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Environmental Monitoring and Management Plan

LPC Channel Deepening Project: Stage 1

Lyttelton Port Company
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Lyttelton Port Company

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Definitions

Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata: includes the waters off Northern Banks Peninsula in Pegasus Bay

Baseline Monitoring Period: 12-month period of monitoring undertaken over 1 November 2016 – 31 October 2017

Dredging: encompasses all dredging and disposal activities

Consent Authority: Canterbury Regional Council

Consent Holder: Lyttelton Port Company

Authorised Marine Farmers: means any marine farm that, as at the date this consent is first exercised, exists or which holds an existing but unimplemented resource consent.

Extraordinary natural event: a significant and self-evident natural event that has clearly caused an Exceedance of the Tier-3 trigger at one or more of the turbidity monitoring stations. The high-concentration turbidity plumes could have been generated from a tsunami, a weather event causing significant flooding, extreme off-shore swells, or a land slip.

Project Website: www.lpcharbourwatch.co.nz – contains a summary of the real-time turbidity monitoring data, monitoring reports, environmental management plans, trigger reports and other information as required under the Consent Conditions.

The Consents: refers to CRC172455 and CRC172522

Abbreviations

ADCP: Acoustic Doppler current profiler

ADP: Accidental Discovery Protocol

ALG: Aquaculture Liaison Group

BHD: Back Hoe Dredge

BMP: Biosecurity Management Plan

CHPT: Consent Holder Project Team

CD: Chart Datum

CDP: Channel Deepening Project

DMP: Dredge Management Plan

EMMP: Environmental Monitoring and Management Plan

LPC: Lyttelton Port Company

MMMP: Marine Mammal Management Plan

NTU: Nephelometric Turbidity Unit

PRG: Peer Review Group

TAG: Technical Advisory Group

TSHD: Trailer Suction Hopper Dredge

TSS: Total Suspended Sediments

1 Introduction

1.1 Background

Lyttelton Port Company Limited (LPC) is undertaking a Channel Deepening Project (CDP) to deepen and extend the navigation channel and associated swing basin/berth pockets in Lyttelton Harbour/Whakaraupō. The channel will be widened, deepened and lengthened to accommodate larger vessels and will be undertaken in at least two stages. This Environmental Management and Monitoring Plan (EMMP) covers the first stage of dredging.

The dredge spoil will be disposed of at a designated disposal ground, located approximately 5 nautical miles offshore of the Harbour Heads. Activities associated with dredging are authorised under resource consents issued by the Canterbury Regional Council in December 2017 and confirmed by the Environment Court in March 2018. The first stage of the CDP will commence in mid-2018 with an anticipated duration of 3-6 months depending on equipment used.

A key component of the resource consent conditions is the monitoring and management of the dredging, via an adaptive management process, as well as associated environmental monitoring before during and after the dredging. This EMMP outlines all the monitoring required as part of both the resource consent conditions and also the best practice philosophy adopted by LPC for the project.

A draft EMMP[1], undertaken by Tonkin +Taylor, was submitted as part of the resource application for the disturbance and disposal activities associated with the CDP. This EMMP is an amended version of that to reflect the final conditions of the resource consents and the progression of the document from supporting a resource consent application to project implementation. This revised version is authored by Enviser Ltd, the consultancy overseeing the environmental monitoring and management throughout all phases of the CDP.

The Consent includes requirements for a 12-month baseline monitoring period in order to establish existing environmental conditions in Lyttelton Harbour/ Whakaraupō and offshore Banks Peninsula. This was completed by LPC in October 2017. The results of the monitoring and management are summarised in the Baseline Monitoring Report which is available on the project website (www.lpcharbourwatch.co.nz).

1.2 Purpose

The purpose of this EMMP is to detail the environmental monitoring and management of the dredging and disposal activities associated with the CDP and to ensure consent compliance.

The EMMP is required as part of Resource Consents CRC172455 and CRC172522 granted by the Canterbury Regional Council for activities associated with Dredging in December

[1] Tonkin & Taylor Ltd. (2016). Channel Deepening Project Draft Environmental Monitoring and Management Plan. Christchurch.

2017. LPC, as the Consent Holder, is ultimately responsible for the implementation of all monitoring and management requirements detailed as part of this plan. The Dredging Contractor must also comply with all relevant parts of the resource consent conditions and this EMMP.

More specifically, the purposes of the EMMP are to:

- Ensure the effects of the CDP on the coastal environment are within those predicted by modelling and the assessment of environmental effects.
- Outline the turbidity monitoring and adaptive management actions that shall be implemented by the Dredge Contractor and LPC in order to minimise the risk of dredge-related elevated turbidity causing adverse effects on sensitive receptors, including Authorised Marine Farms.
- Provide a framework for the assurance monitoring, which shall be implemented by LPC . The results of the assurance monitoring shall be used to evaluate any actual or potential biological and physical effects and compare them with:
  - Those predicted effects in the information filed in support of the application[2] and;
  - The assurance monitoring data collected during the baseline monitoring period.
- Ensure compliance with consents.

1.3 Objectives

This EMMP outlines the monitoring and management proposed for the CDP as well as for the first five years after the completion of the dredging (referred to as post-dredge monitoring).

Primarily, it implements an adaptive management approach based on the results of real-time turbidity monitoring throughout Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata. In addition, it outlines a monitoring regime for the dredging and post-dredging phases of the project (referred to as "assurance monitoring"). The assurance monitoring focuses on potential longer-term effects on key ecological habitats and communities and the physical environment as well as quality control.

The main objectives of the EMMP are to:

- Ensure dredging and disposal activities are managed to protect the commercial (aquaculture, finfish etc.) interests and the wider community's cultural and recreational interests;
- Ensure stakeholder engagement is ongoing through all phases of the CDP and provide procedures for handling complaints;
- Specify a framework for adaptive management of the dredging and disposal activities based on results of real-time turbidity monitoring in order to reduce the risk of unanticipated effects occurring;

[2] LPC (2016). Channel Deepening Project: Consent Applications. Christchurch.

- Detail an assurance monitoring programme for appropriate and relevant monitoring of the physical, biological and ecological environments in Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata;
- Ensure stakeholder engagement is ongoing through all phases of the CDP and provide procedures for handling complaints;
- Detail reporting requirements and frequency for results of the management and monitoring;
- Specify roles and responsibilities of groups involved in monitoring and management during and after the completion of dredging; and
- Set out other relevant management plans required during dredging including the Dredge Management Plan (DMP) and the linkages and cross references to those plans.

1.4 Regulatory requirements

This EMMP is a requirement of the consent conditions for the following resource consents granted to LPC (the Consent Holder) by the Canterbury Regional Council (the Consent Authority).

- CRC172455 – A Coastal Permit, under section 12 of the Resource Management Act 1991, to:
  - dredge (disturb) seabed material for the purposes of deepening, extending and widening a shipping (navigation) channel that includes a ship-turning basing, and berth pockets;
  - dredge (disturb) seabed material for the purposes of the construction of a reclamation in Te Awaparahi Bay; and
  - deposit seabed material (from the above activities) on the seabed.
- CRC172522 – A Discharge Permit, under sections 15, 15A and 15B of the Resource Management Act 1991, to:
  - discharge contaminants (seabed material and water) into water associated with channel deepening dredging as described in CRC172455;
  - discharge (dump) dredge material from a ship into water at the disposal ground as described in CRC172455; and
  - discharge contaminants (seabed material and water) from a ship into water associated with channel deepening as described in CRC172455.

For the purposes of this report, CRC172455 and CRC172522 are collectively referred to as "the Consents".

1.5 Environmental monitoring and management

Three types of monitoring and management approaches are proposed for the duration of the CDP:

- Adaptive Dredge Management – based on real-time turbidity monitoring
- Assurance Monitoring and Review – of physical and ecological environments
- Management Protocols – implemented during dredging

The following sections detail the requirements for each monitoring and management type.

1.5.1 Adaptive management

General adaptive management facilitates a continuous monitoring – evaluation – adjustment loop in which management responses are dictated by real-time monitoring and environmental conditions (refer Figure 1.1). The Central Dredging Association (CEDA) states:

"The need for integrating adaptive management into dredging projects is already becoming recognised but will probably increase in future, in reaction to an ever growing awareness of the need for protection of the environments as well as in connection to the ecosystem services approaches" (CEDA, 2015).

Figure 1.1: Adaptive management cycle (CEDA, 2015)

In the New Zealand context, adaptive management usually refers to altering the overall scope of the project in response to measured effects i.e. limiting the footprint of the activity in response to monitored effects. In the context of this project the adaptations are proposed to be two-fold and based on two different timeframes:

- Adapting day-to-day dredging operations in response to real time measurements of the mechanism of effect, rather than the effect itself.
- Adaptation of the overall monitoring and management between the various stages of the project.

This approach not only delivers the 'typical' adaption of the activity based on measured effects, but also places the adaptation process one step earlier to control the primary mechanism (turbidity plumes) that may cause the effects.

This two-phase adaptive management approach is prescribed further in this EMMP and will ensure risks associated with the CDP are well managed, as well as recognising the coastal system is complex and some uncertainty exists in the way predicted effects may manifest.

Adaptive management is identified by Te Hapū o Ngāti Wheke, Te Rūnanga o Koukourārata and Te Rūnanga ō Ngāi Tahu as the key method to manage the potential effects of dredging activities on important rights, values and interests such as mahinga kai.

Successful adaptive management for the CDP will rely on the following:

- The robust real-time water quality monitoring network.
- At least one year of baseline monitoring of existing water quality conditions collected prior to commencing dredging activities.
- Establishment of tiered trigger levels, based on the aforementioned baseline monitoring of the background turbidity as well as the modelled dredge plumes.
- Guidelines for management responses and reporting at each tiered trigger level to ensure appropriate responses to elevated turbidity levels.
  - The Third Tier is a point of compliance under consent conditions. The lower tier triggers are to inform management responses for the dredging operator.
- Involvement of key stakeholders throughout the project.

It is important to note that whilst the adaptive management framework includes possible management responses, prescriptive management actions for the dredge activities in response to trigger level exceedance are not specified. The complexity of the coastal system means that a prescribed management response may be suitable one day (or in one current scenario) and not the next. Instead, the actual operational management measures implemented will be the responsibility of the Dredging Operator in co-ordination with the Consent Holder. This will allow management measures to be flexible and adapt to various conditions. It will also allow the Dredging Operator to refine the management responses as the project progresses, further reinforcing the 'learning by doing' approach of adaptive management.

1.5.2 Assurance monitoring

The purpose of assurance monitoring is to monitor the environment to observe if longer timescale potential effects occur and, if so, ensure the effects are within anticipated levels. It is expected the monitoring will give confidence that the adaptive management approach is achieving the objectives outlined above. The following constitutes the assurance monitoring:

- Sub-tidal, intertidal and benthic ecological surveys
- Water Quality Monitoring
- Dredge Spoil quality monitoring
- Physical beach shore monitoring
- Bathymetric surveys
- Inspections of marine farms (where necessary).

Assurance monitoring was undertaken for over a year during the baseline monitoring period and will continue during and post-completion of dredging.

1.5.3 Other management protocols

A number of other management plans and protocols have been produced for specific aspects of the CDP, these include:

- Dredge Management Plan (DMP)
- Marine Mammal Management Plan (MMMP)

- Biosecurity Management Plan (BMP)
- Marine-based Accidental Discovery Protocol (ADP).

All these plans are available at the project website (www.lpcharbourwatch.co.nz).

1.5.4 Baseline Monitoring Period

Baseline monitoring for the CDP commenced 1 November 2016. A full 12 months of baseline data has been collected, in accordance with the methodologies and frequencies outlined in Appendix 1: Table of Monitoring and frequency of monitoring of the Consents. This includes:

- Real-time turbidity monitoring
- Physical shoreline monitoring
- Sub-tidal, intertidal and benthic ecological surveys
- Water Quality Monitoring
- Bathymetric surveys

A summary of the data collected during the baseline monitoring period is contained in the full Baseline Monitoring Report is available on the project website (www.lpcharbourwatch.co.nz).

1.6 Groups

Three key groups will ensure LPC receives ongoing advice from key stakeholders. These groups will also review all monitoring undertaken and management actions taken.

- Peer Review Group (PRG)
- Technical Advisory Group (TAG)
- Aquaculture Liaison Group (ALG)

In addition, the Consent Holder Project Team (CHPT) comprises LPC's internal project team and is to liaise with these groups throughout the duration of the dredging stage and during post-dredge monitoring.

LPC is responsible for ensuring open communication with key stakeholders throughout the project - in particular with Te Hapū o Ngāti Wheke, Te Rūnanga o Koukourārata and Te Rūnanga ō Ngāi Tahu, given the importance of mahinga kai interests in the project area.

The following summarises the four groups and their roles in the CDP, for further details on these groups refer to Section 8:

- **CHPT** – responsible for the collection and assessment of turbidity monitoring data, preparation of all monitoring and management reports required as part of the resource consent conditions, circulation of the reports to relevant groups and the Regulator as required, assessment of monitoring data to ensure all requirements are being met and ensuring dredging operations are being appropriately adapted to prevent and/or respond to trigger level exceedance.
- **TAG** – responsible for providing advice to LPC on both the monitoring results and methodology as well as review the effectiveness of the management responses undertaken by the Dredge Operator to trigger level exceedance. The group consists of technical experts with the relevant experience and knowledge on the project and

shall meet regularly to discuss the monitoring results (both real-time and assurance). This group will not provide specific advice on the day-to-day dredge management responses.

- **PRG** – responsible for providing a high level independent peer review of the monitoring results (real-time and assurance) and effectiveness of dredge management decisions to provide confidence that the consent conditions and methods proposed in this EMMP are being adhered to.
- **ALG** – provides a forum for communication between the aquaculture industry and the Consent Holder in order to discuss the monitoring required by this EMMP and the associated consent condition, therefore ensuring that any adverse effects on Authorised Marine Farming activities are avoided or remedied.

1.7 Key Personnel Contact Details

Table 1.1 summarises LPC's key project staff and contact details for each.

Table 1.1: Summary of key contacts, roles and responsibilities

Name	Role/Responsibility	Organisation	Contact details
Martin Watts	Project Director	LPC	martin.watts@lpc.co.nz 021 729 567
Kristy Jones	Project Manager	LPC	kristy.jones@lpc.co.nz 021 246 2086
Jared Pettersson	Project Environmental Adviser	LPC/Enviser Ltd	Jared.pettersson@lpc.co.nz 021 679 838
Pieter Jan Stuiver	Project Manager	Boskalis	pieter.jan.stuiver@boskalis.com 027 640 0115
Paul Bartley	Dredge Contractor Works Manager	Boskalis	paul.bartley@boskalis.com
Leonie Anderson	Water quality monitoring and real-time data analysis	Vision Environment	Leonie@visionenvironment.com.au
Ross Sneddon	Project Marine Ecologist	Cawthron Institute	Ross.Sneddon@cawthron.org.nz
Dr Brett Beamsley	Project Hydrodynamic Modeller	MetOcean Solutions Ltd.	b.beamsley@metocean.co.nz
Dr David Fox	Project Environmental Statistician	Environmetrics Australia	david.fox@environmetrics.net.au

1.8 Report structure

This EMMP has been composed to set out the proposed monitoring and management plans for the duration of the CDP (including baseline and post-dredging) and is structured as follows:

- Section 2 describes the proposed works and location and setting of the project.
- Section 3 provides an overview of the sensitivity of the existing ecological, social, cultural and economic environments including a summary of the baseline monitoring data.

- Section 4 details the monitoring and management approaches for the implementation of the adaptive dredge management approach.
- Section 5 outlines the assurance monitoring.
- Section 6 outlines the additional environmental management protocols to be employed by the dredging company during dredging.
- Section 7 outlines the reporting requirements for each stage of management.
- Section 8 summaries the group makeup, roles and responsibilities.

2 Description of the proposed works

2.1 Requirement of channel deepening

The CDP will deepen, enlarge and extend the main navigational channel and associated swing basin/berth pockets. Lyttelton Port (The Port) is currently New Zealand's third largest deep-water port and provides a vital link to international trade routes and a key role in the global transport network. However, the current channel does not have the draught to cope with the international trend for increasing vessel sizes. Deepening the channel will allow the Port to keep up with international trade demand which is a key facilitator of the regional and national economy. As part of the construction methodology, dredging will also be undertaken for sections of the footprint of the proposed Te Awaparahi Bay reclamation.

2.2 Location and extent of deepening works

The existing channel is 180m wide, 11.9m deep and approximately 6.5km in length. Stage 1 of the Channel Deepening Project will see the channel widened to 200m, increase in length to approximately 9km and increase in depth by approximately 2m. The swing basin is also being deepened and enlarged increasing the width from approximately 450m to 615m. This will involve the dredging of approximately 5 million cubic metres (m^3) sediment. In addition, a further approximately 1 million $m^3$of material will be dredged to allow for:

- Deepening of the existing berth pockets at Cashin Quay;
- The creation of new pockets to serve the container terminal at Te Awaparahi Bay; and
- Removal of upper layers of sediment (to approximately -20 m CD[3]) within the proposed Stage 1 reclamation footprint at Te Awaparahi Bay as part of the reclamation construction methodology.

The navigation channel dredging and the reclamation dredging are separate projects and may be undertaken by difference dredge contractors.

