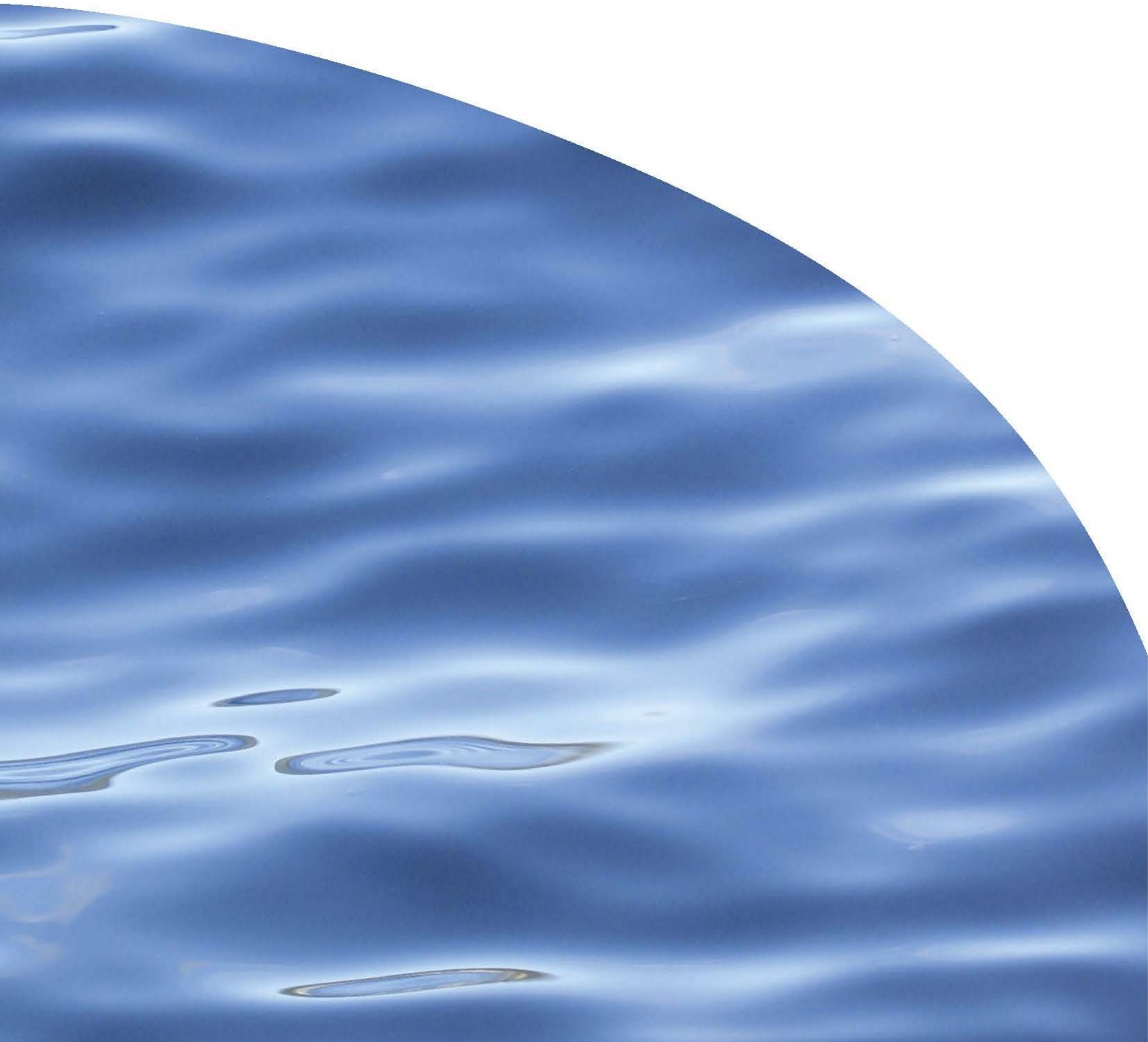
REPORT NO. 2648

REVIEW OF NORTHLAND REGIONAL COUNCIL'S CONSENT CONDITIONS FOR DREDGING



REVIEW OF NORTHLAND REGIONAL COUNCIL'S CONSENT CONDITIONS FOR DREDGING

DONALD MORRISEY, PAUL BARTER

Prepared for Northland Regional Council

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Ross Sneddon

APPROVED FOR RELEASE BY:
Natasha Berkett

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EXECUTIVE SUMMARY

Northland Regional Council (NRC) wishes to review consent conditions for dredging activities in Northland harbours. The purpose of the review is to determine whether conditions applied to date that relate to mixing zones and allowable changes in water clarity, colour and turbidity, are unnecessarily restrictive. The review presented in this report focusses on numerical standards, rather than sizes of mixing zones, to make the recommendations applicable to a wider range of locations.

