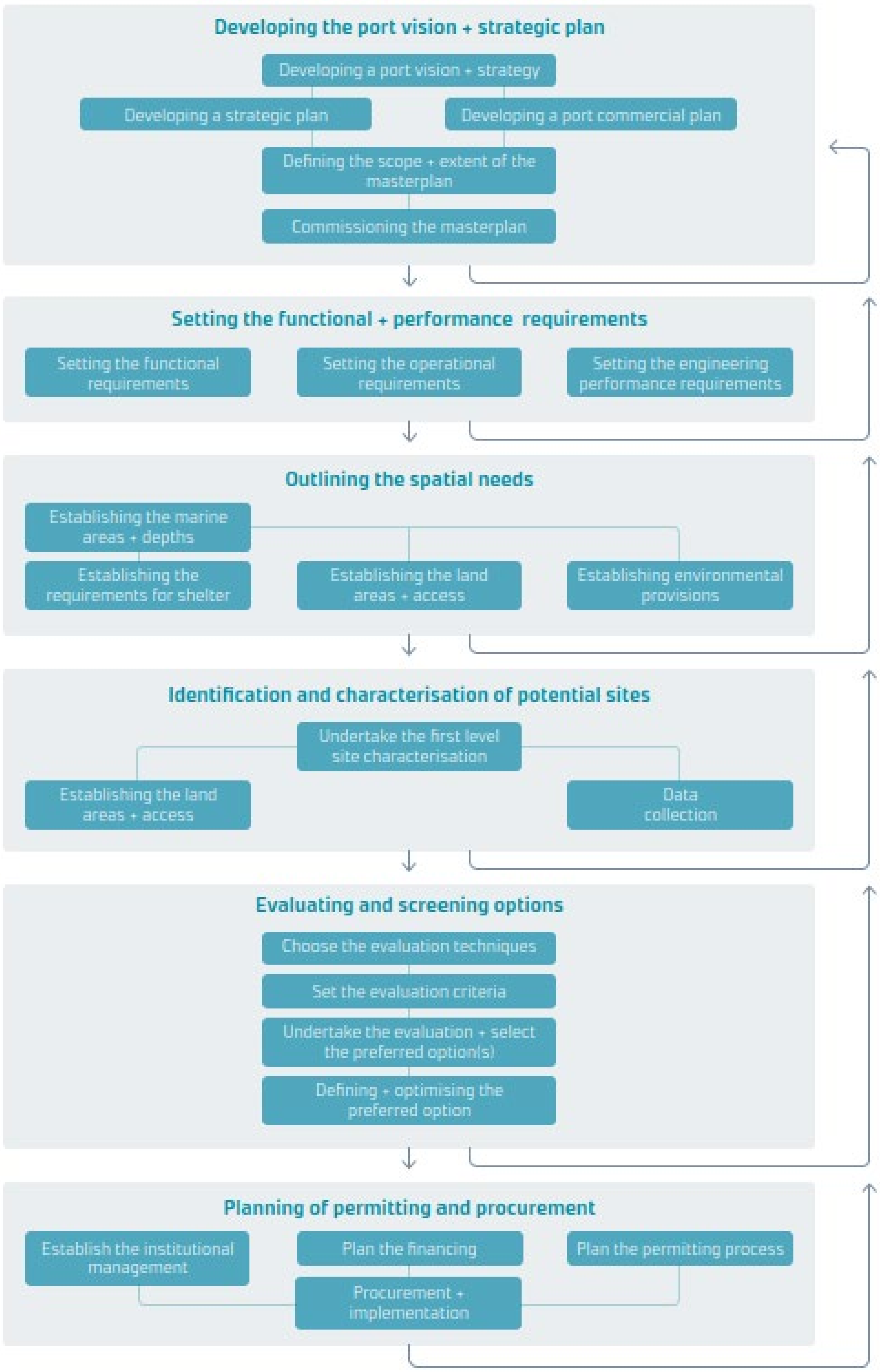

Figure 1.2: Detailed master planning process for a major greenfield port, reproduced from PIANC (2019).

1.4 Supporting information

This Final Summary Report consolidates the findings of the Manukau Harbour Port Feasibility Study. The detail that is summarised here is synthesised from a series of Technical Working Papers (TWP) prepared by the project team. A list of these working papers is shown in Table 1.1 and the working papers are provided alongside this report.

Table 1.1: Overview of Technical Working Papers (TWP)

Ref.	Title	Author	Purpose
TWP 01	Ship traffic and design vessels	Pacific Marine Management	• Set out future shipping traffic density and design ships that a port in the Manukau Harbour would likely be required to accommodate.
TWP 02	Fieldwork	Tonkin & Taylor Ltd.	• Provide factual reporting of the fieldwork carried out as part of the study.
TWP 03	Coastal	Tonkin & Taylor Ltd.	• Provide a synthesis of the existing coastal, geological, and environmental knowledge of the Manukau Harbour to inform other assessments. • Summarise results from the field data collection, analysis of the Manukau Bar and numerical modelling relating to the existing conditions and processes. • Summarise the likely implication of the proposed dredging works in terms of channel stability, sediment infill and impacts on coastal processes.
TWP 03a	Historic bar and channel dynamics	The University of Auckland	• Summarise analysis of historic satellite imagery and bathymetric data to characterise the behaviour of the Manukau Bar over time.
TWP 03b	Metocean modelling	MetOcean Solutions Ltd.	• Summarise the wave and current (hydrodynamic) numerical modelling and additional metocean analysis.
TWP 03c	Sediment transport modelling	MetOcean Solutions Ltd.	• Summarise the sediment transport numerical modelling to predict sediment infill to the concept navigation channel.
TWP 04	Navigation channel design	Royal HaskoningDHV	• Summarise the concept navigation channel design process from initial concept to depth refinement and verification.
TWP 05	Navigation operability	Pacific Marine Management	• Determine operability criteria for ships and compare the metocean conditions at Manukau with other ports to understand operational constraints. • Explore other operational constraints to navigation that may affect technical feasibility.
TWP 06	Dredging	Royal HaskoningDHV	• Summarise the findings of the dredge assessment regarding constructability of channels and basins, methodologies for dredging, environmental issues and mitigation measures, quantities and costs of the capital dredging and reclamation works, and quantities and cost of maintenance equipment and maintenance works.
TWP 07	Engagement	Tonkin & Taylor Ltd.	• Summarise the engagement with iwi and stakeholders undertaken as part of the study.
TWP 07a	Institutional knowledge	Pacific Marine Management	• Summarise engagement with institutional knowledge holders i.e., port operators, pilots and ship masters, harbourmasters, shipping lines and marine insurance underwriters.

2 Methodology

A high-level overview of our methodology is provided in the flow diagram in Figure 2.1. At the study inception we set key assumptions on what a Manukau Harbour port would likely require, so that we could test feasibility on that basis. These assumptions are provided in Section 3.

Phase 1 included gathering the information we needed to undertake the study. This was a combination of using existing datasets and gathering further information from the field. The fieldwork, along with satellite imagery analysis and numerical modelling helped to build up our understanding of the site conditions.

This knowledge fed into **Phase 2** to enable the design process for the navigation channel to be undertaken and to understand weather-related operational constraints. We also explored other potential operational constraints within this phase through engagement with stakeholders.

With the navigation channel conceptually designed, the dredge volumes and work methods were explored in **Phase 3**, alongside understanding factors affecting the feasibility of this such as weather conditions, the dynamics of the Manukau Bar, and rates of sediment infill to the channel. Within this phase mitigation measures to control sediment infill were also explored and cost estimates established.

To assess other risk factors associated with the development of a greenfield port in the Manukau Harbour we held two risk workshops and engaged with institutional knowledge holders. Our scope was to focus on technical feasibility, but for completeness have identified additional consenting risks. We have separated planning/consenting related risks from engineering technical feasibility risks and provide two risk registers (Appendix A).

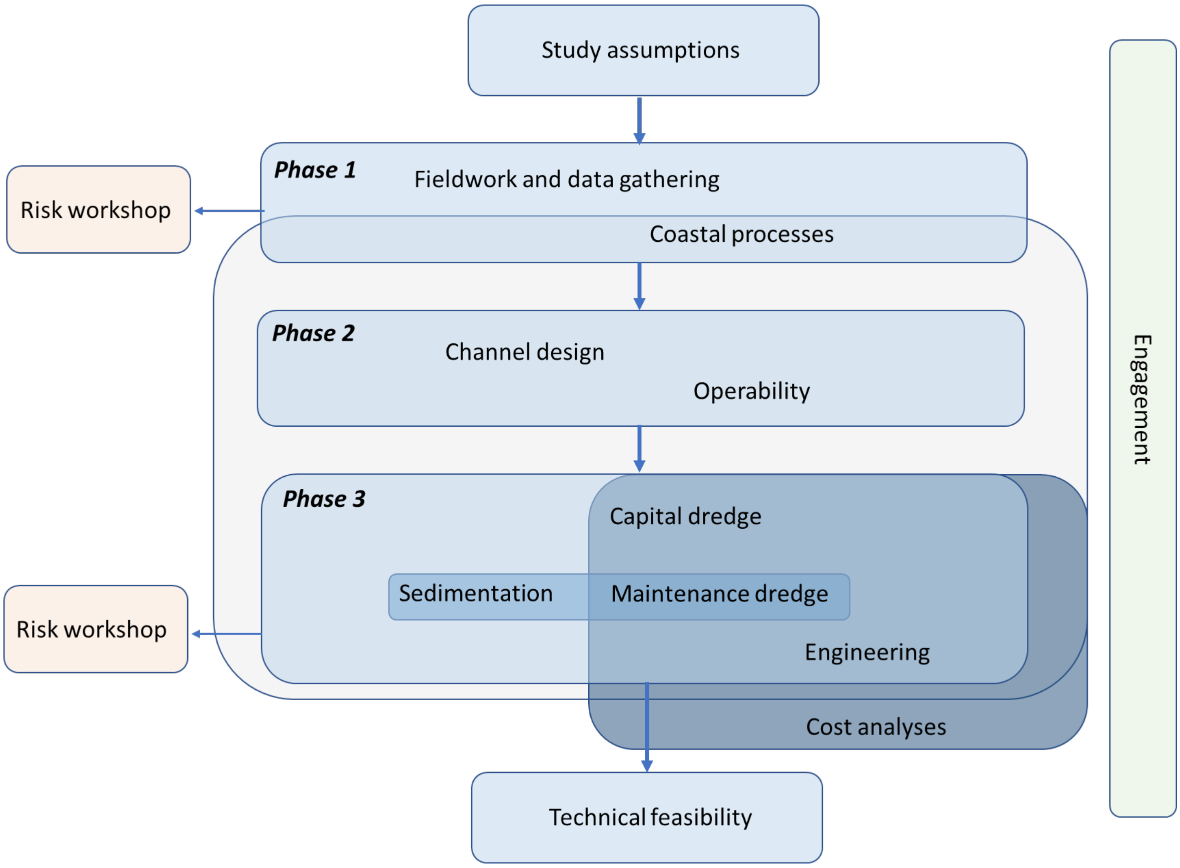

Figure 2.1: Flow diagram providing a high-level overview of the study methodology.

3 Port development assumptions

The Ministry has asked that we consider a port within the Manukau Harbour to be a large-scale hub import/export port for New Zealand. To test feasibility of this, assumptions about the port needed to be made regarding cargo throughputs and marine traffic. These determine the types of vessels that would service the port and its spatial needs, both from a navigation perspective but also landside requirements. These assumptions are provided in the following sub-sections and are largely based on previous work by others which forecast to the year 2079, with the team conducting review and sense checking. Consultation with NZ Ports and Shipping Lines has also taken place to test key assumptions. For consistency, the same design horizon as previous studies have been used with two development horizons considered. Stage 1 forecasts to the year 2049 and stage 2 to 2079. This acknowledges that full port capacity would not be needed initially and the 25-30 year timeframes align to typical resource consent and container terminal concession agreement timeframes.

3.1 Cargo

The 2019 statistics from the Ministry of Transport's Freight Information Gathering System (FIGS) were selected as representative trade statistics for New Zealand's seaborne trade as they closely fit the trends for 2012-2019 and are representative of cargo volumes pre-Covid pandemic. In 2019 seaborne trade totalled 68 million tonnes, distributed through the port network as presented in Table 3.1.

Table 3.1: Total seaborne trade volumes in 2019, split by major port and type (MoT, FIGS)

NZ port	Total throughput (million tonnes)	
	Containers	Bulk/ breakbulk
Port of Tauranga	8.2	11.0
Port of Auckland	3.8	1.9
Lyttelton	2.3	2.9
Napier Port	1.7	2.9
Port Otago	1.2	1.4
CentrePort	0.6	2.5
Port Nelson	0.4	1.4
South Port	0.4	2.6
PrimePort Timaru	0.3	1.1
Other ports	0.1	21.2
Total	**19**	**49**

In the analysis of upper North Island port options, Sapere (2020) analysed cargo growth to assess the capacity of the Port of Auckland and explore alternative options for meeting this future demand. The year 2019 was used as the baseline and forecasts were for 60 years to 2079. We have used these forecasts to make assumptions about a Manukau Harbour port (refer to TWP01 – Ship Traffic and Design Vessels for methodology and rationale). The resulting forecast cargo throughputs for a Manukau Harbour hub port are presented in Table 3.2 for 30 and 60 years from the baseline. This covers all the upper North Island containerised imports and exports plus the vehicle and dry bulk that presently trade through the Port of Auckland, 50% of southern port container imports and exports as tranships, and the liquid bulk cargo for the Auckland region that are presently imported through Marsden Point.

These forecasts were tested with NZ Ports and Shipping lines. We received general agreement from Shipping Line participants on the forecast growth rate with one NZ Port participant considering the forecasts may be high based on their method for determining growth, which was on a by population basis and not on a combination of population growth and GDP growth. In either case, there is no change to the design vessel assumptions which is the relevant information for this study, informing the navigation channel design.

Table 3.2: Forecast trade volumes for a Manukau Harbour Hub Port

Cargo type	Forecast annual throughput by year 2049	Forecast annual throughput by year 2079
Containers	4 M TEU imports/exports, 1M TEU feeder ships to/from southern ports	8 M TEU imports/exports, 2 M TEU feeder ships to/from southern ports
Vehicles	172,500 CEU	345,000 CEU
Dry bulk	2.3 M t	4.6 M t
Liquid bulk	Peaks in 2030, then declines to below present levels	7.5 M t. Assumes Auckland Region cargo is imported through Manukau Harbour

3.2 Marine traffic

New Zealand's container trade is serviced by trade lanes from North Asia, Southeast Asia, North America, Australia, and the Pacific with about 15 ship calls per week in total. Although cargo volumes have increased over time this call pattern has remained relatively static with ship size increases accommodating the additional demand. In 2010, the average size container vessel to call at New Zealand was 2,700 TEU and largest 4,100 TEU, by 2019 the average increased to 4,050 TEU and largest to 8,000 TEU. A breakdown of all overseas ship visits in 2019, taken from MoT FIGS, is provided in Table 3.3.

Table 3.3: Overseas ship visits in 2019, split by major port and type

NZ Port	Vessel type, calls per year					
	Container	Bulk	Vehicle	Tanker	Cruise	Other
Port of Tauranga	759	412	12	95	113	95
Port of Auckland	589	106	179	20	127	102
Lyttelton	315	113	72	99	20	42
Napier Port	295	196	0	26	71	49
Port Otago	186	36	0	0	100	1
CentrePort	146	118	72	53	111	17
Port Nelson	121	77	49	16	6	18
South Port	80	95	0	49	0	26
PrimePort Timaru	51	114	0	31	13	23
Other ports	94	499	0	265	334	138
Total	**2636**	**1766**	**384**	**654**	**895**	**511**

Worldwide there are currently few container ships in the range 8,000 – 10,000 TEU, however newbuild orders are mostly for new-Panamax (10,000 – 14,000 TEU) and larger 16,000 – 23,000+ TEU. When these very large ships are introduced into the main East-West trade lanes, the new-Panamax size is likely to be brought into the North-South trade lanes, including Australia and New Zealand.

Using the cargo forecasts, we have estimated the likely marine traffic for a Manukau Harbour port to comprise of approximately 1,880 visits per annum by 2079 (excluding fishing vessels, service craft etc. which would exceed 2000). The split by vessel type is presented in Table 3.4 and further details on these assumptions can be found in TWP01 – Ship Traffic & Design Vessels.

Table 3.4: Forecast marine traffic for a Manukau Harbour Hub Port

Vessel type	Forecast marine traffic by year 2049	Forecast marine traffic by year 2079
Container	750	750
Coastal feeder	350	350
Vehicle carrier	230	300
Bulk carrier	165	270
Multi-purpose and reefer	110	120
Tanker	85	90
Cruise	0	0
Total	**1,690**	**1,880**

3.3 Design vessels

As discussed in Section 3.2, ships calling at New Zealand have increased in size over time. This has required port infrastructure upgrades including dredging wider and deeper channels to accommodate them. Estimating future ship sizes serving a Manukau Harbour hub port is therefore important for this feasibility study so that a navigation channel can be designed to safely accommodate them.

The percentage increase in containerised cargo volume correlates closely to the percentage increase in container ship size, whereas the number of ships for the bulk and breakbulk trades (including vehicles) is expected to grow in line with trade growth. This, along with the makeup of the marine traffic to service the cargo forecast and future trade patterns were used to define a range of design vessels for consideration for a Manukau Harbour port. These are projected to the same design horizon as the cargo volumes i.e. year 2079 and discussed further in TWP01. The largest vessel considered in the study is the 15,000 TEU container ship, which is considered the largest over this timeframe and would eventuate if trade were combined with the eastern seaboard of Australia trades. A summary of key parameters of the design vessels are provided in Table 3.5. Should larger ships become the norm over this timeframe, then this would affect the dimensions of the navigation channel, this is discussed further in Section 5.3.

Table 3.5: Select design vessel parameters for a Manukau Port

Parameter	Container			Bulk	Vehicle	Tanker	
	15,000 TEU[1]	10,000 TEU[2]	7,000 TEU[2]	50,000	8,500 CEU	LR2[3]	MR
Deadweight (t)	200,000	125,000	81,000	40,000	41,250	110,000	50,000
Length overall (m)	365	351	272	195	230	260	210
Beam (m)	53.6	45.8	42.8	29	40	45.0	32.2
Max draft (m)	16.0	15.0	15.0	11.5	11.5	15.5	12.6
Load factor	67%	90%	90%	100%	85%	100%	100%
Operational draft (m)	12.4	14.2	14.3	11.5	10.2	15.5	12.6
Air draft (m)	59	53.2	49.3	38.5	49.8	39.5	31.4

Notes:

1. The 15k TEU container vessel is the widest design vessel and was used to determine the channel width.
2. The 7k TEU container vessel has the largest operational draft and was used to determine the minimum required channel depth. Container vessels usually call at ports on a schedule, which is independent from the tide, therefore all tide access for container ships is assumed.
3. The LR2 tanker is an infrequent caller and therefore assumed to use high water to enter the port; as a result its draft is not used to determine the required channel depth.

3.4 Spatial needs

In simple terms, a port requires land, water, and air space to operate:

- Landside space includes the wharves, port terminal, handling areas, and hinterland connections.
- Water space includes anchorage, navigation channels, berthing, passing lanes and turning areas.
- Airspace includes the ships' height above the water line and the port equipment above the wharf deck and terminal area such as cranes and container stacks.

The following sub-sections provide an overview of the assumptions we have made regarding the spatial needs of a Manukau Harbour port. We have been asked to exclude hinterland connections (transport links) from this study as this would be a later consideration as part of the site selection process.

3.4.1 Port area

We have assumed that a Manukau Harbour port would be on reclaimed land connected to the shoreline via bridge or causeway, which aligns with previous studies. To meet the forecast cargo volumes the port area, reclamation and dredge volumes have been estimated and are presented in Table 3.6. These are rough order-of-magnitude estimates to allow the dredging assessment to take place.

Table 3.6: Manukau Harbour port area assumptions

Stage of development	Port footprint (ha)	Reclamation volume (m^3)[1]	Capital dredge volume (m^3)[2]
Stage 1 to year 2049	112	10M	20M
Stage 2 to year 2079	126	10M	15M
Total	**238**	**20M**	**35M**

1. Rough order-of-magnitude, location independent, reclamation volumes have been determined using a base level of 0 m CD assuming a natural bank would be utilised. The reclamation height is assumed to be 2 m above Highest Astronomical Tide with an additional 20% allowance made for settlement and ground improvement. Reclamation slopes are 1V:2H.

2. Rough order-of-magnitude, location independent, capital dredge volumes for the port area have been determined using a base level of -2 m CD for the berth areas, and -5m CD for the turning areas and passing lanes. These assume natural channels would be selected for the port area. Dredge slopes are 1V:5H and dredge depths -16 m CD.

3.4.2 Representative port location

A representative site, Site B shown in Figure 3.1, has been chosen to test feasibility. This has the longest channel and shortest land connection of the three Port Future Study (2015) sites which were also carried through to the Sapere (2020) studies. Technical feasibility for other sites within the harbour, with shorter channels and longer land connections, can be drawn from the representative site.

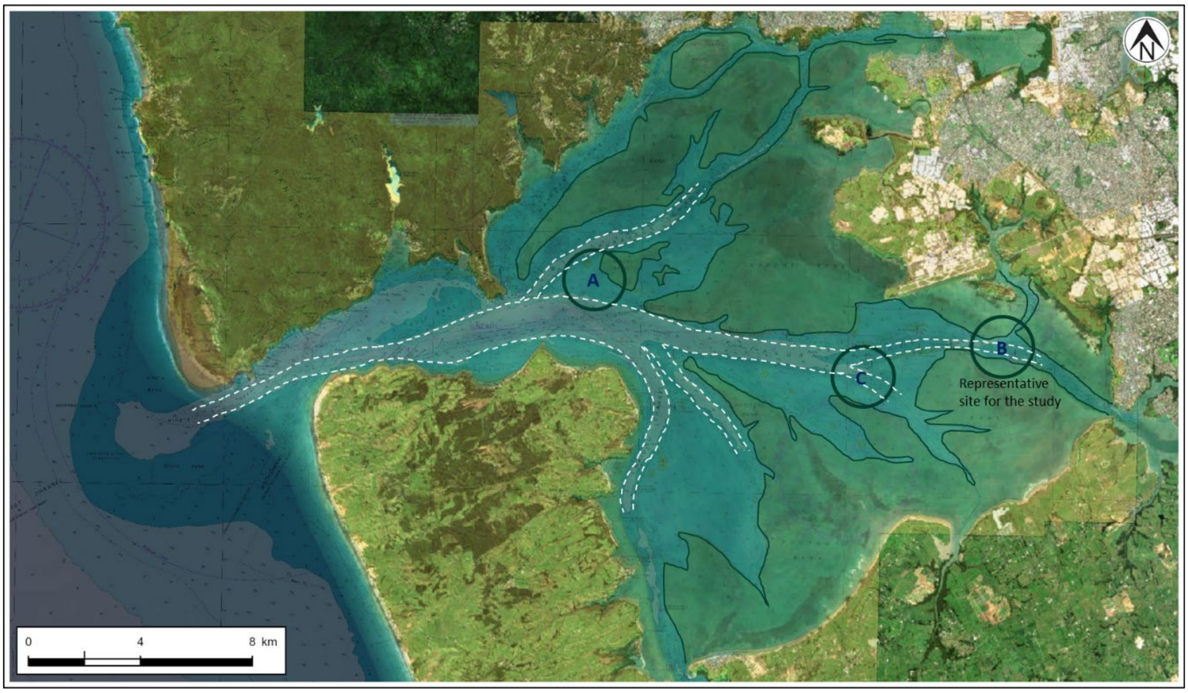

Figure 3.1: The Manukau Harbour with the main naturally deep tidal channels shown by white dashed lines, and indicative port locations identified by the Port Future Study (2015) and carried through to the Sapere (2020) studies shown with blue circles labelled A, B, and C. Location B is the representative site for the study.

This is not a preferred site but a representative site to allow analysis to be undertaken to assess feasibility. We acknowledge each port location will have its own technical challenges to overcome, however these will be secondary to the technical feasibility of opening and maintaining a navigation channel allowing safe marine access to the harbour. Once inside the harbour, the technical challenges are reduced and more influenced by other (e.g., social, environmental, economic) factors beyond the scope of this study. The choice of port location must therefore remain an open question for future stages that take account of hinterland connections and other social, economic, and environmental factors.

3.4.3 Port equipment

The highest machines in a port are container ship-to-shore cranes. A super post-Panamax crane has a boom-up height (when not working) of about 120 m above the wharf deck and 77 m when the boom is down i.e. higher than the mast of the ship it is working. These airspace spatial needs are used in Section 5.4.4 to assess the intrusion to the Auckland International Airport airspace.

4 Site conditions

This section is a brief summary of the site conditions, further detail can be found in TWP03 – Coastal.

4.1 Setting

The Manukau Harbour is New Zealand's second largest estuary, located to the southwest of the Auckland isthmus. It covers 344 km^2 and comprises shallow, intertidal banks interspersed with deeper channels. It has a catchment size of 1,100 km^2 with three main inlets providing freshwater and fine sediments.

Throughout this report we refer to the 'open coast' as the area exposed to the Tasman Sea, the 'harbour entrance' as the confined stretch between north and south head, and the 'inner harbour' as the sheltered area in the upper reaches of the harbour. Key features of the harbour are provided in

Figure 4.1.

The opening of the shoreline on the west coast creates a tidal inlet which is a complex system of sediment storage and transport. Tidal inlet systems, regardless of size, tend to have similar morphology (Davis, 2013) comprising an accumulation of sediment at the landward end of the inlet (flood-tidal delta), and an accumulation of sediment at the open water end (ebb-tidal delta).

Both types of delta (i.e., flood-tidal and ebb-tidal) are submarine accumulations of sediment (sand, in the case of the Manukau) in the shape of shallow 'bars' that are incised by deeper channels. The channels convey the bulk of the tidal flows (and therefore the bulk of the tidal prism), and the shallow bars are shaped by waves (more so on the ebb-tidal delta, which is exposed to the full force of ocean waves, than the flood-tidal delta, which is sheltered to varying degrees from ocean waves). Hicks & Hume (1996) found a relationship between the volume of the tidal exchange, or tidal prism of an estuary and the size of the ebb-tidal delta, with larger estuary systems having larger deltas. Deltas act as sediment sinks along sandy coastal systems (Davis, 2013), with the sediment that comprises them potentially having a long residence time (in the delta) before continuing along the coast. This natural delta system is of key significance to the study and is discussed further in the following sections.

The harbour entrance is approximately 2 km wide and confined by the north head, Whatipū, which is a volcanic headland fronted by an extensive beach 1 km in width at its maximum, and the south head, Āwhitu, which is an eroding coastline consisting of consolidated sand deposits.

Key infrastructure within the harbour includes Auckland International Airport, Māngere Wastewater Treatment Plant, Onehunga Wharf, New Zealand Steel, and the LPG Marine Terminal in the Papakura Channel which connects to shore via a 5 km pipeline.