2.3 Dredging equipment and execution

Channel deepening will be primarily undertaken by a Trailer Suction Hopper Dredge (TSHD). TSHDs have a trailing suction pipe (or pipes) attached to a suction head that is capable of removing a lateral section of seabed. The seabed material is delivered into the hopper (hull) of the dredge. The hopper capacity of the dredge will be between 15,000 m^3 and 35,500 m^3. The spoil will then be disposed of to sea at the spoil disposal ground.

The TSHD is appropriate for the predominantly soft sediments found in the Lyttelton Harbour seabed. However, other types of dredges may need to be used, for example if areas of more consolidated sediment are found, or space constraints prevent the use of a TSHD. In these instances, a grab dredge or back hoe dredge may be required. It is

[3] Chart Datum

anticipated that a backhoe or grab dredge may be needed for the following parts of the dredging:

- Portions of, or all of the reclamation related dredging
- Portions of the berth pocket deepening
- Some of the detailed areas of the swing basin, i.e. corners.

To provide final levelling and assist in dredging tight corners, a sweeping spread will be deployed. This will include a sweep vessel (tug or similar) and a sweep bar or plough which is dragged across the sea floor.

2.4 Timeframes

This stage of channel deepening will commence in mid 2018 and is anticipated to take approximately 3-6 months to complete.

The reclamation dredging will commence in the 3rd or 4th quarter of 2018 and is anticipated to take approximately 3-12 months to complete (depending on method).

At least one more stage of dredging will be required in order to provide vessels with a draught of up to 14.5 m access to the Port, should this be required by LPC.

A formal review of the performance of this EMMP will be undertaken upon completion of Stage 1 and updates to monitoring frequencies, locations and other matters made as necessary prior to the commencement of Stage Two of the CDP (refer to Section 7.6 for further details).

3 Existing environment

The following gives a brief outline of the physical, ecological, biological, cultural and recreational environments of Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata. For further information refer to the LPC Channel Deepening Project Assessment of Environmental Effects (LPC, 2016) and the appended technical reports submitted as part of the Resource Consent Application.

3.1 Physical environment

3.1.1 Geography

Lyttelton Harbour/Whakaraupō is the eroded caldera remnant of an extinct volcano. The harbour has high marine cliffs at its entrance and along its sides. In its natural condition the harbour seabed is unusually flat and an almost constant gradient of 1:1000.

Pegasus Bay is a relatively shallow embayment north of Banks Peninsula and is part of the continental shelf. The bathymetry of the bay shows the continental shelf consists of two sections – a near shore steeply sloping zone which extends to the 10 m depth contour and has a relatively steep gradient of approximately 1:65 and an offshore gently sloping zone. Around the 35 m contour the gradient steepens to the Pegasus Canyon which reaches a maximum depth of 1600 m.

Both the Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata seabed are predominantly silt (60%), though there are slightly coarser sediments on the northern side of the harbour and exposed fine sands on the southern side of the harbour.

3.1.2 Waves

Offshore of Banks Peninsula, in Pegasus Bay, the wave climate is largely dominated by southerly swell conditions mixed with infrequent northeast and southeast wave events. In comparison, the wave climate at the capital spoil disposal ground is predominantly from the east-northeast due to refraction of waves around Banks Peninsula. Wave height at this location is usually less than 2.0 m though wave heights of over 3.5 m do occur.

In Lyttelton Harbour/Whakaraupō, mean wave height is at a maximum at the Harbour entrance and decreases towards the upper end of the harbour due to the effects of shoaling, refraction and friction. Mean wave height also reduces with distance from the Harbour entrance, from approximately 0.8 m, to 0.2 m at the centre of the harbour and then approximately 0.1 m in the Upper Harbour. Wave periods also decrease further into the Harbour, from nine seconds at the harbour entrance to seven seconds in Governor’s Bay, due to the dissipation of swell waves.

3.1.3 Tides/Currents

Oceanic currents are influenced by tides, wind and thermohaline conditions (temperature and salinity differences in the water). In Lyttelton Harbour/Whakaraupō, tidal conditions are the main influence on currents. The largest tidal currents occur in the shallow waters around the ends of the Cashin Quay and Naval Point breakwaters and around the Harbour Heads. Relatively large currents also occur at various places around Quail Island due to tidal dissipation.

3.1.4 Meteorological

Coastal winds in Christchurch are mostly characterised by strong onshore north-easterlies during summer and slightly weaker south-westerlies in winter that blow off-shore. Low pressure systems pass through Pegasus Bay on average every six to seven days and are often dominated by strong southerly winds and high swells. Outside of the heads of Lyttelton Harbour/Whakaraupō, the ocean is exposed to the prevailing oceanic swell; however, Banks Peninsula protects the Harbour from these strong weather events.

3.2 Predicted turbidity plumes

Dredge plume modelling has been conducted to assess the predicted suspended sediment concentrations and plume pattern due to dredging in the channel and disposal activities offshore. The dredge plume dispersion in the channel is dominated by tidal forces and seiche and remains mostly within the channel as shown in Figure 3.1. During ebb, the current and hence the plume is directed outwards of the bay in North-East direction. During flood, the current and plume are directed inwards in South-West direction.

It is expected that suspended sediment plumes will be visible behind the dredge during channel dredging and around the dredge during disposal. These plumes may extend hundreds of metres behind/around the dredge. The visual presence of a plume does not mean the suspended sediment concentration are above what is expected or predicted by the modelling.

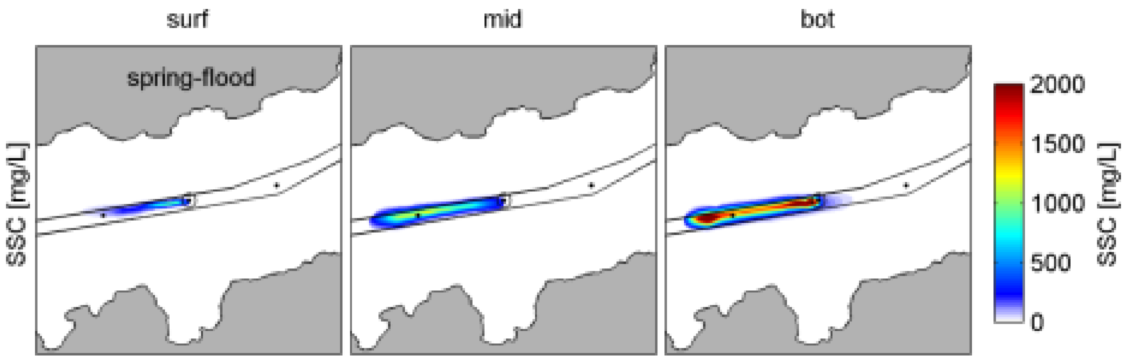


Figure 3.1: Modelled dredge induced suspended sediment concentrations at three depths at peak flood flow during spring tide with seiche (MetOcean Solutions Ltd., 2016

At the disposal site, the dredge plume pattern follows the tidal and oceanic current patterns which are directed along the coast in North-West direction during flood period and South-East direction during ebb as shown in Figure 3.2. The dispersion pattern is also dominated by wind induced currents during strong wind periods from North-East (mainly in summer) and South-West (mainly in winter) direction. Suspended sediment concentrations drop typically below 100-200 mg/l within 1km of the disposal location.

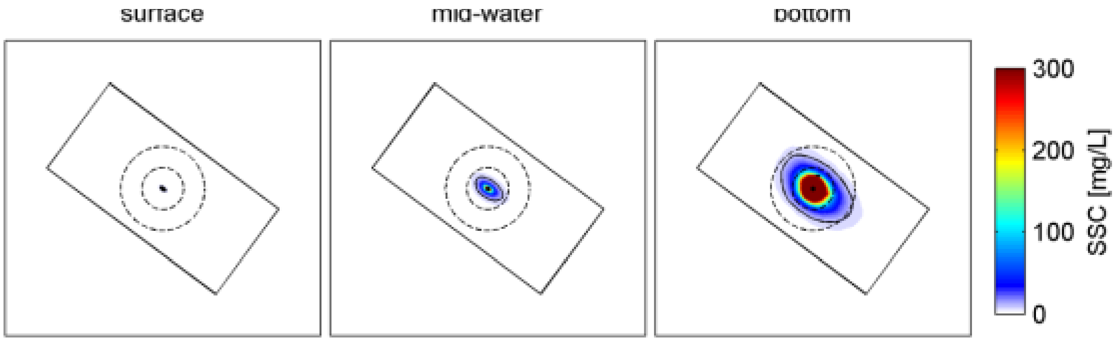


Figure 3.2: Modelled suspended sediment concentrations for 10 years hindcast modelling for one hopper load with a volume of 18,000 m^3. The 10 mg/l contour line is shown in dark and dashed lines show radius of 500 and 1000 m from disposal location. (MetOcean Solutions Ltd., 2016).

Based on the dredge plume model study it is expected that the turbidity triggers will not be exceeded at the monitoring station due to dredging and disposal activities.

3.3 Ecological Habitats

Ecological habitats vary between the depth contours and physical environments of Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata.

3.3.1 Muddy bottom

The benthic habitats of Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata typically consist of relatively uniform semi-consolidated mud. As a consequence the communities living in these areas are comparatively sparse with a prevalence of marine worm organisms as well as taxa (populations of organisms) such as ostracods, crabs and small marine crustaceans. The area of the proposed channel extension has a lower abundance and range of fauna compared to the spoil disposal ground (Cawthron, 2016).

3.3.2 Sub-Tidal

The shallow sub-tidal reefs along the exposed coastline are dominated by a variety of kelp - including giant kelp *(Macrocystis spp)*, common kelp (*Ecklonia spp)* and bull kelp *(Durvillaea spp)*. A number of other taxa occur, including tunicate *(Urochordata)*, and a rich understorey of bryozoans, mussels, ascidians and sponges. Marine mollusc are also common, predominantly pāua *(Haliotis)*, topshell *(Diloma aethiops)* and Cooks Turban snails *(Turbinidae)*. The sea urchin *(E. chloroticus)* has been recorded at depths of three to five meter (Cawthron, 2016).

3.3.3 Intertidal

Intertidal communities mainly consist of tubeworms and barnacles as well as periwinkles, limpets, chitons and cat's eye snails in the upper shoreline zone. In mid-shore zones species of mussels, oysters and algae become more prevalent. These communities are also evident at low-shore zones in addition to sponges and tunicates.

A variety of sea crustaceans are found around Banks Peninsula. These include, at varying extents of population and individual shell sizes, the following species: Tuatua/Bivalve Clam *(Paphies subtriangulata)*, pipi *(Paphies australis)*, tupaki/cockle kūtai (green lipped mussel), pāua, tio (oyster), kina (sea urchin) and pūpū (cat's eye) (Cawthron, 2016).

3.4 Biological Environment

3.4.1 Fisheries

A range of fish species (both flatfish and finfish) are supported in the relatively shallow and semi- sheltered waters of Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata. The waters support customary, commercial and recreational fisheries.

3.4.1.1 Customary fisheries

There are 21 species of finfish important to mana whenua rights, values and interests (particularly customary fisheries and mahinga kai), in Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata. These include pātiki/flounder *(Rhombosolea retiaria),* hoka/ling *(Genypterus blacodes)*, and pīoke/rig *(M. antarcticus)* (refer Section 6.1 of the CIA (Jolly, 2016) for a full list of these species). There is active customary fishing of these species in Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata (Cawthron, 2016).

There are Mātaitai reserves in both Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata, provided for under the Fisheries Act 1996. The Rāpaki Mātaitai Reserve was established in 1998 as the first Mātaitai in New Zealand. The Koukourārata Mātaitai Reserve, extending across the whole of the Harbour, was established in December 2000. Mātaitai Reserves recognise traditional fishing grounds that are important for customary food gathering, and are intended to protect, enhance and sustain the customary fishery for future generations (Jolly, 2016).

3.4.1.2 Commercial Fisheries

There are 18 main commercially caught finfish species in the area including bluenose (Hyperoglyphe antarctica), NZ sole (*Peltorhamphus novaezeelandiae*), flatfish (various species), red cod (*Pseudophycis bachus*.), terakihi (*Nemadactylus macropterus*), gurnard (*Chelidonichthys kumu*), common warehou (*Seriolella brama)*, barracouta (*Thyrsites atun*), giant stargazer (*Kathetostoma giganteum*), school shark (*Galeorhinus galeus*), blue moki (*Latridopsis ciliaris*), alfonsino (*Beryx splendens*), blue cod (*Parapercis colias*) and elephant fish (*Callorhinchus milii*). The Ministry of Primary Industries data extract for Pegasus Bay species records that flatfish is targeted inshore, with elephant fish (*C. milii*) and red gurnard (*Chelidonichthys kumu*) representing high value by-catch – especially in the area just offshore of Godley Heads (Cawthron, 2016).

3.4.2 Marine mammals

The footprint of the shipping channel extension and associated spoil disposal site are located within the boundaries of the Banks Peninsula Marine Mammal Sanctuary (BPMMS). The Sanctuary covers approximately 413,000 hectares and places restrictions on activities within its boundaries for the protection of fisheries and marine mammals (in particular the endangered Hectors dolphin/upokohue).

More than 25 cetacean (marine mammal) species have been sighted or stranded within the waters of Banks Peninsula. However, only the Hector's dolphin and New Zealand fur seal reside in the harbour year-round with the southern right whale often sighted offshore of Banks Peninsula.

Hector's dolphin/upokohue is endemic to New Zealand waters. Of the estimated 14,900 Hector's dolphins known to occur around the South Island, approximately 2,000–4,000 dolphins are found in the waters of Pegasus Bay year-round. The dolphins generally reside in the bays and harbours of Banks Peninsula in the summer and autumn months and move further offshore in the cooler months.

Several New Zealand Fur Seal breeding colonies are located throughout the more eastern and southern bays of Banks Peninsula (more than 20 km away from Lyttelton Harbour/Whakaraupō and the offshore disposal ground). However, New Zealand fur seals often cover large distances away from their breeding grounds and thus are commonly seen within Lyttelton Harbour/Whakaraupō and Port Levy/ Koukourārata and Pegasus Bay.

Regular sightings of southern right whales occur each year off Banks Peninsula, in particular in the northern bays and along the Lyttelton Harbour coastline, as whales migrate back to their traditional wintering and calving grounds around New Zealand. At the current sighting rate, at least one or two southern right whales are expected to appear within or near Lyttelton Harbour each winter where they will remain for anywhere from a few days to several weeks (Cawthron, 2016).

3.4.3 Avifauna

The coastlines of Lyttelton Harbour/Whakaraupō and Port Levy/ Koukourārata provide diverse habitat locations for a number of marine birds to undertaken nesting, roosting and foraging activities. The main avifauna habitats in the region include the inter-tidal rocky shoreline, the outer harbour wave-cut platforms, exposed reefs and sand beaches, the Inner Harbour inter-tidal mud- flats, the large conifers around the Harbour and coastal cliffs, Quail Island and the waters close to the seabed.

Assessment of avifauna in the region determined a total of 17 species which associate with the waters of Lyttelton Harbour/Whakaraupō, Port Levy/Koukourārata and offshore Banks Peninsula and have local breeding or wintering populations onshore of the area. These birds include (among others) penguins, fairy prion and sooty shearwater, tern, shag, gull and waders. They inhabit two major ecosystems; coastal (including the outer Lyttelton Harbour and the offshore area where dredged material will be disposed) and intertidal areas within the Lyttelton Harbour (Boffa Miskell, 2016).

3.4.4 Aquaculture

Commercially, a number of mussel farms have established along the bays and headlands of northern Banks Peninsula, from Port Levy/Koukourārata to Squally Bay. In total, there are 24 active consents, held by 6 different consent holders around the area. Consents have been issued to authorise the growing of a number of species, including green shell mussels (*Perna canaliculus*), blue shell mussels (*Mytilus galloprovincialis*), macroalgae (*Macrocystis pyrifera, Ecklonia radiata, Gracilaria spp., Pterocladia lucida, and Undaria pinnatifida*), and for the collection of mussel spat. To date only green shell mussels are farmed along with the collection of green shell mussel spat (Ogilvie, 2016).

3.5 Cultural Environment/Mahinga Kai

The channel dredging and spoil disposal grounds are located in the coastal marine area of the takiwā (traditional territories) of Te Hapū ō Ngati Wheke (Rāpaki) and Te Rūnanga ō Koukourārata. The coastal marine area is known as Te Tai ō Mahaanui and is identified in the Ngāi Tahu Claims Settlement Act (NTCSA) 1998 as a Statutory Acknowledgement site, reflecting the particular cultural, spiritual, historical and traditional associations of Ngāi Tahu to this area.

Te Hapū o Ngāti Wheke is the Ngāi Tahu Papatipu Rūnanga representing the hapū Ngāti Wheke, who hold mana whenua and mana moana (customary authority) over Whakaraupō. Te Rūnanga o Koukourārata is the Papatipu Rūnanga representing the hapū Ngāti Huikai, who hold mana whenua and mana moana over Koukourārata and the northern bays of Te Pātaka ō Rākaihautū (Banks Peninsula).

Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata are cultural landscapes with strong traditions of mahinga kai. Ngāi Tahu have lived and fished in the waters of both harbours and offshore for generations. There are numerous settlement sites, wāhi taonga (treasured places) and wāhi tapu (sacred sites) that hold the stories of Ngāi Tahu migration, settlement and resource use.