The Regional Coastal Plan classifies upper parts of Whangarei Harbour, (where water clarity is naturally lower) differently to the middle and lower harbour. However, for purposes of water-quality management, the same water-quality standards for clarity and colour apply to both classifications (no more than 20% reduction in visual clarity and a change in colour of no more than 10 Munsell units). These standards, which are also incorporated into the current dredging consents, were originally intended to apply to Class A waters, where visual clarity is an important characteristic of the waterbody (MfE 1994), and to protect aesthetic values (ANZECC 2000).

There is large background variation in Secchi depth, turbidity and total suspended solids (TSS), which frequently exceeds 20% deviation from long-term median values, at monitoring stations throughout the harbour. Where turbidity is naturally high and variable, it is probable that biota are adapted to cope with these stresses. From an aesthetic and contact-recreation perspective, expectations of visual water clarity for the upper harbour are likely to be lower than for the middle and lower harbour.

These factors suggest that the current standards are overly restrictive for naturally more turbid parts of the harbour. A more adaptable approach to developing standards would be a risk-based one. This would take into account differences in types of sediment and background turbidity in different parts of the harbour, together with differences in ecological, recreational and cultural values and vulnerability to suspended sediments.

The Ministry for the Environment (MfE 1994) and ANZECC (2000) advocate a maximum change of 20% for waters where visual clarity is an important characteristic and that are managed specifically to protect this feature. This is not the case for any waters in Whangarei Harbour, with the possible exception of the area around the Motukaroro Marine Reserve which is popular for diving and has relatively high (but variable) natural visual clarity.

For other waters, the Ministry for the Environment suggested that “the visual clarity should not be changed by more than 33–50% *depending on the site conditions*”. Site conditions include the background variability in water quality and the value of the waterbody. ANZECC advised that selection of water clarity guidelines needs to consider inherent variability within the waterbody and use site-specific information to develop appropriate local limits.

Following this guidance, and following the characterisation of different parts of the harbour described in the present report, we have applied the upper and lower bounds (33% and 50% change) to different parts of harbour.

We make the following recommendations.

- The consent conditions for dredging should focus on visual clarity (measured as Secchi depth), rather than turbidity or TSS. Water clarity is strongly linked to optical water quality, is more precise, and is easier to measure.
- The consent conditions for dredging should be based on aesthetic considerations. Water clarity is an important characteristic for parts of the harbour used for contact recreation. The protection of aesthetic values is also likely to protect the habitat of sighted aquatic animals and the photosynthetic requirements of plants.
- Reduction in visual clarity due to dredging should be no more than 50% in the upper harbour and no more than 33% in the middle and lower parts of the harbour.
- Exceedances of the 33% and 50% criteria are acceptable providing that the absolute Secchi depth is not less than the 20th percentile of the long-term Secchi depth monitoring data for the upper or middle/lower parts of the harbour, as appropriate.
- Turbidity and TSS should continue to be monitored to allow variability in turbidity to be better defined and provide the basis for better defining statistically-based guidelines.
- Breaches of these guidelines should trigger more intense monitoring of Secchi depth, turbidity and TSS to determine whether the breach is a sustained event (more than, say, one day's duration). If so, dredging should be stopped or mitigation measures put in place.

Temporal restrictions on dredging activities are also proposed to avoid the period of peak recreational use of parts of the harbour (December–March) and periods of spawning and settlement of fish and shellfish (October–January).

This approach to development of guidelines can be applied to other harbours and estuaries in Northland.

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1. BACKGROUND

1.1. Introduction

Northland Regional Council (NRC) wishes to review consent conditions for dredging activities in Northland harbours to determine whether those applied to date are unnecessarily restrictive.

The specific conditions in question are those relating to mixing zones and allowable changes in water clarity, colour and turbidity. This discussion therefore focusses on these variables and does not consider others for which water-quality standards exist in the Regional Coastal Plan for Northland (the RCP) or in consent conditions for dredging, such as temperature, pH, toxic substances, dissolved oxygen or nutrients.

We have focussed our consideration of whether conditions are too restrictive on the numerical standards. An alternative or complementary approach would be to revise the extent of the zone of reasonable mixing. However, this would need to be done on a case-by-case basis because it depends partly on the patterns of water movement and topography of a given dredging location, and is therefore not particularly adaptable for use in different locations.

1.2. Coastal water-quality management in Northland

1.2.1. Regional Coastal Plan

The RCP lists three principal tools used to maintain or enhance Northland’s coastal water quality: water-quality management plans, water-quality classification, and conditions on resource consents. The last of these form the focus of the present study, but water-quality management plans and classification provide the context within which consent conditions are set.

