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Analysis Report

Point Nepean Kingfish Reef
Total Hydrographic

Reference V21-005-R001
Revision B
Date 25 June 2021

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1 Introduction

1.1 The Project

The Victoria Fisheries Authority (VFA) is assessing the suitability of a site in Port Phillip Bay for the placement of artificial fish aggregation structures. Similar structures have been previously installed offshore of Torquay (Victoria), Newcastle (New South Wales) and more recently in a number of locations around Western Australia and the Northern Territory. The intention of these structures is to enhance the aggregation of Yellowtail Kingfish (*Seriola lalandi*). Kingfish principally feed on small fishes such as yellowtail scad (*Trachurus novaezelandiae*), blue makerel (*Scomber australasicus*) and other schooling species. Furthermore, Kingfish are known to prefer areas of high or eddying currents, as well as areas where waves break such as on islands or shores with steep slopes.

The proposed project location is in southern Port Phillip Bay, between Point Nepean and the township of Portsea (38° 17’58”S, 144°40’36.5”E, Figure 1). This site is at the eastern terminus of an arm of the Entrance Canyon in a bowl-shaped depression.

1.2 Scope of Services

FSC Range were engaged by Total Hydrographic to:

- describe the tidal flow characteristics at the site for a 12-month period as well as specifically for October 2021,
- estimate the annual sediment transport quantities and direction of transport at the site, and
- provide an assessment of the geometric size as well as the speed and direction of sand wave movements at the site.

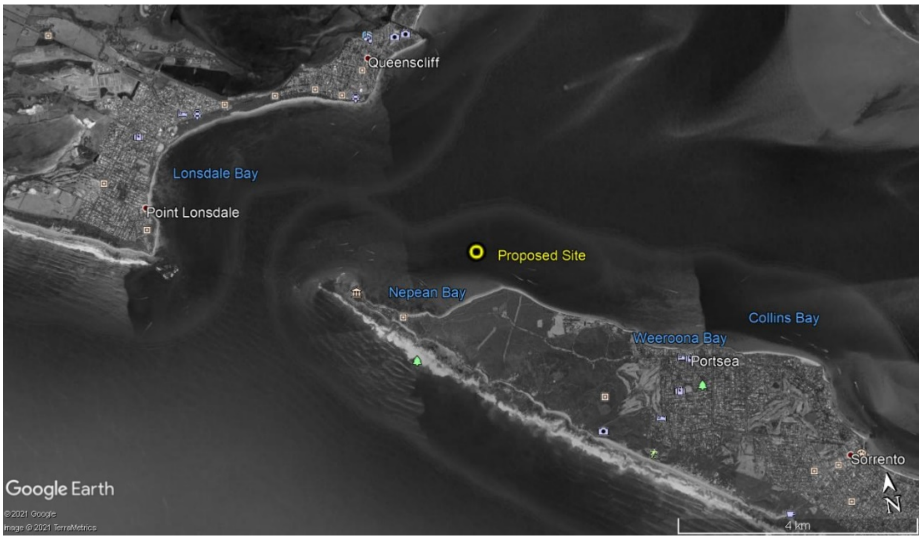

Figure 1 – Location of the proposed site within Port Phillip Bay.

1.3 KEY RESULTS

Tidal Currents

- The tidal elevation range at the site is estimated to be 1.1 m and lags the tide offshore of the heads by approximately 10 min.
- The estimated maximum tidal current at the site range during flood (rising) tide is 0.8 m s^{-1} and 1.2 m s^{-1} during ebb (falling) tide.
- The tidal currents are estimated to be predominantly directed parallel with the South Channel during both flood and ebb tide.
- An eddy forms to the south of the site that results in the generation of tidal currents towards the entrance during flood tide.

Sediment Transport

- The net sediment transport rate in this region due to tidal currents is estimated to be 500 – 5000 $m^3\ m^{-1}\ yr^{-1}$. The transport rate may be enhanced by waves in some areas.
- The sediment transport rate cannot be verified due to the lack of calibration data and the actual value could vary by up to one to two orders of magnitude.
- The sediment is predominantly transported from East to West at the site, following the ebb tidal current flows.

Sand Waves

- Sand waves were observed in the survey data in this region but were not observed within the depression. Smaller ripple-type bed features were observed within the depression.
- The sand waves have an average height of 2.1 m and length of 68.9 m.
- The sand waves appear to be propagating to the west, consistent with the ebb tidal flow direction.
- The migration rate of these sand waves is estimated to be 1 – 10 m yr^{-1}. These values are consistent with published migration rates for sand waves of these dimensions.