The rich resources of the harbour brought Ngāi Tahu to settle in the area, and mahinga kai continues to be an integral part of the relationship between mana whenua and the coastal environment. This includes customary food gathering and the establishment of Mātaitai Reserves, and the contemporary development of marine farms. The importance of the relationship of mana whenua with the coastal environment, including the kaitiaki (guardianship) role, is recognised by the RMA 1991 and the New Zealand Coastal Policy Statement 2010 (NZCPS).

As kaitiaki, Te Hapū o Ngāti Wheke and Te Rūnanga o Koukourārata are working to protect and restore the cultural and ecological health of the harbours and wider coastal environment. This includes the fundamental importance of water quality to sustaining mahinga kai which is abundant, diverse, and safe to eat, and the ability to access these resources. Fourteen types of shellfish and 21 species of finfish (Ogilvie, 2016) have been identified by the Te Hapū ō Ngāti Wheke application for a mātaitai reserve (Te Hapū o Ngāti Wheke Incorporated, 2014), and by Te Hapū o Ngāti Wheke Tangata Tiaki.

Engagement with Te Hapū o Ngāti Wheke, Te Rūnanga o Koukourārata and Te Rūnanga ō Ngāi Tahu is ongoing and will continue throughout the CDP to ensure protection of all values, rights and interests in the harbours before, during and after the channel deepening activities.

3.6 Recreational values

The close proximity of Lyttelton Harbour/Whakaraupō to Christchurch City means it is a popular recreational destination for Christchurch and Canterbury locals as well as domestic and international tourists. In particular, the Harbour is valued for its fishing, swimming, biscuiting, water skiing, general boating, picnic locations and wake and knee boarding. Some diving and snorkelling occurs in and around the outer harbour and pāua, mussels and crayfish are found at specific sites.

Swimming is popular at sites with relatively sandy beaches, such as at Cass and Corsair Bays, despite poor water clarity. The shoreline provides many on-land recreation opportunities, including walking, heritage and sightseeing opportunities at Godley and Adderley Head, Ripapa and Quail Islands, Diamond Harbour and the road-accessible bays stretching from Naval Point at Lyttelton to Camp Bay east of Purau.

In terms of recreational fishing, a wide variety of fish species has been reported in Lyttelton Harbour/Whakaraupō with most fishing taking place from boats in the Outer Harbour. The best recreational fishing is reported to be further off the coast, although Kingfish are reported to be caught off Taylors Mistake after Christmas (AEE, 2016). During summer The Port area is frequented by juvenile fish of species such as red cod, yellow eyed mullet, blue warehou, spiny dogfish and green pufferfish. Adult fish such as red cod and quinnat salmon have also been caught in the harbour (Rob Greenaway & Associates, 2016).

3.7 Archaeological Environment

Human activity has been occurring in and around Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata for over 800 years. The first occupants of the area were Waitaha, followed by Ngāti Māmoe in the 16th century and Ngāi Tahu in the 18th century. For centuries, Lyttelton Harbour/Whakaraupō was a major travel route between Ngāi Tahu settlements and mahinga kai areas. The Port itself was established by European settlers in 1850. There is still the potential for accidental discoveries of taonga (treasures), kō iwi tangata (human skeletal remains) or European artefacts when dredging areas of previously undisturbed seabed.

3.8 Navigation and Navigational Aids

The existing dredged channel extends to within approximately one nautical mile of the Heads, and is marked by the Governors Bay Precision Entrance Light (PEL). PEL Sector Lights indicate the vessel position in confined waterways by using sectors of colour to convey information about the location of the vessel with respect to the channel centreline.

A second PEL leading light is located on the headland between Diamond Harbour and Purau Bay. This sector light marks the outer (un-dredged) approach route aligned roughly 060-240°N(T) along the line between the pilot transfer station (approximately two nautical miles east north east of The Heads, outside the pilotage limit) and the outer (eastern) end of the dredged channel.

There is an existing turning area opposite the Cashin Quay container terminal area. This irregularly- shaped area is dredged to a maintained depth of -11.9 m CD, and is up to approximately 600 m wide (close to the Sticking Point breakwater structure), with extents of the dredged area marked by a series of transit marks.

Access to the inner basin (dredged to a maintained depth of -10.5 m CD) is through a relatively narrow entrance between the Z-Wharf and Naval Point Oil Wharf.

In addition to the two PEL sector lights the innermost navigation fairways are marked by a comprehensive system of transit marks. However, other than the Spoil Ground special buoy and the Parsons Rock beacon, navigation buoys and beacons are sparse in the approaches to The Port.

3.9 Baseline Monitoring Data

The baseline monitoring period ran from 1 November 2016 till 31 October 2017. Over this time a significant amount of data was collected across the following aspects:

- Real-time and self logged turbidity and water quality monitoring
- Physical shoreline monitoring
- Sub-tidal, intertidal and benthic ecological surveys
- Water Quality Monitoring
- Bathymetric surveys

A full baseline monitoring report has been produced. The main body of that report summarises the findings of the monitoring, with the full detailed findings included in appendices. The Baseline Monitoring report is which is available on the project website (www.lpcharbourwatch.co.nz).

4 Dredge management

Two primary management methods will be employed throughout the operational phase of the project:

- **Proactive Operational Management**: utilises forecast and real time environmental information (i.e. tides, wind, waves, weather etc.) to guide operational management decisions during dredging. Undertaken as part of common dredging practice.
- **Adaptive Dredge Management**: based on real-time turbidity monitoring - implements an adaptive management approach in response to predetermined trigger levels.

4.1 Proactive operational management

The Dredge Contractor is responsible for proactive operational management of the dredge and disposal activities. This will take into consideration the hydro-meteorological conditions, predicted plume movement based on hindcast modelling (MetOcean Solutions Ltd, 2016) and the real-time water quality information (turbidity, waves and currents). The purpose of proactive operational management is to constantly assess the daily planned dredge operations to minimise the risk of a dredge-induced trigger exceedance.

The proactive operational management measures are detailed further in the Dredge Management Plan (DMP), available on the project website (www.harbourwatch.co.nz).

4.2 Adaptive dredge management

During the dredging operations, the location of both dredging and disposal will be managed in response to results of real-time turbidity monitoring. Monitoring of the real-time turbidity at 14 locations throughout Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata was undertaken as part of the Baseline Monitoring Period and will continue during the dredging.

12 months of baseline data has been collected by LPC and was used to determine the two trigger values (Tier 1 and 2) and the compliance level (tier 3). These are based on higher order percentiles (80^{th}, 95^{th} and 99^{th}) of the collected turbidity background data combined with modelled dredge turbidity.

Tier 1 and Tier 2 trigger levels serve as a warning tool for the Dredge Operator and Consent Holder. If these are exceeded, dredging activities may need to be modified, taking into account the hydro-meteorological conditions and the predicted plume directions, in order to reduce the turbidity at the location of exceedance.

If the Tier 3 compliance level is exceeded, dredging activities must cease in the vicinity of the exceedance location, unless the exceedance is caused by an extraordinary natural event.

4.2.1 Real-time turbidity monitoring

The objective of the real-time turbidity monitoring program is to provide continuous real-time information on turbidity levels to inform the management of the dredging operations. The dredge operations will be managed in real-time by comparing the real-time turbidity data with pre-established trigger levels as defined in section 4.3.

The real-time turbidity monitoring occurs 0.75-1 m below the surface (readings are taken and telemetered every 15 minutes), with benthic turbidity meters storing data on a data logger which is to be downloaded monthly. Only the surface turbidity measurements are used to manage the dredging activities.

4.2.2 Locations of monitoring sites

In determining the locations of the monitoring sites the broad objectives were to:

- Provide two lines of monitoring between the offshore ground and the shoreline.
- Encircle the channel works with monitoring instruments located between the channel and shoreline.
- At least one reference site on the outer coast away from predicted increases in turbidity.

In order to achieve the above objectives, 14 real-time subsurface turbidity loggers have been installed. 13 of the monitoring sites will be used for the adaptive dredge management, the 14^{th} (OS4) is a reference site which does not have triggers attached to it. The reference site will be used for qualitative comparisons and to provide information to the ecological assurance monitoring, which has subtidal sites nearby. The monitoring locations have been chosen based on the above objectives, analysis of predicted plume dispersion based on hydrodynamic models and locations of environmental and cultural significance. Where possible, the instrument locations have been co-located with ecological monitoring sites.

Each monitoring site (situated either inshore or offshore) consists of a buoy with a combination of instruments capable of monitoring different water quality parameters, as described in Section 4.3 and in the monitoring reports.

The real-time turbidity data is to be compared to pre-established triggers as part of the tiered management system approach, as described in section 4.3. The remaining water quality and current/meteorological monitoring data will be used to give an indication to the Dredging Operator of the MetOcean and physiochemical conditions and also form part of the assurance water quality monitoring (refer section 5.5).

The monitoring locations are shown in Figure 4.1. The scale of the dredging and disposal footprints means different monitoring locations may detect increased turbidity from the channel dredging, spoil disposal or both activities (Table 4.1).

Table 4.1: Management purpose of monitoring locations in relation to dredge activity

Measurement purpose	Sentinel monitoring sites
Turbidity plumes generated during disposal at spoil disposal ground and for informing dredge management procedures	SG1, SG2b, SG3, OS3, OS5, OS6
Turbidity plumes generated from dredging in the channel and for informing dredge management procedures	UH1, UH2, CH1, CH2, OS1, OS2, OS5, OS6, OS7
Turbidity close to mussel farms and as reference location (note this site is not used for compliance)	OS4

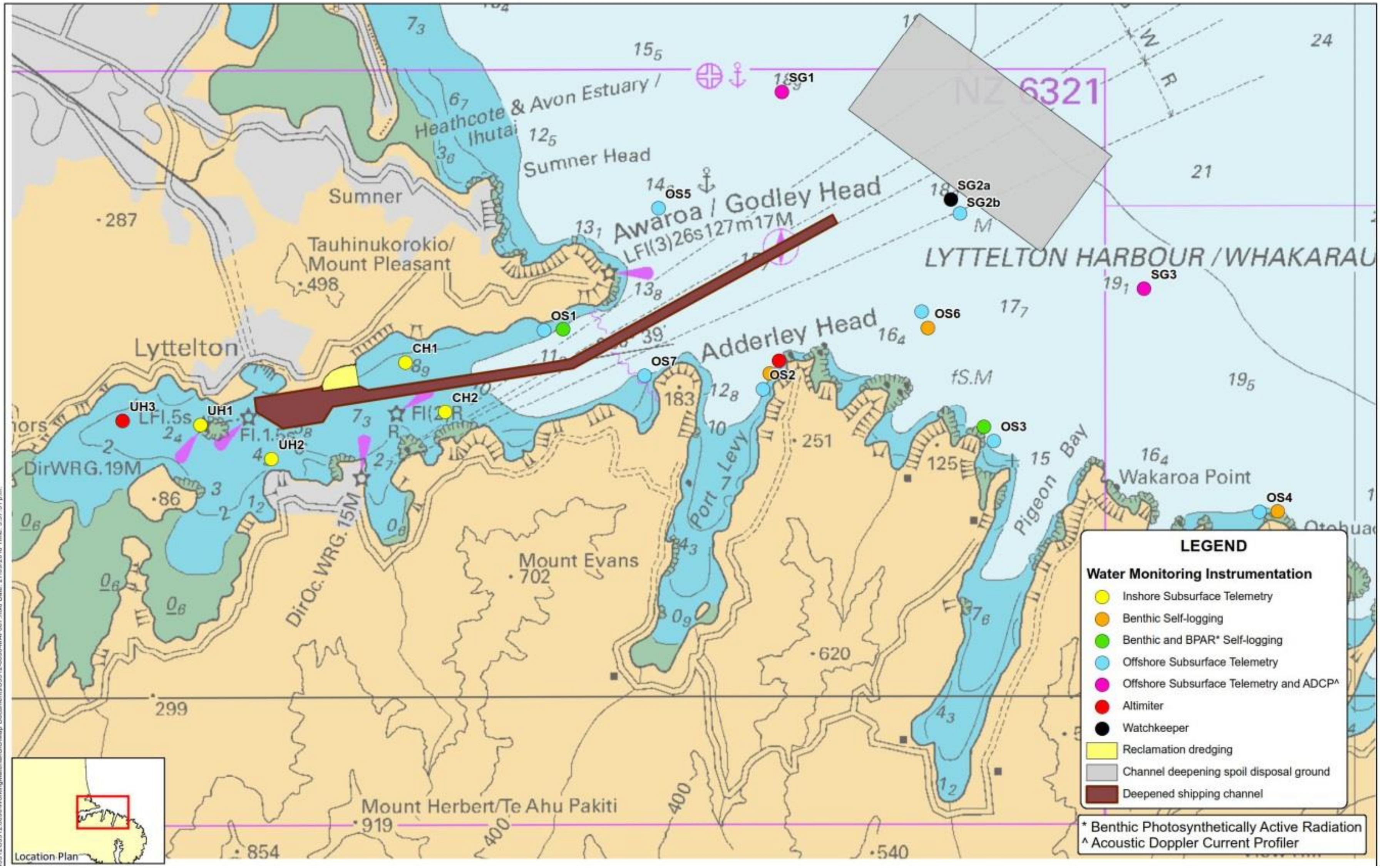


Figure 4.1: *Monitoring locations*

4.2.3 Instrument type

The type of instruments deployed at each location are dependent on the monitoring location as well as the hydrodynamic and meteorological conditions and predicted plume extents. All locations (aside from UH3 at Rāpaki) have a surface telemetered real-time turbidity setup. A number of locations also have self-logging benthic turbidity, benthic light and two also have self-logging bed level altimeters. Where turbidity is measured, dissolved oxygen, temperature, conductivity and pH are also measured. Three locations (at the offshore ground) also measure the current profile, with one location also measuring wave height, direction and period as well as general meteorological data.

Details of instrument types deployed at each location are given in Table 4.2. More detail on the specific instruments is contained within the water quality monitoring report prepared by Vision Environment (Vision Environment, 2016) and available on the Project Website (www.lpcharbourwatch.co.nz).

4.2.4 Adjusting monitoring locations post-deployment

Due to the complexity of the coastal environment it may be necessary to adjust the monitoring locations during dredging operations.

Four instrumentation zones have been established (refer Plan CRC172455B) which have requirements for the number of monitoring stations required in each, as per Condition 8.5 of the Consents. Should adjustments be required to the monitoring locations, LPC is responsible for ensuring that the following instrumentation zone criteria are met:

- Channel Zone – at least 6 monitoring locations.
- Inshore Zone – at least 3 monitoring locations with at least one providing water quality information close to Authorised Marine Farms.
- Spoil Ground Zone – at least 3 monitoring locations.
- Offshore Zone – at least 2 monitoring locations.

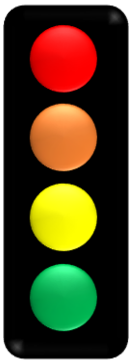
Table 4.2: Summary of instrumentation at each monitoring location

Monitoring Site	Buoy type		Instrument					
	Off-shore	In-shore	Benthic self-logging data logger	Surface Turbidity Data Logger	Self-Logging Benthic PAR^	Self-logging Benthic Altimeter	ADCP*	Watch keeper
UH1		✓		✓				
UH2		✓		✓				
UH3		✓				✓		
CH1		✓		✓				
CH2		✓		✓				
SG1	✓			✓			✓	
SG2a	✓							✓
SG2b	✓			✓				
SG3	✓			✓			✓	
OS1	✓		✓	✓				
OS2	✓		✓	✓	✓	✓		
OS3	✓		✓	✓	✓			
OS4-reference site	✓		✓	✓				
OS5	✓			✓				
OS6	✓		✓	✓				
OS7	✓			✓				

*Acoustic Doppler Current Profiler
^ photosynthetically active radiation

4.3 Tiered trigger system

Adaptive dredge management is to be implemented through a system of triggers which, when exceeded, require management responses (Figure 4.1). This system is based upon comparing the real-time (but manually validated) monitoring information collected against pre-established and agreed tiers of intensity (NTU)/duration (hours) combinations to ascertain the degree of management required.



Tier 3 compliance level: Cease dredging in the vicinity of the monitoring station(s) showing the exceedance

Tier 2 trigger: Turbidity levels increasing – increase management actions

Tier 1 trigger: Warning, elevated turbidity levels commence management actions

Normal operating conditions

Figure 4.1: tiered trigger system

Each tier has broad management and reporting requirements in order to determine the cause of the trigger level exceedance and, where appropriate, take measures to reduce the exceedance and/or prevent turbidity from increasing. Reporting requirements are detailed further in Section 7 and group roles and responsibilities in Section 8.

Thirteen of the fourteen real-time monitoring sites have been assigned turbidity trigger values (the reference site will not have triggers values). Throughout the dredging activities the surface telemetered turbidity data recorded at these locations will be continuously assessed against the trigger limits.

It is important to note that the design of the trigger system means natural events will cause exceedances of the trigger and compliance levels. It is expected that due to natural events, 20% of the time Tier 1 will be exceeded, 5% of the time Tier 2 will be exceeded and 1% of the time the compliance level will be exceeded. Consequently, an exceedance of the trigger or compliance levels may not be associated with dredging activities but due to naturally fluctuating turbidity levels.

4.3.1 Data processing and display

The real-time turbidity data collected by the monitoring buoys requires a number of data processing steps to ensure its validity. These steps include automatic data validation (SMART algorithm), manual validation and smoothing filters (KZ filter). Figure 4.2 sets out the data processing steps.