The Sapere (2020) studies found that Manukau Harbour's proximity to the existing industrial area and distribution centres of South Auckland, and to road and rail networks, would make a port cheaper to build and would result in lower transport costs and emissions (due to proximity to end market) than other port location options investigated. It was acknowledged by Sapere (2020) and in the Port Future Study (2015) that a port here would need careful site selection to work around the airport flight paths and associated height restrictions (known as the Obstacle Limitation Surface). The implications of this are discussed further in Section 5.4.4.

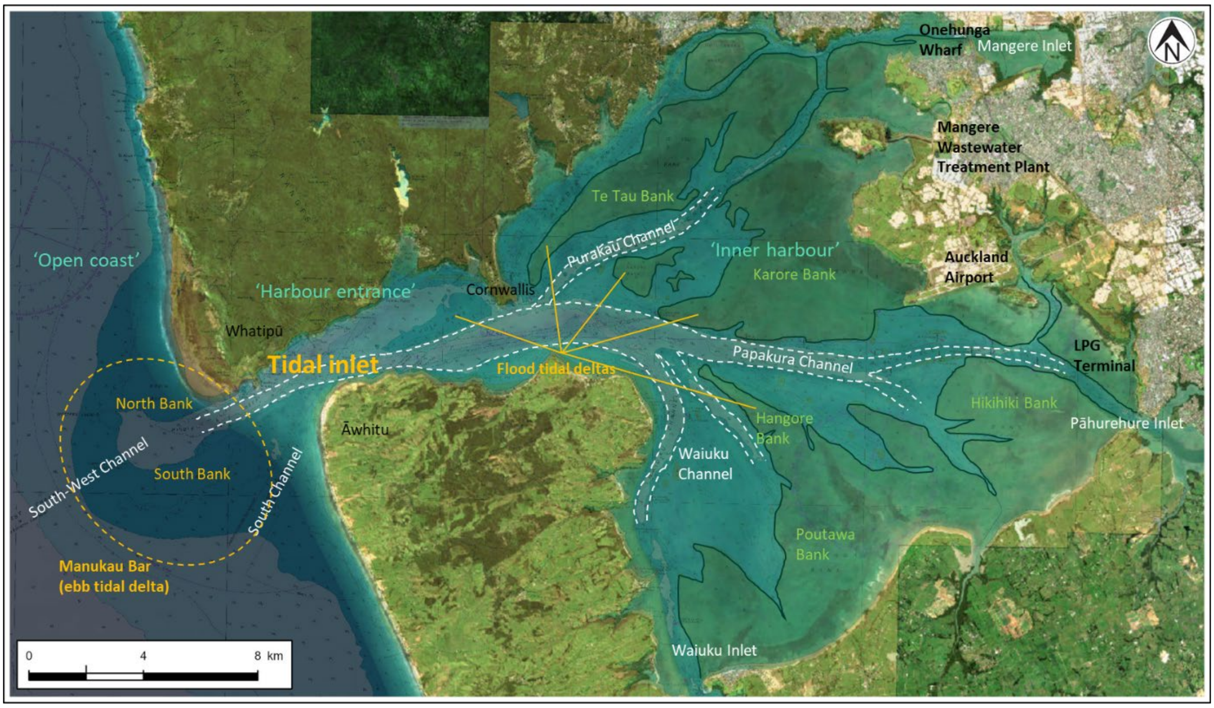

Figure 4.1: Setting and key features of the Manukau Harbour.

4.2 The Manukau Bar

The feasibility of opening and maintaining a navigation channel to the Manukau Harbour is complicated by the presence of the Manukau Bar. "Manukau Bar" is the colloquial term referring to the ebb-tidal delta, i.e. the shallow sandy environment at the seaward side of the harbour entrance. Sand is transported across the bars of the ebb-tidal delta towards the harbour by waves, and is transported offshore, primarily in the channels, by tidal currents. The Manukau Bar has been estimated to store around 1,250 M m^3 of sand covering an almost 50 km^2 area. Understanding the Bar, how it evolves over time, and what forms and drives change, is therefore critical to the study.

Historic satellite imagery, charts and survey data allowed the long-term morphology (change over time) of the Manukau Bar to be investigated. The position of the main South-West Channel appears to undergo a semi-regular (approx. 30 year) cyclic process of movement towards the northwest followed by breaching through the south. This process, shown in satellite imagery in Figure 4.2, appears to have been ongoing since records began in the early 19th century. The present channel (as of 2023) has recently breached to the south and is now slowly moving towards the southwest. This movement has also been observed by ships' pilots, master mariners, and mana whenua consulted with as part of the study.

The configuration of the ebb-tidal delta, that is, the spatial disposition of the channels and bars that make up the delta, has significant implications for creating and maintaining a navigation channel to the harbour. Refer to TWP03a – Historic bar and channel dynamics, and TWP03 – Coastal, for further details of the behaviour of the Manukau Bar over time.

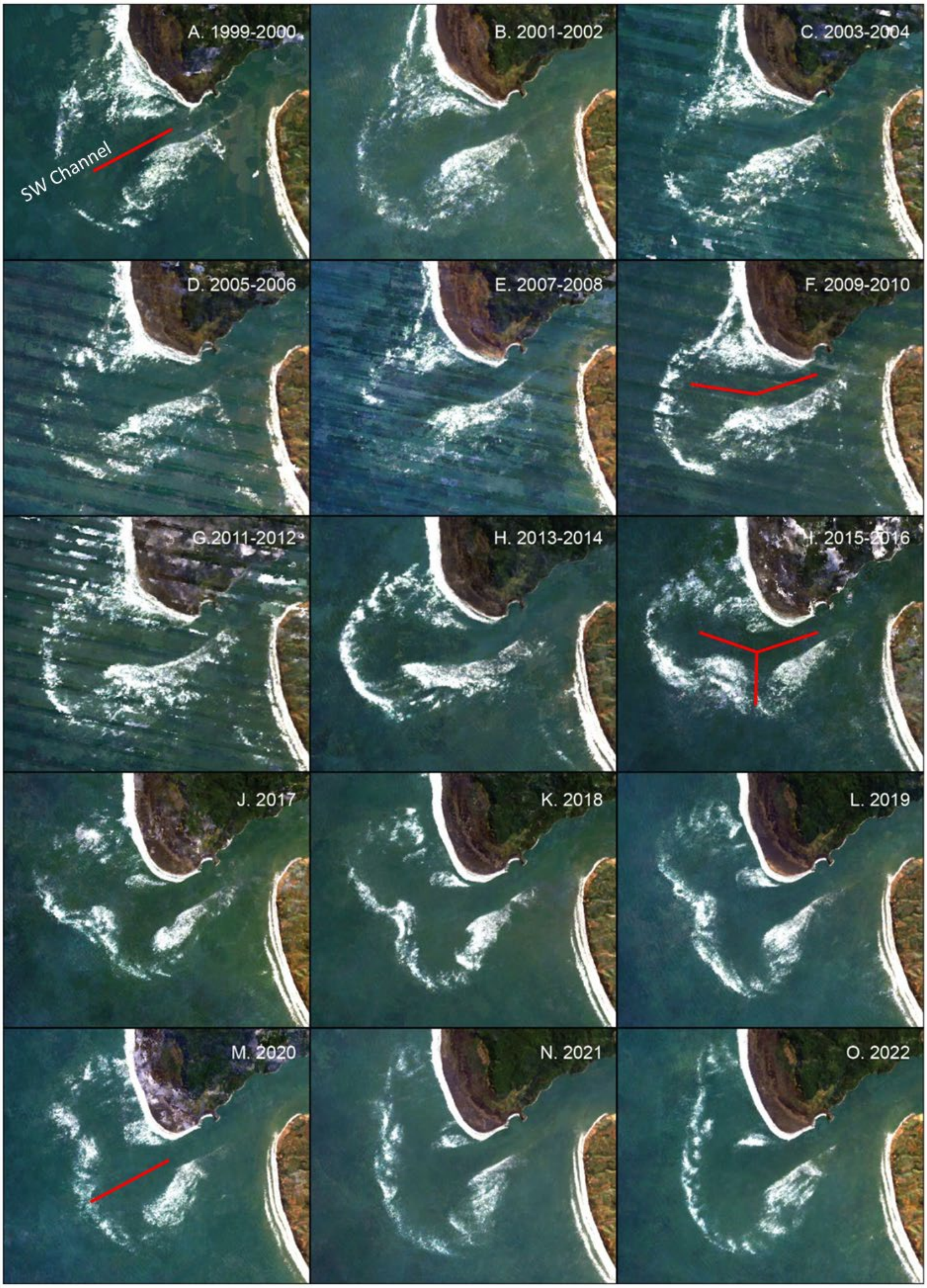

Figure 4.2: Satellite imagery of the Manukau Bar over time indicating a gradual migration of the main SW channel to the north (2009 to 2015) before a channel bifurcation starting in 2015 and re-establishment of a main SW channel around 2019-2020, as indicated by the red lines.

4.3 Metocean conditions

Understanding and being able to quantify the metocean conditions (winds, water levels, waves, and currents) at the site was fundamental to the study. They are used as inputs for the navigation channel design, and to understand ship operability, determine the 'workability' of dredgers, and drive the sediment transport numerical models.

To derive metocean conditions that could be used by the project team, we used a suite of wave and hydrodynamic numerical models built, calibrated, and verified from field measurements. We complemented existing datasets with newly gathered information from the field using oceanographic instruments deployed offshore and, in the harbour, to measure water levels, waves and currents. Waves are large on the open coast and smaller within the confines of the harbour; winds are predominantly from the southwest; and the tidal exchange of water generates currents focused in the deeper channels, which get complex at the harbour entrance (Figure 4.3).

Figure 4.3: General overview of metocean conditions at Manukau Harbour.

4.4 Bathymetry

A bathymetric survey was undertaken as part of the Manukau Harbour Port Feasibility Study to map seabed depths, concentrating on the ebb-tidal delta, harbour entrance and inner harbour channels to the representative port location. Traditional survey methods using a vessel were not possible in the shallow areas over the Manukau Bar as it was too dangerous. Instead, we used a helicopter to deploy a device to measure the water depth and, through data post processing, we derived bed levels in areas where hydrographic survey was dangerous. We combined these new datasets with existing information to form a complete submarine surface across the study area, which is shown in Figure 4.4. This was used to build the numerical models, design the navigation channel, and quantify the dredge volumes. Comparison to historic charts, historic surveys and satellite imagery provided insight into changes over time, which revealed that the inner harbour tidal channels are stable in comparison to the Manukau Bar, which is highly dynamic. This is illustrated by comparing a survey from 1989 with the new survey data (2023), shown in Figure 4.5. The 1989 survey shows the main channel through the ebb-tidal delta deflected to the northwest (as had been observed in the satellite imagery analysis shown in Figure 4.2) whereas the 2023 channel is oriented perpendicular to the adjacent shoreline in a southwest orientation.

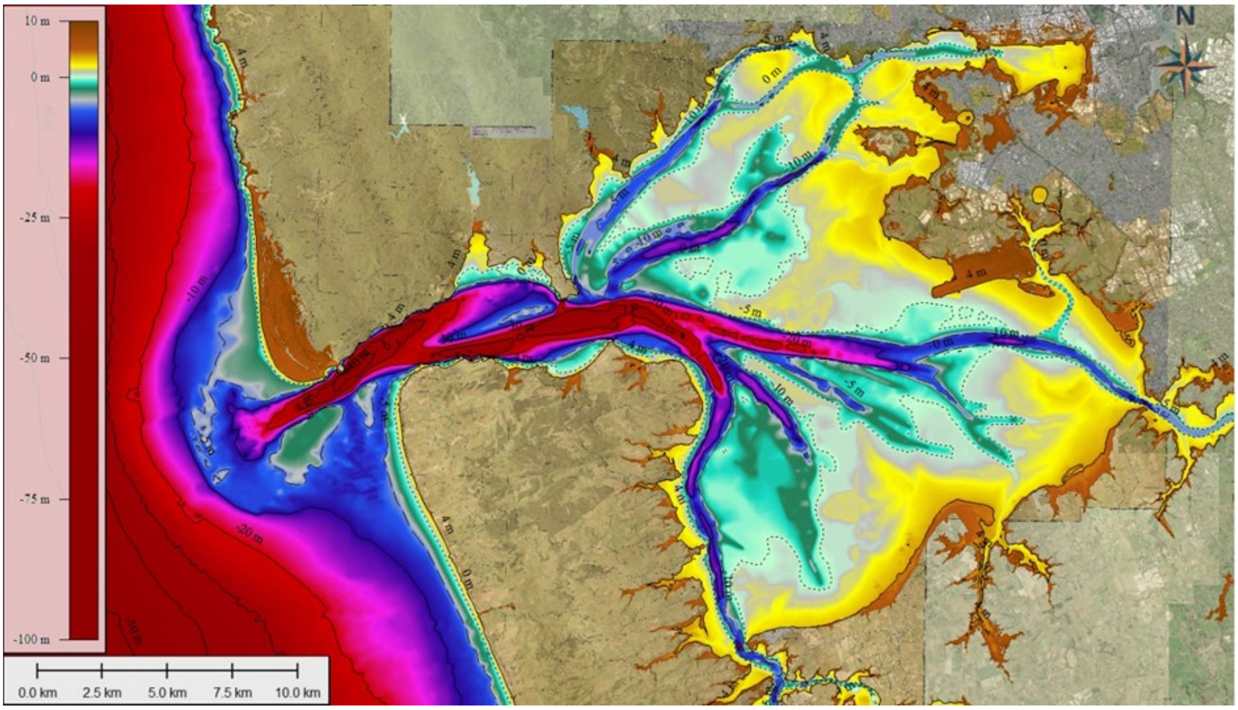

Figure 4.4: Manukau Harbour bathymetry, built from a combination of new and existing sources (depths in metres, relative to Chart Datum).

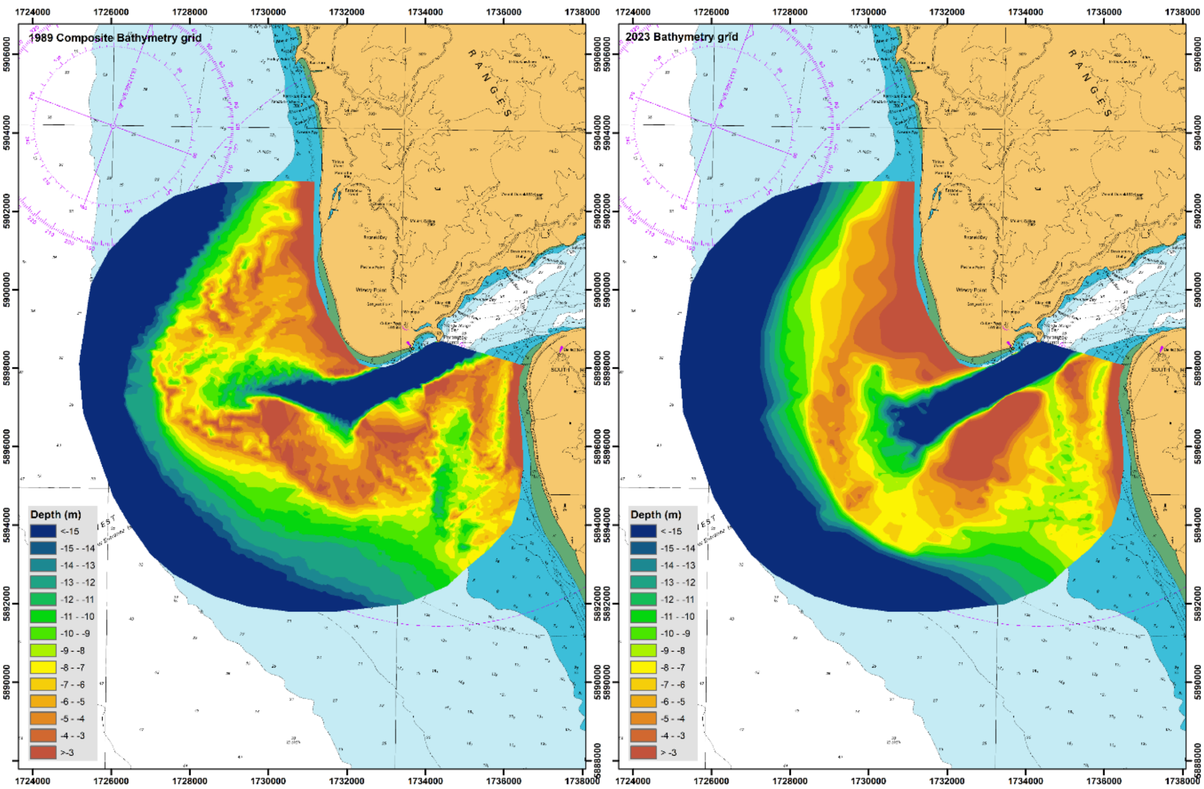

Figure 4.5: Bathymetry comparison 1989 (left panel) and 2023 (right panel) for the Manukau Bar (depths in metres, relative to Chart Datum).

4.5 Ground conditions

Understanding surface sediments and subsurface ground conditions was important for designing the side slopes of the navigation channel, determining suitable dredge methodologies, and providing inputs to the sediment transport modelling.

We reviewed the geological history and published geology for the harbour, analysed logs from existing boreholes, reviewed existing channel slopes and collected and tested sediment samples to determine sediment size, density, and geochemical properties.

The geological history of the harbour is complex, but in simple terms it is a river valley that has been 'drowned' by sea level rise. During glacial periods (the last being around 20,000 years ago) the mean sea level was 100 m below present-day. As post-glacial sea levels rose, river channels were drowned to form the contemporary harbour channels, which have been infilling with sediment since their formation. Very generally, outer reaches of the harbour have been infilling with sandy marine sediments, and inner reaches by fine terrigenous sediments.

The surface sediments change from fine to medium sands at the Manukau Bar to fine sand and silts with coarse shell within the upper reaches of the harbour channels and inlets (Figure 4.6). Geochemical testing showed low to negligible levels of contamination for the range of tests undertaken (refer to TWP06 – Dredging for test results).

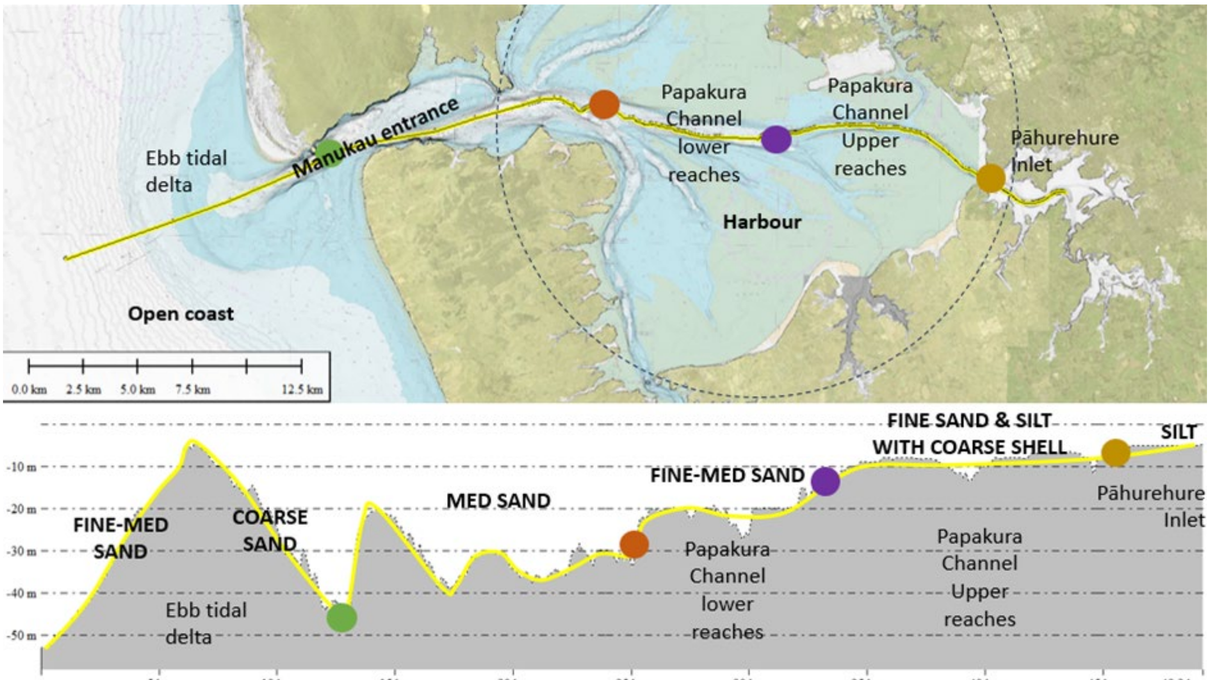

Figure 4.6: Summary of sediment characteristics along the main tidal channel from ebb-tidal delta to Pāhurehure Inlet.

Limited geotechnical information (existing boreholes) on the characteristics of subsurface material below the surface sediments has been used to derive preliminary soil models for the entrance bar and inner harbour areas. These assumed geotechnical conditions were used to develop the scope of dredging works and associated cost estimates and are an important risk factor for the project. Full details of the adopted soil models can be found in TWP06 – Dredging.

4.6 Sediment transport

To predict dredged-channel sediment infill rates and assess potential control/mitigation measures, we first needed to understand sediment movements by waves and currents. To do this, we investigated sediment transport on the open coast, around the ebb-tidal delta (Manukau Bar), and in the tidal channels inside the harbour using general principles combined with empirical and numerical models that assimilate sediment transport theory. A conceptual model of sediment transport is shown in

Figure 4.7.

On the open coast, predominant waves from the southwest that arrive slightly oblique to the coastline drive longshore sediment transport to the north. Highly energetic and oblique waves from the northwest drive longshore transport in a southerly direction, however, this is less frequent. We estimate the gross longshore transport rate south of the Manukau Bar to be 1–2 M m^3/year and the net transport to be 0.75–1.9 M m^3/year towards the north.

Strong tidal currents and wave action drive sediment around the Manukau Bar system in a complex but generally circular pattern. Sediment is transported along the coast from the south and deposited in the main channel during flood (incoming) tides with some transported to the flood-tidal delta within the harbour. On ensuing ebb (outgoing) tides, sediment is transported offshore through the main channel and deposited onto the terminal lobe (outer part of the bar) as tidal currents dissipate. A combination of wave action and flood tides drive sediment from the offshore bars inshore, and north and south to adjacent bars. Sediment on these adjacent bars is then moved inshore over the shallow bar system, re-entering the main channel forming a semi-closed system. Some sediment is lost from the system as it is transported north by longshore processes.

It has been shown that the volume of sediment being transported around the Manukau Bar is considerably higher than that being transported along the open coast by longshore transport processes, with only a small fraction of the sediment that circulates within the ebb-tidal delta "leaking" out into the longshore transport system. This large amount of sediment in circulation is a key factor for the maintenance of a navigation channel in this location.

Within the harbour, tidal currents concentrated in channels transport sand at rates that are orders of magnitude smaller than on the ebb-tidal delta. Tidal currents tend to be asymmetric and ebb-dominated, which drive sand transport seaward over the long term, adding to the sediment accumulated in the deltas either side of the harbour entrance. In contrast, silt is typically remobilised from shallow areas by wind waves breaking on intertidal flats, uplifting deposited fine sediments and increasing silt concentration within the tidal channels. The suspended silt is then transported out of the harbour as part of tidal exchange or resettles on the intertidal flats.

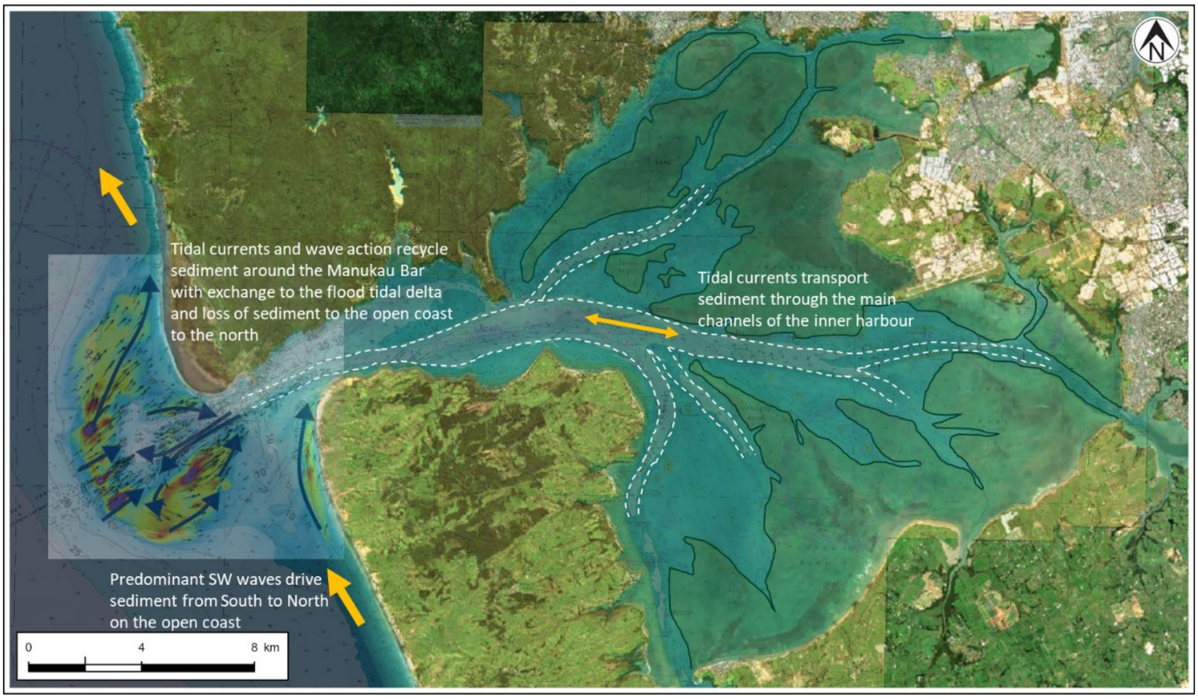

Figure 4.7: Simplified conceptual model of sediment transport around the Manukau Harbour.

5 Navigation

Due to commercial pressures leading to vessel size increases trans-Tasman, coastal and Pacific Island cargo ships ceased using Onehunga Wharf in the years leading up to 2012, and bulk carriers carrying cement ceased in 2016. Today, commercial fishing boats operating out of Onehunga Wharf and recreational users still use the harbour. The hydrographic chart, used by mariners for navigation, provides the following restrictions and cautions about the harbour entrance:

- It is not recommended that vessels enter or leave Manukau Harbour during the hours of darkness. No vessel of 500 tonnes gross or greater may cross the bar during the hours of darkness.
- Depths on the bar and the entrance to the Manukau Harbour are subject to frequent change and it is dangerous for mariners without recent local knowledge to attempt to enter the harbour. The lights and beacons are of limited assistance in the approach channels.

Review of vessel track data from 2014 to 2016, provided in Figure 5.1, shows the routes taken to enter and exit the harbour by crossing the Manukau Bar. Both a south and north-west oriented channel have been used over this time period. The exit of the north-west channel varies from the south-west to north-west over the 3 years reflecting the changing position of the natural channels, as has been described in Section 4.2, highlighting the difficulty for navigation.