2 Methods

2.1 Numerical Model

To estimate the currents, sediment transport and sand wave geometry at the proposed site, we used our Port Phillip Bay Tidal Forecast Model. The flexible mesh numerical model has been specifically developed to describe the complex entrance configuration at Port Phillip Heads, the configuration of the canyon in that region, and the shape of the coastline around Port Phillip Bay as well as the Victorian offshore coastline (Figure 2). The model is highly refined around the entrance to Port Phillip Bay to capture the complex canyon bathymetry in this region of the bay as well as through the bay's entrance (Figure 3). Technical details of the numerical model are described in Appendix A. The numerical model was forced using the TPXO8 atlas, which was applied along the southern boundary that extends in our model from Cape Otway in the west to Cape Liptrap in the east.

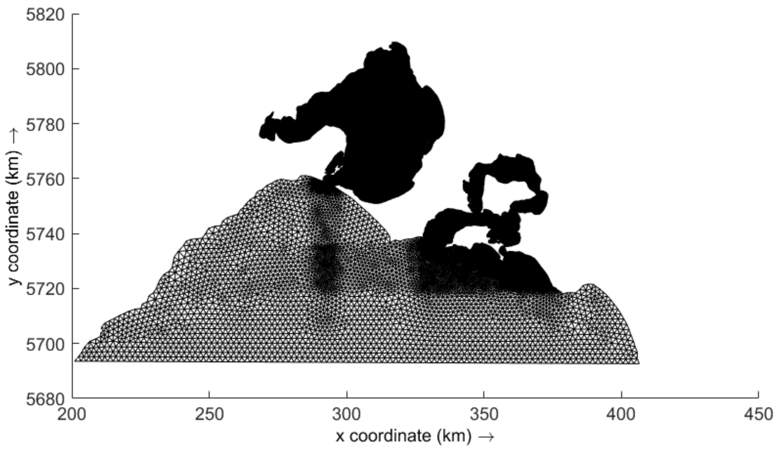

Figure 2 – Port Phillip Bay Tidal Forecast Model interpolated bathymetry.
The numerical model extends from Cape Otway in the West to Cape Liptrap in the East.

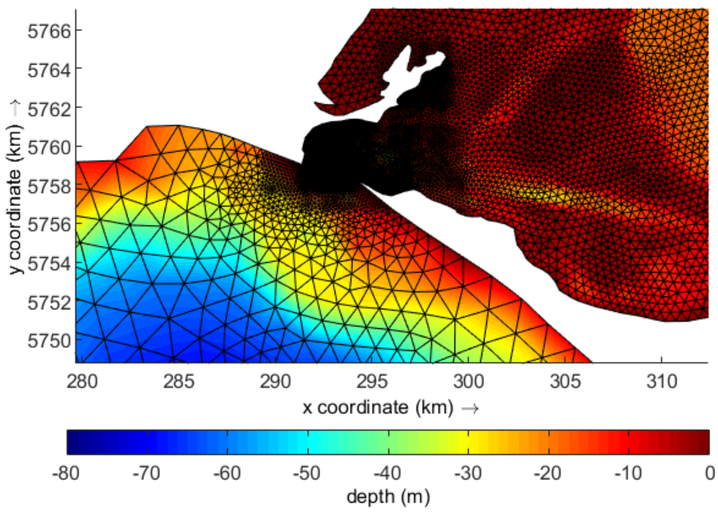

Figure 3 – Port Phillip Bay Tidal Forecast Model mesh and bathymetry.
The mesh and bathymetry is shown for around the entrance to Port Phillip Bay and region where the proposed site is located.

2.1 TIDEL ELEVATION, SPEED AND DIRECTIONS

We simulated the tidal currents for two periods:

- For the period 01-01-2021 to 31-12-2021
- For the month of October 2021

We used the data from the year-long simulation period to estimate the tidal elevation range, speed and direction. The shorter simulation period was used to estimate the conditions during the period when the reef is expected to be installed.

Maximum and Minimum Speed and Direction

The maximum and minimum tidal current speed and direction, as well as the duration of slack water, were quantified based on the numerically derived tidal currents at the site.

Tidal Forecast for October 2021

We extracted the tidal forecast at the site for the month of October 2021 from our numerical model simulation. Our forecast is referenced to the geographic center of the depression, where the structures are intended to be installed.

2.2 ESTIMATED SEDIMENT TRANSPORT

The sediment transport rates in the region were assessed based on the sediment transport formulae proposed by van Rijn (1993) and van Rijn (2000), and applied to the tidal hydrodynamic model results. As there is no field data that has been specifically collected at the site for this project, we use sediment data that has been collected in other studies (Table 1) to define the sediment grain size parameters in the sediment transport formulae. We used D_{50} = 350 µm.