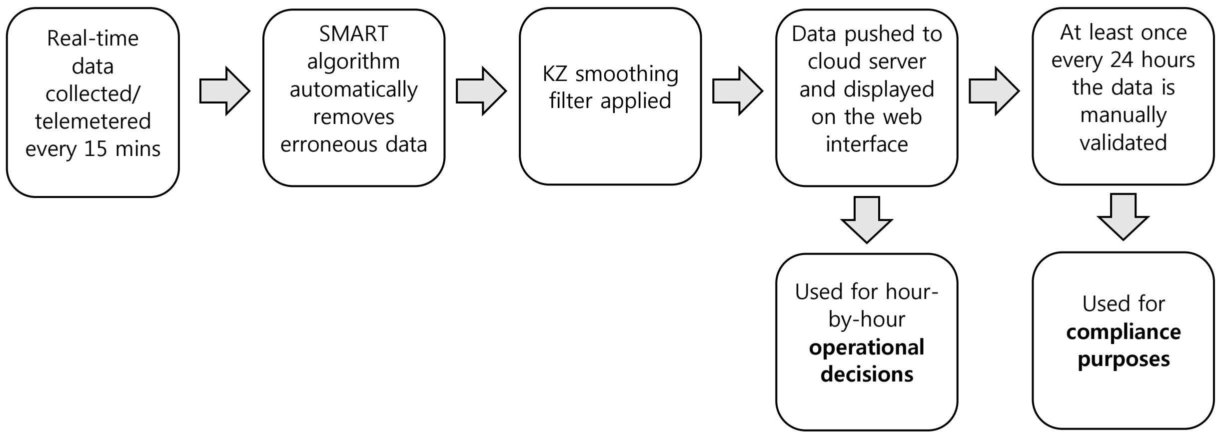


Figure 4.2 Example data processing flow chart for turbidity data

Data processing of the real-time turbidity monitoring data is required in order to ensure the gathered data is appropriate for analytical purposes. The data processing comprises a series of automated steps (SMART and KZ filter) and a manual validation step. The automated routines provide the real-time data which is immediately displayed on the website interface. This data will be used for hour-by-hour management of the dredge.

Whilst the automated routines are robust, manual validation of the data is required to ensure the data is 100% correct. As manual validation requires an experienced person to undertake it, manual validation will only occur once every 24 hours in typical conditions. If the Tier 3 compliance limit is being approached, more regular manual validation will occur (i.e. 6-hourly or shorter). **Final measurement of compliance with the Tier 3 compliance limits (intensity and duration) will be made against the manually validated data only**.

4.3.2 Tiered Triggers

As per Condition 9.1 of the Consents, there are two turbidity triggers (Tiers 1 and 2) and one compliance level tier (Tier 3 Compliance Level) which have an associated turbidity intensity and allowable duration component. The **turbidity intensity** is a measure of the cloudiness of the water (in NTU or Nephelometric Turbidity Units) while the **allowable duration** is the amount of time in a 30-day rolling window that the turbidity at any given monitoring site may exceed the turbidity intensity.

Once the allowable duration above the turbidity intensity has been exceeded at a monitoring location, a **trigger event** has occurred, requiring the management actions set out below – dependent on the level of event occurring. The trigger event ceases when either the turbidity drops below the allowable turbidity intensity or the allowable hours are no longer in exceedance.

The Tier 1 and Tier 2 turbidity triggers are internal triggers, alerting the CHPT and Dredging Operator that the turbidity at the monitoring location has increased (either dredging or natural cause related). The Tier 3 Compliance Level trigger requires dredging (in the location of the trigger event) to cease. Dredging can recommence in that location once***:***

- ***Recorded turbidity at that location has dropped below the intensity level, or***

- ***The duration of exceedance at that location drops below the allowable duration, or***
- ***The event causing the turbidity increase has been classed as an extraordinary event in accordance with condition 9.8 of the Consent.***

It is important to note that exceedances of any of the trigger levels can occur due to natural events and may not always be directly related to the dredging activities. The causes of the trigger level/compliance level exceedances will be investigation as described in the following sections.

A brief summary of how the turbidity triggers are calculated is presented in the following sections. Details of the management actions required in response to each trigger are set out further below. The turbidity intensity and allowable duration associated with each tier are tabulated in the following sections.

4.3.3 Calculation of trigger levels

The calculation of trigger levels requires a series of steps, firstly to process the measured baseline turbidity data then to combine the processed baseline data with the modelled dredge turbidity.

The data processing of the measured baseline turbidity data is required in order to ensure the gathered data is appropriate for analytical purposes (refer Figure 4.2). In summary the data first receives functional validation (a combination of automatic (SMART) and manual methods) to remove erroneous data. The data then runs through a statistical QA/QC process and missing data is imputed (if required). Next the data is smoothed using a Kolmogorov–Zurbenko (KZ) filter. The smoothed measured turbidity data is now combined with the model predicted turbidity (which has been converted from TSS to NTU) to create the complete 12 month baseline turbidity data set.

The 80th, 95thand 99th percentiles for each monitoring location are then calculated from the complete baseline turbidity data set. The final step is to make an adjustment to the percentiles to account for the sample size effects. The methodology for processing the raw data is set out in graphical form in Figure 4.3 and in more detail in the Trigger Value Establishment report[4] available on the project website (www.lpcharbourwatch.co.nz).

The trigger values for each Tier and the subsequent management and reporting actions are set out in the following sections.

[4] Trigger value establishment, LPC Channel Deepening Project. Environmetrics, 2018.

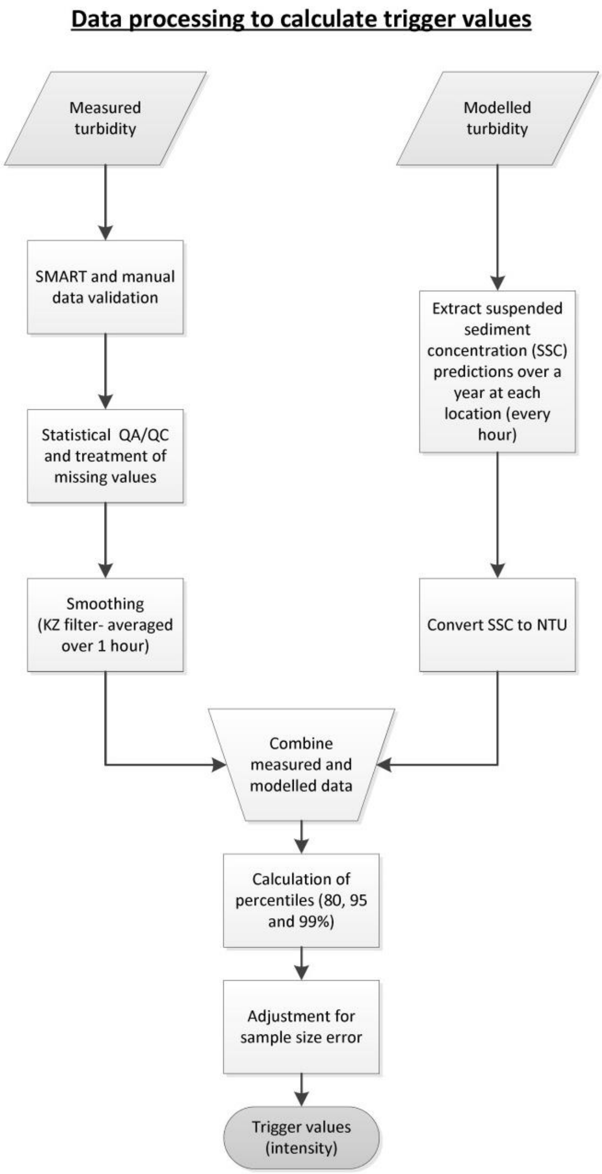


Figure 4.3: Example data processing flow chart (Fox D. R., 2018)

4.3.4 Tier 1 – Internal Trigger

Percentile: **80th**

Duration: **144 hours (6 days)**

	UH1	UH2	CH1	CH2	OS1	OS2	OS3	OS5	OS6	OS7	SG1	SG2b	SG3
Turbidity (NTU)	15.1	13	11.6	10.4	9.9	8.9	8.9	6.2	7.3	9.2	6.3	6.9	4.7

Once a Tier 1 trigger event has occurred the CHPT will investigate the potential causes by utilising some or all of the following methods:

- Investigate the following:
  - Examine the monitoring equipment for any faults/defects/biofouling that may have influenced data collection.
  - Analyse and compare the results against:
    - Background turbidity levels measured during baseline and trends at reference/other nearby sites
    - Recent meteorological and current/wave/tide conditions (particularly any extreme events)
    - Turbidity levels and trends at all monitoring sites for at least 48 hours prior to exceedance.
  - Consider sediment transport patterns in Lyttelton Harbour/Whakaraupō, Port Levy/Koukourārata and wider Banks Peninsula using aerials/satellite imagery.
  - If necessary, examine the environs of the monitoring site to ensure no natural processes (e.g. landslips, seaweed build up etc.) are contributing to the elevated turbidity level.
  - If necessary, undertake manual soundings of turbidity in the area to verify instrument readings.
  - Consider the location of dredging/disposal in the two days preceding exceedance.

Based on the above, the investigation shall determine the likelihood of the trigger event being due to the dredging in order to analyse how and why the event occurred. If it is determined at all likely that the dredging activities have contributed to the increased turbidity level, the Dredging Operator may, as soon as practicable, adjust the dredging operations in order to prevent turbidity further increasing at the location. Where the extent to which the dredging has contributed to the trigger event is uncertain, a precautionary approach shall be taken assuming the dredge has contributed to the exceedance.

Dredging operation modification to reduce plume extent/concentration may include the following (based on the discretion of the dredging operator and advice from other members of CHPT:

- Change of disposal location within spoil grounds
- Change the dredging location

- Alteration of overflow regime
- Alteration of vessel speed during dumping
- Modification of dredge phase with respect to tide phase/meteorological conditions.

A monitoring location shall be deemed no longer in a trigger event immediately upon the turbidity levels reducing to below the specified turbidity trigger level. Note that the smoothed rolling average (using the KZ method) of the data, not the instantaneous 15 minute reading, is used for comparison with trigger levels. Furthermore, it is important to note that whilst the trigger event has ceased when turbidity has dropped below the turbidity trigger level, the duration may still be at its limit. Therefore any exceedance of the turbidity trigger may instantly cause a trigger event until the 30 day rolling window clears the last elevated turbidity occurrence and the amount of accumulated exceedance hours are reduced.

Records shall be kept of Tier 1 trigger events, number of trigger events and associated investigations or actions. For clarity, a trigger event report is not required for Tier 1.

4.3.5 Tier 2 – Internal Trigger

Percentile: 95th

Duration: 36 hours (1.5 days)

	UH1	UH2	CH1	CH2	OS1	OS2	OS3	OS5	OS6	OS7	SG1	SG2b	SG3
Turbidity (NTU)	21.4	19.6	17.6	15.2	15.1	12.4	14.2	11.2	11.5	14.2	9.6	10.6	7.4

Once a Tier 2 trigger event has occurred the CHPT will, as soon as practicable, investigate the potential causes by utilising some or all of the following methods as well as those set out in the Tier 1 trigger:

- Notify the TAG of the trigger event (via automated email).
- Dredging operator is to increase the management measures in order to further reduce the turbidity levels at the location of exceedance.
- Undertake further review of the monitoring data and environmental factors which may be causing a natural increase in turbidity (as set out for Tier 1).
- If deemed necessary undertake additional monitoring in the area of exceedance to further investigate the turbidity plumes.

A monitoring location shall be deemed no longer in a trigger event immediately upon the turbidity levels reducing to below the specified intensity level, or the exceedance time dropping below the allowable duration. As for Tier 1, any exceedance of the turbidity trigger level may immediately cause a trigger event until the rolling 30-day period has cleared the last elevated turbidity occurrence and the amount of accumulated exceedance hours are reduced.

Records shall be kept of Tier 2 trigger events, number of trigger events and associated investigations or actions. For clarity, a trigger event report is not required for Tier 2.

4.3.6 Tier 3 Compliance Level

Percentile: **99th**

Duration: **7.2 hours**

	UH1	UH2	CH1	CH2	OS1	OS2	OS3	OS5	OS6	OS7	SG1	SG2b	SG3
Turbidity (NTU)	42.9	30.2	28.1	22.7	23.4	17.3	30.6	18.3	18.8	22.7	13.9	20.1	13.1

Tier 3 Compliance Level is a compliance trigger level as specified in Consent Condition 9.1. The CHPT/Dredging Contractor shall take all practicable steps to avoid dredge turbidity plumes causing a Tier 3 Compliance Level trigger event.

If a monitoring location records a Tier 3 Compliance Level exceedance (i.e. exceeding the turbidity intensity for more than 7.2 hours in any 30-day rolling period) the following shall occur:

- **Dredging must cease in the vicinity of the monitoring location**. The distance at which the dredge is no longer within the vicinity of the monitoring location is determined by the CHPT and should take into consideration the predicted suspended sediment plume extent from the dredging and/or disposal activities as well as the current and forecast Meteorological and current/wave conditions.
- The CHPT/Dredge Contractor shall undertake an investigation into the likely cause of Trigger Event and produce a short compliance level exceedance report. This should include the following points.
  - Condition of monitoring equipment and any faults/defects that may have influenced data collection.
  - Analysis and comparison of the results against:
    - Background turbidity levels
    - Recent meteorological and current/wave/tide conditions (particularly any significant events)
    - Turbidity levels and trends at all monitoring sites for at least 48 hours prior to exceedance
    - Sediment transport patterns in Lyttelton Harbour/Whakaraupō, Port Levy/Koukourārata and wider Banks Peninsula using ADCP data and aerials/satellite imagery.
  - Any coastal changes near the monitoring site t (e.g. landslips, seaweed build up etc.) which may be contributing to the elevated turbidity level.
  - The dredging programme in the two days preceding exceedance.
- Dredging can only recommence if (in accordance with Conditions 9.7.1 through 9.7.3 of the Consents):
  - The number of Tier 3 exceedance hours has fallen below the 7.2 hours available at that station over a 30-day rolling period; or
  - The turbidity recorded at that station is less than the Tier 3 NTU Intensity value; or
  - The exceedance is deemed due to an extraordinary natural event (in accordance with condition 9.8).
- If LPC and the CHPT deem the exceedance is due to an extraordinary natural event (as defined in the advice note below condition 9.8.2) then dredging can continue in the vicinity of the monitoring location provided that:

- A written report, demonstrating the elevated turbidity is due to an extraordinary natural event and not dredging, is provided to the Canterbury Regional Council within 24 hours of the exceedance, AND
- The Canterbury Regional Council does not notify LPC, within two working days of the report being provided, that the report is NOT being accepted.

- The 'extraordinary natural event' report is to be provided to the TAG and the PRG and available to be viewed by the public on the Project Website (www.lpcharbourwatch.co.nz).

5 Assurance monitoring

The purpose of assurance monitoring is to provide confidence that the adaptive management approach is achieving the objectives of the EMMP i.e. to ensure that longer time scale effects of the CDP are not beyond anticipated and provide protection to the various cultural, physical and ecological environments present in Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata. The assurance monitoring collected during the dredging and post-completion phases of Stage One of the CDP will be compared to the already collected baseline monitoring data.

Assurance monitoring comprises:

- Sub-tidal, intertidal and benthic ecological surveys
- Water Quality Monitoring
- Dredge Spoil quality monitoring
- Marine mammal monitoring
- Bathymetric surveys
- Physical beach shore monitoring
- Inspections of marine farms (where necessary).

An outline of the monitoring is given below. For full details of the required frequency of the monitoring refer to Section 5.7 or Appendix 1 of the Consent.

5.1 Ecological monitoring (subtidal, intertidal and benthic – soft shore/rocky reef)

Objective: identify any changes to soft shore and rocky reef communities' that may result from the CDP dredging and disposal activities. This monitoring particularly focuses on any longer time scale ecological response to potential dredge-related elevated turbidity. This monitoring aims to give assurance that the ecological communities have not been impacted, over time, more than predicted, by the CDP.

Upon completion of the ecological monitoring, the results shall be recorded and reported as part of the four monthly ecological monitoring report (refer Section 7.3).

5.1.1 Subtidal rocky shoreline

Surveys of subtidal rocky shoreline communities shall be undertaken at no fewer than six locations, as set out in Plan CRC172455C, Appendix A. The surveys shall be undertaken at every four months during the baseline and dredging phases. Two surveys shall be undertaken after each deepening stage, at 4-6 months and 8-12 months post-cessation of dredging. Due to the surveys being weather dependent the frequencies are approximate only.

The methodology of each survey will cover the following (full detailed methodology is included in Appendix B):

- Dive surveys along three subtidal transect lines, parallel to the shore and at the following depth ranges:
  - Deep transect
    - between 6 – 8 m depth and 30 m in length

    - running near maximum extent of non-coralline macroalgae
  - Shallow transect
    - between 3 – 5 m depth and 30 m in length
    - within kelp forest habitats
  - littoral fringe transect
    - between 0-1 m depth (relative to chart datum) and 50 m long
    - within the shallow subtidal.
- Eight quadrats (measuring 1 square metre (m^2)) at each shallow/deep depth transect with the following recorded at each quadrat:
  - Water depth
  - An estimate of the percentage cover of substrate type
  - An estimate of the percentage cover of canopy forming and understory algae
  - Estimates of percentage cover of encrusting invertebrates (e.g. sponges, ascidians, mussels)
  - Counts of solitary epifauna (e.g. snails, sea urchins, sea stars).
- A count and measure of the number of large invertebrate and mahinga kai species within a one m band (i.e. 50 m^2 area) at each littoral fringe transect.