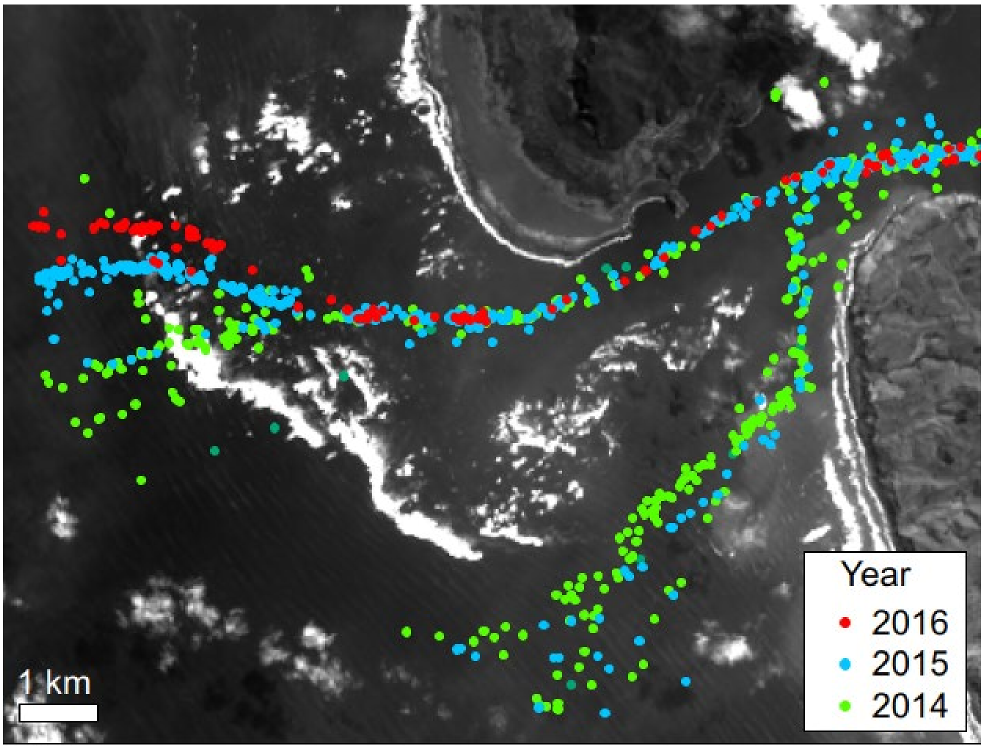

Figure 5.1: Commercial vessel track data for the Manukau Bar between 2014 and 2016.

To allow safe navigation to a port within Manukau Harbour a navigation channel would need to address these restrictions. To do this a defined navigation channel across the Manukau Bar would need to be sufficiently deep and wide to accommodate the types of vessels using it. These would be much larger than the types of vessels that have historically entered the harbour and therefore dredging would be required.

The navigation channel design for this study was undertaken in the following steps. Full details of this process can be found in TW04 – Navigation.

Step 1. An initial concept was designed following the PIANC (2014) guidelines making use of existing information i.e. published hydrographic charts and environmental data.

Step 2. The initial concept was then refined using the updated bathymetry from the fieldwork campaign, and numerical model results defining the wave and currents in the proposed channel alignment. Using these inputs, dynamic under-keel clearance calculations were undertaken to determine safe but optimised channel depths from the initial concept.

Step 3. The optimised channel design was then verified using fast time simulations. These investigated a range of extreme weather scenarios and simulated the ships' horizontal excursions to confirm the width of the channel design.

5.1 Route selection and initial concept

Route selection was made as short as possible to reduce transit times and utilised the naturally deep tidal channels as much as possible. The navigation channel was divided into three sections taking account of the differing environmental conditions along the alignment and conceptually sized according the PIANC (2014) guidelines. The channel sections and an indication of the areas requiring dredging are shown in Figure 5.2 and include:

- Section A: 'Entrance Channel', the open and exposed area at the harbour entrance, including the Manukau Bar.
- Section B: 'Middle Section', the passage between the northern and southern headlands with mainly deep-water where wind and currents show a tunnelling effect, longitudinal to (along) the channel alignment.
- Section C: 'Port Approach', the inner harbour area where the governing wind and wind driven waves are perpendicular to (across) the navigation channel.

Both a southern oriented entrance (South Channel) and a south-western oriented entrance (South-West Channel) were initially considered (Step 1 of the design) but reduced to just the South-West Channel for later design stages. This decision followed comparison of indicative capital dredge volumes (South Channel approx. 50% more by volume), and a preference from most ship masters and pilots consulted as part of the study for a channel oriented with the predominant wave direction from the south-west.

The decision was made to design the Entrance Channel (Section A) and Port Approach (Section C) to accommodate one-lane of traffic to minimise dredging volumes. The Middle Section (Section B) is naturally deep and wide and therefore can accommodate two-lane traffic in its designed width. The channel configuration (one-way – two-way – one-way) was proposed as it is deemed sufficient for the envisioned traffic.

A complete two-way channel was considered but discarded due to the relatively low traffic volume during the design life. The channel width is less than the length overall of the largest design vessel, which causes a concern in case such a vessel would lose control and gets stuck ("Suez Canal Ever Given" situation), but the mitigation for this situation would be either to restrict access of these vessels during high wind or wave conditions, or to widen the one-way channel slightly to avoid this situation. This will be a commercial decision and not a strictly technical consideration, therefore would need to be revisited at later stages. Some delays to shipping during maintenance dredging will need to be accepted in the one-way channel and can be managed with a proper contractual arrangement with the dredging contractor. A reasonable shipping delay to maintenance dredging has been taken into account based on experience in other ports. Should commercial shipping traffic increase to such an extent that maintenance dredging delays are significant, dredging capacity could be increased (larger dredger or supplementary dredger), again this would need to be re-evaluated at later design stages to refine.

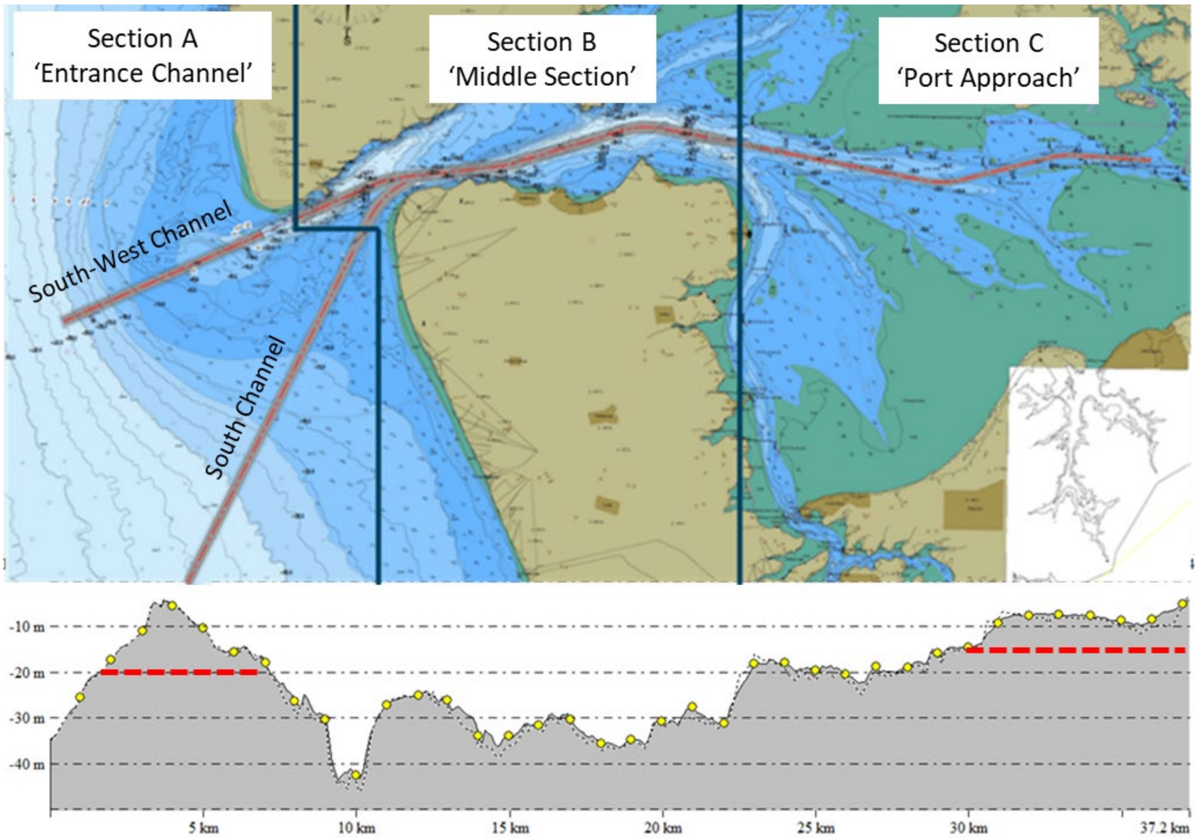

Figure 5.2: Top: Navigation channel sections, broken up to reflect differing environmental conditions. Bottom: long section through the South-West Channel alignment with indicative areas to be dredged shown with red dashed lines.

5.2 Optimising the depth and verifying the design

When assessing the required channel depth to ensure safety for vessels while in transit, the risk of bottom touch is an important factor. Waves and currents affect the motions of a vessel when sailing through the channel resulting in vertical motions of the vessel. To avoid the vessel hitting the bottom of the channel due to these motions, additional margin is required. The margin in water depth, exceeding the vessel draft, is called the "gross under-keel clearance" or gross UKC.

Results from the under-keel clearance study showed that the 7,000 TEU container ship, with the deepest draft of 14.3 m, was the critical design vessel and that depths of the channel could be reduced from the initial concept without affecting safety levels. This resulted in a depth reduction of 1.5 m for the Entrance Channel (Section A) and 1.7 m for the Port Approach (Section C), thus reducing the amount of dredging required.

Ship manoeuvring models were used to test the design vessels in the proposed channel design for a range of extreme weather conditions. The ship model calculates the horizontal motions of the ship and is used to determine if the widths and bends are sufficient. To do this the design vessel with the largest beam, the 15,000 TEU container ship with beam of 53.6 m, was used. Results show that the channel width and bend radii are sufficient but that width reduction at this stage of design is not recommended, but could be looked at through real-time ship simulation studies to optimise. This level of detail was not required to test feasibility and is therefore left for later consideration.

5.3 Concept navigation channel

Taking on-board the results from the under-keel clearance assessment, and ship modelling the final concept navigation channel dimensions and capital dredge volumes, are shown in Table 5.1 with sections of the route in Figure 5.2 and a scaled drawing provided in Appendix B. Side slopes were established based on existing natural slopes and through slope stability modelling. Over-dredging is a necessary allowance to accommodate the vertical accuracy of dredging equipment under the site conditions; this adds 1 m to the depth at the Entrance Channel (Section A) and 0.5 m to the Port Approach (Section C).

As mentioned in Section 3.3, the largest container ship considered in this study is the 15,000TEU. Should even larger ships, say 20,000 TEU capacity, wish to use the navigation channel, the width, following PIANC empirical calculations, would increase by 30 m for Section A, 41 m for Section B, and 22 m for Section C. However the depth would still be dictated by the 7,000 TEU vessel. Channel dimensions are considered conservative at this concept stage, following PIANC guidelines, and future design steps (e.g. real time simulation) should be used to refine the channel geometry and take account of revised vessel forecasts.

Table 5.1: Concept navigation channel (South-West) dimensions and capital dredge volume

Section	Width (m)	Depth (m CD)	Over dredge (m CD)	Side slopes	Length (km)	Capital dredge volume (M m^3)[1]
A **Entrance Channel**	295	-19	-20	1V:25H above -12mCD 1V:7.5H below -12mCD	9	13.8
B **Middle Section**	410	Naturally deep	Naturally deep	1V:5H	15.3	0
C **Port Approach**	220	-16	-16.5	1V:5H	12.6	13.9
				Total	**36.9**	**41.6**

[1] Includes over dredge allowance and side slopes, based on the 2023 bathymetry.

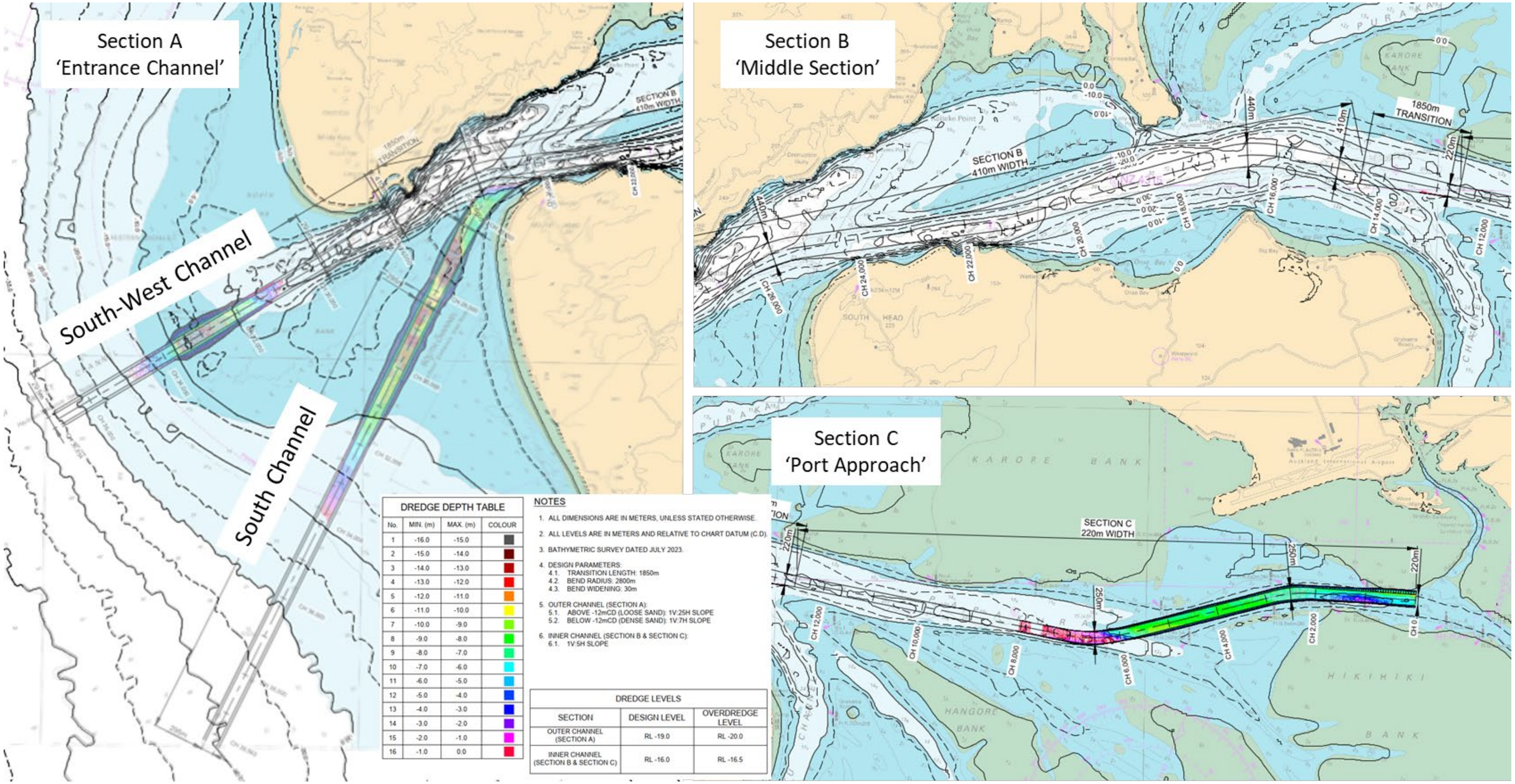

Figure 5.3: Concept navigation channel, with both the favoured South-West and alternative South entrance channel shown for the Entrance Channel (Section A). Dredge depths below current bed levels are colour coded (refer to Table 5.1 for dimensions and Appendix B for scaled drawing).

5.4 Operational constraints

Extreme weather conditions can interrupt or even suspend port operations, which has a knock-on commercial impact. Therefore, understanding if the Manukau Harbour would present unacceptable levels of downtime due to weather is an important factor to investigate. As well as weather, other operational constraints relating to navigation and port operations have been considered and are discussed here. Full details can be found in TWP05 – Navigation Operability.

5.4.1 Pilotage

A maritime pilot is an experienced and highly skilled sailor who has detailed knowledge of a particular waterway. A port within Manukau Harbour would use a pilot to bring ships safely through the Entrance Channel to the port within the harbour. Pilots are transferred to ships offshore to undertake this. Small vessels such as fishing boats and pleasure craft will not require a pilot to transit the Entrance Channel, and regular users such as the Masters of coastal feeder ships or coastal bulk carriers can apply for pilotage exemptions. Pilotage therefore relates primarily to the overseas ships and high-risk domestic ships such as tankers and chemical carriers visiting Manukau.

Pilotage suspension is the most probable cause of being unable to enter or leave the Manukau Harbour. Suspension is more a function of pilot and pilot boat safety than the size of ship, although larger ships are more able to offer a lee (shelter) for a pilot boat than smaller ships. Pilotage suspension criteria for international 'benchmark' ports, San Francisco, Columbia River, Botany Bay and Melbourne, and international guidance (PIANC), have been used to arrive at likely pilotage suspension rates for a port within the Manukau. It must be noted that the international port limits are different to one another owing to the site-specific weather conditions and constraints. Establishing the limits at Manukau therefore cannot be determined to within a narrow band, but they are likely to sit within the wider band of the international port limits and through comparison judgement can be made.

Offshore weather conditions at Manukau Harbour have been compared to the international guidance and benchmark ports' thresholds. Our analysis (refer to TWP05) shows that the number of events likely to cause pilotage suspension would be between 12 and 28 per year or 1.0 to 2.3 per month, with more in winter and fewer in summer, representing between 0.3% and 0.7% as a percentage of total pilot transfers throughout the year. This is higher than the benchmark ports, where suspension rates were between 0.1% to 0.3%, however the duration of suspension at Manukau (5 to 24 hours) is similar e.g. at the low-end to Melbourne (1 to 4 hours) and at the high-end to Botany Bay (12 to 24 hours).

Currently, Port of Auckland and Port of Tauranga are constrained to slack water or very low tidal currents at high water for movement of large container ships i.e. for about 3 to 4 hours every 12. Although not strictly comparable to the Manukau situation as the tidal water level is easily predictable and can be operationally managed, whereas the restriction at Manukau would be dictated by storm events with shorter forecast horizons, this indicates short duration downtime is acceptable.

Ultimately the level of pilotage suspension will be a commercial decision that will need further investigation at later stages of design if a Manukau Harbour port was to progress. At this stage the conclusions drawn (refer to TWP05 – Navigational operability) are that this level and duration of suspension do not look overly onerous and could be accommodated by a commercial port.

5.4.2 Exiting and entering the harbour

Exiting the harbour, the limitation to ships relates to the ability of the ship, crew, and cargo to withstand the ship motions. We have used a threshold of 0.15 g RMS vertical accelerations on the ship's bridge in assessing this. Large ships, and even medium sized ships greater than about 125 m length, will not experience difficulties when exiting the harbour across the bar. Short ships will respond most to the waves at Manukau Bar with ships less than 100 m length having occasions when exit is restricted. In any given year, our analysis shows that 16 ships of 35 m length, for example a fishing boat or service craft, and 3 ships of 65 m length would be restricted. These sizes can already cross the bar and the wave conditions and under keel clearances in a dredged channel will be less onerous than for the existing bar bathymetry and thus less restrictive.

Entering the harbour across a bar exposes ships to the risk of surf-riding and broaching from the following seas. Our analysis shows that large ships, and even medium sized ships greater than about 100 m length, will not experience difficulties when entering the harbour across the bar. Short ships are more prone to broaching so it is critical that the ship proceeds slowly enough so that the waves can overtake and pass beneath the ship. The International Maritime Organisation's intact stability guidelines have been used to show that for ships as short as 35 m, once waves reach 1.4 m in height (which is 95% of the time), the safe maximum speed limitation is 10.8 knots. For longer ships, 100 m in length, these limits rise to 18.3 knots in seas greater than 4.0 m wave height. The maximum speed and wave height limit continues to rise with ship length therefore, the ships at risk are those less than 100 m in length.

In summary, there is not an operational constraint to large and medium sized ships when exiting or entering the harbour through the bar channel. However, ships of a size that can presently enter the harbour (below 100 m) may have operational restrictions to avoid excessive motion, surf-riding or broaching however these restrictions would be less than for the existing bar bathymetry.

5.4.3 Anchorage

Anchorage is defined as the area where vessels drop anchor either awaiting entry into port or to undertake cargo handling, passenger transfer, bunkering or other cargo operations associated with the port. Anchorages are usually located in an outer harbour area or in the outer approaches to the port (PIANC, 2019).

Anchoring offshore of Manukau Harbour is not considered to be a problem as there is plenty of sea-room in suitable depths. The bottom is fine sand and broken shells, generally considered to be good holding ground. Should weather conditions dictate that a ship cannot stay at anchor, there is sea-room (the Tasman Sea) where it can heave anchor and steam, in circles if necessary.

Anchoring inside the Manukau Harbour, while not defined as part of this study, could take place in an area off the Middle Section of the navigation channel which is naturally wide and deep.

In summary, anchorage does not pose an operational constraint for a Manukau Harbour port.

5.4.4 Air draft

An airport's Obstacle Limitation Surface (OLS) provides maximum heights for structures and activities around the airport. A port within the Manukau Harbour would either need to work around the Auckland International Airport airspace restrictions or seek exemption through the Civil Aviation Authority.

The larger design vessels used in the feasibility study typically have an air draft, the overall height from waterline to top of mast, of about 60 m to 70 m above Mean Sea Level (MSL) with allowance for tide and increased water levels (of up to 1 m) due to sea level rise. The highest machines in a port are container ship-to-shore gantry cranes with a super post-Panamax crane having a boom-up height (when not working) of about 120 m above the wharf deck (about 130 m above MSL), and 77 m when boom-down, i.e. higher than the mast of the ship when it is working.

Figure 5.4 shows the Auckland Airport's OLS overlaid on a plan of Manukau Harbour and Figure 5.5 shows two limiting contours from the OLS; one at 70 m above MSL to cater for maximum expected ships' air draft, and another at 130 m above MSL for the height of ship to shore gantry cranes with boom-up. These limiting contours are both on the conical slope of the OLS which slopes from 52 m above MSL by the runway to 157 m above MSL at the harbour fringes.

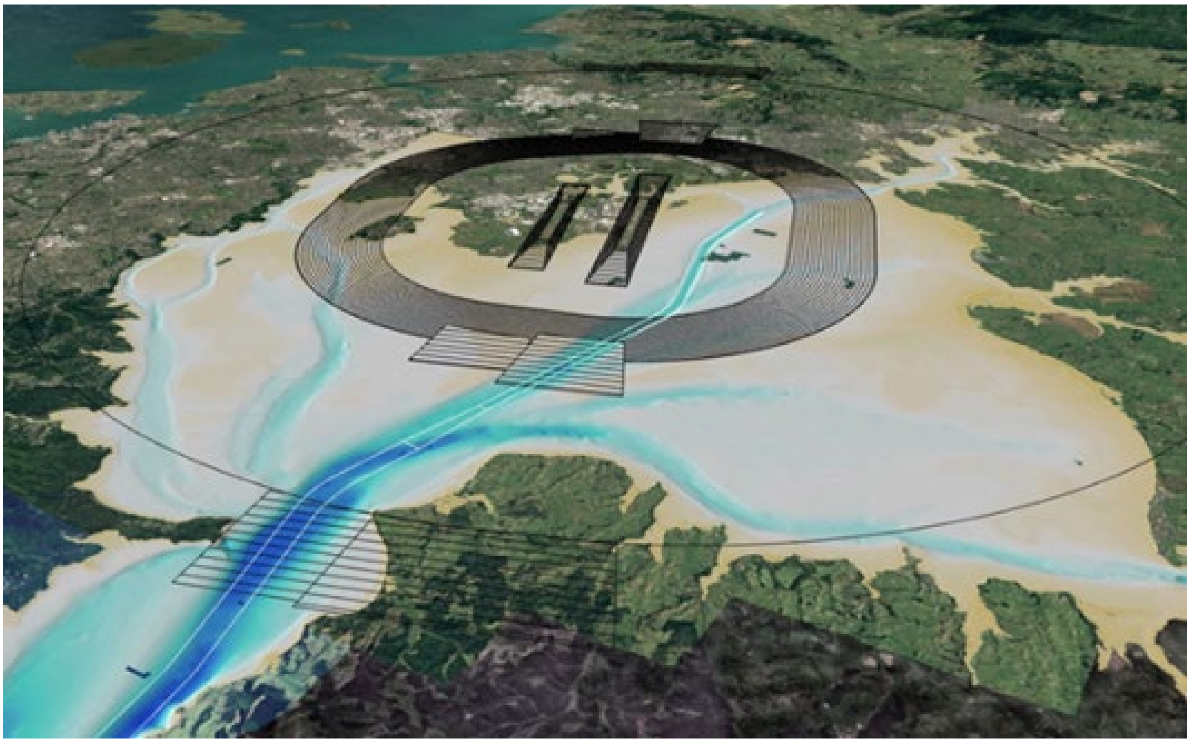

Figure 5.4: Auckland International Airport Obstacle Limitation Surface within the Manukau Harbour.