Water-quality management plans specify action to be taken to protect and, where necessary, enhance water quality of discrete waterbodies such as harbours and estuaries and their catchments. A water-quality management plan for Whangarei Harbour was produced in 1990 and reviewed and updated in 2012.

The RCP classifies areas of Whangarei Harbour for water-quality purposes and provides water-quality standards for each classification (Figure 1). The classifications are:

- General Quality Standard (CA), which provides for virtually all uses, including shellfish collection and protection of marine ecosystems.
- Contact Recreation Standard (CB), which provides for contact recreation but not for marine ecosystems or aesthetic value.

To date, the only Northland waterbodies to have been classified are Whangarei Harbour and the Bay of Islands.

The standards relating to water clarity and colour for both the CA and CB classifications are that the visual clarity shall not be reduced by more than 20% and the hue shall not be changed by more than 10 Munsell units. These standards are specified in Appendix 4 (*Regional Coastal Plan for Northland Coastal Water Quality Standards*) of the RCP.

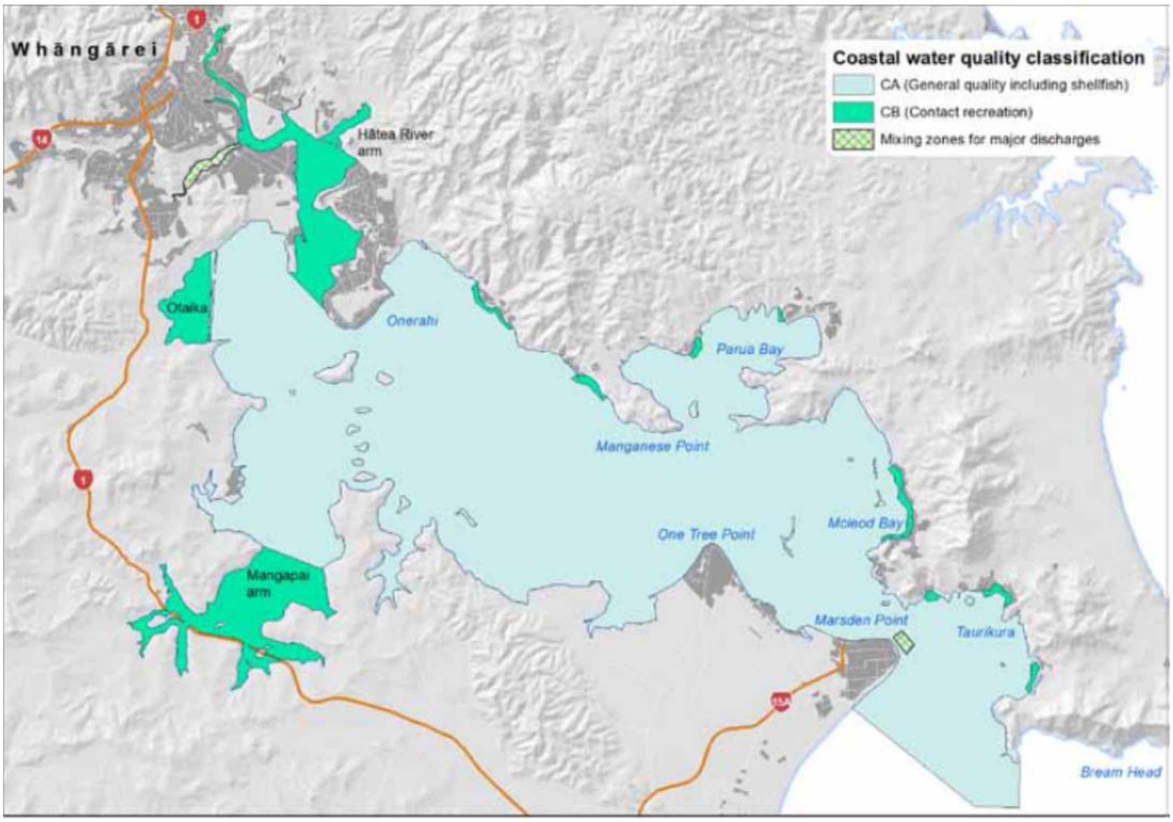


Figure 1. Coastal water quality classifications from the Regional Coastal Plan for Northland.

1.2.2. Conditions on current consents for dredging

Current consents for dredging in Whangarei Harbour (and presumably other coastal waters of Northland, such as Opua) contain conditions that include standards for water clarity, natural hue, turbidity and concentration of total suspended solids (TSS).