To estimate the time and spatially averaged sediment transport rate at the site, we simulated the transport that occurred during one lunar cycle, and then scaled that result to determine an annual rate. We used the same approach to determine the time-averaged transport direction.

Table 1 – Sediment data from other studies that have been conducted in the region.

D_{50} [µm]	Standard Deviation [µm]	Samples [-]	Location	Reference
351	94	19	Observation Bank and surrounds	(Nielsen & Williams, 2016) (Nielsen & Williams, 2017)
391	173	9	South Channel	(Cardno, 2011) cited by De Koning (2017)
125 - 500	Unknown	13	Great Sands	Port of Melbourne Corporation cited by De Koning (2017)
Silty Sand	-	-	Near site	(Beasley, 1966)
Fine Sand	-	-	Near site	(Holdgate, Geurin, Wallace, & Gallagher, 2001)

2.3 Sand Wave Geometry

Multi-beam bathymetry indicated that sand ripples and sand wave features are present at the site (Figure 4). A distinct ledge around the margin of the depression is also present. To quantify the sand wave geometry nearby the site, we constructed a Triangulated Irregular Network and then interpolated the multi-beam survey data that was collected by Total Hydrographic onto that network. We then extracted three transects from this interpolated bathymetry (Figure 4). The transect data was analysed to define the sand wave height, length, and non-linearity.

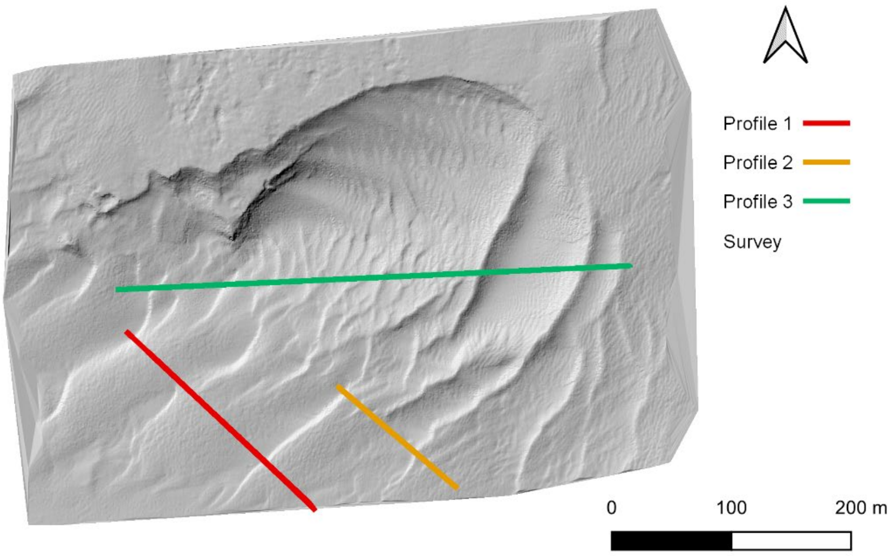

Figure 4 – Interpolated multibeam survey with the three transects indicated.
The multi-beam survey data was provided by Total Hydrographic and was acquired in 2021.

To estimate the migration speed of the observed sand waves, we used the prediction model proposed by Knaapen (2005). We discuss the limitations of this model later.

3 Results

3.1 Tidal Current Speed and Direction

Due to the large area of Port Phillip Bay and the narrow entrance with complex bathymetry, very strong tidal currents are generated. The deep canyon in this area is bounded by Rip Bank, and curves around the relatively shallow Nepean Bank. Currents measured on Nepean and Rip Bank can be up to ~2.3 m s^{-1} (Provis, 1997), while currents >3.5 m s^{-1} have been measured within The Rip (Provis & McCowan, 1999). To the north of the site, the South Channel extends somewhat parallel to the shoreline. Currents of 0.5-0.8 m s^{-1} have been measured in this channel (Prytz & Heron, 1999; Walker, 1999).