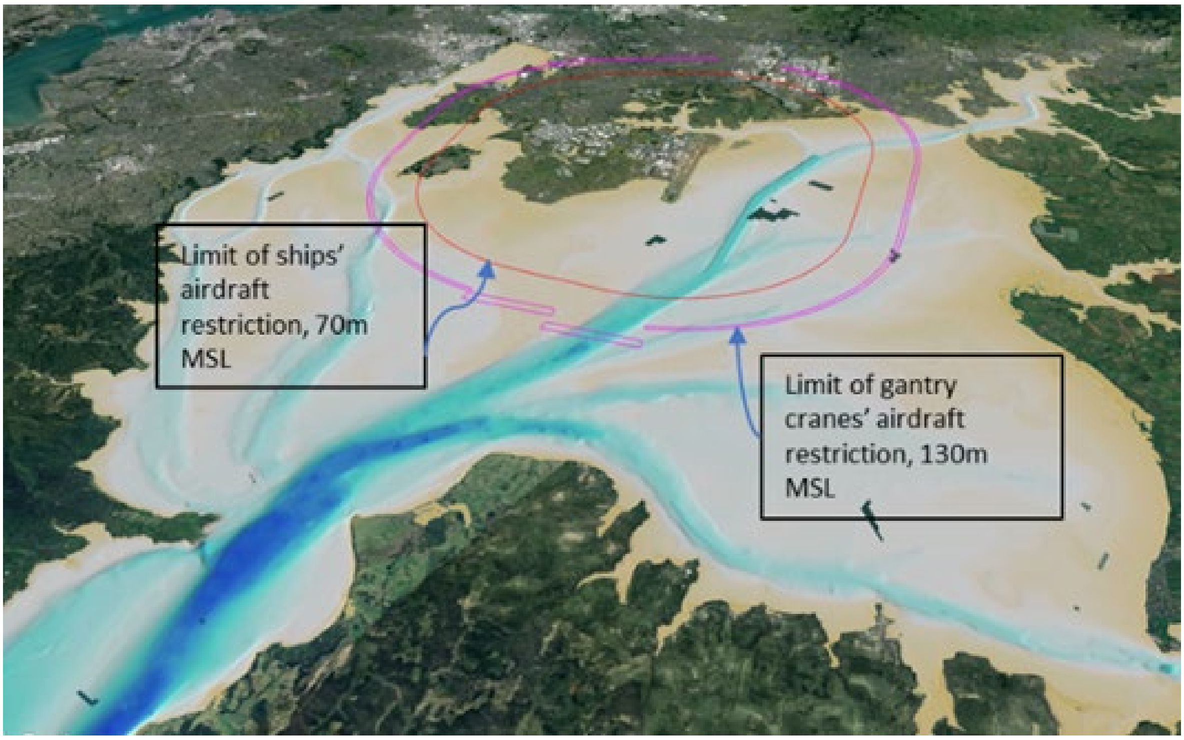

Figure 5.5: Air draft limits for ship and gantry cranes in relation to the Auckland International Airport Obstacle Limitation Surface.

To be clear of the OLS, the gantry cranes at the port would need to be located outside these limiting contours so that crane booms are not an obstacle. The figures show that some natural tidal channels and potential port sites are within the OLS limitations (including the representative site chosen for this study), while other natural tidal channels and sites are clear. A discussion with Auckland International Airport, which administers the OLS, indicated that should a port location within these limiting contours wish to be considered, an aeronautical study would be required to assess risks and consider any exemption which would need to be approved by the Civil Aviation Authority. This is a process that has been followed by other major airports / seaports, for example Sydney Airport, but it is acknowledged that each airport and regulatory authority is different so the ability to seek exemption is unknown.

In summary, there are potential port locations within the harbour that do not intrude on the OLS and that if there is a preferred location that does intrude, there is a process for considering exemptions. Should exemption not be possible then this would limit the choice in the site selection process. The representative site chosen for this feasibility study (refer to Figure 3.1) would not be clear of these limiting OLS contours. The operational constraint this poses to a port within the Manukau Harbour would need to be further analysed at later stages.

5.4.5 Biosecurity

Biosecurity requirements for all incoming vessels require vessels to have a clean hull when arriving to New Zealand. Short stay vessels, i.e., most commercial ships, must call only at 'places of first arrival'. Our expectation is that a major new port such as Manukau would be designated as a place of first arrival. The vast majority of short stay vessels are compliant. If a ship were to fail an inspection, it must leave New Zealand within 24 hours. This can mean it goes elsewhere, or a common practice, it can be cleaned outside the 12-nautical mile limit at one of three places in New Zealand where this typically takes place: off Great Barrier Island, near Tauranga (both of which are low wave energy locations) and off Lyttelton. All of these locations are on the East coast of New Zealand. Due to the severe wave climate offshore of Manukau this would not be a suitable location for cleaning. Therefore, the implication for Manukau is that if a ship chooses cleaning outside the 12-nautical mile limit, it would need to go further than ships at most other New Zealand ports. This is considered a moderate consequence in our risk assessment compared with a ship at any other port. Most container ships pass inspections, and it is mostly bulkers that fail, therefore the probability for Manukau is considered rare.

In summary, while this is an operational consideration with consequences, it is not considered a fatal flaw to a port in this location. ISS-McKay Limited, one of New Zealand's ship agencies, and a hull cleaning diver have been consulted to reach this conclusion.

5.4.6 Aids to navigation

Physical aids to navigation, both land-based and placed in the sea, are today still the main method for marking channels and obstacles. Virtual aids to navigation are now also used, especially at major ports, but as a secondary method. Virtual aids to navigation use Automatic Identification System (AIS) which needs an AIS receiver or Electronic Chart Display and Information System (ECDIS) to receive. Offshore of Manukau Heads is a severe weather zone therefore physical aids to navigation that are placed in the sea off Manukau will be more prone to damage and displacement than land-based or those in more sheltered areas. The backup of virtual aids is possible and over time systems will continue to develop, and virtual AIS aids to navigation are expected to become more common. As ECDIS is now almost universal, we do not consider risks to physical aids to navigation to be a serious risk in the timeframe for a new port at Manukau.

In summary, with proper management, aids to navigation are not considered to pose an operational constraint to navigation for a Manukau Harbour port.

5.4.7 Channel sedimentation

The ability for channel sedimentation to cause an operational constraint has been assessed by analysing the rate of infill (estimated through numerical modelling refer to Section 7) which may result in reduction in the depth in the channel. Normally, this will not present a problem to ship operability; at the expected levels of sedimentation, in all but the most severe weather, even maximum design draft vessels will have more than sufficient under keel clearance.

That is to say, only large ships wishing to transit the bar channel at maximum channel draft allowance and in severe wave conditions will be subject to delay through sedimentation, and will need to wait for higher tide or the weather to abate. Therefore, accounting for the rate of infill that has been modelled, it is unlikely that sedimentation will cause delays of any significance to large ships; the combination of a maximum draft ship wishing to transit, waves severe enough to limit its under keel clearance and infill all occurring is rare. On a rising tide, delays would be no more than 1 or 2 hours and no longer than 12 hours if a falling tide. If infill is greater than the tidal range can cover, delays may increase to 10 to 48 hours for weather to abate. Smaller ships do not have drafts that might cause issues.

In summary, sedimentation is therefore not considered a significant operational constraint to safe navigation and port operations. The risk however, will still need to be managed. To do this, monitoring of infill and channel depth generally will need to be done on a day-to-day basis by daily soundings by a pilot vessel. Consideration could also be given to survey carried out by two jet skis (one for safety) with state-of-the-art hydrographic survey equipment with real time data link to onshore. In addition, the maintenance dredger should provide first indications of changes in channel depth when restarting after severe weather.

6 Changes to coastal processes

This section provides a brief overview of the changes to coastal processes resulting from a dredged navigation channel. Full details of this analysis are provided in TWP03 – Coastal, TWP03b – Metocean modelling, TWP03c – Sediment transport modelling. The dredged channel would:

- Allow the tide to enter Manukau Harbour more efficiently, slightly increasing tidal prism (by around 0.5% during spring tides) and advancing the rate of tidal propagation.
- Increase currents within the dredged navigation channel both on the bar and within the harbour and decrease in adjacent (shallower) areas. The most notable effect is over the Manukau Bar where the flows are increased by over 1 m/s (or around 50%) due to the greater flow efficiency and less friction provided by the deeper channel.
- Refract waves in the deeper channel and, during outgoing tides around the tidal jet. Focus waves on either side of the channel, to the south during southwest waves and to the north during northwest waves.
- Increase sediment transport over the bar and cause greater scour within the middle parts of the dredged channel, with material being deposited further offshore as a more seaward bar develops and at the landward end of the dredged channel. Slightly increased onshore transport is shown to occur on the shallow bar adjacent to the channel due to the increased wave refraction/focussing (refer to Figure 6.1).
- Increase flood-tidal (shoreward) transport of fine to medium sands from lower reaches/seaward extents of the inner harbour into the dredged area (refer Figure 4.6).

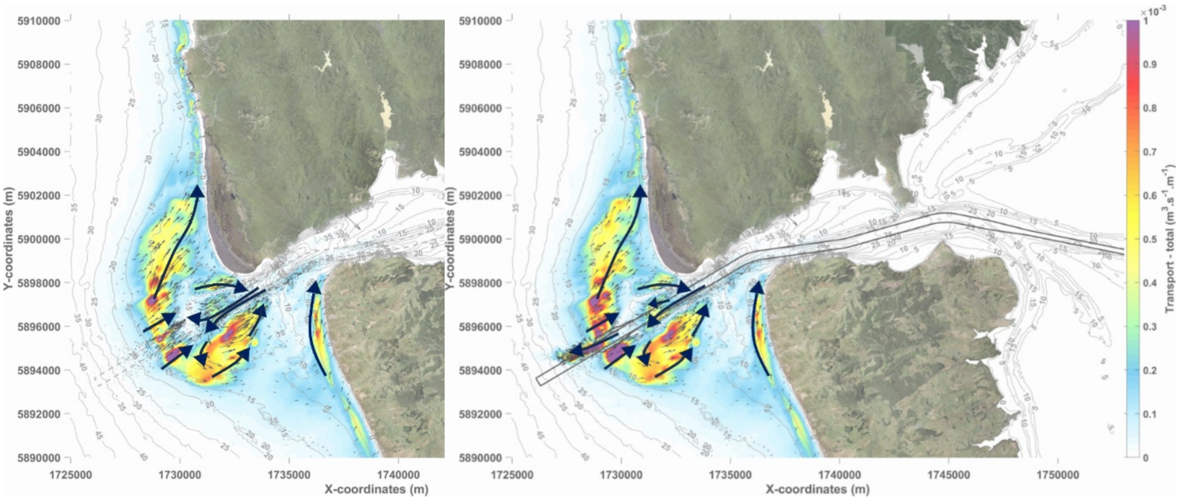

Figure 6.1: Mean sediment transport during large wave conditions with conceptual sediment transport pathways overlaid in blue arrows for existing situation (left) and with the dredged navigation channel (right).

In summary, there will be changes to the coastal processes that will need to be assessed in more detail as part of an effects assessment to determine if they result in adverse effects and whether they could be avoided or mitigated to acceptable levels.

7 Maintenance implications

The proposed navigation channel was incorporated in the sediment transport model and scenarios replicating the wave climate and tidal flows were run. Model runs show where sediment is transported and deposited so that sediment accumulation above the design depth of the channel could be quantified to provide a rate of sediment infill. This has then been used to determine the dredge equipment and methodology for maintaining the channel. Full details are provided in TWP03 – Coastal and TWP03c – Sediment transport modelling.

There are three areas where sediment infill is predicted; the Entrance Channel across the Manukau Bar; the Port Approach; and the Port Area. The following sub-sections provide an overview of the results, which feed into the following section on dredging.

7.1 Entrance Channel

Sediment infilling the dredged channel in the Entrance Channel (Section A) (refer to Figure 7.1) above the design depth is found to range from 5 M to 7.7 M m^3/year with an average of 6.55 M m^3/year. Increased wave heights due to climate change will increase these estimates by around 10% by 2070-2099. To account for model uncertainty and future effects of climate change, 15% has been applied to the mean infill rate to arrive at **7.5 M m^3/year infilling the dredged channel in the Entrance Channel (Section A)**. The annual volume of sediment infill is equivalent to 0.4 to 0.5% of the total volume of sand in the ebb-tidal delta.

The 7.5 M m^3/year infilling is considerably higher than the estimated longshore transport rate (gross 1–2 M m^3/year and net to the north of 0.75–1.9 M m^3/year; see section 4.6). This suggests that the infilling is a result of sediment naturally circulating within the ebb-tidal delta and is manifest as a readjustment of the profile within the dredged channel. This profile adjustment and the areas used to calculate infill are shown schematically in Figure 7.2.

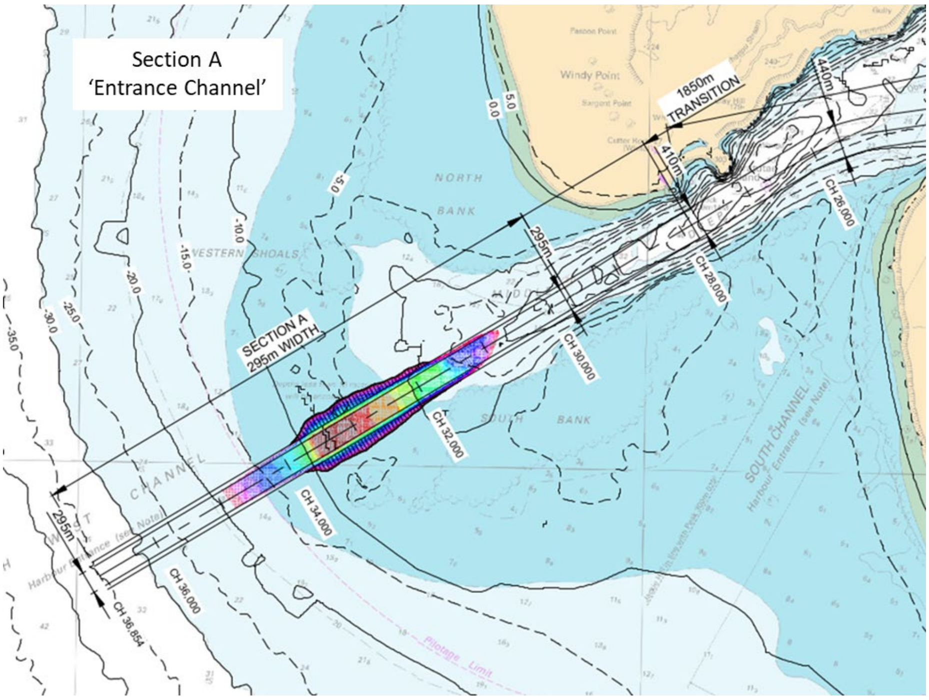

Figure 7.1: Entrance Channel (Section A) of the navigation channel design – South-West Channel.

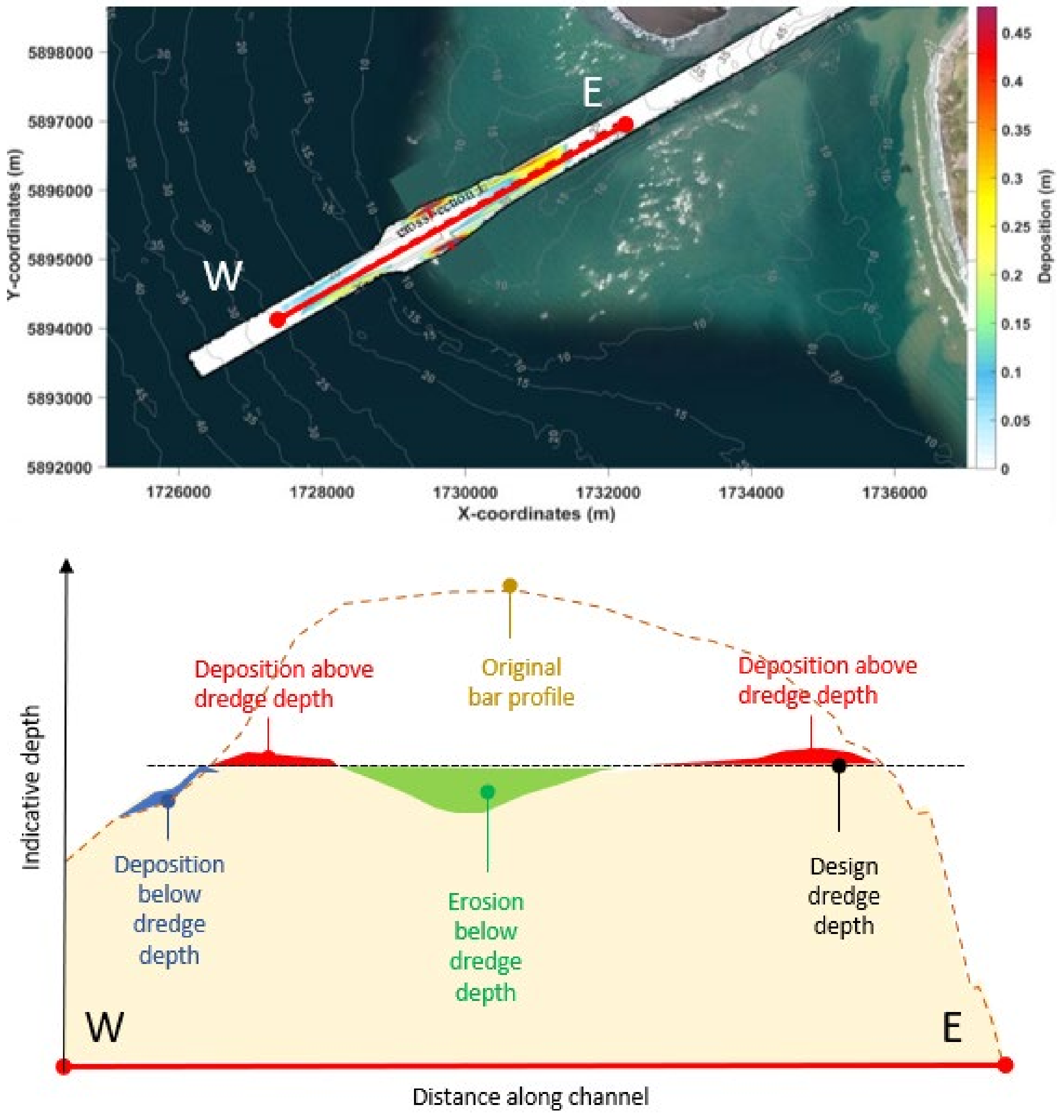

Figure 7.2: Schematic showing definition of areas used to calculate sediment infill volumes.

A modelling approach that assumes that this material is constantly removed has been adopted to estimate the total material infilling the dredged channel above the design depth. This approach is found to slightly over-estimate infill rates during longer storm events and may over-predict in the longer-term if rates of deposition decrease as the eroding area within the channel reach a more stable depth. However, based on current understanding of the processes, it is a reasonable representation for a maintained navigation channel in the long-term.

Much of the infill occurs in high-energy winter months so the ability to maintain the channel to a design depth will therefore be dependent on the dredger being able to operate in adverse sea conditions (high waves) and its dredging capacity per day. Sensitivity testing indicates that if the daily production rate is not sufficient or the wave height threshold to enable working is too low, then the channel will be difficult to clear before another period of infill is likely to occur. Therefore, careful selection of the dredge equipment is required.

During certain stages of the channel and bar evolution, large volumes of sediment (several million m^3) are forced by waves and currents from the south bank across the proposed channel alignment. However, these changes are likely dependent on sufficient material accumulating on the southern banks to interrupt the strong tidal flows once they are pushed into the channel and force the channel to the north. By selective placement of the maintenance dredge material, the accumulation of sediment is assumed to be able to be managed to control this process. If this was not the case and sediment continued to accumulate on the south bank and be forced into the channel, either rapid dredging would be required (ideally before the event), or potentially managed by training structures (discussed further in Section 7.4).

A high-level assessment of infill rates for the South Channel, which requires a substantially longer length of capital dredging (shown in Figure 7.3), and which is in a more sheltered sector of the ebb-tidal delta, was undertaken. There is less infill into the base of the channel compared to the South-West channel (likely due to lower flows and less readjustment within the channel), but higher infill onto the side batters owing to their longer length, resulting overall in a higher (compared to the South-West Channel) infill rates of 10 M m^3/year.

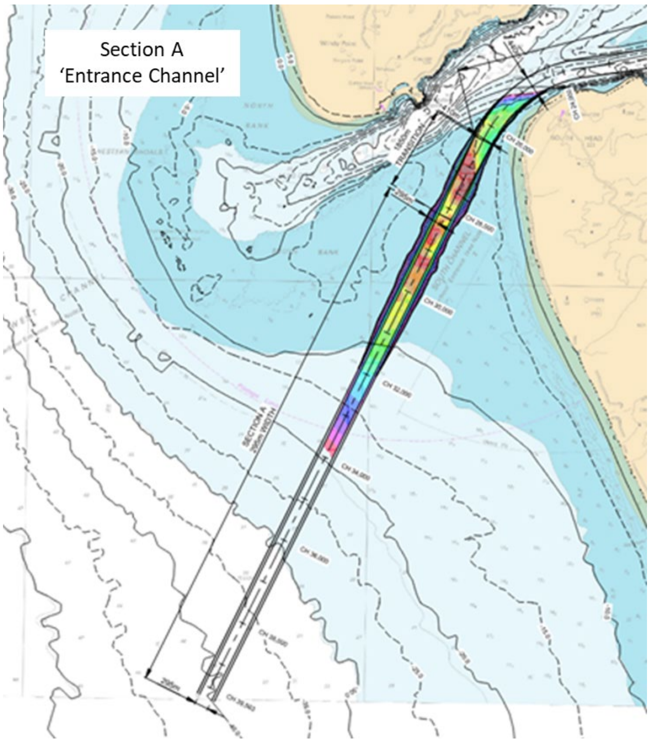

Figure 7.3: Entrance Channel (Section A) of the navigation channel design – South Channel.

7.2 Port Approach

Inside the harbour, most of the sand transport occurs along harbour channels in response to tidal currents that are typically ebb-dominant. We estimate **0.40 M to 0.45 M m^3/year** of sand infill entering the dredged channel base and side batter slopes. This excludes fine silts and clays, for which inner-harbour channels are typically ebb-tidal conduits between the upper harbour and the open coast (see section 4.6). We did not model fine-sediment transport processes inside the harbour (which include wave resuspension of fines on intertidal flats) due to their comparatively low estimated volume. A conservative upper fine-sediment accumulation rate of 5 mm/year, which has been measured in upper, sheltered reaches of the harbour, and which will be a significant over-estimate of any fine-sediment accumulation in a dredged channel, results in infill by fines of 5,000 m^3/year. This is much smaller than the estimated sand infill rate, which we therefore ignore.

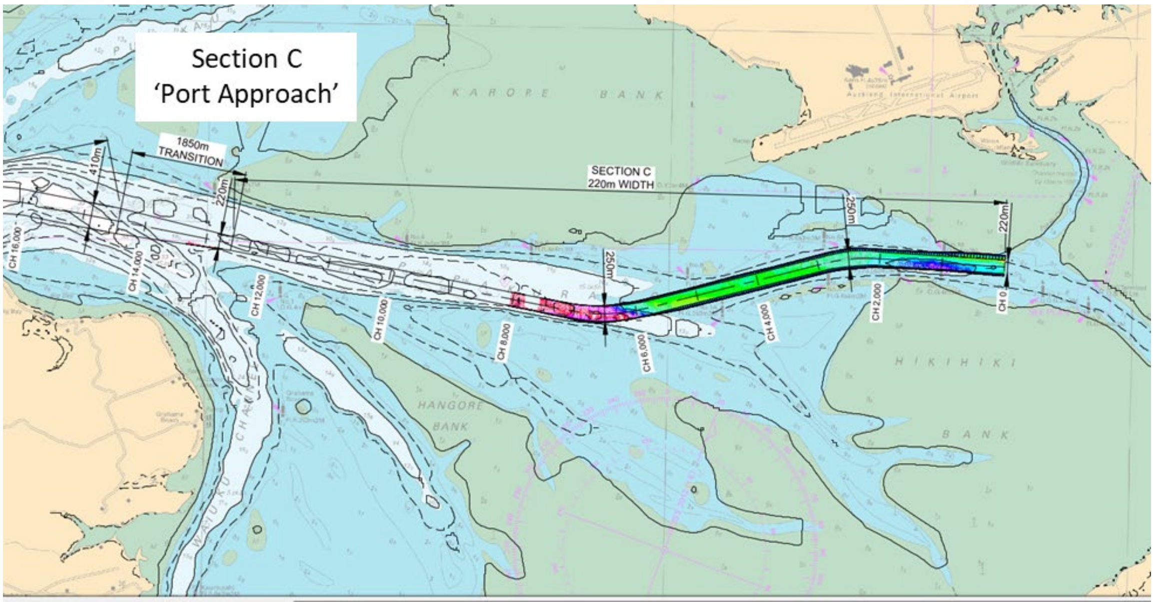

Figure 7.4: Port Approach (Section C) of the navigation channel design.

7.3 Port Area

As the port location is only representative for the purposes of this study, sediment infill in the dredged areas for the port (passing lane, berth and turning areas) has been based on maintenance dredge rates from other ports as **0.25 M m^3/year.**

Adding this to the estimated infill in the Port Approach (Section 7.2), gives the **full inner harbour maintenance requirement of 0.7 M m^3/year** (Stage 1 only).

7.4 Engineering mitigation

A range of engineering measures were explored to reduce the volume of maintenance dredge material, provide greater capacity for sediment infill to occur before maintenance dredging would be required, or potentially train the channel if stability of the channel alignment cannot be maintained by dredging alone. This is summarised in Table 7.1 where the only suitable measure is likely to be dredged sediment traps with other structures unlikely to be effective or suitable in this environment due to the very large scale of the area and dynamic and high energy environment.

A dredged sediment trap is a dredged area into which sediment accumulates/infills before that sediment reaches the main navigation channel. This may be adjacent to the channel or below the design depth (i.e. over-dredging). While this system does not reduce the total infill volume as the trap needs to be periodically emptied by dredging, the system will allow greater infilling to occur before the main channel is affected and provides a buffer for very large infilling episodes which could otherwise close the navigation channel.

Based on sediment transport and deposition processes, the location where a sediment trap would provide most benefit would be at the inner 1.5 km of the dredged channel over the bar. Over-dredging, for example an additional 1 m depth along the inner 1.5 km of the dredged channel, would decrease the number of episodes per year where sedimentation may become problematic for navigation. This option is shown in Figure 7.5 and could be further investigated, and the cost-benefit evaluated, at later design stages.

We considered the effectiveness and benefits of using training walls (breakwaters) however, the processes occurring at the mouth to the Manukau differ from river ports where these have been successful. Sediment isn't moving alongshore and bypassing the river via a river bar, but rather sediment transported from the south enters the flood tide (south) channel and is then transported offshore and onto the bar during the ebb tide. The processes on the bar are cyclical with material being transported out of the channel onto the adjacent shallow banks and then recirculated into the main channel before being eventually lost out of the system to the north. Therefore, sediment infilling the channel is substantially due to onshore-offshore flows rather than lateral and training walls (breakwaters) alongside the dredged channel are therefore unlikely to be effective in reducing infill.

If the accumulation of sediment on the south bank and/or the movement of this sediment into the channel cannot be managed by maintenance dredging, a structure along the southern channel margins could provide benefit. However, the previously mentioned challenges of implementing such a structure remain and preference would be to manage such accumulation through maintenance dredging. Dredging feasibility is discussed further in Section 8 but it is considered that the rates of infill that have been estimated (7.5 M m^3/year plus over-capacity allowance) can be managed with a medium sized Trailing Suction Hopper Dredger with 10,000 m^3 hopper capacity. Therefore, it is unlikely a training/control structure would be required.