For example, the consent for maintenance dredging of the Hatea River Channel, Whangarei Town Basin and Kissing Point mooring area (CON20110795804) includes the following conditions:

- *The visual clarity (as measured using a black disk or Secchi disk) of harbour water shall not be reduced by more than 20% of the background visual clarity (or natural hue changed by more than 10 Munsell units) at the time of measurement.*
- *The turbidity of the water (Nephelometric Turbidity Units (NTU)) shall not be increased by more than 20% of the background visual clarity at the time of measurement.*
- *The Total Suspended Solids (TSS) shall not exceed 40 g/m^3 above the background measurement.*

These standards apply beyond a 100-m mixing zone from the dredger. The consent holder takes daily clarity and colour measurements at the down-current boundary within the area of changed clarity or colour. The same measurements are also taken at least 50 m up-current from the dredging activity, against which to assess the change in down-current conditions. Three measurements are taken at each location and the median values used to assess compliance with the specified standards.

The consent for capital and maintenance dredging for the construction and operation of a new ship-launching and docking facility, and associated quayside work in the lower Hatea River (CON20090629913), requires that:

- Any discharge arising from dredging shall not cause a conspicuous change in the colour or clarity of the receiving waters at or beyond a 200-m mixing zone.

'Conspicuous' is defined as natural visual clarity being reduced by more than 20% and hue by more than 10 Munsell units. At least twice-daily visual inspection of water quality is required during dredging operations to identify any visually observable change in "clarity (turbidity) or change in the hue in the waters" at or beyond the boundary of a 200-m mixing zone.

Observers undertaking the daily visual inspection to identify any change in clarity or colour as required by the consent, may not be able to detect a 20% change in clarity when background clarity is already low. The Ministry for the Environment (MfE 1994) noted that although people can generally detect changes in the visual clarity of water larger than 10–15%, sensitivity may not be as great when clarity is already low. However, data from dredge monitoring in the Town Basin Whangarei Harbour (see Section 1.2.3, below) suggests that observers were, in fact, able to detect changes less than 20%.

1.2.3. Compliance with current conditions

Secchi depth was measured by the contractor during maintenance dredging of the Hatea River channel, Town Basin and Kissing Point mooring area in November–

December 2011, May–June 2012, July–August 2013 and May–June 2014. Data (Secchi depth, turbidity, TSS, salinity, temperature, ammonium and trace metals) were also collected by NRC during August 2010, November–December 2011, May–June 2012, July–September 2013 and May–July 2014. The contractor and NRC did not measure colour hue.

During these periods, the standard for visual clarity (no more than 20% reduction in Secchi depth) was breached on 43% (36 out of 84) of the times of sampling. The maximum recorded level of exceedance was a 68% reduction in clarity and the median exceedance was 34%.

Turbidity exceeded the standard in the consent conditions (no more than 20% increase above background) in half of the eight times it was measured by NRC. The maximum exceedance was 16.9 NTU relative to a background value of 3.1 NTU (452% difference).

Northland Regional Council measured TSS on 11 occasions. Total suspended solid limits (> 40 g/m^3 above background) were not exceeded on any of these occasions.

2. ARE THE CURRENT CONSENT CONDITIONS FOR CLARITY AND TURBIDITY APPROPRIATE?

2.1. Comparison of consent standards with background

Northland Regional Council has operated the Whangarei Harbour Water Quality Monitoring Programme since 1986. However, the design, including variables measured, has been adapted and changed over time (as described in the Whangarei Harbour Water Quality Action Plan [2012]). The programme currently involves 17 sites throughout the harbour from the Town Basin and lower Hatea River to Mair Bank at the harbour entrance (Figure 2: one site was added to the programme about a year ago and is not included in the analysis described below). Each site is monitored every two months for a range of variables including temperature, salinity, water clarity (Secchi depth), concentration of TSS and turbidity (NTU).

Figure 2. Water-quality monitoring stations in Whangarei Harbour (from Cornelisen *et al*. 2011).

Inspection of the Secchi, TSS and turbidity data shows that there is considerable temporal variation, in addition to variation among monitoring stations (Table 1). Plotting time series for salinity, Secchi depth, turbidity and TSS together (see

Appendix), indicates some correspondence between reduced water clarity and freshwater run-off to the harbour (indicated by salinity values), as might be expected. However, the relationship is inconsistent and not particularly clear. Salinities at upper harbour sites are extremely variable, presumably because the relative contributions of harbour and river water change over the tidal cycle, and this will obscure any effect of increased run-off when measurements are made relatively infrequently.

Taking the median value at each station as the ‘background’ value, the difference between the lower (Secchi) or upper (turbidity) 5 percentile and the background value, ranges from 30–62% for Secchi depth, and 69–1,009% for turbidity. Although these comparisons are not analogous to exceeding the standard (they represent temporal, rather than spatial, variation), they place any exceedance due to dredging in a context of ‘natural’ variation. From this perspective, at least 5% of monitoring data would be outside the standards for clarity and turbidity specified in the consent conditions. In the case of Secchi depth, the percentage of monitoring data falling below the standard as a result of background variation ranges from 10% (4 records) at the Town Basin to 36% at Mangapai River and Snake Bank (15 and 12 records, respectively).