5.1.2 Intertidal rocky shoreline

Intertidal biological communities will be surveyed at four locations throughout Lyttelton Harbour/Whakaraupō (refer Plan CRC172455C, Appendix A). Surveys shall be undertaken at the same frequency as the subtidal surveys. Due to the surveys being weather dependent the frequencies are approximate only.

The methodology of each survey will cover the following (full detailed methodology is included in Appendix B):

- Survey of 50 m shoreline at each site.
- Recording of substrate characteristics.
- Recording of zonation patterns of intertidal fauna and flora at high, mid, low and tidal pools using a categorical scale.
- Representative photos of habitats and taxa were also obtained.
- Taxonomic nomenclature based on the World Register of Marine Species (WoRMS Editorial Board 2016).

5.1.3 Benthic (soft sediments)

Benthic sampling shall be undertaken to record the physical, chemical and biological nature of benthic habitats. Two groups of sites are to be sampled, a set of 14 sites for the dredging phase and a further 5 sites for the pre and post dredging phases (refer CRC172455E, Appendix A). The sites should be sampled at the same frequency as the subtidal survey work.

The methodology of each survey will cover the following (full detailed methodology is included in Appendix B):

- Sediments will be collected using a 0.1m^2 stainless steel Van Veen grab from 19 samples.

- The collected sediment samples shall be analysed for:
  - Sediment chemistry, in particular indicative metal contaminants
  - Sediment grain size distribution and organic content
  - Sediment-dwelling macroinvertebrate communities (infauna).
- Triplicate grabs will be conducted at each station and at each, the grab contents will be sub- sampled for the sediment and infauna analyses.

5.2 Marine water quality monitoring

Objective: monitor any changes in water quality throughout Lyttelton Harbour/Whakaraupō and Port Levy/Koukourārata that could potentially be attributed to the dredging activities and provide a mechanism to evaluate the benthic-subsurface turbidity relationship.

Water quality monitoring shall be undertaken at each of the monitoring locations described in Section 4 and set out in Figure 4.1.

Refer to Table 5.1 for a summary of proposed monitoring at each station and the Environmental Monitoring Reports, Vision Environment (2016) on the Project Website (www.lpcharbourwatch.co.nz) for further information.

5.2.1 Water sampling

Monthly water quality sampling shall be undertaken for the following:

- Total Suspended Solids (TSS)
- Nutrients (Total phosphorous, orthophosphate, total nitrogen, ammonia, nitrate, total Kjeldahl nitrogen)
- Chlorophyll
- Total and Dissolved Metals (Aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybedenum, nickel, selenium, silver, tin, vanadium and zinc).

Biannual water quality sampling will also be undertaken for:

- 22 individual acid herbicides
- 179 individual multiresidue pesticides
- Total petroleum hydrocarbons an BTEX.

Duplicate water samples for all parameters will be collected at 10% of sites as per established protocols (equates to 1 site per round), with a field and laboratory blank collected per sampling day. Samples will be undertaken and analysed in accordance with standard protocols derived from worldwide authorities, including Australian and New Zealand Standards for water quality sampling (ANZECC).

Table 5.1: Summary of discrete grab sampling approach (Vision Environment, 2016)

Sites	Depth profiling	Sub-surface metals & nutrients	Sub-surface organics	Sub-surface TSS	Mid-column & benthic TSS
SG1 SG2 SG3; OS1 OS2 OS3 OS4 OS5 OS6 OS7	Monthly	Monthly	Biannually	Monthly	Monthly
CH1 CH2 UH1 UH2 UH3	Monthly	Monthly	Biannually	Monthly	- (water too shallow)

5.3 Dredge hopper validation samples

Objective: provide assurance that the dredged spoil does not contain levels of contaminants or toxins beyond expected. This monitoring occurs during the dredging only and is a quality control to provide assurance that contaminant surveys undertaken at select locations in the Harbour prior to dredging are representative of the material being dredged. LPC is voluntarily undertaking this sampling and it is **not required** by any consent condition.

Methodology: Two grab samples shall be collected from the dredge hopper into laboratory supplied containers. The samples shall be collected following a representative dredge run for the period (i.e. location in channel, depth dredged etc.). The samples shall be labelled with the hopper load number and the approximate dredge location shall be recorded alongside a unique sample identifier.

Samples shall be **collected fortnightly** from the hopper in a manner which ensures samples are representative of different locations throughout the dredging footprint.

- Samples shall be couriered, under chain of custody documentation and on ice, to the laboratory.
- Samples shall be tested by an IANZ credited laboratory for the following determinants:
  - Organic content
  - Trace metals (As, Cu, Cr, Cd, Ni, Hg, Zn)
  - Grain size.
- Results shall be tabulated and compared to the ANZECC ISQG-low guidelines.

5.4 Bathymetric surveys

Objective: give an indication of the change in seabed along the channel and at the offshore disposal ground during dredging and post completion of each stage. This will be compared to baseline bathymetric surveys and, for the disposal ground, predicted sediment dynamics from morphological modelling (MetOcean Solutions Ltd, 2016) as part of model validation and to give assurance that sediment dispersion is occurring as predicted.

Methodology: The bathymetric surveys shall be undertaken annually in accordance with condition 8.9 and as shown on Figure and at the frequencies given in Table 5.2 below. The survey shall comprise perpendicular transects down the navigation channel, the swing basin and at the disposal ground. Refer to Plan CRC172455E and Table 5.1 below for approximate locations. Survey accuracy and method shall be standard for all surveys.

Table 5.1: Bathymetric transect locations

Transect Number	Transect Type	Length (m)	NorthX	NorthY	SouthX	SouthY
1	Navigation Channel	18641.0	396185.867	798042.518	397114.44	796425.336
1a	Navigation Channel	1076. 5	397814.411	795740.882	398781.834	795265.442
2	Navigation Channel	1771.5	399988.321	797832.797	400265.186	796082.333
3	Navigation Channel	2432.3	402064.39	798845.358	402697.981	796496.022
4	Navigation Channel	2676.4	404106.372	799156.103	404308.44	796486.241
4a	Navigation Channel	2016.8	405313.019	799400.714	408471.713	802619.482
5	Navigation Channel	2639.9	406378.426	799799.115	407442.65	797382.119
5a	Navigation Channel	3372.5	408472.924	802619.746	410377.072	799835.747
6	Spoil Ground	12284.2	418274.315	804356.847	406604.653	800504.215
7	Spoil Ground	8436.9	415529.658	805223.461	410235.411	798650.036
8	Spoil Ground	11587.1	410138.235	806288.919	419476.92	799421.705

NB All co-ordinates are in Mt Pleasant 2000 grid

Table 5.2: Bathymetrical monitoring frequencies

Project Phase	Frequency
Baseline	One full survey as per Plan CRC172455E
During Dredging	Regular localised bathymetric surveying of the channel and the disposal ground undertaken as normal practise during dredging and reported as part of the monthly monitoring report. At least one full survey as per Plan CRC172455E undertaken within one month of completing the dredging.
1-5 years post-completion of a dredging stage (or until consolidation occurs)	One full survey annually.

5.5 Physical shoreline surveys

Objective: monitor and assess any changes on the rocky and soft shores of Banks Peninsula and Pegasus Bay.

Methodology: The following physical shoreline monitoring will be taken at the locations shown in Plan CRC172455D, Appendix A:

- Fixed photo-point monitoring to visually assess beach level changes or fine sediment deposition.
  - Fixed position photography at the same location and tide where possible.
  - Collected 3-monthly during baseline monitoring, during dredging and for a period of 2 years post-dredging then 6 monthly for the years 3-5 post-dredging.
- Sediment texture (PSD) of soft shore areas incl. fines <63 micron.

  - Collect surface sample from intertidal beach face at high, mid and low tide points (i.e. three samples in total from each location).
  - 6 monthly throughout the baseline, dredging and two years post-dredging, then annually for the 3-5 years post-dredging.
- Beach profile survey from established benchmark (note there are some already existing Sumner and Brighton). This can be done using staff and level, total station or real time kinematic satellite navigation.
  - Spring low tide, pick up all changes in grade.
  - Required horizontal accuracy +/- 0.1m, vertical accuracy +/- 0.05m.
  - 6 monthly throughout the baseline, dredging and five years post-dredging.
- Shoreline analysis
  - Initially derive historic shoreline positions of Lyttelton Harbour monitoring beaches (not including Sumner/New Brighton beaches as there are already records at these areas).
  - Annually for five years as additional aerial photographs/satellite imagery become available.

It is noted that beaches around Avon-Heathcote estuary mouth may be affected by changes in the flow regime resulting from bed-level shifts occurring during the Christchurch earthquakes. This should be taken into consideration when interpreting results (though may be impossible to differentiate).

5.6 Marine mammal monitoring

Objective: provide assurance that the CDP is not affecting dolphin activity in (in particular the Hector's Dolphin/upokohue) in the waters of Lyttelton Harbour/Whakaraupō and offshore Banks Peninsula.

Methodology: Through the use of passive acoustic devices (C-POD), ascertain the presence of marine mammals prior to, during and after dredging. This will enable comparisons to be made and identification of any changes in marine mammal behaviour which could be attributable to the dredging activities.

- Deployment of self-logging C-PODs at four locations in order to collect echo-location activity. These will be located as per Plan CRC172455F, Appendix A.
- Monthly or 6-weekly collection of self-logging data and maintenance.
- Four-monthly reporting of monitoring data and results.
- Final reports detailing the reporting results, consideration of the echolocation recorded in context to the dredging and disposal activities and investigation of any echolocation-activity.

5.7 Monitoring frequency

The following table (Appendix 1 of the Consent) sets out the monitoring frequency required by the consent.

Appendix 1: Table of Monitoring and frequency of monitoring

Type of monitoring	Parameter	During Baseline and During Dredging		After Dredging Stage
		Monitoring	Collection	
Real Time Monitoring (Turbidity and Water Quality) For the purposes of this table "telemetered" means the delivering of the monitoring data electronically to LPC as the data is recorded unless otherwise specified in the table	Turbidity (NTU)	At least every 30 minutes	Telemetered Logged and collected	4 months
	Benthic PAR ($Mol/m^2/d$)	At least every 30 minutes	Monthly	
	Bed Level (altimeter)	At least every 30 minutes	Monthly	
	pH	At least every 30 minutes	Telemetered or Logged and	
	• Temperature • Conductivity • Dissolved Oxygen	At least every 30 minutes	Telemetered or Logged and collected	
	Water dynamics (current speeds and direction and waves)	At least every 30 minutes	Telemetered Sent 6-hourly	
Sample/Survey (Water Quality and Ecology)	Nutrients (phosphorus and nitrogen) and chlorophyll a (µg/L)	Monthly		Monthly for four months
	Total and dissolved metals (µg/L)	Monthly		
	TSS mg/L	Monthly		
	Organic chemicals – 22 individual acid herbicides - 179 individual multiresidue pesticides - Total petroleum hydrocarbons and BTEX	6-Monthly		One survey within 4 months of dredging ceasing
	Soft-Sediment Benthic	4-Monthly Survey (subject to weather conditions)		One survey within 4-6 months of dredging ceasing and one survey between 8-12 months from dredging

Type of monitoring	Parameter	During Baseline and During Dredging		After Dredging Stage
		Monitoring	Collection	
	Shoreline Ecology • Sub-tidal • Inter-tidal			ceasing
	Underwater Acoustic Monitoring	Continuously	Logged and collected Monthly	For a period of 3 months
Monitoring of Physical Parameters	Photo-point monitoring[1]	3-monthly		3-monthly for first 2 years 6-monthly for the following 3 years
	Sediment size analysis[2]	6-monthly		6-monthly for first 2 years Annually for the following 3 years
	Beach profile survey[3]	6-monthly		6-monthly for 5 years
	Shoreline analysis[4]	A Baseline assessment of historical shoreline (Lyttelton harbour only) Annually for five years as aerial photographs/satellite imagery become available		
	Seabed (Bathymetric) Survey	Annually		Annually for 5 years

[1] To visually assess beach level change or fine sediment deposition from fixed locations and aspects
[2] To quantify sediment size on beach to determine changes in texture and composition
[3] To quantify changes in profile geometry and/or location from an established benchmark
[4] To determine changes in shoreline position using aerials photographs or satellite imagery

Survey requirements to achieve beach profile:

- Survey using staff and level, total station or RTKGPS
- Survey during spring low tide, pick up all changes in-grade
- Required horizontal accuracy +/- 0.1m, vertical accuracy of +/- 0.05m

An Unmanned Aerial Vehicle (UAV) survey may be used in place or augment photo-point monitoring, beach profile survey and shoreline analysis.

Bathymetric survey accuracy shall be +/- 0.1m to +/- 0.5m in the vertical and horizontal directions respectively for comparable to every other survey undertaken in the same location. The error for each reading is expected to be in the order of 2-8 cm.

6 Other management protocols

In addition to the adaptive management and assurance monitoring detailed above, appropriate management to mitigate potential effects on marine mammals, procedures for accidental discoveries, incidents and fatalities and complaint reporting will be required throughout the construction period. Specific protocol outlined by the dredging company is included in the Dredge Management Plan. All plans are available on the project website (www.harbourwatch.co.nz).

6.1 Dredge Management Plan

A Dredge Management Plan (DMP) is to be prepared by the Consent Holder/Dredge Contractor prior to the commencement of dredging. The purpose of the DMP is to specify how dredging practices and procedures will ensure that any actual or potential adverse effects on the marine receiving environment are avoided or otherwise mitigated to the greatest extent practicable.

The DMP includes the following information:

- Number and type of dredgers to be used;
- Methodology and operation of the dredger(s);
- Details of spatial control and recording for dredging and disposal activities;
- Maintenance of equipment and systems;
- Storage and handling of hazardous substances;
- Details of outdoor lighting mitigation to manage bird strike risk;
- Liaison with water sports clubs (i.e. Naval Point Club/Charteris Bay yacht Club) to identify potential conflicts between the dredging program and organised sporting events and identify measures to resolve these conflicts;
- Utilisation of a 'green valve' (also referred to as 'environmental valve');
- Details of the training for a person involved in the operation of the dredge so that he/she may recognise any potential archaeological material including koiwi tangata or taonga; and
- A description of all other necessary measures to avoid or mitigate adverse effects on the receiving environment to the greatest extent practicable during the operation of the dredge vessel; including measures relating to biofouling, management of waste, and refuelling.

6.2 Marine Mammal Management Plan (MMMP)

As the project location is within marine mammal habitats (specifically Hectors Dolphins), a Marine Mammal Management Plan (MMMP) is to be prepared prior to the commencement of dredging to set out required management responses in relation to marine mammals. The purpose of the MMMP is to specify how the risk of vessel collision and the risk of impacts from dredge noise on marine mammals are to be reduced as much as practicable.

The MMMP shall include:

- Requirements for a regular crew member on the dredge to be a designated marine mammal observer and undertake record keeping requirements;
- Details of training of the designated observer by a suitably qualified marine mammal expert;
- Information protocols with the Department of Conversation to help anticipate potential seasonal interactions with whale species;
- Detailed guidelines for the vessel, including speed limits, to reduce and chances of mortality from vessel strikes with whales, particularly Southern Right Whales;
- Description of the methods to characterise underwater noise produced during the operation of the dredge vessel to determine whether there is a potential for a temporary threshold shift in hearing to occur in marine mammals and any measures to reduce this potential effect; and
- Description of the measures to maintain the vessel, including all dredging equipment, to reduce underwater noise.

6.3 Marine-based Accidental Discovery Protocol (ADP)

A Marine-based Accidental Discovery Protocol (ADP) applies to the works, as is protocol for all projects undertaken by LPC.

The ADP includes the following processes for accidentally discovering a material of archaeological significance during Stage One of the CDP:

- In the event of any discovery of archaeological material, the consent holder shall immediately:
  - Cease Dredging operations in the affected area, and mark off the affected area using GPS coordinates on the dredge vessel;
  - Advise the Consent Authority of the disturbance; and
  - Advise the Southern Regional Office of Heritage New Zealand of the disturbance.
- If the archaeological material is determined to be koiwi tangata (human bones) or taonga (treasured artefacts) by Heritage New Zealand, the consent holder shall immediately advise the office of Te Hapū o Ngāti Wheke of the discovery.
- If the archaeological material is determined to be koiwi tangata (human bones) by the Heritage New Zealand, the consent holder shall immediately advise the New Zealand Police of the disturbance.
- Dredging may only recommence within the marked location if the Consent Authority provides a written statement to the consent holder that it is appropriate to do.

6.4 Biosecurity Management Plan (BMP)

The purpose of the BMP is to reduce the risk of a biosecurity incursion.

The BMP shall include the following:

- Description of the dredge vessel and its attributes that affect risk (e.g. voyage speed, maintenance history, prior inspection, voyage history since last dry-docking and antifouling).
- Description of the key sources of potential marine biosecurity risk from ballast water sediments and biofouling.
- Findings from previous inspections.
- A description of the risk mitigation taken prior to arrival in New Zealand, including:
  - Routine preventative treatment measures and their efficacy, including the age and condition of the antifouling coating, and marine growth prevention systems for sea chests and internal sea water systems;
  - Specific treatments for submerged and above-water surfaces that will be undertaken to address IHS and CRMS requirements prior to departure for New Zealand. These could include, for example, in-water removal of biofouling, or above-water cleaning to remove sediment;
  - Additional risk mitigation planned during transit to New Zealand, including expected procedures for ballast water management; and
  - Expected desiccation period of above-water surfaces on arrival to New Zealand (i.e. period of air exposure since last dredging operations).
- An assessment of the biosecurity risks to Authorised Marine Farming activities from dredging/disposal activities and methods to be used to minimise those risks to the greatest extent practicable.
- The nature and extent of pre-border inspection that will be undertaken to verify compliance with Import Health Standard (IHS) and Craft Risk Management Standard (CRMS).
- Record keeping and documentation of all mitigation undertaken to enable border verification if requested by Ministry of Primary Industries and to facilitate final clearance.