The results from our numerical model study indicate that the magnitude of the tidal currents and the flow patterns differ during flood and ebb tide. During flood tide, currents increase in magnitude as they enter Port Phillip Bay and, due to the arrangement of the coastline and the bathymetry, are directed along the South Channel (Figure 5). A region of relatively lower currents exists on the southern side of the channel because of this deflection. An eddy also develops on this side of the channel, which results in the currents closer to the coastline being directed towards the entrance. This eddy has been observed in other numerical model studies. Our numerical results suggest that at the location of the site, the currents are still relatively large and during the peak flood tide can be as large as 0.8 m s^{-1}. Our simulations suggest that this

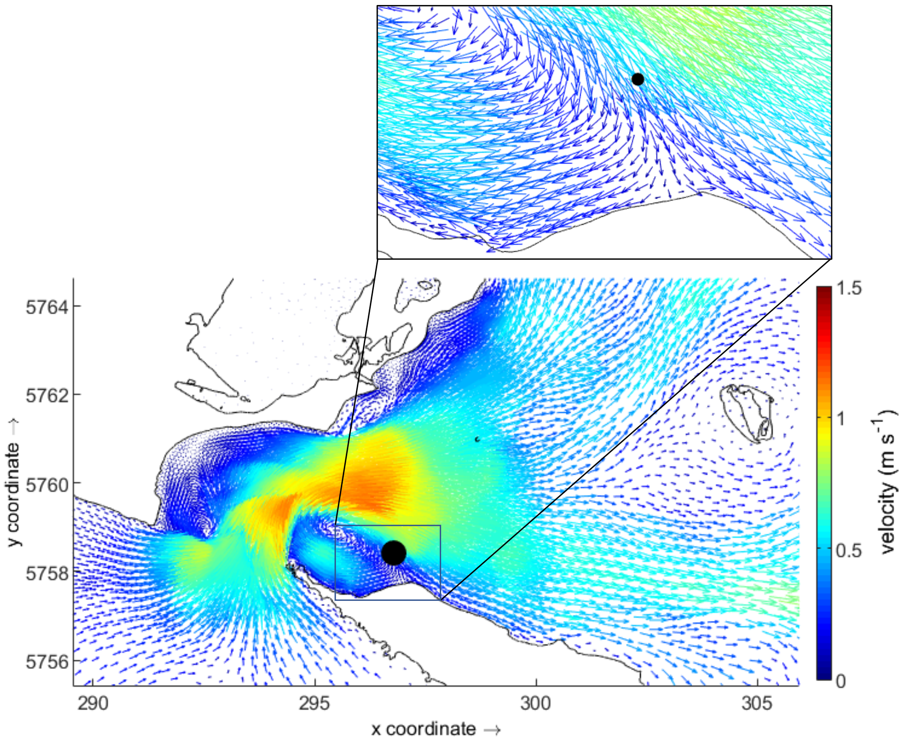

Figure 5 – Example flood tide current magnitude and direction.
The tidal currents are high through the entrance to the bay but decrease in magnitude as they propagate through the channels and the bay more generally. An eddy can develop near the site (indicated by the black dot). The site is typically located on the edge of this eddy.

eddy migrates into Port Phillip Bay during the flood tide, but does not appear to cross the proposed site in a way that changes the direction of the currents.

During ebb tide, strong offshore currents can develop around the southern portion of Port Phillip Bay as the bay drains (Figure 6). During this phase of the tide, the currents are directed towards the entrance of the bay. The currents throughout the region are generally larger than those observed during flood tide. Our numerical results suggest that at the location of the site, the ebb tide currents are larger in magnitude (up to 1.2 m s^{-1}) than the currents observed during flood tide. Both the flood and ebb tide currents predicted in our numerical modelling are consistent with other studies that have included this region (Nielsen & Williams, 2016).