The standard for TSS (no more than 40 g/m^3 above background) was breached by only two data (both from the Limeburners Creek bridge on Port Road in the upper harbour) across all stations and times of sampling. Measurement of TSS was done much less frequently than Secchi depth or turbidity, however, and of the remaining 14 monitoring stations, 10 had no, or only two records.

Another feature that is clear from the monitoring data is the background spatial variation in water clarity, turbidity and TSS among different parts of the harbour. Upper harbour monitoring stations are clearly much more turbid than middle and lower harbour stations. This will reflect factors such as riverine sediment inputs, the nature of the sediments at or upstream from a monitoring station, the amount of wind and wave activity to resuspend the sediment, and the ability of water movement to disperse sediment in suspension. Where turbidity is naturally high and variable, it is probable that biota are adapted to cope with these stresses. From an aesthetic and contact-recreation perspective, expectations of visual water clarity for the upper harbour are likely to be lower than for the middle and lower harbour.

Table 1. Summary of data from the 15 Northland Regional Council (NRC) water-quality monitoring stations in Whangarei Harbour.

		Secchi depth (m) (standard = no more than 20% reduction from background)				TSS (g/m^3) (standard = no more than 40 g/m^3 above background)				Turbidity (NTU) (standard = no more than 20% increase above background)			
Station	**Dates**	**No. data**	**Median**	**5%ile**	**% difference**	**No. data**	**Median**	**95%ile**	**No. data > standard**	**No. data**	**Median**	**95%ile**	**% difference**
NRC Sampling Site: 100211 Upper Whangarei Harbour @ Mid Town Basin	09/01/90–26/11/14	73	1.1	0.5	54.5	23	14.0	365.0	2	60	5.0	21.5	334.9
NRC sampling site: 109233 Whangarei Harbour @ Port Marker H26, SE corner of pile berths	26/03/08–13/11/14	41	1.0	0.7	30.0	2	51.7	90.7	Insufficient data	43	5.0	16.1	222.8
NRC sampling site: 106968 H & H Slipway @ H & H Slipway Sediments	26/03/08–13/11/14	41	1.0	0.6	40.0	2	183.2	341.4	Insufficient data	43	5.7	21.3	274.4
NRC sampling site: 100207 Upper Whangarei Harbour @ Limeburners Creek Bridge Port Rd	20/01/92–13/11/14	44	1.0	0.5	48.7	46	25.5	73.3	2	62	7.7	85.0	1008.9
NRC sampling site: 100204 Upper Whangarei Harbour @ Kissing Point	19/11/04–13/11/14	71	1.1	0.6	50.0	2	45.5	73.0	Insufficient data	83	6.0	63.7	961.2
NRC sampling site: 104563 Upper Whangarei Harbour @ Boat Ramp (Port Whangarei)	26/03/08–13/11/14	42	1.2	0.8	34.7	2	37.5	57.8	Insufficient data	43	5.3	11.5	116.6
NRC sampling site: 100200 Upper Whangarei Harbour @ Kaiwaka Point	17/08/07–13/11/14	50	1.1	0.8	29.8	10	12.5	32.3	0	64	6.2	21.8	250.2
NRC sampling site: 100177 Mangapai River @ Pile No 23	26/03/08–13/11/14	41	0.8	0.5	37.5	1	23.0	23.0	Insufficient data	41	8.9	15.0	68.7
NRC sampling site: 109231 Whangarei Harbour @ Portland off old cement wharf	26/03/08–13/11/14	42	1.1	0.6	44.2	1	13.0	13.0	Insufficient data	42	6.7	16.3	143.5
NRC sampling site: 109230 Whangarei Harbour @ Onerahi SE off Sea Scouts	26/03/08–18/09/14	37	1.4	0.7	51.4	0	ND	ND	Insufficient data	39	5.0	10.6	111.4
NRC sampling site: 101082 Whangarei Harbour @ Tamaterau	17/12/90–18/09/14	57	2.3	1.0	55.2	0	ND	ND	Insufficient data	62	2.9	9.6	237.2
NRC sampling site: 100263 Lower Whangarei Harbour @ One Tree Point	03/12/90–28/10/14	41	3.5	2.1	40.0	42	6.0	32.9	0	40	1.0	2.7	170.0