6.5 Complaints

Records shall be maintained by the Consent Holder of any complaints logged relating to the CDP activities. Complaints shall be directed to the Project Environmental Advisor (Jared Pettersson – contact details in Section 1.7).

The records shall cover the following:

- The location of the reported nuisance or effect.
- The date and time of the complaint.
- A description of the weather conditions at the time of complaint, if relevant.
- Any possible cause of the nuisance or effect.
- Any management actions undertaken to address the cause of the complaint, and the name of the complainant, if offered.

LPC shall follow LPC's standard complaint response protocol to ensure these are adequately responded to.

The record of complaints shall be provided to the CRC every 4 months, or on request.

An aggregated summary of complaints received for each month shall be provided to the TAG no later than the end of the following month.

6.6 Incidents

In the event of a more than minor spill (>5l) or leak of oil, fuel or other hazardous substance to water Te Rūnanga ō Ngāi Tahu, Te Hapū o Ngāti Wheke and Te Rūnanga o Koukourārata shall be notified to inform whanau who may use the area for mahinga kai. The Harbourmaster shall also be notified of more than minor spills.

6.7 Fatalities

The following are to be notified in the event of an on-site accident resulting in a human fatality:

- Te Hapū o Ngāti Wheke if the incident is in Whakaraupō .
- Both Te Hapū o Ngāti Wheke and Te Rūnanga o Koukourārata if the incident is offshore. As mana whenua, Ngā Rūnanga are responsible to ensure that correct tikanga is followed in such an event.

7 Reporting requirements

7.1 Tier 3 Compliance Level Exceedance Report

As specified in Condition 9.8.1 of the Consents, in the instance where a Tier 3 Compliance Level trigger has occurred and it is considered due to an extraordinary natural event and not the dredging, LPC may provide a report to the Canterbury Regional Council within 24 hours of the trigger exceedance demonstrating this is the case. If accepted, LPC may continue dredging in the vicinity of the triggered monitoring location. If, within 2 working days of receiving the report, ECan notify LPC that it does not accept the event was extraordinary, dredging must cease in the vicinity of the monitoring location until a trigger event is no longer occurring.

The report shall include:

- Results of investigations occurring as part of the management responses detailed in Section 4.6.
- Determination of whether the event was likely to be dredge related or not.
- Management actions taken in response to the event and the results of the action i.e. changes in location of the dredge and turbidity levels as a result of this.
- Graph summarising the turbidity at the exceedance location over the monitoring period.

The report is to be provided to the TAG and PRG for review and put on the Project Website for public viewing.

7.2 Monthly Monitoring Reports

A monthly report shall be prepared by the CHPT during and at least four months after the dredging which consists of a summary and evaluation of water quality assurance monitoring undertaken over the period. The report shall be provided to the TAG and ALG no later than by the end of the third working week of the month. The report shall include any monitoring or equipment issues that occurred during the period.

At least four monthly reports are to be prepared post-completion of dredging.

Completed by: CHPT

Reviewed by: TAG and ALG

7.3 Quarterly monitoring reports

A quarterly report shall be prepared by the CHPT every three months during and after a dredging stage. These reports shall include the monitoring and management response measures and results carried out during the four-month period, collation of all monitoring undertaken and details of any triggers that have been exceeded, the management response measures carried out and the results of monitoring after the management response measures have been completed.

At least one quarterly report is to be prepared post-completion of the dredging. Physical shoreline monitoring does not need to be included in the post-dredge quarterly monitoring report and is to be reported on June 1 following the dredging instead.

All quarterly reports are to be prepared by the CHPT and reviewed by the TAG. The PRG shall review the report for the purposes of providing advice to the Canterbury Regional Authority.

Completed by: CHPT

Reviewed by: TAG, ALG, PRG, advice given to CRC

7.4 Dredging Stage Completion Report

Within a year of the dredging, a Dredging Stage Completion Report shall be prepared by the CHPT. The report shall contain a summary/collation of the following:

- Dredging activities
- Final bathymetry survey results and analysis
- Monitoring undertaken during the period and a comparison of results to the baseline monitoring
- Trigger exceedances, investigation results and management responses
- Evaluation of the general performance of the EMMP including:
  - Evaluation of the adaptive management approach and management responses undertaken by the EMMP and whether or not the objectives and purpose of the plan were met
  - Evaluation of the monitoring methodology and results
  - Recommendations for improving the EMMP, monitoring and/or management responses for future dredging stage(s).

A copy of the completed report shall be provided to the ALG, TAG, CRC and PRG. The TAG is to provide advice to the Canterbury Regional Council on whether changes to the monitoring and management regime are required should further dredging occur OR for the post-completion monitoring. The PRG shall review the report and provide comments on whether the monitoring and management measures set out in this EMMP and required as part of the Consent Conditions have been adhered to and whether they should be accepted by the Canterbury Regional Council.

8 Group roles and responsibilities

Successful dredge management relies on good communication, liaison and input from a number of key parties throughout the monitoring and management stages. To ensure all relevant technical experts and stakeholders are appropriately involved in the dredge management process the following groups shall be established and implemented through the relevant conditions of the Consents, as outlined below:

- Consent Holder Project Team (CHPT) – Condition 10
- Technical Advisory Group (TAG) – Condition 11
- Aquaculture Liaison Group (ALG) – Condition 12
- Peer Review Group (PRG) – Condition 13

All groups shall be established at least three months prior to commencing dredging.

8.1 Consent Holder Project Team

The CHPT is to be established by LPC and may include any expertise deemed necessary. However, at a minimum, the Consent Holder shall ensure the CHPT includes employees, or persons engaged by LPC, with at least the following expertise:

- An assigned (contractor or employee) project manager for LPC
- Dredging operator
- Hydrodynamic modeller
- Water quality
- Statistician

The roles of the CHPT will include:

- Daily operations and proactive management of the dredge taking into consideration:
  - Real-time turbidity monitoring
  - Water quality monitoring
  - MetOcean conditions and forecasts
- Preparation of the 1-monthly, 4-monthly and end-of-stage monitoring reports and circulation to the ALG, TAG and the PRG and the Canterbury Regional Council, as required (refer Section 7)
- Continually examine the monitoring data to ensure the appropriate information is being gathered
- Ensure the Dredge Contractor has the required monitoring information and the appropriate management responses are completed in a timely manner.

The requirements for the CHPT group roles and members are set out in Condition 10 of the Consents.

8.2 Technical Advisory Group (TAG)

This purpose for this group is to give technical advice to the CHPT on matters of individual member expertise. The group shall consist of no more than 12 members as follows:

- Up to three members from Te Hapū o Ngāti Wheke, Te Rūnanga o Koukourārata and Te Rūnanga ō Ngāi Tahu with suitable qualifications and experience in:
  - Mahinga kai
  - Marine ecology and/or water quality
  - Tikanga Māori
- Up to two technical representatives of the local marine farms with the following expertise:
  - A suitably qualified person who has direct experience in operating a marine farm and is currently managing or operating a marine farm in the vicinity of the project; and
  - A suitably qualified person, experienced in assessing environmental effects of/on aquaculture activities or a related discipline.
- Up to seven members from the Consent Holder with suitable experience and qualifications in:
  - Marine ecology
  - Aquaculture
  - Marine environmental monitoring
  - Hydrodynamic modelling
  - Statistician with experience in natural resource management.
  - No more than two other members of the CHPT

The role of the TAG is to:

- Review the monthly, quarterly and Dredging Stage monitoring reports prepared by the CHPT and where necessary provide advice to the CHPT in writing on whether the monitoring programme detailed in the EMMP requires amendment (including the location of monitoring stations and the parameters monitored for).
- Review any exceedances of the turbidity triggers contained in the EMMP and where necessary provide written advice to the CHPT on whether the monitoring programme detailed in the EMMP needs to be amended to better understand whether exceedances are attributed to Dredging or other environmental parameters.
- Provide advice on any other technical matters as sought by the Consent Holder.
- The TAG will not direct the nature or specifics of dredge management responses.
- LPC shall provides comments back to the TAG if any advice is rejected.
- Where the TAG does not have the expertise in any of the areas it is required to report on, it may engage the services of an appropriate expert on a relevant matter to the TAG.

The Consent Holder shall provide any administrative support necessary for the TAG to carry out its functions. The Consent Holder shall establish the TAG at least 3 months prior to the first commencement of dredging. The Consent Holder shall offer to hold meetings at a frequency appropriate for the dredging programme and reporting intervals.

The requirements for the TAG group roles and members are set out in Condition 11 of the Consent.

8.3 Aquaculture Liaison Group

The purpose for this group is to:

- Enable LPC and the aquaculture industry to share information relating to the CDP.
- Discuss the monitoring required in relation to authorised marine farming activities.
- Ensure any effects on marine farming activities are avoided or remedied.
- Allow the aquaculture industry to provide input into the preparation of the management plans detailed in Section 6 of this EMMP.

The group shall consist of:

- One representative from Sanford Limited
- Up to three representatives from the Authorised Marine Farmers from Northern Banks Peninsula.
- Up to three representatives from LPC.

The Consent Holder shall invite representatives of the ALG to attend a meeting at least once prior to dredging commencing, 3-monthly during dredging and for the 12 months following commencement of dredging and then 6 monthly thereafter.

The requirements for the ALG group roles and members are set out in Condition 12 of the Consents.

8.4 Peer Review Group (PRG)

The purpose of this group is for independent review of documentation and decisions to provide confidence to the CRC that the project is in compliance with the consent conditions and the EMMP.

The group shall consist of three scientists who shall be independent of the Consent Holder, and who collectively are recognised by their peers as having satisfactory experience, knowledge and skill in the following (as condition 13 of the Consent) areas:

- Marine Ecology (including aquaculture and seafood resources)
- Hydrodynamic modelling
- Coastal processes.

The members of the PRG must be approved in writing by the CRC before they commence their oversight and review functions.

The PRG must be established at least 2 months prior to the commencement of dredging.

Note the PRG may engage the services of an appropriate expert to add comment on matters outside their expertise (at the discretion of the Consent Holder).

This group is responsible for:

- Reviewing the EMMP and any amendments undertaken to the plan.
- Reviewing the following reports for the CHPT and providing advice to CRC on whether these have been prepared in accordance with the EMMP:
  - Baseline monitoring report
  - 4-monthly monitoring reports

  - Pre-dredging stage report where any subsequent dredging stage is to commence five or more years after the completion of the final 4-monthly monitoring report prepared for the previous dredging stage
  - Dredging Stage Completion Report
  - Trigger Three Exceedance report.
- Reviewing Tier 3 Compliance Level trigger responses – in particular the decision by the CHPT to continue dredging in an unusual event (for example a storm surge or flood of the Waimakariri River).
- Providing written advice to CRC after a dredging stage on whether any condition(s) should be subject to review.
- Advice to the CRC shall be in writing and the PRG need to recommend to the CRC whether EMMP can be certified and, if not, why not.

The requirements for the PRG group roles and members are set out in Condition 13 of the Consents.

9 Applicability

Enviser Ltd has prepared this report for Lyttelton Port Company in accordance with the agreed scope. No other party may rely on this report, or any conclusions or opinions within it, for any purpose without the express written permission of Enviser Ltd.

The opinions and conclusions within this report are based on the information that was viewed during preparation of the report.bi

Prepared for Enviser Ltd by:

Jared Pettersson
Director
CPEng, CMEngNZ, IntPE

Reviewed for Enviser Ltd by:

Bianca Sullivan
Director

K:\PMO\Current Projects\1 - Group A - R&G\A13A - Dredge Environmental Monitoring\Dredge phase - Environmental Management\EMMP\EMMP for council certification 3JulyAmended.docx

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Appendix A: Project Figures

Plan CRC172455A: **Overall site map**

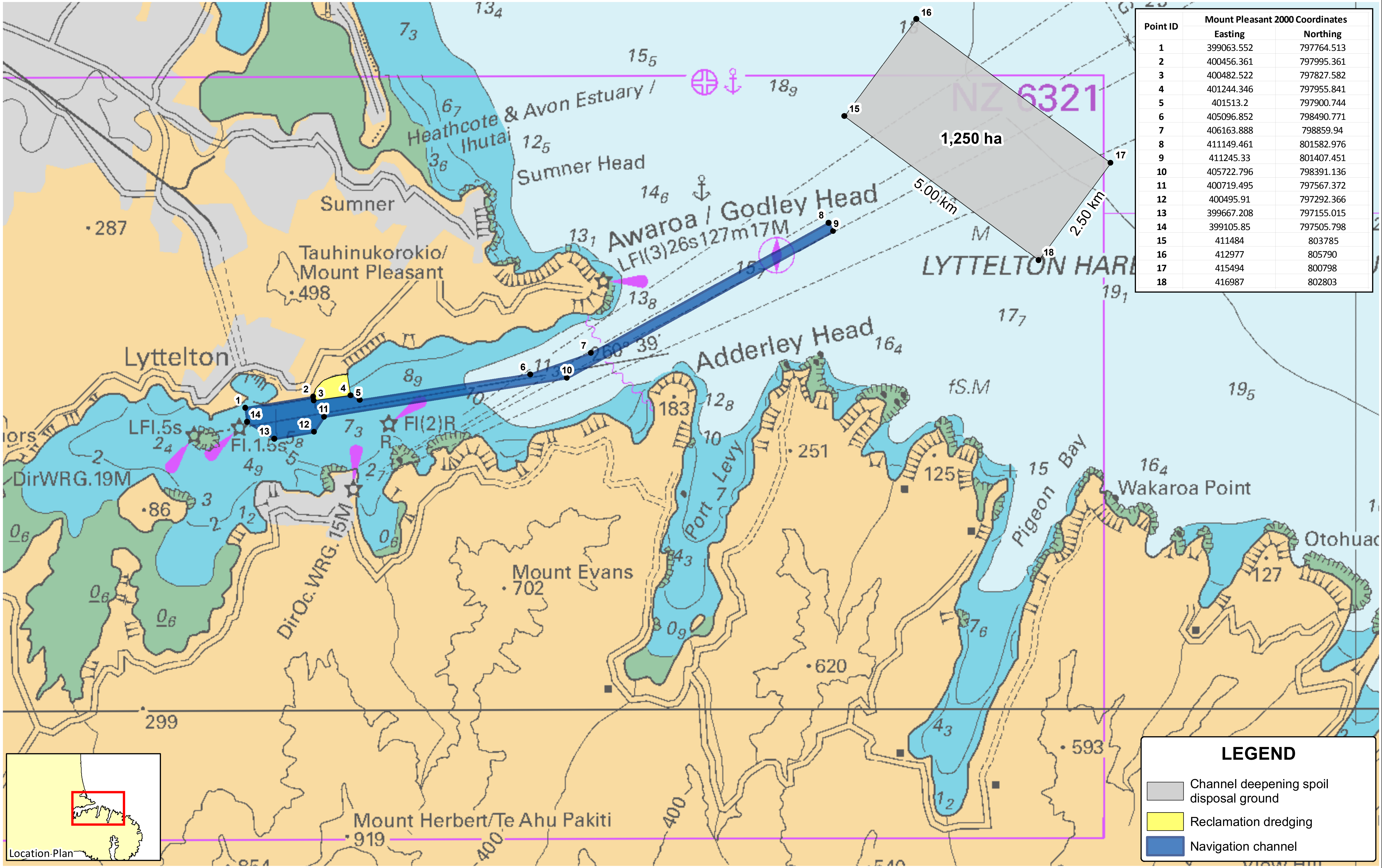
Plan CRC172455B: **Instrumentation Zones**

Plan CRC172455C: **Ecological Monitoring**

Plan CRC172455D: **Physical shoreline monitoring**

Plan CRC172455E: **Bathymetrical monitoring**

Plan CRC172455F: **Marine Mammal Monitoring**



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3	400482.522	797827.582
4	401244.346	797955.841
5	401513.2	797900.744
6	405096.852	798490.771
7	406163.888	798859.94
8	411149.461	801582.976
9	411245.33	801407.451
10	405722.796	798391.136
11	400719.495	797567.372
12	400495.91	797292.366
13	399667.208	797155.015
14	399105.85	797505.798
15	411484	803785
16	412977	805790
17	415494	800798
18	416987	802803

LEGEND

- Channel deepening spoil disposal ground
- Reclamation dredging
- Navigation channel

Notes: Note 1. Chart NZ 6321 Lyttelton Harbour / Whakaraupo sourced CC-By Land Information New Zealand.
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Note 2. Basemap sourced LINZ under CC-BY.
Note 3. Lyttelton Port Recovery Plan areas were sourced from Environment Canterbury under CC-BY.