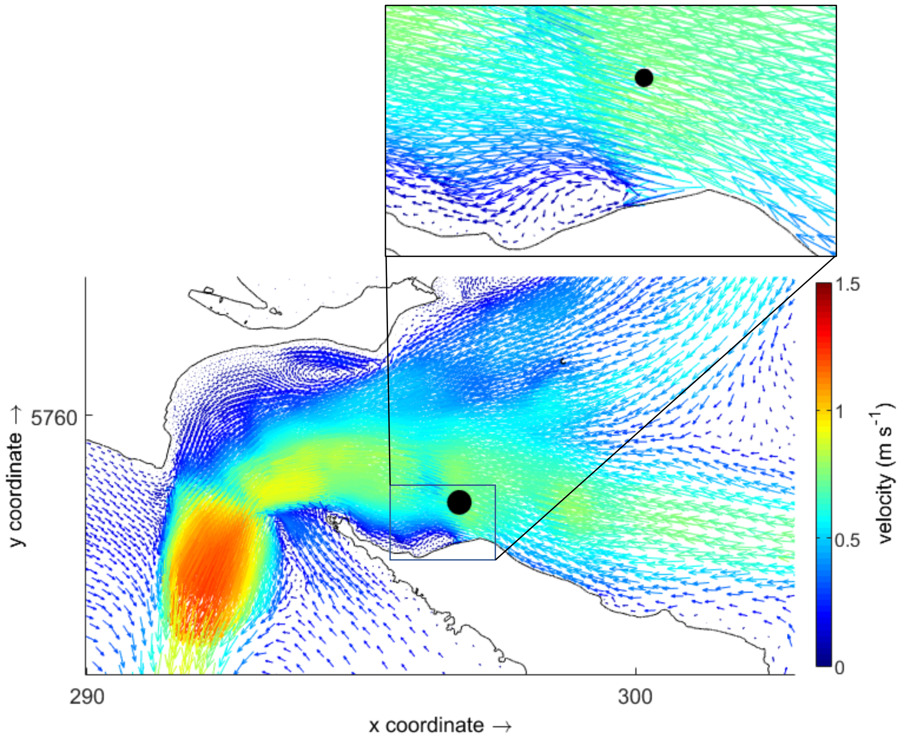

Figure 6 – Example ebb tide current magnitude and direction.
The tidal currents are high through the entrance while within the bay lower velocity currents clearly stream via the channels. At the site (indicated by the black dot) the currents are directed towards the entrance and are similar in magnitude to those observed within the channels.

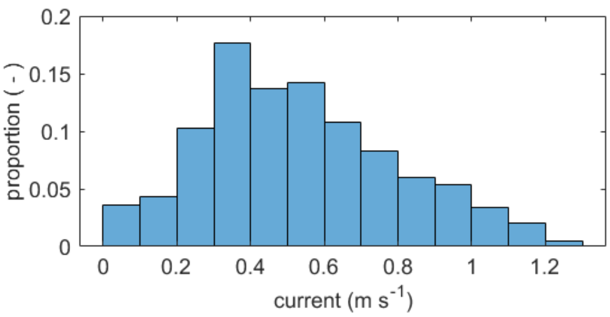

Figure 7 – Histogram of 30 min current magnitudes at the site.
Approximately 60% of the time the currents are within the range of 0.2 and 0.7 m s^{-1}. The maximum currents higher than 1.2 m s^{-1} are estimated to only occur <5% of the time.

3.1 Tidal Elevations

A comprehensive study undertaken by Provis (1997) demonstrated that the tidal range within the bay rapidly reduces away from the entrance. Indeed, a very large reduction in the M2 (~65%) and K1 (~50%) tidal constituents already occurs between Rip Bank and Queenscliff (a distance of 5.4 km). Along the South Channel, the tidal amplitude continues to decrease towards Hovell Pile, and both the M2 and K1 constituents lag those observed at Rip Bank (M2 by ~97° and K1 by ~74°). Our numerical results indicate that at the site, the tidal range is approximately 1.1 m and that the tide at this location lags that offshore at Rip Bank by approximately 10 minutes. We note that to further constrain these predictions, instrumentation would need to be deployed at the site.

3.1 Tidal Forecast for October 2021

This section has been left blank and will be updated to include the month requested by VFA.

3.2 Sediment Transport

The most comprehensive assessment of the bed sediment characteristics was undertaken by Beasley (1966). This assessment has been supplemented by several targeted studies within specific projects over time. The most relevant recent study that was that by (Nielsen & Williams, 2016), who quantified the sediment characteristics and transport rates near Portsea. We note that the location of the proposed site is beyond the domain reported in that study and is located closer to the entrance to Port Phillip Bay.

Our results suggest that the net bed load transport (Figure 8) is an order of magnitude smaller than net suspended load transport (Figure 9). For both transport regimes, the site is subjected to relatively lower sediment transport than other areas nearby. The time-averaged direction of transport is similar for both regimes; the sediment is transported towards the entrance. This transport direction is consistent with the ebb flow tidal current direction. Our results are consistent with those presented by Provis & Mohal (2011), although we note that in that study the estimated magnitude of the sediment transported was not reported.

The net estimated annual rate of tidally driven sediment transport in the region where the structures are proposed is approximately 500 – 5000 $m^3\ m^{-1}\ yr^{-1}$; based on a sediment grain size (D_{50}) of 350 μm. Within the depression, the rate of sediment transport is smaller. We note that there is considerable uncertainty around these values and that these estimates do not account for sediment transport that is enhanced by waves, which may also make a contribution to the total sediment transported in this region.