		Secchi depth (m) (standard = no more than 20% reduction from background)				TSS (g/m^3) (standard = no more than 40 g/m^3 above background)				Turbidity (NTU) (standard = no more than 20% increase above background)			
Station	**Dates**	**No. data**	**Median**	**5%ile**	**% difference**	**No. data**	**Median**	**95%ile**	**No. data > standard**	**No. data**	**Median**	**95%ile**	**% difference**
NRC sampling site: 109227 Whangarei Harbour @ Snake Bank mid NE side	26/03/08–18/9/14	33	3.4	1.7	49.4	0	ND	ND	Insufficient data	40	1.0	3.2	221.0
NRC sampling site: 100264 Lower Whangarei Harbour @ Adjacent to the mouth of Blacksmiths Creek	03/12/90–28/10/14	36	3.8	1.4	62.0	42	12.0	34.0	0	40	1.0	3.4	240.0
NRC sampling site: 100192 Lower Whangarei Harbour @ NZRC Jetty	15/04/91–18/09/14	56	4.1	2.0	51.2	0	ND	ND	Insufficient data	60	1.0	3.4	244.3
NRC sampling site: 100190 Lower Whangarei Harbour @ Mair Bank Outer Marker Pile	3/12/90–28/10/14	54	3.9	2.2	43.8	50	3.5	33.6	0	69	1.0	2.3	130.0

Secchi data were also combined from monitoring stations in different parts of the harbour (upper and middle/lower) to provide a broader spatial perspective on temporal variation and compliance with the current consent standard (Table 2). In the upper harbour 16% of data were reduced by more than 20% of the median and the equivalent figure for the middle and lower harbour was 34%. If the long-term median value is taken as representative of background conditions, therefore, there are a significant number of 'breaches' of the standard that are not related to dredging activities.

Table 2. Summary of data from water-quality monitoring stations in the upper and middle/lower parts of Whangarei Harbour.

	Middle–Lower Harbour[1]	**Upper Harbour[2]**
No. Secchi. readings	277	445
Monitoring period	June 2004–Oct 2014	Nov 04–Nov 14
Secchi median (m)	3.5	1.0
Secchi 20%ile (m)	2.3	0.8
80% of median Secchi (m)	2.8	0.8
No. values < 80% of median	95	70
% of values < 80% of median	34	16

[1] Tamaterau, One Tree Point, Snake Bank, Blacksmiths Creek, NZRC Jetty, Mair Bank
[2] Town Basin, H&H Slipway, Limeburners Creek, Kissing Point, Port Whangarei, Kaiwaka Point, Mangapai, Portland

2.2. Comparison with other clarity and turbidity guidelines

2.2.1. Water-quality standards in the Resource Management Act

The Resource Management Act 1991 (RMA; see Table 3) specifies that there shall be no…

- *"production of any conspicuous oil or grease films, scums, or foams, or floatable or suspended materials"*
- *"conspicuous change in the colour or visual clarity"*

…due to the discharge of water or contaminants into receiving waters (after reasonable mixing).

Table 3. A summary of the water quality standards from the relevant water quality guidelines (from Clements & Barter 2011).

Indicator/document	Type of impact	Value perspective	Guidelines/standards
Water clarity			
RMA 1991	Visual clarity		There shall be no conspicuous change in colour or visual clarity.
MfE 1994	Visual clarity	Aesthetic	For Class A waters*, where visual clarity is an important characteristic of the waterbody, the visual clarity should not change by more than 20%. For other waters, the visual clarity should not be changed by more than 33-50% depending on the site conditions.
	Light penetration	Ecological	In waters deeper than half the euphotic depth, the euphotic depth should not be changed by more than 10%.
			In waters shallower than half the euphotic depth, lighting should not be reduced by more than 20%.
ANZECC 1992	Visual clarity	Aesthetic	To protect the aesthetic quality of a waterbody #: the natural visual clarity should not be reduced by more than 20%.
	Light penetration	Ecological	To protect aquatic ecosystems, the natural euphotic depth should not be permitted to change by more than 10% for marine waters.
	Visual clarity	Aesthetic	To protect the visual quality of waters for swimming, the horizontal sighting of 200 mm diameter black disc should exceed 1.6 m.
ANZECC 2000	Visual clarity	Aesthetic	Same as ANZECC 1992.
	Light penetration	Ecological	Same as ANZECC 1992.
Water colour			
RMA 1991	None stipulated		There shall be no conspicuous change in colour or visual clarity.
MfE 1994	Hue	Aesthetic	For Class A waters* where hue is an important characteristic of the waterbody, the hue should not change by more than 5 points on the Munsell scale. For other waters, the hue of the waterbody should not be changed by more than 10 points on the Munsell scale.
	Brightness (reflectance)	Aesthetic	The reflectance of water should not be changed by more than 50%.
ANZECC 1992	Hue	Aesthetic	To protect the aesthetic quality of a waterbody #, the natural hue of the water should not be changed by more than 10 points on the Munsell Scale.
	Brightness (reflectance)	Aesthetic	To protect the aesthetic quality of a waterbody #, the natural reflectance of the water should not be changed by more than 50%.
ANZECC 2000	Hue	Aesthetic	Same as ANZECC 1992.
	Brightness (reflectance)	Aesthetic	Same as ANZECC 1992.