A3 SCALE: 1:70,000

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Plan CRC172455A

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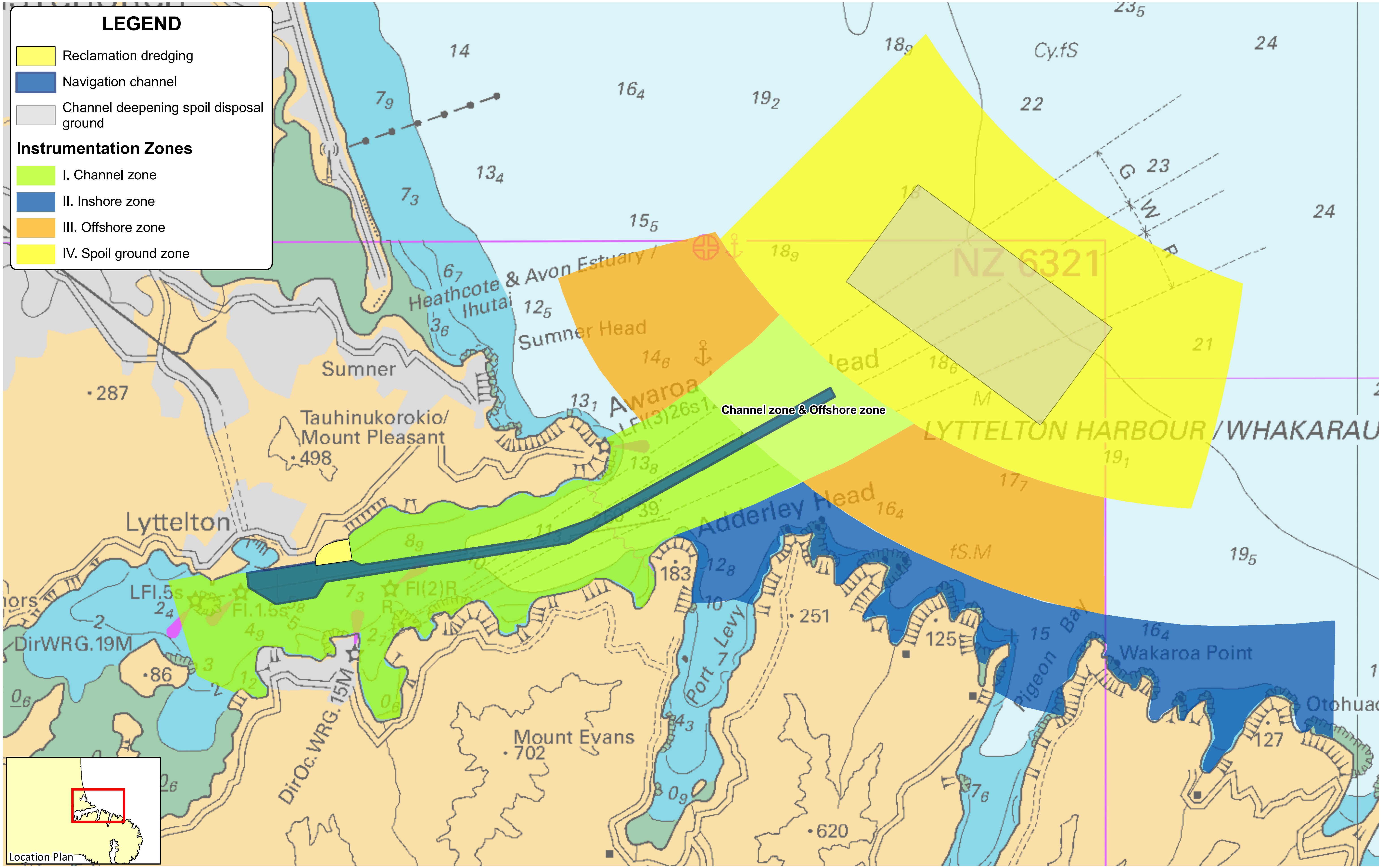

Notes: Note 1. Chart NZ 63 Kaikoura Peninsula to Banks Peninsula sourced CC-By Land Information New Zealand.
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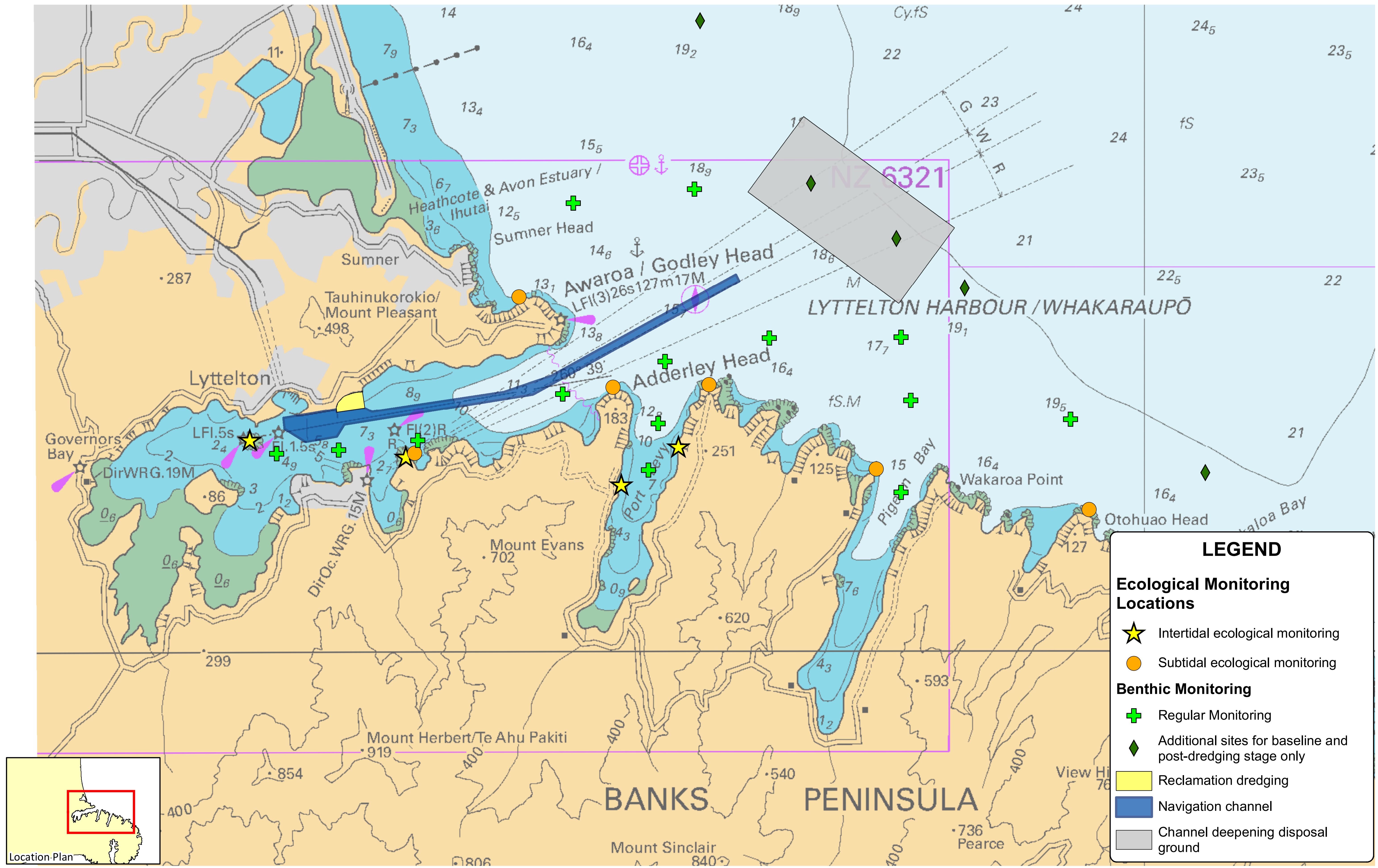

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Note 4. Location of monitoring points is currently indicitive, intended for illustrative use only.

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Plan CRC172455C

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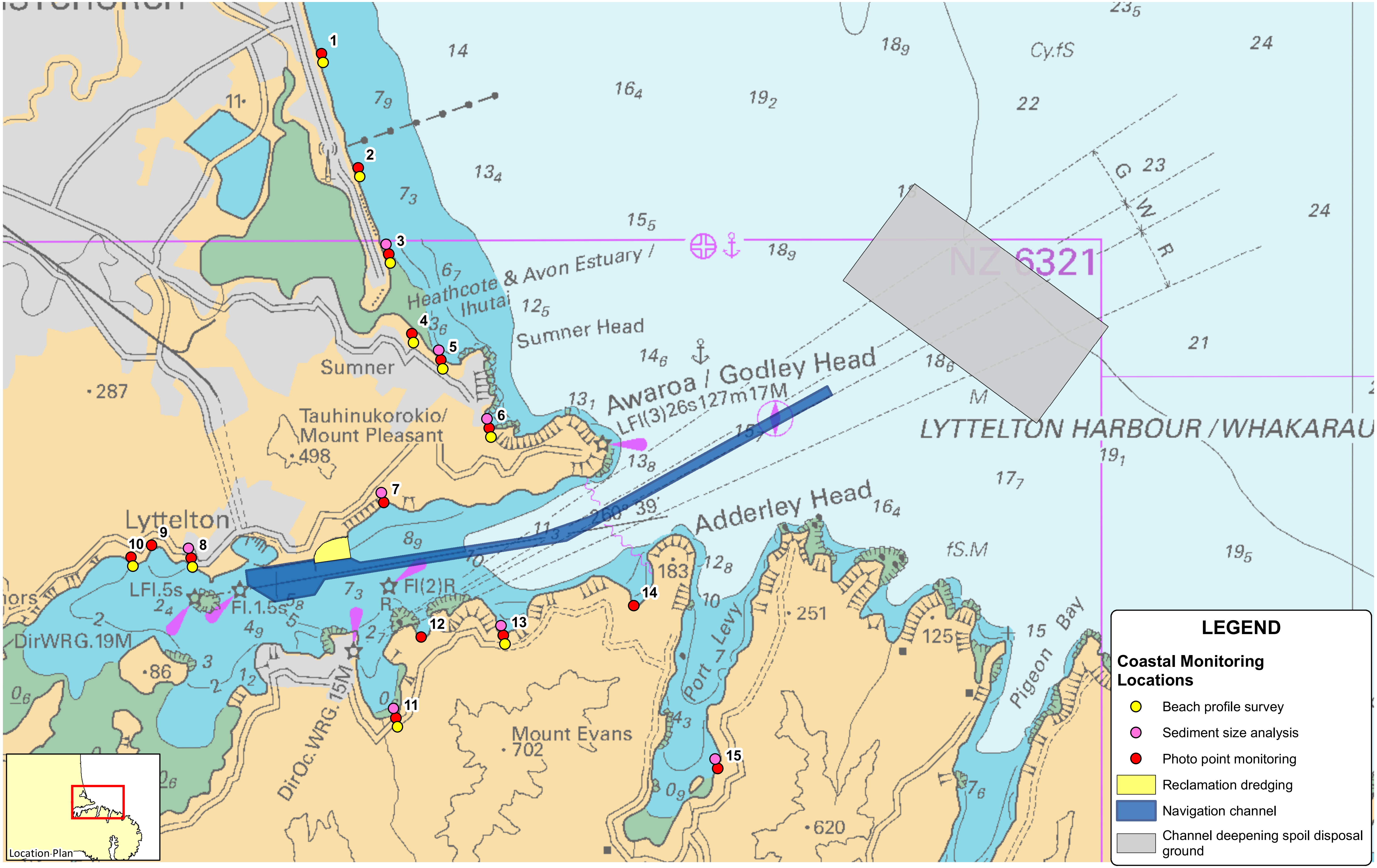

Notes: Note 1. Chart NZ 63 Kaikoura Peninsula to Banks Peninsula sourced CC-By Land Information New Zealand.
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A3 SCALE: 1:70,000

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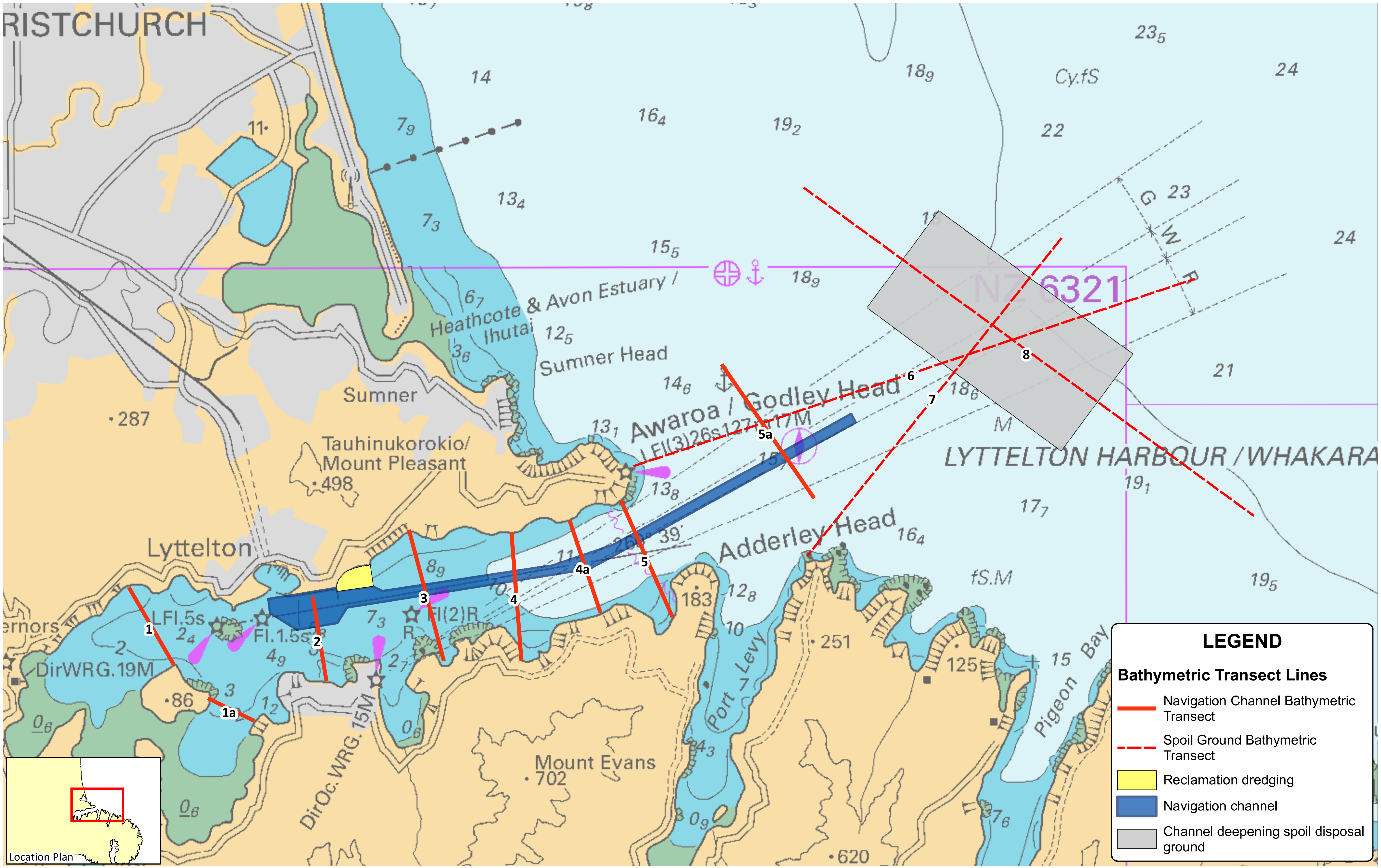

Notes: Note 1. Chart NZ 63 Kaikoura Peninsula to Banks Peninsula sourced CC-By Land Information New Zealand.
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A3 SCALE: 1:70,000

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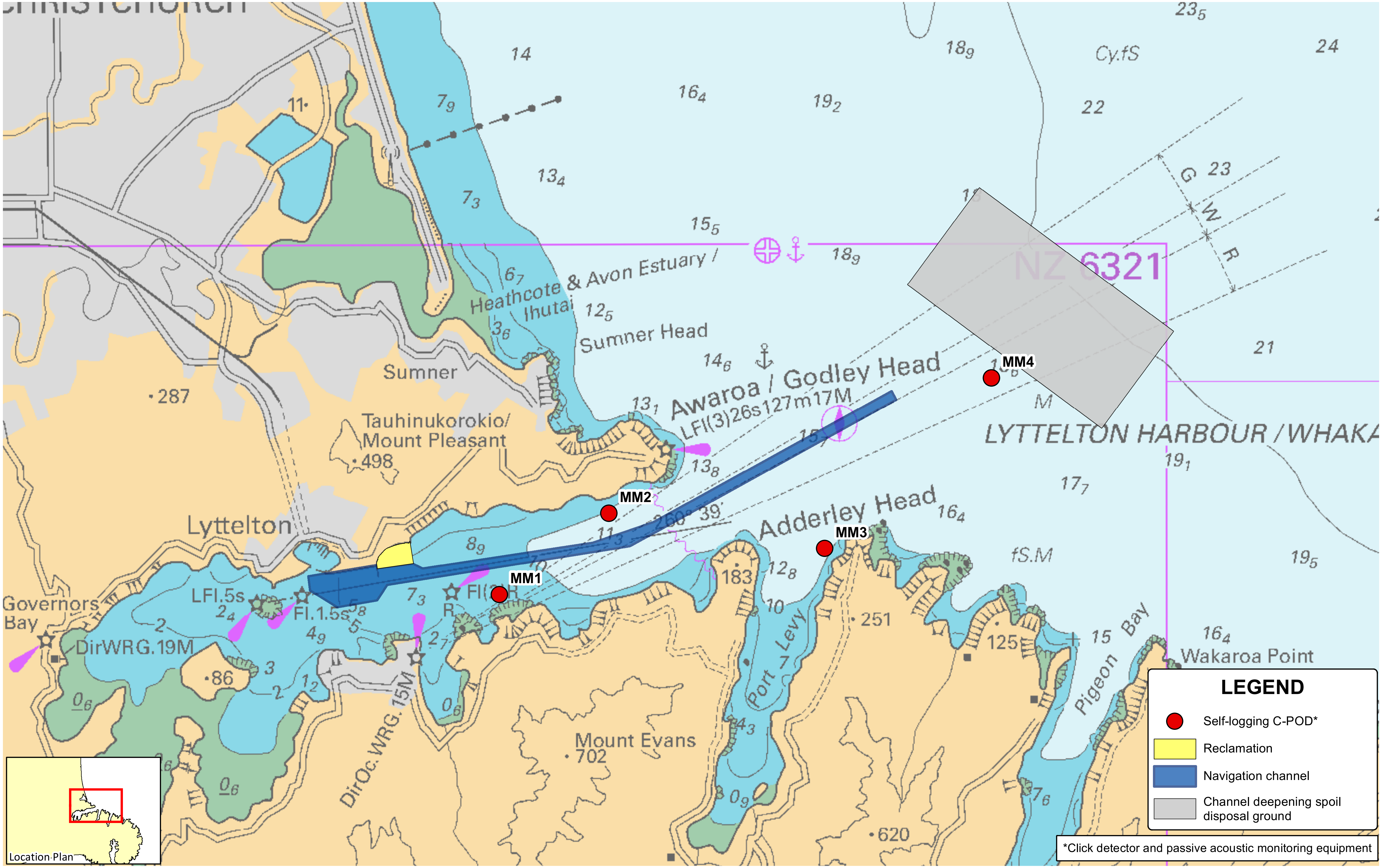

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Note 4. Location of monitoring points is currently indicitive, intended for illustrative use only.