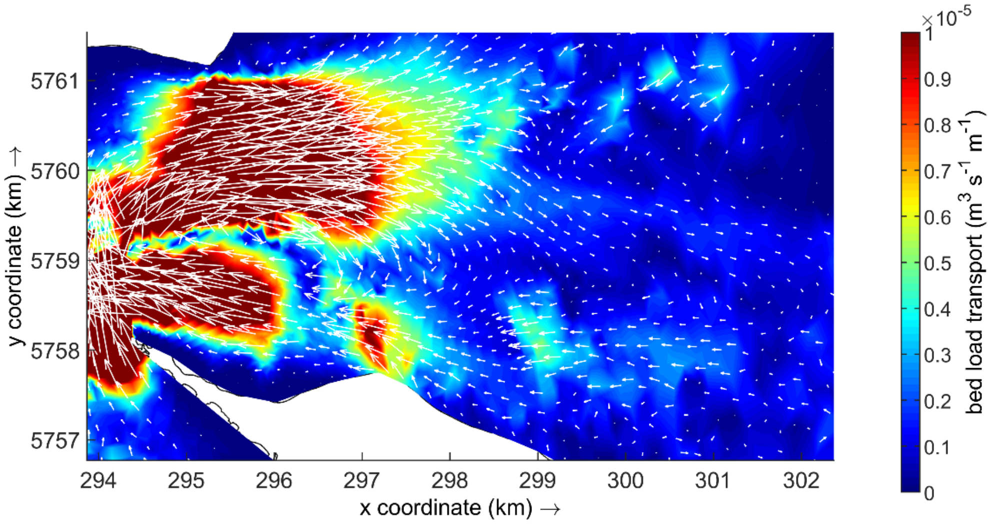

Figure 8 – Time averaged bed load sediment transport.
The bed load sediment transport is relatively lower in the region nearby the proposed site when compared to other locations in the south of Port Phillip Bay. The sediment tends to be directed towards the entrance at this site, reflecting the typical ebb flow current directions.

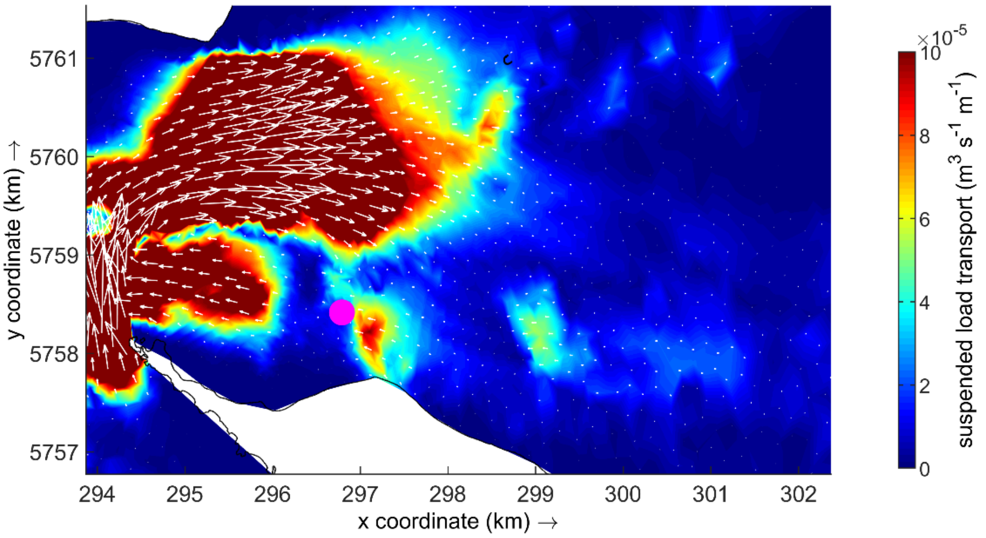

Figure 9 – Time averaged suspended load sediment transport.
The suspended load sediment transport is relatively lower in the region nearby the proposed site. The sediment tends to be directed towards the entrance at this site. The purple dot indicates the location of the proposed site.

3.3 SAND WAVES

The tendency for sand waves to form at a given location depends on the water depth, tidal flow magnitude and the sediment grain size. The sand wave growth regime model proposed by Hulscher (1996), that was extended Borsje et al (2009), was adapted and has been applied to Port Phillip Bay by De Koning (2017). That study indicates that at the proposed site, the water depth, tidal flow magnitude and sediment grain size are conducive to the development of sand waves (De Koning, van Thiel de Vries, & Borsje, 2018). Our analysis of three transects (Figure 10) and four waves reveals that in this region the average sand wave height is 2.1 m (σ=0.2 m), length is 68.9 m (σ=15.7 m) and nonlinearity is 0.6 (σ=0.06). These results are consistent with the geometric properties of other sand waves that have been measured in southern Port Phillip Bay (De Koning R. , 2017), although we note that most of these waves were measured from sequential surveys within the South Channel.