*Waters protected due to their important aesthetic, visual clarity or colour characteristics.
For recreational use, waters are considered for primary contact activities, such as swimming, bathing and other direct water-contact sports to protect the health and safety of the user.

Indicator/document	Type of impact	Value perspective	Guidelines/standards
Suspended materials			
RMA 1991	None stipulated		The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials.
MfE 1994			Recommends visual clarity standards for any optical effects of water.
ANZECC 1992			No standards for suspended materials.
ANZECC 2000			No standards for suspended materials.
Suspended sediments			
RMA 1991			No standards for suspended sediments.
MfE 1994			Recommends visual clarity standards for any optical effects of water.
ANZECC 1992			Sediment quality guidelines in regards to contaminants and nutrients loads.
ANZECC 2000			Sediment quality guidelines in regards to contaminants and nutrients loads.
Suspended solids (TSS) or suspended particulate matter (SPM)			
RMA 1991			No standards for suspended solids or suspended particulate matter.
MfE 1994			Recommends visual clarity standards for any optical effects of water.
ANZECC 1992	TSS	Ecological	Numeric standards for treated sewage discharged from vessels, live fish tank, stormwater and/or wastewater discharges.
	SPM	Ecological	To protect aquatic ecosystems, increases in SPM should be limited such that optical guidelines are maintained and that the seasonal mean nephelometric turbidity does not change by more than 10%.
ANZECC 2000	TSS	Ecological	Recommends range of reference and default trigger value for various ecosystems based on suspended solid levels and TSS limits for some discharge activities.
	SPM	Ecological	Recommends that load-based guidelines be developed for SPM to address non-optical impacts.

The Third Schedule of the RMA also lists water-quality classes for the purpose of classifying waterbodies. These classes, and their associated standards (see below) differ from those specified in the Northland RCP (Classes CA and CB). The water-quality classes listed in the Third Schedule include:

- Class AE Water (being water managed for aquatic ecosystem purposes).
- Class F Water (being water managed for fishery purposes).
- Class FS Water (being water managed for fish spawning purposes).
- Class SG Water (being water managed for the gathering or cultivation of shellfish for human consumption).
- Class CR Water (being water managed for contact recreation purposes).
- Class A Water (being water managed for aesthetic purposes).
- Class C Water (being water managed for cultural purposes).

Among these, only Classes CR, A and C have (narrative) standards relating to water clarity and colour. For Class CR Water, "(t)he visual clarity shall not be so low as to be unsuitable for bathing". For Class A and C Waters, the quality of the water shall not be altered in those characteristics which have a direct bearing upon the specified aesthetic, cultural or spiritual values.

2.2.2. Guidance for application of RMA water-quality standards

The Ministry for the Environment (MfE 1994) provided guidance to water users and managers on the application of the statutory standards for optical water quality specified in the RMA (Table 3). They recommended that guidelines should be based on methods directly related to optical quality (black disk visibility or Secchi depth), rather than on management of turbidity or concentrations of suspended solids, as had previously been the case.

The preference of MfE (1994) for measurement of optical quality over measurement of turbidity or TSS is based partly on ease of use and cost-effectiveness, but also on the greater precision of the results obtained. Although Secchi disk measurements appear to be rather subjective and approximate, their precision (usually within 10%) is comparable to that of other methods "…*and better than some, notably turbidity…*" (MfE 1994). The precision of turbidimeters has improved since that report, but nevertheless nephelometric turbidity provides a *relative* index of the scattering of an incident beam of light compared with that of a standard (Barter & Deas 2003). As such, turbidity is influenced by the nature of the material in suspension, specifically its light-scattering properties. Consequently, relationships between turbidity and clarity are site-specific. From their comparison of variability among and within different models of turbidimeters, Barter and Deas (2003) concluded that turbidity is best not used as the sole means of determining changes in clarity for regulatory purposes, but rather as an ancillary measure supporting more direct measures of clarity (such as black or Secchi disk, or transmissivity).

With respect to visual clarity, MfE (1994) recommended that:

- For Class A waters where visual clarity is an important characteristic of the waterbody, the visual clarity should not be changed by more than 20% (visual clarity should be measured with a black disk.)

The Ministry for the Environment (1994) noted that, although people can detect small changes in clarity (*i.e.* 20%), this represents the lower bound of a conspicuous change and the RMA does not require the protection of all waters to the high degree specified by this guideline. Regional councils have traditionally permitted increases in turbidity or concentrations of suspended solids of 50–100% (corresponding to decreases in clarity of 33–50%). Consequently:

- For other waters, the visual clarity should not be changed by more than 33% to 50%, depending on site conditions.