Table 7.1: Summary of engineering mitigations option assessment

Engineering measure	Effectiveness in reducing total infill	Effectiveness in accommodating greater infill volumes	Effectiveness in maintaining channel alignment	Likely cost	Suitability
Control structures i.e. training walls (breakwaters)	Unlikely effective	Unlikely effective	Likely effective	Very high	Unlikely suitable
Sand bypassing system	Unlikely effective	Unlikely effective	Unlikely effective	Very high	Unlikely suitable
Dredged sediment trap	Unlikely effective	Likely to decrease episodes of problematic infill	Unlikely effective	Moderate	Likely suitable for further investigation

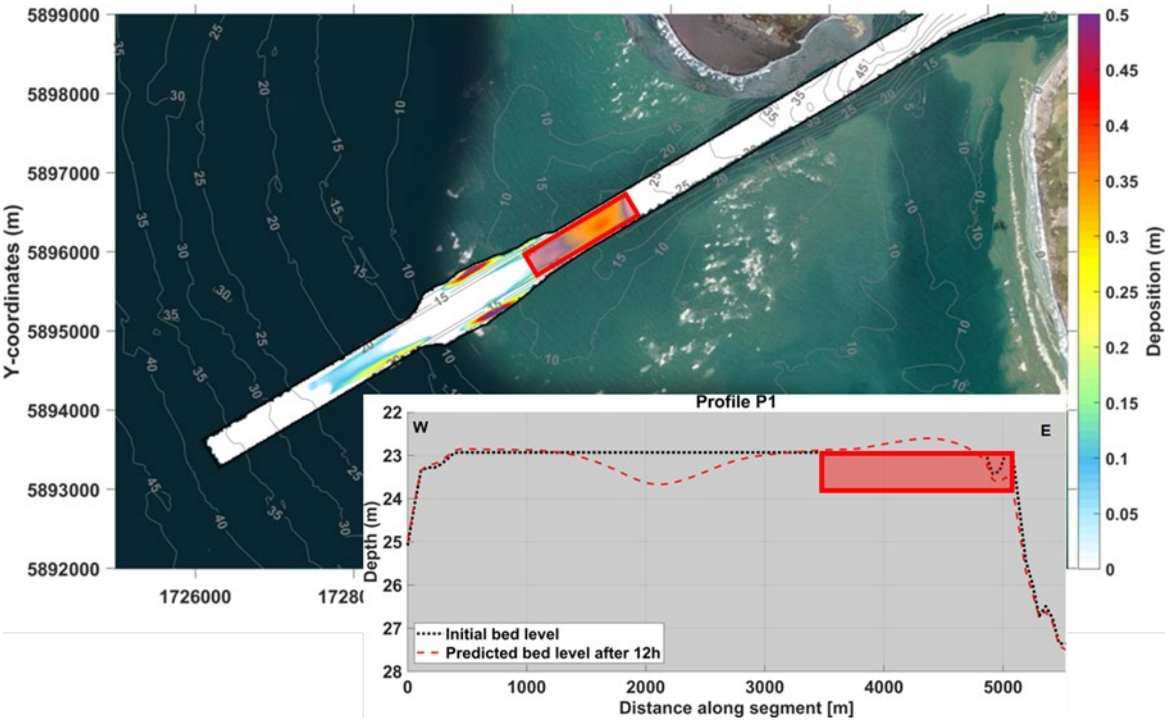

Figure 7.5: Potential over-dredge area or sediment trap (red polygon) to provide more space for sediment deposition before removal is required.

7.5 Placement of dredged material

The dredging assumption is that capital and maintenance dredge material from the Entrance Channel (Section A) would need to be placed back into the active coastal system. This is required to avoid de-stabilising the dynamic equilibrium of sediment transport that exists at the Manukau Bar and to mitigate adverse effects to adjacent and downdrift shorelines. The calculated maintenance dredge volumes are substantially larger than the calculated longshore transport rates on adjacent beaches, so if the material were all placed downdrift it may affect existing coastal processes and, over time, shrink the bar system (though the annual infill and dredge rate is 0.4 to 0.5% of the total ebb-tidal delta volume). A reduction in the ebb-tidal delta volume may have adverse effects on adjacent coastlines and/or the flood tide delta as sand is 'sourced' from elsewhere to bring the system back to equilibrium. Placement of dredge material would need to be designed to maintain the existing sediment transport circulation patterns on the bar and generally keep these circulation patterns in balance.

The ability to maintain existing sediment transport circulation patterns will be dependent on dredged materials being placed in sufficiently shallow water to propagate onto the bar and open coast beach in a reasonable (months rather than years) timeframe. While a full analysis of the movement of a placed dredge material is outside the scope of this study, the potential for this material to be retained in the littoral system has been assessed.

Most of the capital dredge is proposed to be undertaken using a Trailing Suction Hopper Dredger with a hopper capacity of 20,000 m^3. Taking account of the vessel draft whilst loaded, under keel clearance requirements for the given wave climate, tidal fluctuations and placement method, the shallowest contour this dredge could place would be between 18.4 and 19.9 m CD (water depths between 18.9 m and 21.9 m depending on tide). For the maintenance dredge, using the 10,000 m^3 hopper capacity TSHD, placement can be slightly shallower between the 15.1 and 16.6 m CD contour (water depths between 15.6 m and 18.6 m depending on tide). Refer to Table 7.2 for the safe placement contours and water depths for the various TSHDs.

Table 7.2: Safe placement depths for fully laden Trailing Suction Hopper Dredgers

TSHD Capacity (m^3)	Max significant wave Hs (m)	Draft loaded (m)	UKC (m)	Indicative additional margin for initial door/valve draft plus rise of seabed during dumping (m)	Tidal range (m)	Shallowest contour prior to dumping (m CD)	Water depth range (m)
2,000	1.75	4.9	2.6	2.0	0.5 - 2.0	-7.5 to -9.0	8 to 11
5,000	2.5	7.0	3.3	3.0	0.5 - 2.0	-11.3 to -12.8	11.8 to 14.8
10,000	3.0	9.5	3.6	4.0	0.5 - 2.0	-15.1 to -16.6	15.6 to 18.6
20,000	3.5	11.5	3.9	5.0	0.5 - 2.0	-18.4 to -19.9	18.9 to 21.9

To assess at a high level whether this material is within the active coastal system, the closure depth has been calculated. This indicates the likely limit of sediment exchange with the nearshore, and while this calculation has been developed for open coast beaches and may not be applicable to the offshore bar environment, it gives an indication which is generally supported by the sediment transport model results. The inner closure depth (seaward boundary of significant transport caused by waves in a typical year) is calculated at 13.6 m, and the outer closure depth (the limit in which significant waves can entrain sediment and cause transport) is calculated as 83 m.

Further investigation would be required to determine whether sediments can be placed in such a way that they can migrate onto the bar and remain in the littoral system. This may require partially loading the dredgers to reduce their draft, the use of smaller dredgers to double handle material in order to place within the inner closure depth, or placement within the deeper entrance channel and tidal currents are relied upon to re-distribute sediment into the system, although this may lead to greater ongoing maintenance volumes.

In conclusion, placement of dredge material back into the active coastal system is complex and needs further work as part of an effects assessment to determine whether a dynamic equilibrium can be achieved to avoid adverse effects to the bar and adjacent shorelines. This analysis indicates a possible high risk that would need to be looked at. This would require sediment dispersion and longer-term morphological modelling along with investigation into a range of placement methods.

8 Dredging

To open the navigation channel, capital dredging is required, and to keep the channel operational ongoing maintenance dredging would be required. This section summarises findings from TWP06 – Dredging, for full details and analysis please refer there.

8.1 Dredging scenarios

The dredging works can be divided into three main elements:

- Entrance Channel - dredging of a channel through the Manukau Bar (referred to as Section A);
- Port Approach - dredging of a channel within the inner harbour leading to the port (referred to as Section C); and,
- Port Area - dredging of a passing channel, turning basin, and berth pockets at the port (terminal) within the inner harbour.

The Manukau Bar is in an open, exposed area, and is a dynamic feature. Two channel alignments were considered through the Manukau Bar: a South-West Channel and a South Channel.

Due to the dynamic nature of the Manukau Bar, the minimum depth along the alignment of the South-West Channel, and to a lesser extent along the alignment of the South Channel, at the commencement of dredging could vary depending on the state of the Manukau Bar at the time. The minimum depth along the alignment of the channels at the commencement of dredging has a significant influence on the selection of dredging equipment and dredging methodology, and hence cost. For this reason, three different scenarios were considered for the South-West Channel based on the minimum depth which may exist along the alignment of this channel, as evident in three separate surveys. With less variability in depth along the alignment of the South Channel (and less emphasis on this option in this study), a single scenario was considered for the South Channel.

The adopted minimum depths for each scenario are summarised in Table 8.1. Scenario 2 is adopted as the Base Case for dredging of the South-West Channel as it represents the most contemporary bathymetric information (2023) and has been relied upon for the navigation channel design.

The concept design for the Port Approach and Port Area are common to both channel alignments through the Manukau Bar and a representative port location was assumed as described in Section 3.4.2.

Table 8.1: Dredging scenarios

Scenario	Bathymetry[1]	Channel	Entrance Channel minimum depth (m CD)
1	2010	South-West	-6.4
2 (Base Case)	2023	South-West	-4.8
3	1989	South-West	-1.5 to -2.0
4	2023	South	-4.4

[1] 2010 = Port of Auckland Limited survey of harbour entrance, 2023 = bathymetric survey undertaken as part of the study, 1989 = historic chart

8.2 Stage of port development and dredging

As outlined in Section 3.4 the study assumption is that port development will be staged. The breakdown of dredging activities is provided in Table 8.2, which includes port reclamation works.

Table 8.2: Stage of port development and dredging components

Stage	Dredging component
Stage 1 to year 2049	Entrance Channel (Section A) - Channel through the Manukau Bar
	Port Approach (Section C) - Channel within the inner harbour leading to the port
	Port Area: Passing channel, turning basin, and berth pockets
	Port Area: Port reclamation
Stage 2 to year 2079	Port Area: Additional passing channel, turning basin, and berth pockets
	Port Area: Additional port reclamation

8.3 Disposal of dredge material

The following principles were adopted for the disposal of capital dredging material:

- Material dredged from the Entrance Channel would be maintained within the active open coast system. The placement of this material would be subject to future assessment of environmental effects and has not been considered in detail in this study.
- Material dredged from the Port Approach and Port Area, that has engineering properties suitable for use in the reclamation of land for the port, would be placed in the reclamation area. Excess suitable material from Stage 1 dredging is not stockpiled for possible use in the Stage 2 reclamation due to the lengthy period of time between Stage 1 and Stage 2, i.e., 25 to -30 years. Based on the available soil information, a high-level geotechnical assessment concluded that dynamic compaction would be the most likely and suitable ground improvement method to address liquefaction risk, and that allowance for 20% of the reclamation height should be considered for subsoil consolidation, dynamic compaction densification and the backfilling of dynamic compaction craters. The reclamation volumes therefore include this allowance.
- Material dredged from within the Port Approach and Port Area that is unsuitable for use in the reclamation for the port due to poor engineering properties (low sand content and/or high clay content), or that is excess to reclamation requirements, would be placed in an offshore dredge material ground (DMG).

The principles adopted for maintenance dredging were that:

- maintenance dredge material from the Entrance Channel would be placed within the active open coast system, and;
- maintenance dredge material from the Port Approach and Port Area would be placed in an offshore DMG.

For preparation of the cost estimates it was assumed that an offshore DMG would be located approximately 5 nautical miles (approximately 10 km) seaward of the crest of the Manukau Bar in about 60 m water depth.

8.4 Dredging volumes

Stage 1 capital dredging volumes (including an allowance for infilling during the capital dredging) ranged from 36.5 to 54.2 M m^3 for the South-West Channel and was 76.5 M m^3 for the South Channel. The capital dredging volume for Scenario 2 (Base Case) was 36.5 M m^3. The common inner harbour plus port area dredging volume was 34.6 M m^3. This results in a total capital dredging volume for Scenario 2 (Base Case) of 71.1 M m^3.

Ongoing maintenance dredging following Stage 1 was estimated at 8.2 M m^3/year for the South-West Channel, predominantly at the Manukau Bar (7.5 M m^3/year). Ongoing maintenance dredging for the South Channel was estimated at 10.7 M m^3/year, again predominantly at the Manukau Bar (10 M m^3/year).

Stage 2 capital dredging volumes (including an allowance for infilling during the capital dredging) was estimated at 15.15 M m^3, with ongoing maintenance dredging of 0.15 M m^3/year.

It is evident that establishment of an offshore DMG is a critical requirement for the project. In Stage 1, an offshore DMG would receive an estimated 24.6 M m^3 (34.6 M m^3 minus 10 M m^3 for reclamation) of capital dredge material and subsequently an estimated 0.7 M m^3/year of maintenance dredge material. In Stage 2, a further estimated 8.9 M m^3 of capital dredge material and 0.15 M m^3/year of maintenance dredge material would need to be taken to an offshore DMG.

The additional factor evident for Stage 2 is that, based on the adopted soil model, 6.1 M m^3 of capital dredge material is suitable for use in the reclamation, however the estimated reclamation requirement is 10.0 M m^3 and hence there is a shortfall of 3.9 M m^3 of suitable material. This shortfall would require further investigation in future studies, informed by the need for further port expansion and associated navigation channel widening, collection of additional geotechnical information and refinement of the adopted soil model.

The dredging volumes for Stage 1 and Stage 2 are summarised in Table 8.3 and Table 8.4 respectively. It should be noted that gross volumes are inclusive of over-dredging.

Table 8.3: Stage 1 - Summary of capital dredging and ongoing maintenance dredging volumes

Item	Volume (million m^3)			
	South-West Channel			South Channel
	Scenario 1	Scenario 2 (Base Case)	Scenario 3	Scenario 4
Capital Dredging				
(i) Channel through Manukau Bar				
(a) Volume to design profile plus over dredging (gross volume)	17.2	13.8	26.9	36.2
(b) Infill during capital dredging program	22.9	22.7	27.3	40.3
Sub-total for (i)	*40.1*	*36.5*	*54.2*	*76.5*
(ii) Channel within inner harbour plus port area				
(a) Volume to design profile plus over dredging (gross volume)	33.9	33.9	33.9	33.9
(b) Infill during capital dredging program	0.7	0.7	0.7	0.7
Sub-total for (ii)	*34.6*	*34.6*	*34.6*	*34.6*
Total (i) + (ii)	**74.7**	**71.1**	**88.8**	**111.1**
Ongoing Maintenance Dredging				
(i) Channel through the Manukau Bar	7.5/yr	7.5/yr	7.5/yr	10.0/yr
(ii) Channel within inner harbour plus port area	0.7/yr	0.7/yr	0.7/yr	0.7/yr
Total (i) + (ii)	**8.2/yr**	**8.2/yr**	**8.2/yr**	**10.7/yr**

Table 8.4: Stage 2 - Summary of capital dredging and ongoing maintenance dredging volumes

Item		Volume (million m^3)
Capital Dredging		
(i)	Volume to design profile plus over dredging (gross volume)	15.0
(ii)	Infill during capital dredging program	0.15
	Total (i) + (ii)	15.15
Ongoing Maintenance Dredging		0.15/yr

8.5 Dredging equipment selection

The dredging works would be carried out by a range of equipment depending on several factors including geotechnical conditions, access (water depth), exposure to metocean conditions (workability), and the disposal location for dredge material.

A workability assessment was undertaken to support the selection of various sizes of Trailing Suction Hopper Dredgers (TSHDs) working on the Entrance Channel (South-West Channel and South Channel) and a large Cutter Suction Dredger (CSD) working on the Entrance Channel (South Channel). This assessment has considered the wave climate, currents, and the interaction of waves and currents, for both summer and winter conditions, and the allowable working limits for different types and sizes of equipment. As part of this assessment, calculations were made for the required under-keel clearance (UKC) of TSHDs during dredging. The workability assumptions and findings for the different equipment are summarised in Table 8.5, and the selected equipment for the different scenarios are shown schematically in Figure 8.1 in relation to depths and seasonal working constraints.

Ranking of the four scenarios for dredging a channel through the Manukau Bar, from a workability/equipment selection risk perspective, from lowest risk to highest risk is assessed to be as follows:

- Scenario 4 (2023 bathymetry) - South Channel (lowest risk)
- Scenario 1 (2010 bahtymetry) – South-West Channel
- Scenario 3 (1989 bathymetry) – South-West Channel
- Scenario 2 (2023 bathymetry) – South-West Channel (highest risk)

For Scenario 2 there is a risk that the production rate of the very small TSHD (2,000 m^3) cannot clear the shallow depths fast enough due to very low workability under the exposed conditions on the Manukau Bar (refer Table 8.5). This would happen if poor weather persisted. The workability on the Manukau Bar could be improved by starting works in the summer months, or moving to a purpose-built Walking Jack-up Barge, which would be able to work in the shallower depths, but this would increase the cost. Alternatively, commencement of the works could be delayed until depths over the Manukau Bar improved under natural processes. Timing commencement of the works is therefore crucial to the success of the capital dredging.

A summary of the dredging works for the Entrance Channel, including a comparison of each dredging scenario is provided in Table 8.6. Within the inner harbour, dredging of the Port Approach and Port Area is simpler; a summary of these works is provided in Table 8.7.

It is assumed that under the envisaged infill rates, especially after significant wave events, that a maintenance TSHD will be required at Manukau Harbour for 100% of the time during Winter and 50% during Summer. It is noted that for the 7.5 million m^3 of annual infill estimated for the South-West Channel, a medium TSHD with 10,000 m^3 hopper capacity is more than adequate on average for the maximum workability for wave conditions below 3 m. This nominated dredger size can actually dredge up to 11 million m^3/year with average (monthly) exceedance of waves below 3 m applied for Winter and Summer workabilities. The dredge size of 10,000 m^3 was selected to cover extreme infill caused by prolonged periods (consecutive) of high waves during which the maintenance dredger cannot operate.

Table 8.5: Summary of workability assumptions and findings for Entrance Channels

Insert heading	Dredging equipment	Allowable working conditions			Net effective hours/week	
		Waves (m)[1]	Current (kn)	Wind (kn)	Summer	Winter
South-West Channel	TSHD 2,000 m^3	1.75	3	25	26	13
	TSHD 5,000 m^3	2.5	3.5	30	89	55
	TSHD 10,000 m^3	3.0	3.5	30	111	83
	TSHD 20,000 m^3	3.5	3.5	35	126	112
South Channel	CSD (15,000 kw)	1.0	2.5	25	95	84
	CSD (15,000 kw)	1.0	2.5	25	73	56
	TSHD 5,000 m^3	2.5	3.5	30	89	55
	TSHD 10,000 m^3	3.0	3.5	30	111	83
	TSHD 20,000 m^3	3.5	3.5	35	126	112

1. The allowable working condition for wave height based on the significant wave height (Hs)
2. Two net effective hours/week are provided for the CSD and relate to two different locations within the South Channel
3. Gross operational hours are based on 168hrs/week

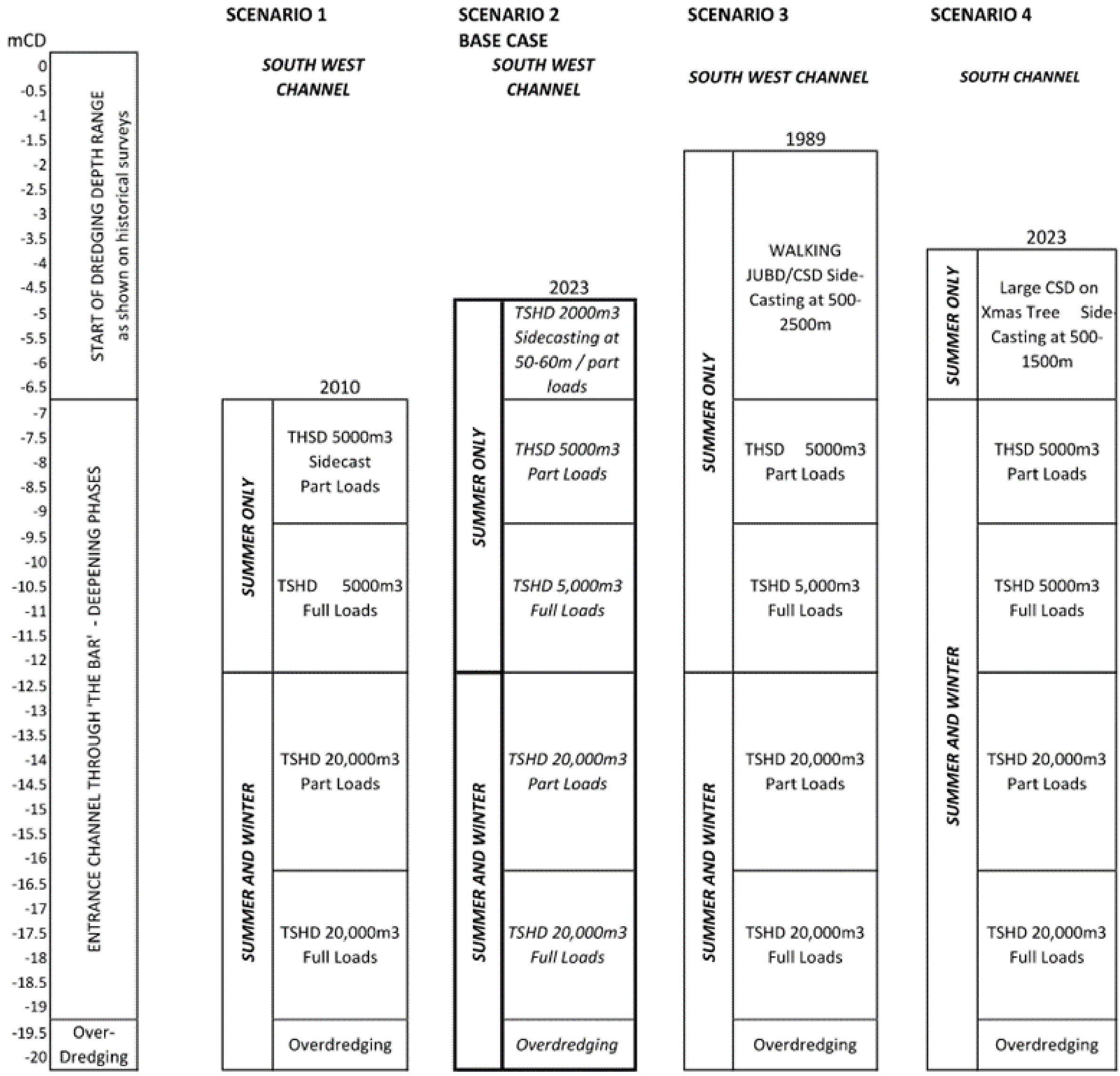

Figure 8.1: Entrance Channel equipment selection for different dredging levels and channel scenarios.

Table 8.6: Summary of Entrance Channel dredging works

Scenario	Depth (m CD)	Dredging works	Equipment and method	Example equipment	Duration
1: SW channel, 2010 bathymetry	-6.4 to -12	Shallow depth dredging	2 x small TSHDs (5,000 m^3) working in tandem with one or both side-casting (part loading initially) or dredging/disposing material within the active coastal system.	 X2 TSHDs (5,000 m^3)	Scenario 1 1.23 years capital works plus 0.89 years maintenance over capital programme, total 2.12 years.
2: SW channel, 2023 bathymetry (highest risk)	-4.8 to -6.5	Shallow depth dredging	Very small TSHD (2,000 m^3) side-casting material at 50-60 m distance, and part loading to full loads subject to existing depths, waves, and tides.	 X1 TSHD (2,000 m^3)	Scenario 2 1.2 years capital works plus 0.87 years maintenance over capital programme, total 2.07 years.
3: SW channel, 1989 bathymetry	-2 to -6.5	Shallow depth dredging	Walking JUB fitted with CSD (650 mm discharge pipeline diameter) side-casting at 500-1500 m distance.	 X1 Walking JUB with CSD	Scenario 3 2.05 years capital works plus 1.24 years maintenance over capital programme, total 3.29 years.
4: S channel, 2023 bathymetry (lowest risk)	-4.4 to -6.5	Shallow depth dredging	Large CSD (15,000 kW, 900 mm discharge pipeline diameter) working with a 'Christmas Tree' anchor configuration and side-casting at 500-2500 m distance. The 'Christmas Tree' anchor configuration can be implemented when a CSD is operating in exposed sea conditions and the forces on its spud anchors would be too large. The 'Christmas Tree' involves the use of an arrangement of 3 wire leads and anchors at the stern to hold the CSD in position without requiring the deployment of its spuds.	 X1 CSD (15,000 kW)	Scenario 4 2.56 years capital works plus 1.54 years maintenance over capital programme, total 4.10 years.
-6.5 to -12 (same for all scenarios)		Intermediate depth dredging	2 x small TSHDs (5,000 m^3) working in tandem with one side-casting and/or the other dredging/disposing material within the active coastal system, with part loading going to full loading when the available depth increases.	 X2 TSHDs (5,000 m^3)	
-12 to -20 (same for all scenarios)		Dredging to design level	2 x large TSHDs (20,000 m^3) dredging/disposing material within the active coastal system, with part loading going to full loading when the available depth increases.	 X2 TSHDs (20,000 m^3)	
Dredging and disposal of infill material during the capital dredging			Completed by the same 2 x large TSHDs.		

Terminology: Trailing Suction Hopper Dredger (TSHD), Jack-up Barge (JUB), Cutter Suction Dredger (CSD). The m^3 refers to the capacity of the hopper of the dredger.

Table 8.7: Summary of Port Approach and Port Area dredging works

Depth (m CD)	Dredging works	Equipment and method	Example	Duration
0 to -5.5	Shallow depth dredging	Large CSD (15,000 kW) pumping into 2 x large TSHDs (20,000 m^3) for disposal at an offshore DMG - unsuitable reclamation material.	 X1 CSD (15,000 kW)  X2 TSHDs (20,000 m^3)	1.88 years capital works plus 0.09 years maintenance over capital programme, total 1.97 years
-5.5 to -9	Intermediate depth dredging	2 x small TSHDs (5,000 m^3) dredging and transporting suitable reclamation materials (sand) for pumping into the reclamation area. or 2 x small TSHDs (5,000 m^3) dredging and transporting materials that are unsuitable for the reclamation for bottom dumping at an offshore DMG.	 X2 TSHDs (5,000 m^3)	
-9 to -16.5	Dredging to design level	2 x large TSHDs (20,000 m^3) dredging and transporting suitable reclamation materials (sand) for pumping into the reclamation area. or 2 x large TSHDs (20,000 m^3) dredging and transporting materials that are unsuitable for the reclamation for bottom dumping at an offshore DMG.	 X2 TSHDs (20,000 m^3)	
Existing depth to -16.5	Dredging outer channel area	Small TSHD (5,000 m^3) dredging and transporting suitable reclamation materials (sand) for pumping into the reclamation area.	 X1 TSHDs (5,000 m^3)	
Existing depth to -16.5	Suitable materials for reclamation area	Large CSD (15,000 kW) pumping directly to reclamation area.	 X1 CSD (15,000 kW)	
-16.5	Dredging inaccessible corners and advance works	Medium BHD loading hopper barges for transport and onshore transfer with dry earthmoving moving equipment for placement within the reclamation area.	 X1 medium BHD	
-16.5	Final levelling at end of works	Tug/Barge Bed-levelling Unit or Water Injection Dredger (WID).	 X1 bed levelling unit	
Dredging and disposal of infill material during the capital dredging.		2 x large TSHDs (20,000 m^3).	 X2 TSHDs (20,000 m^3)	

8.6 Overflowing and restricted overflowing

It is usual practice for a TSHD to operate an overflow system during dredging to maximise the solids content in the hopper and achieve greatest dredging efficiency. A schematic of this system is shown in Figure 8.2. As the slurry (mixture of water and solids) dredged by the TSHD enters the hopper, the solid particles sink to the bottom of the hopper and the clarified water (with some solids) at the top of the hopper is released back into the surrounding waterway.