A3 SCALE: 1:70,000

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Appendix B: Ecological survey methodology

Benthic method statement

Subtidal method statement

Intertidal method statement

BENTHIC SAMPLING

Benthic sampling provides data on the physical, chemical and ecological nature of benthic habitats within the surveyed area. At each of the 19 benthic monitoring stations, sediments are collected using a 0.1 m^2 stainless steel Van Veen grab for a number of analyses as follows:

- Sediment grain size distribution (surficial substrate texture) and organic content
- Sediment chemistry; specifically indicative metal and organic contaminants
- Sediment-dwelling macroinvertebrate communities (infauna).

Triplicate grabs are conducted at each station and for each, the grab contents are sub-sampled for the sediment and infauna analyses.

Sediment texture and chemistry

The analysis of sediment texture (particle grain size distribution) defines the coarseness of sediments and provides an important measure of the physical characteristics of a site that can be used to investigate and interpret differences between sites for other environmental parameters. Chemical contaminants are primarily retained within fine sediments. Metals and some organic compounds can adsorb to particulates and may accumulate over long time periods. Both sediment texture and organic content play an important role in determining the capacity for adsorption and retention of contaminants and allow the assessment of associations between substrate type and the associated sediment faunal communities.

Sub-sampling for sediment physico-chemical analyses

Three 62 mm diameter cores are taken from the contents of each replicate grab by means of Perspex® corers driven into the contents of the grab to a depth of up to 100 mm. The cores are then photographed before sub-sampling. The colour of the sediments, any noticeable odour and the presence/absence of anoxic patches within the sample are noted, as well as the depth to any apparent redox potential discontinuity (aRPD) layer[1].

The top 5 cm of each of the cores are sub-sampled to provide sample material for the analysis of metals[2] concentrations, organic content and particle size distribution. Samples from Harbour stations are composited from triplicate grabs and analysed for polycyclic aromatic hydrocarbons (PAHs). All samples are chilled with ice for

[1] The aRPD refers to the often distinct colour change, between surface and underlying sediments, brought about by the changing redox environment with depth in the profile. This gradient of colour change is in reality continuous but may be reduced to an average transition point (sediment depth) for descriptive purposes.

[2] The metals suite includes arsenic (As), cadmium (Cd)chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn).

transport back to the laboratory. A summary of sediment analyses and analytical methods is given in Table 1.

Table 1 Summary of analytical methods used for sediment characterisation.

Analyte	Method Number	Description
Particle grain size distribution (sediment texture)	Cawthron SOP No. 33074	Wet sieved through screen sizes: >2 mm = Gravel <2 mm – >1 mm = Coarse Sand <1 mm - >500 µm = Medium Sand <500 µm - >250 µm = Medium/Fine Sand <250 µm - >125 µm = Fine Sand <125 µm - >63 µm = Very Fine Sand <63 µm = Mud (Silt & Clay) Size classes from Udden-Wentworth scale
Organic Content as Ash-Free Dry Weight (AFDW)	Luczak *et al.* 1997 (modified)	Sample dried at 105°C then ashed at 550°C
Total organic carbon - 2016	Hill Laboratories in-house method	Acid pre-treatment to remove carbonates if present, neutralisation, [Elementar combustion analyser].
Polycyclic aromatic hydrocarbons (PAHs)	USEPA 8270C	Sonication extraction, SPE clean-up, GC-MS SIM analysis (gas chromatography mass spectrometry selected ion monitoring mode).
Trace metals (As, Cd, Cu, Pb, Hg, Ni, Cr, Zn)	USEPA 200.2	Detected by ICP-MS (inductively coupled plasma mass spectrometry) following nitric/hydrochloric acid digestion

Benthic macrofauna

The ecological assemblage of small animals (larger than 0.5 mm) living in the upper 10 cm of the sediment profile is generally referred to as macrofauna or macroinvertebrates. The infauna, animals living within the sediment matrix, typically form the largest proportion of this group in fine sediment habitats. Infauna have been used for several decades to assess the effects of human impacts in marine environments, since they have been shown to respond relatively rapidly to anthropogenic and natural stress (Pearson & Rosenberg 1978; Dauer 1993; Borja *et al.* 2000).

One 130 mm diameter x 100 mm sediment core is extracted from the contents of each of the three grabs conducted at each benthic sample station. The core is then gently sieved through a 0.5 mm nylon mesh screen with seawater to remove the majority of the fine sediment matrix, separating out the infauna with other coarse material. The residue is then transferred to a sample container for preservation in a solution comprising 3% glyoxal and 70% ethanol.

In the laboratory, macrofauna within the preserved samples are identified and counted with the aid of a binocular microscope. Identifications are made to the lowest practicable taxonomic level. For some groups of infauna, species-level identification is very difficult and, in such instances, infauna are grouped into recognisable taxa (morphologically similar groups). In this manner a list of taxa and their individual abundances are compiled for each station.

Infauna data analysis

Infaunal count data are analysed to ascertain levels of abundance (individual species density), species richness and standardised indices of community diversity and evenness for each station (**Error! Reference source not found.**). These indices were compared between stations and significant differences interpreted with respect to key factors such as seasonal timing, water depth and substrate characteristics.

Table 2 Descriptions of community indices.

Index	Equation	Description
No. species (S)	$\sum s$	Total number of species (s) in a sample.
No. abundance (N)	$\sum n$	Total number of individual organisms (n) in a sample. This included the sum of percentage cover of colonial organisms and solitary individuals.
Evenness (*J'*)	$J' = \frac{H'}{log_e S}$	Pielou's evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.
Diversity (*H'*)	$H' = -\sum P_i \, log_e \, (P_i)$	Shannon-Wiener diversity index describes, in a single number, the different types and amounts of taxa present in a sample. The index ranges from 0 for communities containing a single species to high values for communities containing many species each represented by a similar number of individuals.

The infaunal assemblages recorded at each site were contrasted using non-metric multidimensional scaling (nMDS; Kruskal & Wish 1978) ordination and cluster diagrams using Bray-Curtis similarities between samples in PRIMER v6 statistical software (v. 6.1.6 ©PRIMER-E 2000; Clarke & Warwick 1994; Clarke & Gorley 2001). Abundances were fourth-root transformed to de-emphasise the influence of the dominant species (by abundance). The major taxa contributing to the similarities of each grouping of benthic stations were then identified using analysis of similarities (SIMPER; Clarke & Warwick 1994; Clarke & Gorley 2001).

Comparisons between surveys can be made with a range of statistical methods to investigate potential changes over time including relative changes in benthic variables between stations. The complex shoreline morphology, bathymetry and potential impact sources does not support a traditional BACI (Before-After-Control-Impact) approach to analysis although elements of “Beyond BACI” approaches may be investigated. The identification of suitable control or reference stations in particular, presents a challenge. Rather, the situation is better addressed using linear regression incorporating distance from impact source to investigate impact gradients or changes to pre-impact gradients in a range of variables.

Quantitative subtidal surveys

Field methodology

At each site a 100 m down-shore transect line is positioned perpendicular to the shore, by anchoring one end onto high shore rocks and the other end (offshore) to the seabed using a shot weight (Figure 1). The GPS coordinates of both ends of the transect are recorded to allow relocation for repeat surveys. However, photographic confirmation of the shore-side end enables exact relocation. The dive surveys are conducted along three subtidal transect lines running transversely out from the down-shore transect at three nominal depth ranges and roughly parallel to shore:

i. **Deep transect (hereafter 7 m)**: between 6–8 m depth (mean sea level) and 30 m in length, running near the maximum extent of non-coralline macroalgae.
ii. **Shallow transect (hereafter 4 m)**: between 3–5 m depth (mean sea level) and 30 m in length, within kelp forest habitats (where these were present).
iii. **Littoral fringe transect**: At approximately 0.5 m CD (between 0–1 m depths relative to chart datum) and over a 50 m distance, within the shallow subtidal.

Transects at all depths are located within nominal depth ranges (as above) rather than at precise depths. The reason for this is that the three-dimensional (and sometimes near-vertical) structure of the reef does not allow precise depth control along a transect line. At each site, allowance must be made for tidal state to adjust target depths for the time of the survey. This is especially important for the littoral fringe transects, noting the difference between chart datum and mean sea level (MSL).

7 m and 4 m transects

Along each 7 m and 4 m depth transect, eight 1 m^2 quadrats are haphazardly placed, determined by a pre-set interval of ~4 m between consecutive quadrat centres, with two divers alternating along a 30 m measuring tape. It is noted that, for site LH07 in Lyttelton Harbour, it is not possible to survey a 7 m transect due to the absence of suitable rocky reef habitats in that depth band.

For each quadrat, the following data are recorded:

Water depth (from wrist-mounted dive computers)

An estimate[3] of the percentage cover of substrate type: bedrock (consolidated rock), boulders (>256 mm), cobble (64–256 mm), sand (2–0.5 mm), silt (<0.5 mm) and shell hash

An estimate of the percentage cover of canopy forming and understory algae

Estimates of percentage cover of encrusting invertebrates (e.g. sponges, ascidians, mussels)

Counts of solitary epifauna (e.g. gastrodpods, sea urchins, seastars).

For each (50 m) littoral fringe transect, divers count and measure large invertebrate grazers[4] within a 1 m band (i.e. over an area of 50 m^2). Pāua are counted and measured using digital logging callipers, whereas Cook's turban snails (*Cookia sulcata*) are only counted. Quadrat methods cannot be used for this zone due to shallow water surge conditions at most sites and the presence of large macrophytes in constant movement.

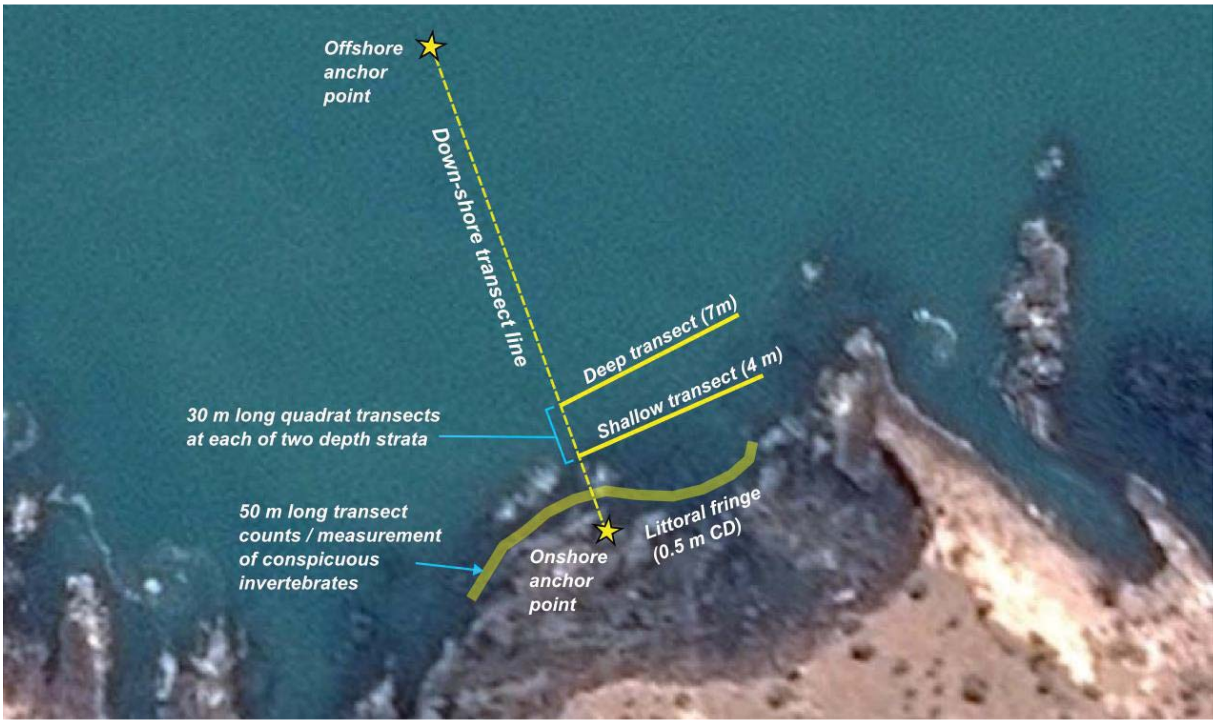

Figure 1 General layout of subtidal shoreline transects used to characterise reef habitats. Being easy to relocate from conspicuous land-marks, the exact position littoral fringe transect relative to the offshore transect line varies between sites.

[3] The 1 m square quadrat frames are gridded into quarters, but finer gridding is not possible due to having to place the quadrat down through any existing macroalgal canopy. As a point of reference for estimates, a 1% coverage may be visualised as a square area 10 cm on each side.

[4] Due to the effective absence of kina (*Evechinus chloroticus*) in this depth range, the targeted species are limited to black foot pāua (*Haliotis iris*) and kaakara or Cook's turban (*Cookia sulcata*).

Statistical analyses

Subtidal quadrat data are analysed to ascertain levels of abundance (total cover and number of individuals), species richness (diversity) and standardised indices[5] of community diversity and evenness for each station (Table 2). For the purposes of the analysis, several subtidal taxa may be aggregated into morphological groups.

Differences in subtidal community structure are determined statistically with respect to water depth, area and sites using a distance-based permutational analysis (PERMANOVA, Anderson 2001) based on Bray-Curtis similarities of the log (x +1) transformed data and 9,999 permutations. Significant terms are then investigated using pair-wise comparisons with the PERMANOVA *t* statistic and 999 permutations.

Assemblage differences among treatment levels may be visualized by Principal Coordinates Ordination (PCO). Similarity Percentages analysis (SIMPER, Clarke 1993) can be used to identify the contribution of each species (or taxon) to observed differences among treatments. Generally, taxa that consistently discriminate between treatments and have a correlation > 0.3 with the PCO axes are displayed as vectors in the PCO plots. Statistical analyses are conducted using PRIMER 6 (Clarke & Gorley 2006; Anderson et al*.* 2008) and R software (R Core Team 2014).

Semi-quantitative intertidal surveys

Intertidal biological communities will be surveyed semi-quantitatively at four sites over at low tide period. Two sites are established in Port Levy (PL03 and PL16), representative of one of the long, sheltered, inner inlets of Banks Peninsula. The other two sites are established in Lyttelton Harbour: LH07 adjacent to Ripapa Island and LH05 at Kamautaurua Island (Shag Reef). These sites span the relatively exposed rocky shore of the central Harbour (LH07) to the relatively sheltered flat rocky shore of the upper Harbour (LH05).

At each site, the rocky shoreline is surveyed over a shore-parallel distance of 50 m, with substrate characteristics and zonation patterns of intertidal fauna and flora recorded. The abundance of fauna and flora is described at each intertidal zonation (high, mid, low and tidal pools) using a categorical scale, ranked subjectively as 'rare', 'occasional', 'common', or 'abundant'. Representative photographs of habitats and taxa are also compiled. Where field identification is not possible, specimens of individual fauna and algae will be collected for later identification. All taxonomic nomenclature is based on the World Register of Marine Species (WoRMS Editorial Board 2016).

[5] Similarity measures and diversity indices are not usually constructed from such "mixed" data sets, but there are no impediments to doing this (Anderson & Underwood 1994). However, there may be problems for the interpretation when data are naturally in different original scales. Thus, the data are log transformed, which preserves information concerning relative abundance or cover of species consistently across samples, but eliminates any large differences in scale among variables (Clarke, 1993).