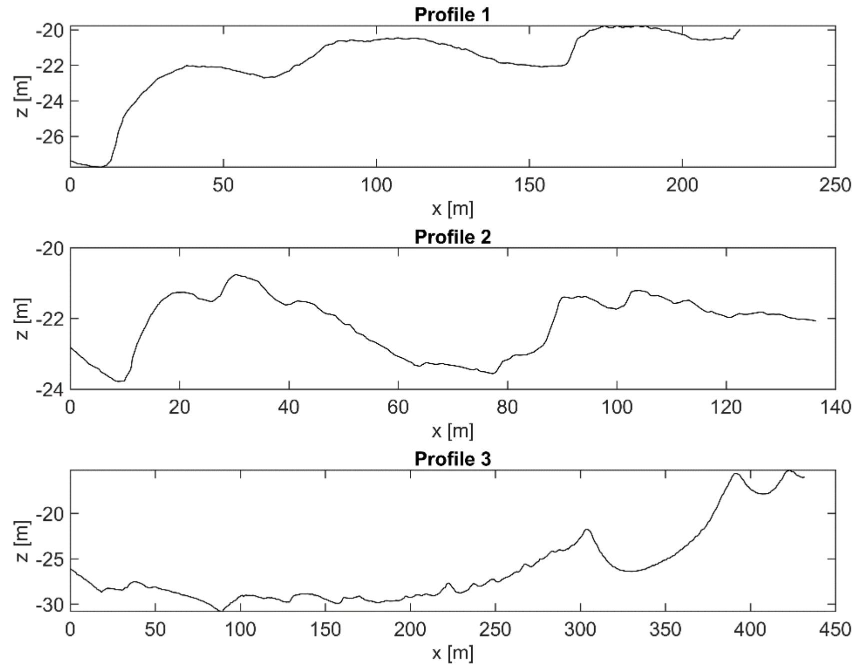

Figure 10 – Transect profiles from multi-beam survey.
Three transect profiles extracted from the multi-beam survey, which indicate the presence of sand waves in the region of the site.

The migration rate of the sand waves in this region is less certain. In the South Channel, sand waves have been suggested to migrate at a rate of >10 m yr^{-1} (De Koning R. , 2017). This rate appears to have been estimated by differencing successive bathymetric datasets. In the region where the site is located, which is typically characterised by lower tidal currents, we estimate the migration rate of the sand waves to be ~1 m yr^{-1}. We note that considerable uncertainty with respect to this estimate, as the estimation methodology used in this study has only been calibrated against the sand wave data collected in the North Sea. Its applicability to Port Phillip Bay is unknown and cannot be verified without the acquisition of considerably more data. Analysis of the geometric form of these sand waves indicates that these waves are propagating in the direction of the ebb tidal currents, which is consistent with the general scientific understanding of this migration process (Besio, et al., 2008).

4 Gaps

- It is well known that this area of Port Phillip Bay is bathymetric and hydrodynamically complex. The absence of high-quality data is a key limitation at this location, and consequently it is not possible to validate the results of this numerical assessment.

- Numerical modelling of sediment transport can be orders of magnitude different from the actual quantities measured. For the next study of this nature, we recommend the deployment of a measurement package at a proposed site to obtain actual currents, water elevation and sediment transport data. FSC Range can provide further information on cost effective options.

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Appendix A – Numerical Model Technical Attachment

Technical Attachment

Document Control Record			
Project	Point Nepean Kingfish Reef		
Project number	V21-005	**Date**	25/06/2021
Subject	Numerical Model of Port Phillip Bay	**Reference**	TECH-001
Client	Total Hydrographic		
Client Contact	Tim Williams	**Range Contact**	Andrew Pomeroy
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Overview

This Technical Attachment details the assembly methodology, parameter choices and validation of the numerical model used in this project. A detailed description of the numerical model physics and how they are implemented is not discussed and the reader is instead referred to the technical documentation for the numerical model platform (Deltares, 2020).

Data Sources

The data sources used in this project are:

- Victorian Coastline (2008)
- Victorian Coastal Nearshore Bathymetry 20m resolution DEM 5m Contours (2008 to 2009)
- Total Hydrographic multibeam bathymetry of the proposed project site (2021)
- Port Phillip Bay Depth Contours at 1:25,000 (1971 to 2000)
- Western Port Depth Contours at 1:25,000 (1974 to 2000)
- Bass Strait Depth Zone Contour Lines at 1:250,000 (1995)
- TPXO8-atlas (Egbert and Svetlana, 2002)

Validation

The numerical model was validated against tide gauge data or predictions at:

- Fawkner Beacon, Port Phillip Bay
- Hovell Pile
- Queenscliff Jetty
- Breakwater Pier
- Point Lonsdale
- Lorne Jetty