To minimise the turbid plumes generated during the dredging process, the discharge of fine sediment laden water can take place via use of a so-called ‘green’ valve. These devices are designed to minimise the entrainment of air in the discharge, which would otherwise cause the discharge mixture to be pulled towards the water surface by rising air bubbles. The green valve also releases the discharge mixture at depth below the keel of the vessel, providing for the fine sediments in the discharge to settle to the seabed more rapidly.

Whether an overflow system is operated or not during dredging by TSHD has a significant influence on the dredging production rate and hence cost. In the New Zealand context this would be in relation to environmental and social constraints. The presented costs in this Final Summary Report assume that overflowing would be allowed. Costs for restricted overflowing are significantly higher (60-70% for capital and around 30% for maintenance dredging) and are provided in TWP06 - Dredging.

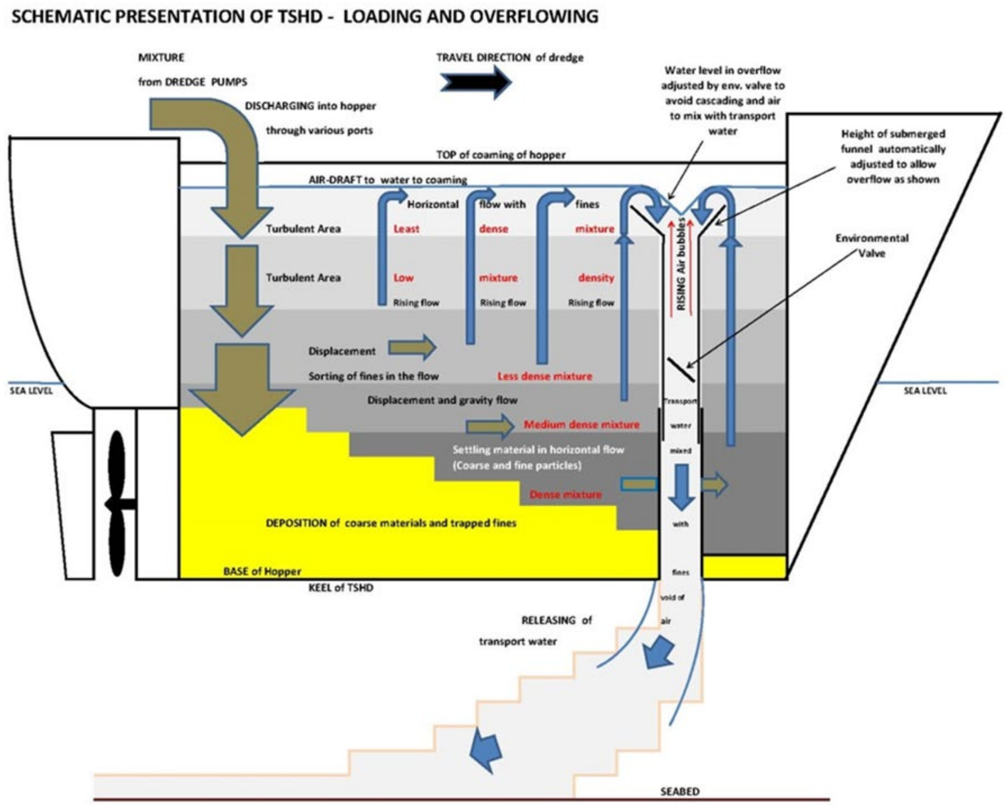

Figure 8.2: *Schematic presentation of TSHD loading and overflowing (note that the funnel cone can be raised to stop overflowing or lowered to increase or start overflowing).*

8.7 Dredging construction schedule

A preliminary dredging construction schedule has been developed for the Stage 1 capital dredging works for each of the channel scenarios through the Manukau Bar and with overflowing from the

TSHDs allowed. Scenarios 1 and 2, inclusive of the Port Approach and Port Area dredging works, have a similar estimated total duration of approximately 4 years. Scenario 3 has an estimated duration of slightly greater than 5 years, and Scenario 4 has the longest duration of approximately 6 years.

8.8 Preliminary cost estimates

Due to the dynamic conditions and the duration of the capital dredging program, infilling of areas subject to capital dredging would occur during the progress of the capital dredging. Accordingly, the cost estimates, which are separated into capital dredging cost and maintenance dredging cost, are made up as follows:

- capital cost – cost of dredging to achieve the design profile plus the cost of removal of infill material for the duration of the capital dredging program; and,
- maintenance cost – ongoing cost on an annual basis to maintain the dredge profile following completion of the capital dredging program.

The estimates for dredging and suitability of sediment for reclamation are subject to the soil model developed for this study, which is based on available information. To achieve a better estimate in the future, borehole data at strategic locations to full design depth plus over-dredging would be required.

A summary of the estimated costs (TSHD overflowing allowed) in New Zealand Dollars (NZD), as of July 2023, of the capital dredging and ongoing maintenance dredging works for Stage 1 and Stage 2 are provided below in Table 8.8 and Table 8.9 respectively, and summarised as follows:

- Stage 1 capital dredging costs were estimated for the different Entrance Channel scenarios and ranged from **$940.5 M to $1,263.7 M**, the Scenario 2 (Base Case) cost was $940.5 M;
- The fixed cost for procurement and mobilisation of a dedicated maintenance dredger (TSHD 10,000 m^3) is **$175.6 M**;
- The ongoing maintenance dredging cost following completion of Stage 1 capital dredging was estimated at **$37.4 M/year** (Scenario 1, 2, and 3) and $49.7 M/year (Scenario 4);
- Stage 2 capital dredging costs were estimated at **$344.5 M** with an ongoing maintenance dredging cost of **$2.1 M/year**.

Cost estimates completed for restricted TSHD overflowing indicated that the combined capital costs for Stages 1 and 2 would increase by 60 to 70%. Similarly, the combined ongoing annual maintenance costs would increase by 27% for Scenario 1, 2 and 3, and by 16% for Scenario 4.

All estimates include a general overall contractor's risk/profit margin of 10 – 15%.

Table 8.8: Stage 1 – Summary of capital dredging and ongoing maintenance dredging costs (overflow allowed)

Item	Present Day Estimated Cost (million NZD)			
	South-West Channel			South Channel
	Scenario 1	Scenario 2 (Base Case)	Scenario 3	Scenario 4
Capital Dredging				
(i) Channel through Manukau Bar				
(a) Volume to design profile plus over dredging (gross volume)	152.7	126.1	259.3	349.8
(b) Infill during capital dredging program	116.4	115.5	138.9	204.9
Sub-total for (i)	*269.1*	*241.6*	*398.2*	*554.7*
(ii) Channel within inner harbour plus port area				
(a) Volume to design profile plus over dredging (gross volume)	593.1	593.1	593.1	593.1
(b) Infill during capital dredging program	14.6	14.6	14.6	14.6
Sub-total for (ii)	*607.7*	*607.7*	*607.7*	*607.7*
(iii) Mobilisation and Demobilisation (including likely remobilisations)	71.2	91.2	237.7	101.3
Sub-total for (iii)	*71.2*	*91.2*	*237.7*	*101.3*
Total Capital Dredging Cost (i) + (ii) + (iii)	**948.0**	**940.5**	**1243.6**	**1263.7**
Ongoing Maintenance Dredging				
(i) Procurement and mobilisations of dedicated maintenance dredge capacity (TSHD 10,000 m^3)	175.6	175.6	175.6	175.6
(ii) Channel through the Manukau Bar	25.8/yr	25.8/yr	25.8/yr	38.1/yr
(iii) Channel within inner harbour plus port area	11.6/yr	11.6/yr	11.6/yr	11.6/yr
Total Maintenance Dredging Annual Cost (ii) + (iii)	**37.4/yr**	**37.4/yr**	**37.4/yr**	**49.7/yr**
Total Maintenance Dredging Fixed Cost	**175.6**	**175.6**	**175.6**	**175.6**

Table 8.9: Stage 2 – Summary of capital dredging and ongoing maintenance dredging costs (overflow allowed)

Item		Present Day Estimated Cost (million NZD)
Capital Dredging		
(i)	Volume to design profile plus over dredging (gross volume)	276.9
(ii)	Infill during capital dredging program	3.0
(iii)	Mobilisation and Demobilisation	64.6
	Total Capital Dredging (i) + (ii) + (iii)	**344.5**
Ongoing Maintenance Dredging		**2.1/yr**

8.9 Comparison to other ports

To put the maintenance dredge requirement for the project into context, we have compared the predicted volumes for Manukau with other ports, both in New Zealand and overseas. This is summarised in Table 8.10 where a ratio between the cargo throughput and maintenance dredge volume has been provided to show relative comparisons. A small ratio (i.e. less than 1) shows more beneficial maintenance dredging to TEU settings than when the ratio is larger than 1.

Table 8.10: Comparison of the predicted maintenance dredge volumes and cargo throughput for Manukau Harbour with other ports

Port	Period	Throughput		Av. Maintenance dredging (m^3/year)	Dredge/ throughput ratio (m^3/TEU eq.)	Dredging Equipment
		TEU	MMT			
San Francisco (Main Ship (Bar) Channel)	Present day	2,400,000		300,000	0.13	TSHD Essayons (5,000 m^3)
Columbia River (River Mouth)	Projected from 2010 to 2020	1,720,000	43	3,000,000	1.74	TSHD Essayons (5,000 m^3) and TSHD Yaquina (800 m^3)
Botany Bay	Present day	2,800,000		-	0.00	-
Melbourne	Present day	3,200,000		770,000	0.24	Backhoe/grab dredgers and TSHDs
POAL	Present day	1,092,000	7.3	65,000	0.06	Backhoe / Environmental Grab dredger
Port of Tauranga	Present day	1,200,000		240,000	0.20	TSHD Albatross (1,860 m^3)
Port of Tauranga inc. other	Present day	2,224,000	26	240,000	0.11	TSHD Albatross (1,860 m^3)
Port of Lyttelton	Present day	500,000		553,846	1.11	TSHD Albatross (1,860 m^3)
Manukau Port (Stage 1)	2049	5,000,000		8,200,000	1.64	TSHD (10,000m^3)
Manukau Port (Stage 2)	2079	10,000,000		8,350,000	0.84	TSHD (10,000m^3)

TEU values include conversion from MMT based on 1 TEU = 25 T

TEU and MMT values (taken from online published sources)

9 Planning considerations

Planning related matters and environmental and social effects are not part of the Manukau Harbour Port Feasibility Study's scope of work. However, for completeness we reviewed the findings of previous reports and assessed any additional risks.

9.1 Review of previous studies

Previous studies have looked at the planning requirements for a Manukau Harbour port. In particular, the Upper North Island Supply Chain Strategy (Sapere, 2020) was supported by the following reports:

- Planning evaluation, Mitchell Daysh, April 2020.
- Scoping and gap assessment of social impacts, Tika Impact Ltd, April 2020.
- Report on stakeholder perspectives, The Policy Shop, June 2020.
- Report on Treaty partner perspectives, The Policy Shop, June 2020.

The planning evaluation (Mitchell Daysh, April 2020) assessed port options in the Manukau Harbour, along with other locations, against the current planning framework, and identified the following as key planning risks:

- Significant ecological values.
- Outstanding natural character and landscape values.
- Mana whenua values.
- Infrastructure – obstacle limitation surface for Auckland International Airport.

Sapere (2020) also identified that:

- Maintaining social license is increasingly important for ports worldwide and environmental issues are at the forefront of concerns.
- Social considerations are pertinent throughout the entire port lifecycle from proposal, commissioning, construction and operation, to decommissioning.
- Social changes relevant to relocation of port activities include community participation, labour force impacts and opportunities, communications, interactions with landscapes, environmental factors and land values.

The Mitchell Daysh report (April 2020) concludes that there are some significant, if not insurmountable, challenges in obtaining the necessary Resource Management Act 1991 (RMA) approvals for new port developments in the coastal environment under current legislation. Legislative change, allowing for planning routes other than a plan change, would need to be pursued for a new port.

9.2 Dredging considerations

We noted that the Mitchell Daysh report (April 2020) focussed on the potential port locations within the harbour but neither the Mitchell Daysh report nor the overarching Sapere report appear to have considered dredging in the vicinity of the Manukau Bar. We have therefore reviewed planning constraints in the vicinity of the Manukau Bar to identify any further planning risks associated with dredging and disposal of dredge material.

There are a number of planning overlays identified near the Manukau Bar in the Auckland Unitary Plan (AUP) maps, as set out in Table 9.1. For this assessment, we focussed our commentary on overlays which would be directly affected by dredging (i.e., in or near the Coastal Marine Area), noting that there are also a number of overlays identified on nearby land (e.g., Āwhitu Peninsula and Waitākere Ranges), which would also need to be taken account of.

Table 9.1: Auckland Unitary Plan planning notations

AUP reference	Commentary
Significant Ecological Areas (SEA)- Marine: • SEA-M2-13a. • SEA-M1-14. • SEA-M1-15a. • SEA-M2-37. SEA - Terrestrial: • SEA_T_181. • SEA_T_5473. • SEA_T_9021. • SEA_T_5539.	These SEAs cover a range of habitats, including rocky shores, coastal cliffs, and dunes. Of relevance, SEA-M1-14 covers Whatipū, a large area of mobile dunes which is the best example of recent (mostly 1900 to 1930) coastal progradation in New Zealand, leaving many sea caves stranded in the hills behind. Schedule 4 of the AUP states: *"It is considered to be a nationally important landform and is also an important and complex habitat for a variety of animal and plant communities."*
Outstanding Natural Features: • ID 129, Ninepin Rock volcanic neck. • ID 250, Whatipū coastal flats. • ID 153, Paratutae wave-cut notch. Outstanding Natural Landscapes: • Area 55, West Coast Āwhitu Peninsula. • Area 73, Waitākere Ranges and coastline.	Similarly, to the Marine SEA identified above, the AUP states that: *"The Whatipū coastal flat (ID250) is an extensive and impressive wilderness area of sandflats and low dunes, most of which were deposited between 1900-1930. A shifting network of wetlands occupies poorly drained areas among the dunes The site is the best example of rapid recent sand aggradation in New Zealand. Significant coastal erosion has affected the area in recent years."*
Outstanding and High Natural Character Areas • Outstanding Natural Character Overlay - AREA 39, Whatipū. • High Natural Character Overlay - AREA 43, Āwhitu Peninsula. • Waitākere Ranges Heritage Area Overlay - Extent of Overlay.	Outstanding and High Natural Character Area overlays cover both sides of the Manukau Heads.
Historic Heritage and Special Character • ID 2177, HMS Orpheus shipwreck site and wreckage. • ID 2194, PS Pioneer shipwreck Wreck site and wreckage of PS Pioneer. • ID 152, Whatipū Wharf site.	Both the HMS Orpheus shipwreck and the PS Pioneer shipwreck are located within the vicinity of the bar and potential dredge area. The HMS Orpheus is New Zealand's worst shipwreck, with 189 lives lost.[1]
Cable Protection Area Control.	This runs between Whatipū Road (Huia) across the harbour to Āwhitu Peninsula. We understand, from consultation with Auckland Council and the Auckland Harbourmaster, that this overlay indicates a historical prohibited anchorage area. The no anchoring zone was to stop vessels getting in the way of vessels using unlit day beacons located at Destruction Gully used for navigating the South Channel. These beacons are no longer in service, and the no anchoring zone has been removed from the hydrographic chart. Therefore, this has not been considered further.

[1] New Zealand's worst shipwreck | NZHistory, New Zealand history online

In addition to the AUP planning notations, the West Coast North Island Marine Mammal Sanctuary covers the Manukau Harbour entrance as shown in Figure 9.1 below. The sanctuary was established in 2008 as a part of the Hector's and Māui dolphin Threat Management Plan, with some restrictions on seabed mining activities and acoustic seismic survey work.

The Marine Mammals Protection (West Coast North Island Sanctuary) Notice 2008 ('the Notice') prohibits seabed mining (see Figure 9.1 below). As part of this study, the project team engaged with the Department of Conservation (DoC), who has confirmed that dredging is not understood to be seabed mining under the definition set out in the Crown Minerals Act.[2] However, it may be prudent to seek legal advice regarding the definition of seabed mining (i.e., whether this would encompass dredging) and the application of the Notice before proceeding further, as this would likely be subject to challenge.

In any case, the potential for adverse effects on Māui dolphins would be a key consideration. DoC also noted that the Manukau Harbour is an important nursery ground for sharks, including juvenile school sharks. In addition:

- Effects of dredging on coastal processes:
  - Placement of capital and maintenance dredge material will affect the geomorphology of the Manukau Bar and adjacent beach systems (including the nationally important dune landform at Whatipū). Since the estimated infill rate is substantially larger than the estimated longshore transport rate on adjacent beaches, if all the dredged material were placed downdrift then it may affect existing coastal processes on adjacent beaches and, over time, reduce the volume of the Manukau Bar system. The annual infill volume is 0.4 to 0.5% of the volume of sand in the ebb-tidal delta.
  - A reduction in the ebb-tidal delta volume may have adverse effects on adjacent coastlines and/or the flood-tidal delta as sand is sourced by natural processes from elsewhere to bring the system back to equilibrium. Placement of dredge material would need to be designed to maintain the existing sediment-transport circulation patterns on the Manukau Bar and generally keep these circulation patterns in balance. This has not been investigated as part of this study and would need careful consideration as part of latter effects assessments.
- Other key impacts may include biosecurity considerations, particularly in relation to invasive aquatic species e.g. caulerpa seaweeds.
- The establishment of an offshore dredged material ground would be a critical requirement for this project. This would be a complex planning process, requiring careful assessment of environmental and cultural effects.
- The dredging assessment has identified a shortfall of suitable port reclamation material for Stage 2 port development i.e. 2049 to 2079. This shortfall would require further investigation in future studies, informed by the need for further port expansion and inner harbour channel widening, collection of additional geotechnical information and refinement of the preliminary soil model (along with cost estimates).

[2] Section 6 of the Notice states, "A person must not carry out seabed mining in the sanctuary created by clause 4(1) unless the seabed mining is undertaken— (a) in the areas of the sea contained in the internal waters within the north-south extent of the sanctuary; or (b) under an existing permit, an existing privilege, or a subsequent permit."
Under the Crown Minerals Act, seabed mining means "to take, win, or extract, by whatever means,— (i) a mineral existing in its natural state in land; or (ii) a chemical substance from a mineral existing in its natural state in land"

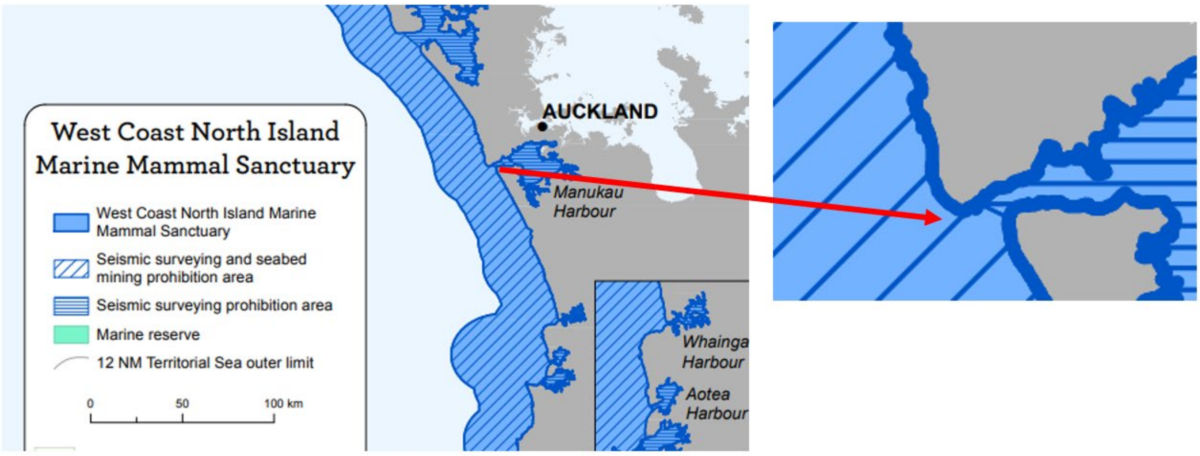

Figure 9.1: Manukau Harbour section of the West Coast North Island Marine Mammal Sanctuary. The Manukau Harbour and Manukau Bar are in the seismic surveying and seabed mining prohibition area. (Source: DoC website: https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-protected-areas/mms-westcoast-northisland-map.pdf)

9.3 Mana whenua considerations

As identified in the Upper North Island Supply Chain Strategy (Sapere, June 2020), mana whenua engagement is critical for this project. Manukau Harbour is of high interest to mana whenua as this body of water links to their rights under the Treaty of Waitangi, and there are a number of overlapping and active claims. The nature of these rights is still in consideration under Crown processes including claims under the Marine and Coastal Area Act (Takutai Moana) Act 2011 (MACA).

The Manukau Harbour is significant for a number of mana whenua groups. There is a long history of settlement in this area. The cultural landscapes, values and history in this area are of deep significance, as set out in the WAI09 Treaty of Waitangi Claim. In their 1930 book 'Legends of the Maori', Sir Pomare and Cowan cited a proverb: "Kei te tua o Manukau, te kite ki muri ki te Kupenga-o-Taramainuku" ("When you pass out beyond the Manukau waters, do not look back until you reach—or pass—the 'Fishing-net of Tara'"). Similarly, two Kaumatua of the Ngati-Mahuta Hapū described the loss of an island off the Manukau Harbour which was, according to one Kaumatua, "Kua kai e te tai" ("It was eaten up by the sea"). This Mātauranga illustrates the dynamic nature of the ebb-tidal delta at the entrance of the Manukau Harbour and highlights the two key challenges this system poses for a) safe navigation of vessels transiting the Harbour and b) understanding the complex, dynamic geomorphic system.

Mana whenua strongly articulated their whakapapa connection and kaitiaki status in relation to the Manukau Harbour. There is concern related to further pollution and the impact of dredging in the harbour and the effects on environment including wāhi tapu, urupā, māra kai sites and other sites of cultural significance. More broadly, mana whenua raised concerns about the effects of development within the harbour on their social, economic, and cultural interests as Treaty partners.

Locating a port in the Manukau would raise significant implications, and the issue of port relocation is significant for mana whenua. The taiao (environment) and the kaitiakitanga of tangata whenua will be significantly impacted by harbour activity.

It is likely that some iwi will be opposed based on findings of the Sapere report and indications provided in discussions with mana whenua during this project however, this would need to be explored further. While Sapere states that "None of the options necessarily has a 'fatal flaw' from the perspective of Māori groups...", if port development is opposed by mana whenua with recognised customary rights over the area, then this would be a very significant challenge.

Should the Manukau Harbour be a preferred option for port development the impacts on the taiao and mana whenua need to be adequately assessed as a key determination on the viability of this project. Mana whenua groups should be engaged early in future decisions and included in a decision-making governance structure.

To understand the full extent of the impacts and identify if avoidance or mitigation of these impacts is possible, engagement would likely require a co-design process (or similar) between Treaty partners, the Crown and mana whenua. Inclusion of mana whenua in assessing feasibility is critical, and mana whenua intend to keep the Crown and Council accountable and transparent for such projects.

Further details of our engagement with mana whenua undertaken as part of this study are provided in TWP07 - Engagement.

10 Risk assessment

Our scope was to focus on engineering technical feasibility. We have therefore separated planning related risks from engineering technical feasibility risks and provide two risk registers. Both are provided in Appendix A. Planning risks are additional risks to those identified in previous studies. The engineering risk register also includes opportunities for future consideration.

To identify and evaluate risks, two risk workshops were undertaken. The first workshop was held after the study assumptions had been set and the team had developed an understanding of the site conditions and constraints. This resulted in a long list of risks with possible control measures that were to be explored further through the study. The second risk workshop was held on completion of all the work to re-evaluate the risks and control measures and populate any additional risks or opportunities that had been identified through the study. Any residually high risks were then evaluated to determine whether they pose a fatal flaw to the technical feasibility and inform our recommendations.

After the risk mitigation process there remains one critical and four high risks. These are summarised in Table 10.1.

Table 10.1: Summary of residually critical and high risks (engineering feasibility)

Risk description	Possible controls	Notes	Residual risk	Future considerations
An offshore Dredge Material Ground (DMG) is disallowed, cannot accommodate excess dredging quantities, or materials unsuitable for reclamation, on land and/or in settling ponds, thereby impacting the feasibility of the project.	Approval for onshore disposal, or approval for disposal beyond the 12 nautical mile limit (i.e. international waters), however, this may still be difficult to achieve.	Establishing a DMG is critical to the feasibility of the project. To avoid future settlement in reclamation/terminals, and large capacity sediment ponds, it is beneficial to dispose of unsuitable soft materials in a DMG.	Critical	This risk relates to consenting and environmental matters rather than technical feasibility but has the potential to be a fatal flaw if disallowed. Future consideration should be given to the ability to approve a DMG of the scale required. Minimising dredging quantities that must be placed in a DMG would support this and could be achieved through channel optimisation, careful site selection and by determining re-use opportunities for unsuitable dredge material.
Environmental constraints result in the overflowing system i.e. release of sediment laden water back into the receiving environment during dredging, not being allowed.	Proceed with restricted overflowing, although this decreases productivity and increases costs and time significantly.	Early recognition of environmental issues and the perception of stakeholder groups must be understood, and clear scientific responses are needed.	High	Overflowing is related to consenting and environmental matters, which would affect time and cost rather than technical feasibility. Future consideration should be given to recent approvals for dredging activities elsewhere in same or similar conditions. Environmental studies to assess the effects of overflowing to the receiving environment, stakeholder consultation, and mitigation measures should also be considered. Costs would need to be commercially evaluated as part of the overall port development and operation.
Different soil, to that assessed in the study, is encountered (e.g. clay/silt/rock) affecting selection of equipment and cost increasing project commercial risk.	Eliminate sensitivity for encountering different material types than assumed. Obtain boreholes and soil data for the areas to be dredged i.e. the	Clay/silt/rock are the materials that would impact the dredging and reclamation methods the most. This may affect alignment of the channels and/or port location.	High	This risk would result in a change to cost and time rather than technical feasibility. Refining the soil model based on newly gathered information will refine the equipment selection, time, and cost of the

Risk description	Possible controls	Notes	Residual risk	Future considerations
	Entrance Channel and Inner Harbour.			dredging works. This would be a later design consideration after the port site selection process and the costs would need to be commercially evaluated as part of the overall port development and operation.
Bathymetric surveys taken over various years show significant level differences for the crest of the Manukau Bar for the South-West Channel, which will require alternative start-up dredging equipment to avoid start delays (years) impacting the cost, programme, and risk profile of the works.	Change dredge method, start works in summer, delay the works until bar depth improves.	Not applicable to South Channel construction, where channel depth appears more stable.	High	This risk primarily changes the cost and time of the dredging works. Some bar configurations present technical challenges and would require the works to be delayed allowing natural processes to increase depths so that dredging could commence. Alternative channel alignments could be investigated, e.g. a South Channel which shows more stable levels but higher dredge volumes.
Inability to control placement of dredged material (sand) in the active coastal zone and on the Manukau Bar effectively, leading to a destabilisation of the system (loss of sediment) and adverse effects to adjacent coast, i.e. due to shallow depths that the dredger is required to place in or adverse weather limiting placement.	Partial loading of the dredger to reduce draft, double handling of dredge material with smaller dredgers to place within the active zone, or strategic placement within the tidal channel allowing currents to distribute material. This may require alternative or multiple disposal locations and discharge methods making it a complex task.	Comprehensive understanding of processes operating on the bar and surrounding coast following dredging will be required. This will require methods for collecting data of seabed levels, a calibrated (potentially operational) morphological model and procedures for adaptive management.	High	The practicality and sustainability of placement of dredge material has not been resolved as part of this study. The inability to place material in the active coastal zone could lead to adverse effects by changing the coastal processes. Future consideration should be given to a range of placement methodologies, in conjunction with dispersion modelling to track the fate of placed material and a long-term morphological model to assess destabilisation of the system over time.

The risk assessment also identified opportunities relating to refining the navigation channel design by proving steeper slopes may be possible or reducing the length, depending on where a port is located, both of which would reduce dredge volumes. If lower sediment infill rates were to be proven, then the size of maintenance dredger may be able to be reduced, which would also be an opportunity.

From a planning perspective, the conclusions drawn in previous studies around RMA limitations remain valid and additional risks associated with dredging works at the harbour entrance and the disposal of dredge material, that were not previously assessed, increase the complexity. We identified additional risks associated with this (refer to Appendix A), including high risks associated with potentially significant adverse effects on ecological values, threatened species, landscape and natural character, coastal processes, mana whenua values and interests, and historic heritage along with risks associated with establishing an offshore dredge material ground and port reclamation within the harbour.

Appropriate management of potential effects will be a key aspect at future stages.

11 Summary

Key findings from the study are as follows:

- Safe marine access to the Manukau Harbour could only be achieved with extensive and ongoing dredging which is shown to be feasible with the range of dredging methods that are available today.
- To form a navigation channel and port area, large volumes (70 to 90 M m^3) of seabed material would need to be removed by capital dredging. This is estimated to take between 4 to 6 years to achieve and cost between $941 to $1,244 million with the configuration of the Manukau Bar at the start of the works dictating the equipment required, cost, time, and risk. Estimates are based on existing soil information and further ground investigation would be required to refine these.
- To maintain the navigation channel, very large volumes of accumulating sediment would need to be removed. This has been estimated to be in the order of 7.5 million m^3/year for the channel through the Manukau Bar and 0.7 million m^3/year for the inner harbour and port area. A dedicated maintenance dredger, capable of operating in the west coast wave climate, would need to be owned by the port and available 100% in winter and 50% in summer to achieve this. The cost of the dredger, a 10,000 m^3 capacity Trailing Suction Hopper Dredger, is estimated to be $176 million, and the ongoing maintenance cost to remove this material is estimated to be $37 million/year.
- Maintenance dredge volumes are very high when compared to New Zealand ports e.g. Port of Lyttelton removes ~0.5 million m^3/year and Port of Tauranga removes ~0.25 million m^3/year, as well as international examples which are considered to have high maintenance dredging regimes e.g. Columbia River Port removes ~3 million m^3/year. The large volumes combined with severe wave climate offshore of Manukau result in a much larger maintenance dredger being required compared to other ports e.g. ~2,000 m^3 capacity dredger used for existing New Zealand ports and 5,000 m^3 for Columbia River Port.
- Material dredged through the Manukau Bar would need to be placed back in the active coastal system to avoid destabilising the balance of sediment over time. To achieve this, the dredger would need to place material in relatively shallow depths and additional steps are likely required e.g. partial loading, multiple handling with smaller dredgers, or alternative placement methods, all of which increase the complexity and cost. There is therefore a low confidence in the ability to manage this without adverse effect which is a high risk for a port in this location.
- Suitable dredged material from the inner harbour would be expected to be used to form the port reclamation. Our estimates show that there would be surplus material and unsuitable material that would need to be disposed of. Whilst careful site selection, channel optimisation or beneficial reuse options may reduce these volumes there would be a need to dispose of material to an offshore disposal ground. The ability to gain approval for this is therefore a critical risk to a port in this location.
- It is usual practice for a Trailing Suction Hopper Dredger to operate an ‘overflow system’ during dredging to maximise the solids content in the hopper and achieve greatest dredging efficiency, therefore our dredge cost estimates have made this assumption. If this was not permitted from an environmental or social perspective, then there would be considerable cost increases for both capital (+60-70%) and maintenance (+30%) dredging. There are recent New Zealand examples where overflowing with a ‘green valve’ has been permitted e.g. Port of Lyttelton. The green valve reduces air entrapment and releases material at the bed to reduce sediment plume dispersion. Environmental effects are site specific and would therefore need to be evaluated for Manukau Harbour, therefore this remains a high commercial risk to a port in this location.

- Intermittent pilotage suspension is the most probable cause of ships being unable to enter or leave the Manukau Harbour. Overseas ships and high-risk domestic ships such as tankers and chemical carriers calling at a Manukau Harbour port would make use of a pilot to safely enter/exit the port through the navigation channel. This requires the transfer of an experienced mariner (the pilot) to ships offshore. The wave climate offshore of Manukau Harbour presents a challenge and, as with other ports in high energy environments such as Sydney and Melbourne, this operation would need suspending from time to time. The level of pilotage suspension will ultimately be a commercial decision; however, our analysis shows that the levels and durations of suspension expected for a Manukau Harbour port are not overly onerous when compared to other ports in high energy environments.
- Excessive ship motions, surf-riding and broaching when entering/exiting the harbour have been considered and do not pose a risk to medium or large ships. Smaller ships (less than 100 m in length) are shown to have restrictions in certain conditions; however, these are the size of vessels that can presently navigate the existing natural channels and the constraints would be less onerous within a defined channel.
- The Manukau Harbour has been shown to be able to provide the required spatial needs of a large-scale port. Port terminal site selection may, however, be restricted by the Auckland International Airport obstacle limitation surface (i.e. their reserved airspace) if intrusion is not permitted. We have shown that there are sites outside of this airspace, but the merits of port locations have not been evaluated. Should sites within the airspace be considered then an aeronautical study and Civil Aviation approval would be required. It is therefore not a fatal flaw to a port in this location but needs further consideration as part of the site selection process to determine the constraint.
- On review of other potential operational constraints, including anchorage, biosecurity processes, aids to navigation and channel sedimentation, the conclusions on navigational operability for a Manukau Harbour port are that the risks do not pose a fatal flaw and could be mitigated to acceptable levels.
- Manukau Harbour is of high interest to mana whenua as this body of water links to their rights under the Treaty of Waitangi, and there are a number of overlapping and active claims. The nature of these rights is still in consideration under Crown processes including claims under the Marine and Coastal Area Act (Takutai Moana) Act 2011 (MACA). There is a long history of settlement in this area as such the cultural landscapes, values and history are of deep significance. Mana whenua strongly articulated their whakapapa connection and kaitiaki status in relation to the Manukau Harbour. There is concern related to further pollution, the impact of dredging, and effects on the environment including wāhi tapu, urupā, māra kai sites and other sites of cultural significance. More broadly, mana whenua raised concerns about the effects of development within the harbour on their social, economic, and cultural interests as Treaty partners.

12 Conclusion

The study concludes that, from an engineering perspective:

1. It is technically feasible to open and maintain a navigation channel to the Manukau Harbour suitable for the size of ship serving a large-scale port.
2. The spatial needs of a large-scale port could be met, and navigational operability risks could be managed.

While the Manukau Harbour is technically feasible, there are a number of significant risks relating to capital and operational costs, consenting and potential adverse effects to physical coastal processes. These risks may be possible to overcome and/or manage, but will likely present challenges in progressing. Further work could be undertaken to fully understand these from an economic, social, environmental, and cultural perspective. We note that this study has focused on the Manukau Harbour as a distinct option and has not compared the findings in the context of the other port development options, which would require further evaluation.

12.1 Future matters to address

Should the Manukau Harbour progress as an option then:

- Port terminal site selection would be required. The Auckland International Airport airspace restriction (obstacle limitation surface) may affect this and needs to be investigated further. A holistic options assessment, considering environmental, social, and cultural opportunities and constraints would be required.
- Locating a port in the Manukau Harbour would raise significant concerns for mana whenua. The impacts on the taiao (environment) and the kaitiakitanga of tangata whenua will need to be adequately assessed as a key determination on the viability of this project. Feedback through this study has been that mana whenua groups should be engaged early in future decisions and included in a decision-making governance structure. To understand the full extent of the impacts and identify if avoidance or mitigation of these impacts is possible, mana whenua have made it clear that there is an expectation for a co-design process (or similar) between Treaty partners, the Crown and mana whenua.
- Identification, assessment, and appropriate management of effects (cultural, social, environmental) will be a key step at future stages to build on previous work. Targeted studies into the ability to manage placement of dredged material back into the active coastal zone to avoid adverse effects e.g. erosion to adjacent shorelines, has been identified as a high risk to a port in this location and would need to be resolved.
- There are high risks associated with the dredging works that may have a significant bearing on the capital and operational costs which would need commercial appraisal taking account of the updated costs from this study.

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14 Applicability

This report has been prepared for the exclusive use of our client Te Manatū Waka | Ministry of Transport, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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Appendix A Risk and opportunity registers

- **Planning risk register**
- **Engineering risk and opportunity register**

Tonkin+Taylor

Title: Planning Risk Assessment - Fatal Flaw Analysis of risks in addition to those identified by Mitchell Daysh (June 2020)

Last updated: 12/06/2024

Project: Manukau Harbour, Port Feasibility Study

Project objetive: To implement and operate a large-scale port in the Manukau Harbour

Register owner: Sarah McCarter

						Without Controls				With Controls					
No.	Date Raised	Entered by	Phase	Category	Risk Description	Likelihood	Consequence	Current Risk Rating	Possible Controls	Likelihood	Consequence	Target Risk Rating	Further controls to be investigated	Status	Notes
1	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Significant adverse effects on ecological values e.g. benthic, wading birds. This includes impacts on ecological values from potential biosecurity risks and changes to coastal processes.	Almost Certain (>85%)	Extreme	Critical	Risk mitigation through: Design port to avoid significant ecological areas and extensive mitigation measures likely. Early planning and environmental assessments to highlight ability to mitigate planning risks further through application of effects management hierarchy (avoid, minimise, remedy, offset).	Almost Certain (>85%)	Severe	Critical	Offsetting could be explored however this would depend on uniqueness of habitat lost	Open	Whatipū, a large area of mobile dunes is considered to be the best example of recent (mostly 1900 to 1930) coastal progradation in New Zealand, leaving many sea caves stranded in the hills behind. Schedule 4 of the AUP states, "It is considered to be a nationally important landform and is also an important and complex habitat for a variety of animal and plant communities."
2	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Significant adverse effects on threatened species e.g. Maui's dolphins (about 55 remaining, nationally critical)	Almost Certain (>85%)	Extreme	Critical	Consideration of noise and dredging works on dolphins that could impact on dredging windows as well as extensive other mitigation measures. Effective controls are unlikely or uncertain at best, and therefore no change in risk assessment with controls.	Almost Certain (>85%)	Extreme	Critical			Additional discussion with marine experts would be required
3	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Marine Mammal Sanctuary prohibits seabed mining over the bar. Under the Crown Minerals Act, seabed mining means "to take, win, or extract, by whatever means,— (i) a mineral existing in its natural state in land; or (ii) a chemical substance from a mineral existing in its natural state in land"	Possible (30% - 55%)	Extreme	Critical	DoC has advised that dredging would not be considered mining, although beneficial use of won sand could affect this. Legal advice on pathways recommended to confirm this - the controls assessment is based on DoC advice. Potential for legal challenge and we recommend legal advice in this regard.	Possible (30% - 55%)	Minor	Medium			Marine Mammals Protection (West Coast North Island Sanctuary) Amendment Notice 2020 states: "A person must not carry out seabed mining in the sanctuary created by clause 4(1) unless the seabed mining is undertaken— (a) in the areas of the sea contained in the internal waters within the north-south extent of the sanctuary; or (b) under an existing permit, an existing privilege, or a subsequent permit."
4	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Significant adverse effects on landscape and natural character, particularly Outstanding Natural Features and Natural Character	Almost Certain (>85%)	Extreme	Critical	Robust options assessment, expert assessment, likely resulting in extenisve mitigation measures	Likely (55% - 85%)	Extreme	Critical			Consideration of impacts on Whatipū dunes required (as well as wider natural character effects including ecological effects and effects on coastal processes)
5	16/02/2023	Sarah McCarter	Pre-Construction	Planning	Significant adverse effects on coastal processes, with impacts on ecology and landscape features such as Whatipū Dunes	Likely (55% - 85%)	Moderate	High	No additional controls identified at this stage, beyond a robust options assessment, expert assessment, extensive mitigation measures taken in relation to ecological and landscape effects.	Likely (55% - 85%)	Moderate	High			
6	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Significant adverse effects on mana whenua values and interests	Almost Certain (>85%)	Extreme	Critical	Early engagement and partnership with relevant iwi, cultural assessment and response / mitigation, noting project unlikely to proceed without partnership with mana whenua.	Likely (55% - 85%)	Extreme	Critical			Kaitiakitanga roles and responsibilities of wāhi tapu (including memorials), mahingā kai, mataitai, fish grounds is high on the agenda of mana whenua. There is a significant risk relating to mahingā kai and severing the connection mana whenua have with their food source and traditional associations to the sand bar.
7	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Relevant iwi do not support port in this location	Likely (55% - 85%)	Extreme	Critical	Early engagement and partnership with relevant iwi, cultural values assessment and response / mitigation, noting project unlikely to proceed without partnership with mana whenua.	Likely (55% - 85%)	Extreme	Critical			Likely that some iwi will be opposed based on Sapere report however, this would need to be explored further. While Sapere states that "None of the options necessarily has a 'fatal flaw' from the perspective of Maori groups...", if a port development is opposed by mana whenua with recognised customary rights over the area, then this is potentially an insurmountable challenge.

						Without Controls				With Controls					
No.	**Date Raised**	**Entered by**	**Phase**	**Category**	**Risk Description**	**Likelihood**	**Consequence**	**Current Risk Rating**	**Possible Controls**	**Likelihood**	**Consequence**	**Target Risk Rating**	**Further controls to be investigated**	**Status**	**Notes**
8	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Significant adverse effects on historic heritage e.g. through disturbance and destruction of PS Pioneer, HMS Orpheus	Likely (55% - 85%)	Extreme	**Critical**	Robust options assessment, expert assessment, mitigation measures. Avoid disturbing PS Pioneer, HMS Orpheus sites. It seems likely the proposed channel would avoid the wreck of the HMS Orpheus; the location of the PS Pioneer would need to be more closely examined by an expert (noting that both wrecks are likely to have moved).	Possible (30% - 55%)	Severe	**High**			Pioneer was wrecked on the Manukau Bar in 1866 after breaking its moorings at Port Waikato. HMS Orpheus was wrecked crossing the Manukau Bar in 1893, resulting in the greatest loss of life in a ship wreck in NZ history.
9	17/05/2023	Sarah McCarter	Pre-Construction	Planning	Impacts on infrastructure e.g. airport obstacle limitations (OLS)	Almost Certain (>85%)	Extreme	**Critical**	Analysis of impacts on these aspects, avoidance and mitigation measures	Possible (30% - 55%)	Severe	**High**	Design port to avoid OLS / risk assessment process		Protection of the OLS has been discussed with Auckland Airport. A cable protection area is indicated on the AUP maps between Whatipū Road (Huia) across the harbour to Āwhitu Peninsula however enquiries with Auckland Council indicate that there is unlikely to be a cable in this area (rather, the overlay is an old prohibited anchorage area which has since been superseded).
10	1/02/2023	Sarah McCarter	Operational	Planning	Biosecurity issues affect navigation, particularly e.g. Caulerpa	Possible (30% - 55%)	Severe	**High**	Analysis of impacts on these aspects, avoidance and mitigation measures, including biosecurity plan. Diver inspections and maintenance may need to be done offshore and would be challenging at this exposed location.	Possible (30% - 55%)	Moderate	**Medium**	Design port to reduce biosecurity risk, take this into account with operational procedures.		Exotic caulerpa can spread rapidly, forming vast, dense underwater fields. Legal controls on some anchoring and fishing activites are in place in 3 locations to help prevent the spread of exotic caulerpa from these affected areas to the rest of the country.
11	15/02/2023	Sarah McCarter	Pre-Construction	Planning	Planning risks associated with the establishment of an offshore dredged material ground, which is a critical requirement for this project.	Almost Certain (>85%)	Extreme	**Critical**	Robust options assessment, expert assessment, mitigation measures.	Almost Certain (>85%)	Severe	**Critical**	The Mitchell Daysh report (April 2020) concludes that there are some significant, if not insurmountable, challenges in obtaining the necessary RMA approvals for new port developments in the coastal environment under current legislation. Legislative change, allowing for alternative planning routes other than a plan change, would need to be pursued for a new port. A similar approach may need to be pursued for a significant offshore dredged material ground, as the permitting is likely to be complex.		
12	15/02/2023	Sarah McCarter	Pre-Construction	Planning	Planning risks associated with reclamation, noting the significant shortfall of suitable reclamation material for Stage 2.	Almost Certain (>85%)	Extreme	**Critical**	Robust options assessment, expert assessment, mitigation measures.	Almost Certain (>85%)	Severe	**Critical**	As set out in the dredging report, further investigation in future studies would be required, informed by the need for further port expansion and associated navigation channel widening, collection of additional geotechnical information and refinement of the adopted soil model (along with cost estimates). Legislative change to allow for alternative planning routes would also include a reclamation of this scale.		

Project Objective
To implement and operate a large-scale port in the Manukau Harbour

Likelihood Rating

	Likelihood	Description
Almost Certain	>85%	Is expected to occur and is almost inevitable
Likely	55% - 85%	Is expected to occur in most circumstances. Not surprised if it happens
Possible	30% - 55%	Might occur in some circumstances
Unlikely	5% - 30%	Could occur in some circumstances, but would be surprised if it happens
Rare	<5%	May occur, but only in exceptional circumstances. It would be highly unexpected

Consequence Table

	Consequence
Extreme	Complete failure to realise project objectives
Severe	Significant reduction to project objectives
Moderate	Some reduction to project objectives
Minor	Minor impact on project objectives
Insignificant	Negligible impact on project objectives
Extreme Opp	Very significant opportunity to project objectives
Severe Opp	Significant opportunity to project objectives
Moderate Opp	Some opportunity to project objectives
Minor Opp	Minor opportunity on project objectives
Insignificant Opp	Negligible opportunity on project objectives

Risk Matrix

		1	2	3	4	5					
		Insignificant	Minor	Moderate	Severe	Extreme	Insignificant Opp	Minor Opp	Moderate Opp	Severe Opp	Extreme Opp
Likelihood	Almost Certain (>85%)	Low	Medium	High	Critical	Critical	Low Opp	Medium Opp	High Opp	Critical Opp	Critical Opp
	Likely (55% - 85%)	Low	Medium	High	Critical	Critical	Low Opp	Medium Opp	High Opp	Critical Opp	Critical Opp
	Possible (30% - 55%)	Low	Medium	Medium	High	Critical	Low Opp	Medium Opp	Medium Opp	High Opp	Critical Opp
	Unlikely (5% - 30%)	Low	Low	Medium	Medium	High	Low Opp	Low Opp	Medium Opp	Medium Opp	High Opp
	Rare (<5%)	Low	Low	Low	Low	High	Low Opp	Low Opp	Low Opp	Low Opp	High Opp
		Consequence					Consequence				

Tonkin+Taylor

Title: Final risk and opportunity register **Last updated:** 18/06/2024
Project: Manukau Harbour, Port Feasibility Study
Project objetive: To implement and operate a large-scale port in the Manukau Harbour

					Without Controls				With Controls					
No.	**Date Raised**	**Phase**	**Category**	**Risk/Opp Description**	**Likelihood**	**Consequence**	**Current Risk Rating**	**Possible Controls**	**Likelihood**	**Consequence**	**Target Risk Rating**	**Future Considerations**	**Status**	**Notes**
1	16/05/2023	Construction	Coastal / marine structures	Fluctuation in seabed level on bar make implementation of coastal structure to control sediment movement unfeasible	Almost Certain (>85%)	Extreme	**Critical**	Assess methods for dredging/controlling sedimentation that do not require bed-mounted structures	Possible (30% - 55%)	Moderate	**Medium**	Not likely feasible	Closed	
2	16/05/2023	Construction	Coastal / marine structures	Breakwater (or similar) required to provide sufficient protection for vessels at berth	Possible (30% - 55%)	Minor	**Medium**	Assess alternative locations, berthing orientation that avoid requirement for breakwaters or similar	Possible (30% - 55%)	Minor	**Medium**	Port location determined by site constraints e.g. Auckland Airport OLS	Open	
3	14/05/2024	Construction	Coastal / marine structures	Sediment accumulation on the southern bar and migration into the channel cannot be managed by maintenance dredging	Unlikely (5% - 30%)	Extreme	**High**	Need for a control structure	Unlikely (5% - 30%)	Moderate	**Medium**	Feasibility of constructing a control structure would need investigating	Open	Size of structure to control sediment movement (length and size of armouring) and disconnect from shoreline makes construction very difficult/expensive
4	17/05/2023	Operational	Coastal processes	Dredged channel and bar changes tidal flows, wave climate and water levels within Manukau Harbour, resulting in increased erosion risk to adjacent shoreline communities	Possible (30% - 55%)	Severe	**High**	Nourishment using dredged sand, or other form of shoreline protection	Possible (30% - 55%)	Moderate	**Medium**		Open	Changes in water level appear small, increases in currents more around channels, risk remains but potentially lower or more around sedimentation
5	14/02/2024	Operational	Coastal processes	Development of delta further offshore and morphological feedback - potential implications on wave/nav/dredging	Likely (55% - 85%)	Moderate	**High**	Dredge, and has been shown that there is capacity to do so	Likely (55% - 85%)	Minor	**Medium**	Long-term morphological modelling at next stage of design to understand implications	Open	Likely to occur but implication and positive feedback unclear
6	14/02/2024	Operational	Coastal processes	Inability to control sand placement in the active coastal zone and on the Manukau Bar effectively, leading to a destabilisation of the system (loss of sediment) and adverse effects to adjacent coast, i.e due to shallow depths that the dredger is required to place in or adverse weather limiting placement	Almost Certain (>85%)	Severe	**Critical**	Part loading of TSHDs to reduce loaded draft and minimise allowable placement depths, double handling of material using smaller dredgers to place material back in to the active coastal system (adding to the cost, complexity and requirement for multiple dredgers), or placing material within the deeper harbour entrance channel to allow tidal currents to redistribute although this may lead to high infill rates	Possible (30% - 55%)	Severe	**High**	Greater understanding of the open coast system. Modelling to establish where material could be placed and confirming dredger can place in close enough to the bar for it to stay within the active coastal system. Longer term morphological modelling and dispersion modelling required as part of an effects assessment.	Open	Scale and complexity of the system would make this difficult
7	17/05/2023	Operational	Dredging	Increased wind/wave action from SW due to climate change increases dredging requirements to maintain open entrance	Possible (30% - 55%)	Moderate	**Medium**	Implications of climate change on infill rate have been modelled. Consider uncertainty of infill rates when assessing size of dredging equipment	Possible (30% - 55%)	Minor	**Medium**		Open	Effect of climate change on infill rates likely not to exceed 10%.
8	17/05/2023	Construction	Dredging	Workability in the bar area during initial capital dredging to -12mCD by small TSHDs is limited leading to increased duration and costs of the works, or need to change dredging methodology	Possible (30% - 55%)	Severe	**High**	Reduce loading, standby during adverse weather, narrower and deeper initial channel, target commencement of works in summer (reduced wave climate), consider purpose designed dredger (walking jack-up barge fitted with CSD)	Possible (30% - 55%)	Moderate	**Medium**	Real time wave monitoring nearby and into the wave direction. Carry out further investigation of the South Channel which has more stable levels but much higher dredge volumes	Open	Risk is dependent on the state of the entrance bar at commencement of the works. The South Channel represents an opportunity due to more sheltered location from waves (increased workability).
9	11/02/2024	Construction	Dredging	Bathymetric surveys taken over various years show significant level differences for the crest of the entrance bar of the South-West Channel, which will require alternative start-up dredging equipment to avoid delay starts (years)	Possible (30% - 55%)	Extreme	**Critical**	Change method, start works in summer, delay the works until bar depth improves.	Possible (30% - 55%)	Severe	**High**	Workability of various dredge methodologies. Carry out further investigation of South Channel.	Open	Not applicable to South Channel construction, where channel depth appears more stable.
10	13/02/2024	Pre-Construction	Dredging	Historical wrecks and sites identified within the footprint of the dredging areas.	Possible (30% - 55%)	Moderate	**Medium**	a) Remove objects and store in similar locations. b) Realign channels, berths, etc.	Rare (<5%)	Minor	**Low**	Emphasis on possible issues	Open	
11	13/02/2024	Pre-Construction	Dredging	Possibility of UXO in footprint to be identified	Rare (<5%)	Moderate	**Low**	UXO to be found and retrieved.	Rare (<5%)	Minor	**Low**	Records to be researched	Open	
12	13/02/2024	Pre-Construction	Dredging	Wave climate, currents, off bow winds may increase or decrease adopted under keel clearance (UKC) levels for dredgers (TSHDs) leading to higher or lower costs.	Likely (55% - 85%)	Moderate	**High**	Further study and modelling of the behaviour of selected TSHDs. Apply dynamic UKC to all TSHD methods in the entrance bar channel.	Possible (30% - 55%)	Moderate	**Medium**	Real time wave and current monitoring nearby and into the wave direction.	Open	More applicable to SW channel than S-Channel, where the wave climate is less severe at the initial shallow section(s). Additionally, due to the more protected location of these shallows, the initial capital works with small TSHDs can be performed with higher production and lower costs.
13	14/02/2024	Pre-Construction	Dredging	Geochemical properties of Inner Harbour sediments may preclude offshore disposal at a Dredge Material Ground (DMG) and/or introduce the need for further environmental controls during dredging, resulting in additional costs or affecting project feasibility (disposal at a DMG)	Unlikely (5% - 30%)	Extreme	**High**	Alternative land based disposal	Unlikely (5% - 30%)	Severe	**Medium**	Further sediment sampling and analysis, including to the design dredge level plus overdredge.	Open	The availability of a DMG and ability to dispose of dredge material at the DMG is critical for project feasibility.