Parameters

The key parameters used in the numerical model are summarised in the following tables:

Table 1 – Numerical model platform

Parameter	Value	Description
Program	D-Flow FM	Numerical model platform used
Version	1.2.105.67088M	Version number of computational kernel
fileVersion	1.09	File format version
Coordinate System	GDA94 – MGA55	Horizontal Coordinate system
Reference Plane	Mean Sea Level	Vertical Reference plane

Table 2 – Model geometry

Parameter	Value	Description
Network	FM	Mesh network type
Mesh cell size	Varies	• 1000 m offshore • 500 m offshore coastline • 250 m Port Phillip Bay coastline • 50 m Port Phillip Heads
WaterLevIni	0	Initial water level at missing values
BedlevUni	-5	Uniform bed level used at missing z values
Blmeanbelow	-999	Below this level the cell center bed level is the mean of surrounding net nodes
Blminabove	-999	Above this level the cell center bed level is the minimum of the surrounding net nodes
AngLat	No Coriolis	Angle of latitude S-N (deg),
AngLon	No solar heat flux	Angle of longitude E-W (deg)

Table 3 – Simulated Processes

Parameter	Value	Description
Sediment	Yes	Sediment transport was estimated for one lunar cycle
Vegetation	Not Used	
Wind	Not Used	
Ground Water	Not Used	
Hydrology	Not Used	
Flow	Yes	Tidal currents are simulated
Waves	Not Used	

Table 4 – Time Parameters

Parameter	Value	Description
RefDate	20210101	Reference date (yyyymmdd)
Tzone	0	Time zone assigned to input time series
DtUser	300	Time interval (s) for external forcing update
DtNodal	21600	Time interval (s) for updating nodal factors in astronomical boundary conditions
DtMax	30	Maximal computation timestep (s)
Dtfacmax	1.1	Max timestep increase factor ( )

DtInit	1	Initial computation timestep (s)
Timestepanalysis	No	Save data for time step analysis
Autotimestepvisc	No	Time limitation based on explicit diffusive term
AutoTimestepNoStruct	No	Exclude structure links (and neighbours) from time step limitation
AutoTimestepNoQout	Yes	Exclude negative qin terms from time step limitation
TStart	0	Start time
TStop	31536000	Stop time
UpdateRoughnessInterval	86400	
RestartFile	No	Is a restart file used
RestartDateTime	N/A	Restart date and time (yyyymmddhhmmss)

Table 5 – Physics Parameters

Parameter	Value	Description
UnifFrictCoef	2.3d-2	Uniform friction coefficient
UnifFrictType	Manning	Uniform friction type
Vicouv	0.1	Uniform horizontal eddy viscosity (m2/s)
Dicouv	0.1	Uniform horizontal eddy diffusivity (m2/s)
Vicoww	5.d-5	Uniform vertical eddy viscosity (m2/s)
Dicoww	5.d-5	Uniform vertical eddy diffusivity (m2/s)
Vicwminb	0	Minimum viscosity in production and buoyancy term (m2/s)
Xlozmidov	0	Ozmidov length scale (m)
Smagorinsky	0.2	Smagorinsky factor in horizontal turbulence
wall_ks	Free slip	Wall roughness type
Rhomean	1026	Average water density (kg/m3)
Idensform	Uniform	Density calculation
Ag	9.813	Gravitational acceleration
TidalForcing	No	Tidal forcing

Table 6 – Key Numerics

Parameter	Value	Description
CFLMax	0.7	Maximum Courant number
TimeStepType	Full implicit step-reduce	Time step handling
maxNonlinearIterations	100	Maximal iterations in non-linear iteration loop before a time step reduction is applied
Limtyphu	None	Limiter type for waterdepth in continuity equation
Limtypmom	Monotone Central	Limiter type for cell center advection velocity
Tlfsmo	3600	Fourier smoothing time (s) on water level boundaries
Turbulencemodel	k-epsilon	Turbulence model
Turbulenceadvection	horizontally explicit and vertically implicit	Turbulence advection

Epshu	1.d-4	Threshold water depth for wet and dry cells
jaupwindsrc	1st-order	Upwind advection at sources/sinks

Table 7 – External Forcing

Parameter	Value	Description
Water Level	TPXO8	Water level (astronomic tide)
Waves	No	Waves
Rainfall	No	Rainfall
QExt	No	User Qin/out
Evaporation	No	Evaporation in water balance,
WindExt	No	Wind

Table 8 – Output

Parameter	Value	Description
HisInterval	1800	History times
MapInterval	3600	Map times

References

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