					Without Controls				With Controls					
No.	Date Raised	Phase	Category	Risk/Opp Description	Likelihood	Consequence	Current Risk Rating	Possible Controls	Likelihood	Consequence	Target Risk Rating	Future Considerations	Status	Notes
14	13/02/2024	Pre-Construction	Dredging	Different soil encountered in the bar area at lower levels, as well as the upper reaches of the Papakura Channel and port terminal waters, affecting selection of equipment and cost, and increasing project commercial risk.	Likely (55% - 85%)	Moderate	High	Eliminate sensitivity for encountering different material types than assumed. Obtain boreholes and soil data for the Bar Channel and Inner Harbour	Likely (55% - 85%)	Moderate	High	Additional site investigation to full depth of dredging	Open	Clay/silt/rock are the materials that would impact the dredging and reclamation methods the most. This may affect alignment of the channels and/or port location.
15	14/02/2024	Construction	Dredging	Opportunity - steeper slopes may be possible, if materials are very dense, somewhat cemented (below -12mCD), thereby reducing dredging volumes, duration, and cost.	Possible (30% - 55%)	Minor Opp	Medium Opp	Prove steeper slopes are stable.	Possible (30% - 55%)	Minor Opp	Medium Opp	Additional geotech investigations & design	Open	Adopted slope designs in the current study are conservative.
16	13/02/2024	Operational	Dredging	Risk - shallower slopes may be required due to ground conditions, thereby increasing dredging volumes, duration, and cost.	Unlikely (5% - 30%)	Severe	Medium	Prove shallow slopes not required	Unlikely (5% - 30%)	Moderate	Medium	Further investigations are required, as well as studies of slope stability in high wave climate and/or high ebb currents.	Open	Adopted slope designs in the current study are conservative.
17	17/05/2023	Pre-Construction	Dredging	Dredge Material Ground (DMG) is disallowed, cannot accommodate excess dredging quantities, or materials unsuitable for reclamation, on land and/or in settling ponds, thereby impacting the feasibility of the project.	Possible (30% - 55%)	Extreme	Critical	Onshore or approvals past 12 nm limit (i.e. international waters), but would still need approvals that may be difficult to achieve.	Possible (30% - 55%)	Extreme	Critical	Minimise dredging quantities that must be placed in a DMG. Carry out studies and seek approval of a DMG.	Open	Reduce the area for approval by minimising dredging quantities that must be placed in a DMG through channel optimisation and careful site selection. Carry out studies to determine re-use opportunities for unsuitable materials to avoid need for DMG.
18	11/02/2024	Operational	Dredging	Environmental constraints i.e. overflowing system not allowed, adversely affect production rates and costs	Possible (30% - 55%)	Severe	High	Restricted overflowing although this impacts productivity and cost significantly	Unlikely (5% - 30%)	Extreme	High	Consider recent approvals for dredging activities elsewhere in same or similar conditions to this work, in the assessment of likely constraints. Environmental studies, stakeholder consultation, and inclusion of mitigation measures.	Open	Early recognition of environmental issues and the perception of stakeholder groups must be understood and clear scientific responses are needed.
19	11/02/2024	Operational	Dredging	Annual maintenance infill volumes are significantly higher than modelled, leading to inability to maintain declared depth and/or higher maintenance costs.	Possible (30% - 55%)	Severe	High	Consider larger dredger or multiple dredgers. Consider judicious positioning/design of sediment traps based on coastal process understanding.	Possible (30% - 55%)	Moderate	Medium		Open	High infill levels over many years will be a cost burden on operating the port.
20	11/02/2024	Operational	Dredging	Severe discrete weather events over longer periods may deposit more infill than expected, causing shallow areas in the bar entrance channel, and reducing declared depth.	Possible (30% - 55%)	Moderate	Medium	a) Station larger maintenance dredge in the Manukau Harbour. b) Maintain (at all times) overdredged areas at the bar and overdredge slopes along the shallow banks or trench at toes of the channel. c) Redesign the outer bar entrance by increasing width and depth.	Possible (30% - 55%)	Moderate	Medium	Establish allowable port delays, waiting for tides and/or removal of material above the declared depth.	Open	The infill following severe events is a major input into the selection of the capacity of the maintenance TSHD to be stationed at the port.
21	13/02/2023	Operational	Dredging	Hydrographic surveys, which require reasonable wave conditions, cannot be completed in a timely manner, causing extended delays for shipping.	Possible (30% - 55%)	Moderate	Medium	Apply best methodologies for traversing swell affected areas by using jet-skis with heave measurement or larger multihull fin-keel/spade-rudder survey vessel. Best practice would be the dredging vessel to carry out surveys.	Unlikely (5% - 30%)	Minor	Low	Monitor world best practice, as such practices are further developed.	Open	
22	16/05/2023	Operational	Dredging	Medium-scale morphological evolution of bar increases quantum of material to be dredged on cyclical basis to magnitudes such that declared depth cannot be maintained	Possible (30% - 55%)	Severe	High	Select maintenance dredging equipment on the basis of conservative predictions. Consider use of multiple dredgers when required. Establish sediment traps. Monitor bar changes.	Unlikely (5% - 30%)	Severe	Medium	Monitor change in bar morphology, quantify volume, calculate size of sediment trap required, assess whether permanent channel would adjust processes. Further investigate a South Channel which is likely to be inherently more stable.	Open	South Channel is an opportunity to mitigate this risk.
23	18/05/2023	Construction	Dredging	Required capital dredge volumes to establish navigation channel may change significantly depending on morphological configuration of bar at commencement.	Almost Certain (>85%)	Severe	Critical	Time capital dredge campaign for particular stage in cycle / change dredge method. Consider the range of possible capital dredging volumes through the bar that could exist at commencement of the works in the assessment of dredging equipment and costs.	Possible (30% - 55%)	Moderate	Medium	Channel alignment adjusted to minimise fluctuations. Consider adoption of a South Channel which exhibits less variability in depth over time.	Open	South Channel is an opportunity to mitigate this risk.
24	14/02/2024	Operational	Dredging	Opportunity for lower infill in South Channel if only considering sedimentation on the bed of the channel.	Possible (30% - 55%)	Severe Opp	High Opp	Further investigate a South Channel.	Possible (30% - 55%)	Severe Opp	High Opp	More detailed modelling to establish whether South Channel offers infill benefits compared to South-West Channel.	Open	Opportunity
25	14/02/2024	Operational	Dredging	Production rates lower than estimated leading to insufficient capacity to cope with infill of the channel	Unlikely (5% - 30%)	Severe	Medium	Size up dredge to increase production rates. Adjust operability limit from significant wave height (Hs) of 3m to 3.5m (the limit of 3.5m is accepted in industry practice but above general guidance).	Rare (<5%)	Minor	Low		Open	
26	14/02/2024	Operational	Dredging	Opportunity to reduce maintenance dredge size due to less infill, leading to capital cost saving i.e. purchase of dredger	Possible (30% - 55%)	Moderate Opp	Medium Opp	Improved understanding of the infill rate. Long term monitoring. Revision of channel alignment including consideration of South Channel.	Possible (30% - 55%)	Severe Opp	High Opp		Open	

					Without Controls				With Controls					
No.	Date Raised	Phase	Category	Risk/Opp Description	Likelihood	Consequence	Current Risk Rating	Possible Controls	Likelihood	Consequence	Target Risk Rating	Future Considerations	Status	Notes
27	10/05/2024	Construction	Dredging	Opportunity for the beneficial re-use of excess inner harbour dredge material e.g. replenishment of inner harbour beaches, rather than disposing to an offshore DMG	Possible (30% - 55%)	Minor Opp	Medium Opp		Possible (30% - 55%)	Minor Opp	Medium Opp	Suitability of the material for beneficial re-use would need to be assessed before this could be determined.	Open	
28	17/05/2023	Operational	Natural hazards	Large seismic event liquefies seabed and infills entrance and access channels resulting in no access for significant time period	Rare (<5%)	Extreme	High	Dredging equipment on standby/owned by port. Design side slopes for seismic event (Limited slope stability modelling undertaken as part of this study indicates limited movement)	Rare (<5%)	Severe	Low		Open	Limited slope stability modelling indicates limited movement - consequence likely reduces
29	17/05/2023	Operational	Natural hazards	Tsunami causes changes to access channel morphology and damage to port infrastructure	Rare (<5%)	Severe	Low	Port design to accommodate tsunami loading using recognised design standards e.g. ASCE 7 or similar. Dredging equipment on standby and owned by port	Rare (<5%)	Moderate	Low		Open	Moderate tsunami (~3m for 2500 year return period event). Effect on channel not assessed by modelling - consequence potentially lower
30	18/05/2023	Operational	Natural hazards	Terrestrial landslide infills entrance channel, blocking access for significant time period	Rare (<5%)	Moderate	Low	Dredge vessels available	Rare (<5%)	Moderate	Low	Slope stability and potential for landslip assessed at later design stages	Open	Not yet assessed but channel is naturally deep adjacent steep side-slopes
31	17/05/2023	Operational	Natural hazards	Seismic event damages port infrastructure	Rare (<5%)	Extreme	High	Design to meet code requirements	Rare (<5%)	Minor	Low		Open	
32	17/05/2023	Operational	Natural hazards	Sea level rise due to climate change increases tidal prism and tidal flows affecting channel and bar morphology	Possible (30% - 55%)	Moderate	Medium	Monitoring and increased frequency of dredging	Possible (30% - 55%)	Insignificant	Low		Open	Not specifically assessed - but potential increase likely allowed for in presented volumes in harbour
33	16/05/2023	Operational	Navigation and operability	Port cannot be used at commercially acceptable level by shipping because of unpredictable frequency and duration of downtime due to weather that causes pilotage suspension	Possible (30% - 55%)	Minor	Medium	Waiting for improved weather is the only possible control.	Possible (30% - 55%)	Insignificant	Low	We have ruled out use of helicopters for pilotage because currently container ships and some other vessel types are not suited for winch access or landing on deck.	Open	Consequence is considered minor because comparison of Manukau's weather conditions, using benchmark ports limiting criteria, show that pilot suspensions occur between once and twice a month for durations of 4 hours to 36 hours.
34	16/05/2023	Operational	Navigation and operability	Large ships (> 125m length): Port cannot be used at commercially acceptable levels because of unpredictable frequency and duration of downtime due to weather such that ships are unable to transit the entrance channel	Rare (<5%)	Minor	Low	No controls required	Rare (<5%)	Minor	Low		Open	Consequence is considered minor because our analysis shows that larger ships (>125m) do not have any weather related downtime
35	16/05/2023	Operational	Navigation and operability	Small ships (<125m length): Port cannot be used at commercially acceptable level because of unpredictable frequency and duration of downtime due to weather such that ships are unable to transit the entrance channel.	Possible (30% - 55%)	Moderate	Medium	Measures to improve weather window such as weather monitoring, DUKC, or operational limitations.	Rare (<5%)	Moderate	Low		Open	Consequence is considered moderate because our analysis shows that smaller ships (<125m) will have some weather related restrictions, but less restrictive than present bar crossings by such ships.
36	16/05/2023	Operational	Navigation and operability	Port cannot be used at commercially acceptable level by shipping through unforeseen event, marine accident related, e.g. sinking of vessel, stranding across channel	Rare (<5%)	Severe	Low	To reduce risk of stranding across channel, restrict ships that are too long to entering/ leaving with following current. Temporary by-passing of port, short term ship size restrictions, tug assist requirement, draft restrictions, daylight only	Rare (<5%)	Moderate	Low		Open	
37	16/05/2023	Operational	Navigation and operability	Insufficient space with natural depth to safely anchor within the harbour	Possible (30% - 55%)	Moderate	Medium	Designate an area outside of navigation channel, and if requried dredge to suit	Unlikely (5% - 30%)	Minor	Low		Open	
38	16/05/2023	Operational	Navigation and operability	A single bar channel oriented wrongly for navigation, e.g. quartering seas causing steering control issues or onset of parametric roll, bow seas (not head on) causing excessive roll and pitch accelerations, thus hindering conning of ship	Unlikely (5% - 30%)	Severe	Medium	Orient channel correctly (which we have done so in this study). Two bar channels. Wait for operable weather conditions	Rare (<5%)	Severe	Low	90% of wave direction is between 225 and 270 degrees, most of which is at wave heights that do not offer any risk to large vessels	Closed	This was taken account of in the design of the Entrance Channel
39	16/05/2023	Operational	Navigation and operability	A channel width smaller than the length of the largest vessel introduces the risk that the vessel can be grounded with bow and stern on opposite sides of the channel. i.e. insufficient width	Rare (<5%)	Severe	Low	Introducing operational limits e.g. restrict ships that are too long to entering/ leaving against current, widen channel, pilot training, (escort-) tug support, salvage readiness, etc.	Rare (<5%)	Moderate	Low	Look at proportion of ships less than a range of lengths, and make width to accommodate most	Open	Since risk is low it does not seem to warrant widening the channel, and operational constraints should suffice
40	16/05/2023	Operational	Navigation and operability	Excessive siltation of the entrance channel may lead to the risk of bottom touch / grounding of some vessels.	Possible (30% - 55%)	Moderate	Medium	Continuous monitoring and regular maintenance dredging. Introduce operational limits.	Unlikely (5% - 30%)	Moderate	Medium	Sand traps / overdredging of channel	Open	Likelihood increased from 'rare' to 'unlikely' (unmitigated), because of the siltation studies.
41	16/05/2023	Operational	Navigation and operability	Grounding of the vessel on the channel slope, e.g. due to human error, engine/rudder failure	Possible (30% - 55%)	Severe	High	Tug support, pilot training and monitoring, aids to navigation	Unlikely (5% - 30%)	Severe	Medium	Since risk is medium it does not seem to warrant widening the channel but could be investigated.	Open	
42	16/05/2023	Operational	Navigation and operability	Grounding of the vessel on the channel slope, e.g. due to heavy winds, strong currents	Possible (30% - 55%)	Severe	High	Tug support, pilot training and monitoring, aids to navigation	Unlikely (5% - 30%)	Severe	Medium	Since risk is medium it does not seem to warrant widening the channel but could be investigated. Fasttime simulations have shown that risk of grounding in the slopes is 'unlikely'. Further analysis using realtime simulation could be undertaken.	Open	

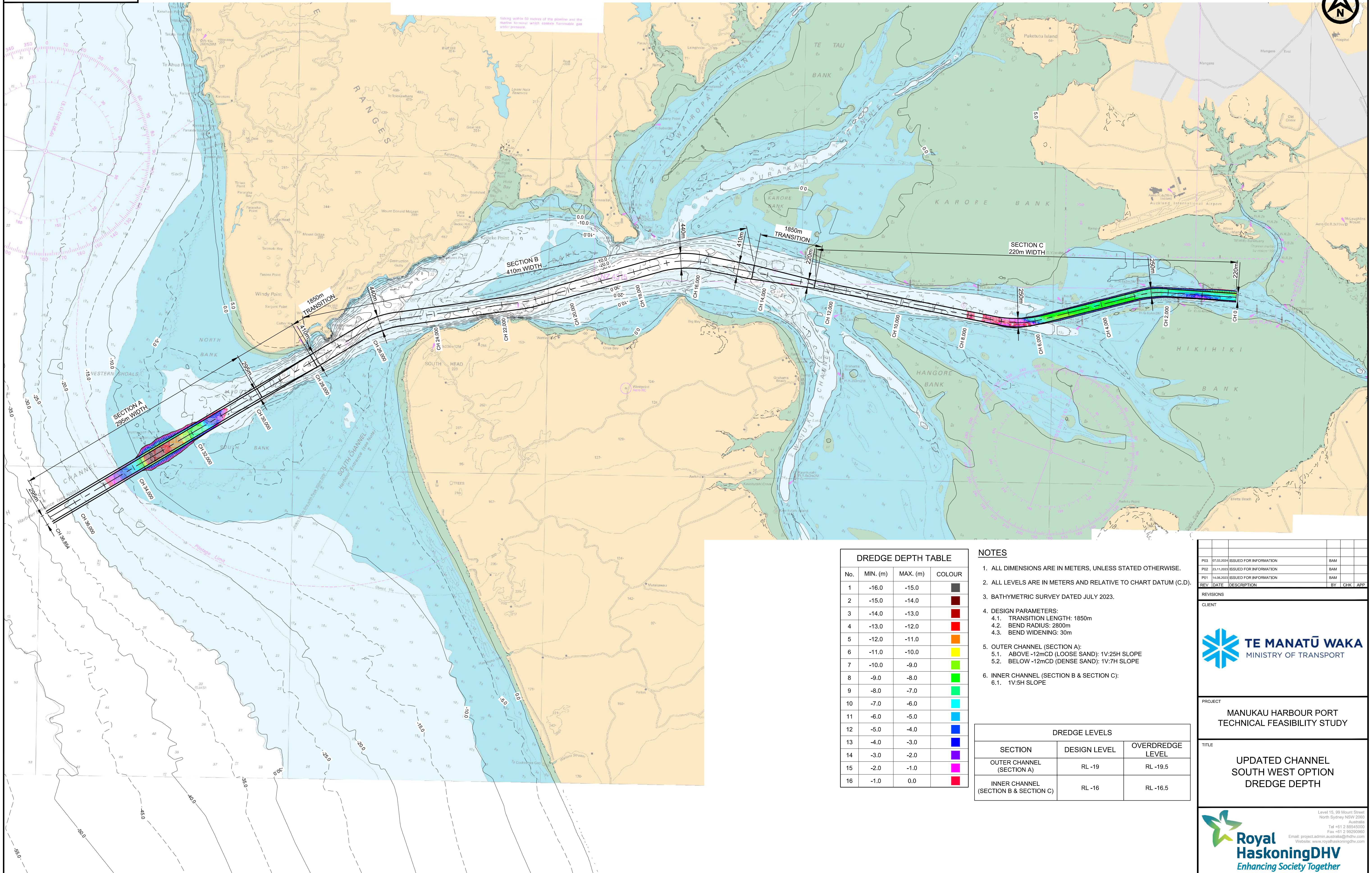
					Without Controls				With Controls					
No.	Date Raised	Phase	Category	Risk/Opp Description	Likelihood	Consequence	Current Risk Rating	Possible Controls	Likelihood	Consequence	Target Risk Rating	Future Considerations	Status	Notes
43	16/05/2023	Operational	Navigation and operability	One-lane traffic may cause delays / congestion / collisions depending on traffic volumes	Possible (30% - 55%)	Minor	Medium	Traffic management and holding/waiting areas in Section B (where more natural water depth is available). It may also be necessary to dredge these holding/waiting areas.	Unlikely (5% - 30%)	Minor	Low	Possibly more traffic congestion expected towards 2079 (4,000 ship pa). 2-way channel may be considered in the second half of 21st century.	Open	
44	16/05/2023	Operational	Navigation and operability	Interference of (maintenance) dredger with commercial traffic potentially leading to delay / congestion / collisions.	Possible (30% - 55%)	Minor	Medium	Port restrictions during maintenance dredging and clear operating procedures.	Unlikely (5% - 30%)	Minor	Low	None	Open	
45	12/02/2024	Operational	Navigation and operability	Loss of Aids to Navigation (ATON) due to severe weather conditions	Possible (30% - 55%)	Minor	Medium	Backup of vitual AIS aids to navigation, Remote monitoring of ATON and have spares available	Possible (30% - 55%)	Insignificant	Low	Virtual AtoNs may become the norm	Open	
46	16/05/2023	Operational	Navigation and operability	Existing users are confronted with a new traffic situation leading to the risk of collision with the new traffic.	Possible (30% - 55%)	Minor	Medium	Create awareness, standard operating procedures	Unlikely (5% - 30%)	Minor	Low	None	Open	
47	15/02/2024	Pre-Construction	Navigation and operability	Opportunity - to reduce cross sectional dimensions of dredged channels	Possible (30% - 55%)	Severe Opp	Critical Opp	Through consideration of use of tidal window, optimisation of channel dimensions using real time simulation and more underkeel clearance investigation, side slope steepness investigations	Possible (30% - 55%)	Severe Opp	Critical Opp	All the possible controls require further investigation	Open	
48	15/02/2024	Pre-Construction	Navigation and operability	Opportunity - to reduce inner harbour dredged channel length when making port location selection	Possible (30% - 55%)	Extreme Opp	Critical Opp	Site constraint, financial and hinterland connection considerations when assessing port location options	Possible (30% - 55%)	Extreme Opp	Critical Opp	All the possible controls require further investigation	Open	
49	17/05/2023	Operational	Navigation and operability	Increased wind/wave action from SW due to climate change (wave height +5%) increases downtime for vessel access	Possible (30% - 55%)	Minor	Medium	Increase depth of channel, reduce tide range operability (i.e. limit low tide access for larger vessels	Possible (30% - 55%)	Minor	Medium		Open	
50	16/05/2023	Operational	Port development	Suitable locations to site a port terminal in the harbour are restricted due to existing site constraints leading to poor access to hinterland connections impacting port economics/functionality	Possible (30% - 55%)	Severe	High	Careful site selection will be required to balance the needs of the port within the site constraints (which has not been undertaken as part of this study)	Possible (30% - 55%)	Moderate	Medium	Further study in future design stages to evaluate port locations and hinterland connections	Open	Site constraints not fully understood, may require negotiation with existing operations/facilities and stakeholders within the harbour
51	17/05/2023	Construction	Port development	Lack of suitable reclamation material from dredging leading to use of consolidation prone port development necessitating longer term duration staging of the port operational area.	Possible (30% - 55%)	Moderate	Medium	Ground treatment, such as dynamic compaction. Use of capital dredge material from the entrance channel (which has good geotechnical properties). Importing of material to form the reclamation.	Unlikely (5% - 30%)	Minor	Low	Assuming reclamation material is derived from the inner harbour dredge material then the port location within the harbour will dictate the material available for this. This remains open for future stages of project.	Open	
52	17/05/2023	Construction	Port development	Lack of availability of suitable rock armour for marine structures around the port	Likely (55% - 85%)	Moderate	High	Alternative solutions e.g. concrete armour	Unlikely (5% - 30%)	Minor	Low		Open	
53	16/05/2023	Pre-Construction	Port development	Ship height, shore crane height, funnel fumes, updrafts off superstructure leading to encroachment of vessels into obstacle limitation surface (OLS) of the Auckland Airport, jeopardizing safety of both aircraft and visiting vessels, resulting in site selected being rejected by Civil Aviation Authority	Possible (30% - 55%)	Severe	High	Locate port outside the airport OLS for which potential sites exist (but their merits have not been evaluated). Seek exemption through a risk assessment. Set operational limits. Limit crane heights.	Possible (30% - 55%)	Moderate	Medium	An aeronautical study would be requried to analyse any breach to the OLS. This would need Civil Aviation Authority approval.	Open	If outside the OLS then residual risk is low, but if exemption required them the ability to achieve this is currently unknown therefore residual risk higher
54	16/05/2023	Operational	Shipping	Marine traffic higher than expected/forecast, creates unacceptable delays to entry and exit.	Possible (30% - 55%)	Minor	Medium	Traffic management and holding/waiting areas in Section B (where more natural water depth is available). Convert channels to two-way, earlier expansion of port facilities.	Unlikely (5% - 30%)	Minor	Low	At future stages of design the port vision/strategic plan and functional requirements will need to be set so that detailed marine traffic forecasting can take place to reduce this risk.	Open	
55	16/05/2023	Operational	Shipping	Ships with deeper draft or longer/ wider dimensions than the design ships become regular callers, leading to congestion or inefficiencies.	Possible (30% - 55%)	Minor	Medium	Operational limitations such as work ships on the top of the tide, await better conditions, use of tugs. Deepening or widening the channel dimensions.	Possible (30% - 55%)	Minor	Medium	At future stages of design the port vision/strategic plan and functional requirements will need to be set so that cargo throughputs and design vessels can be better defined. Phased port development would also help to mitigate ship size increases.	Open	
56	28/07/2023	Operational	Shipping	Ships and cargo unable to be insured because of risk of ships entering, transiting and leaving harbour	Rare (<5%)	Severe	Low	Authoritative insurance industry view is that if the port has been certified safe [by the appropriate Authority, e.g., MNZ)] it is unlikely there would be any issue from a P&I or hull & machinery cover perspective. It would be the same as any other port. Therefore, no control required.	Rare (<5%)	Severe	Low		Closed	

Appendix B Concept navigation channel

- **Concept navigation channel (South-West)**

DRAWING No.
PA3148-RHD-00-XX-DR-ME-0112

DO NOT SCALE



DREDGE DEPTH TABLE

No.	MIN. (m)	MAX. (m)	COLOUR
1	-16.0	-15.0	
2	-15.0	-14.0	
3	-14.0	-13.0	
4	-13.0	-12.0	
5	-12.0	-11.0	
6	-11.0	-10.0	
7	-10.0	-9.0	
8	-9.0	-8.0	
9	-8.0	-7.0	
10	-7.0	-6.0	
11	-6.0	-5.0	
12	-5.0	-4.0	
13	-4.0	-3.0	
14	-3.0	-2.0	
15	-2.0	-1.0	
16	-1.0	0.0	

NOTES

1. ALL DIMENSIONS ARE IN METERS, UNLESS STATED OTHERWISE.
2. ALL LEVELS ARE IN METERS AND RELATIVE TO CHART DATUM (C.D).
3. BATHYMETRIC SURVEY DATED JULY 2023.
4. DESIGN PARAMETERS:
   - 4.1. TRANSITION LENGTH: 1850m
   - 4.2. BEND RADIUS: 2800m
   - 4.3. BEND WIDENING: 30m
5. OUTER CHANNEL (SECTION A):
   - 5.1. ABOVE -12mCD (LOOSE SAND): 1V:25H SLOPE
   - 5.2. BELOW -12mCD (DENSE SAND): 1V:7H SLOPE
6. INNER CHANNEL (SECTION B & SECTION C):
   - 6.1. 1V:5H SLOPE

DREDGE LEVELS

SECTION	DESIGN LEVEL	OVERDREDGE LEVEL
OUTER CHANNEL (SECTION A)	RL -19	RL -19.5
INNER CHANNEL (SECTION B & SECTION C)	RL -16	RL -16.5

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	07.02.2024	ISSUED FOR INFORMATION	BAM		
P02	23.11.2023	ISSUED FOR INFORMATION	BAM		
P01	14.08.2023	ISSUED FOR INFORMATION	BAM		

REVISIONS

CLIENT

TE MANATŪ WAKA
MINISTRY OF TRANSPORT

PROJECT

MANUKAU HARBOUR PORT
TECHNICAL FEASIBILITY STUDY

TITLE

UPDATED CHANNEL
SOUTH WEST OPTION
DREDGE DEPTH

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Enhancing Society Together
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DRAWN	COORD. SYSTEM	DATUM	DATE
BAM	NZTM2000	CHART DATUM	07.02.2024

SCALE	REF.
AS SHOWN	PA3148-RHD-00-00-M3-UPDATED CHANNEL [P03]

DRAWING No.	SUITABILITY	REVISION
PA3148-RHD-00-XX-DR-ME-0112	S2	P03

CHART DATUM

NOT FOR CONSTRUCTION

S0 WORK IN PROGRESS

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