Site conditions include the optical depth of the receiving water, the observer's experience of, and expectations for, the optical quality of the waters in question, the value of the waterbody, and the nature of downstream waterbodies (MfE 1994). Clarity changes are more noticeable in optically shallow waters (*i.e.* those in which reflectance from the bed affects appearance). Changes in clarity are also likely to be less conspicuous in waters where background clarity is variable. Greater protection of water clarity is likely to be appropriate for waterbodies where clarity is naturally high and forms part of the specific value (aesthetic, cultural or spiritual) of that waterbody. Finally, greater protection may be appropriate when sensitive or high-value waterbodies are present downstream of a discharge.

The recommendations for protection against conspicuous changes in colour were that:

- For Class A waters (where hue in an important characteristic of the waterbody) the hue should not be changed by more than 5 points on the Munsell scale.
- For other waters, the hue should not be changed by more than 10 points on the Munsell scale.

Based on a study of user preferences for bathing waters, MfE (1994) recommended an optical-clarity guideline for contact recreation:

- The horizontal sighting range of a 200 mm black disk should exceed 1.6 m.

This black disk distance corresponds to a Secchi depth of 2.2 m and was derived from user preferences for a freshwater stream (MfE 1994). In addition to aesthetic quality, visual water clarity also allows bathers to estimate water depth and identify hazards. Preferences for coastal waters used for bathing are, however, likely to be lower because of naturally lower clarity (MfE 1994). For example, Kaiwaka Point is a popular bathing area in Whangarei Harbour (see Figure 5 of the Whangarei Harbour Water Quality Action Plan [2012]) and is one of the monitoring stations in the Whangarei Harbour Water Quality Monitoring Programme (see Section 2.1). Secchi depth at this location exceeded 2.2 m on only two out of 50 times of sampling between August 2007 and November 2014.

2.2.3. ANZECC guidelines for protection of water clarity

The ANZECC (2000; see Table 3) guidelines for the protection of water clarity and colour specify that:

- To protect the aesthetic quality of a waterbody, the natural visual clarity should not be reduced by more than 20%.
- To protect the visual quality of waters for swimming, the horizontal sighting of a 200 -mm diameter black disk should exceed 1.6 m.
- To protect aquatic ecosystems, the natural euphotic depth should not be permitted to change by more than 10% for marine waters.
- For waters of high aesthetic value, the natural hue of the water should not be changed by more than 10 points on the Munsell scale

The guidelines recommend a range of reference and default trigger values for the protection of various ecosystems based on suspended solid levels and limits for some discharge activities. With respect to suspended particulate matter (SPM), the guidelines recommend that load-based guidelines be developed to address non-optical effects.

With respect to water clarity and colour, therefore, the ANZECC (2000) guidelines are consistent with those provided by MfE(1994). Both favour measures of optical clarity over turbidity and ANZECC (2000) states that "[t]urbidity is not a very useful indicator in estuarine and marine waters. A move towards measurements of light attenuation in preference to turbidity is recommended". Importantly, ANZECC emphasise that, rather than focussing on single numeric guidelines, management of water quality should take a risk-based approach. Local conditions (including variability within the waterbody), values and management objectives should be taken into account when developing appropriate limits.

2.3. Summary

The RCP classifies upper parts of Whangarei Harbour (where water clarity is naturally lower) differently to the middle and lower harbour for purposes of water-quality management. However, the same water quality standards for clarity and colour apply to both classifications (no more than 20% reduction in visual clarity and a change in colour of no more than 10 Munsell units). These standards, which are also incorporated into the current dredging consents, were originally intended to apply to Class A waters, where visual clarity is an important characteristic of the waterbody (MfE 1994), and to protect aesthetic values (ANZECC 2000).

There is large background variation in Secchi depth, turbidity and TSS, which frequently exceeds 20% deviation from long-term median values[1], at monitoring stations throughout the harbour. Where turbidity is naturally high and variable, it is probable that biota are adapted to cope with these stresses. From an aesthetic and contact-recreation perspective, expectations of visual water clarity are likely to be lower for the upper harbour than for the middle and lower harbour.

These factors suggest that the current standards are overly stringent for naturally more turbid parts of the harbour. A more adaptable approach to developing standards would be a risk-based one that takes into account differences in types of sediment and background turbidity in different parts of the harbour, together with differences in ecological, recreational and cultural values and vulnerability to suspended sediments. This is discussed in Section 3.

[1] ANZECC (2000), for example, recommended median concentrations of suspended particulate matter for comparison with their guidelines, rather than single, spot measurements.

3. RECOMMENDATIONS FOR ALTERNATIVE STANDARDS FOR DREDGING CONSENTS

3.1. Risk-based classification of different harbour regions

The following discussion focusses on Whangarei Harbour but the approach proposed is applicable to other coastal waterbodies in Northland.

3.1.1. Current classifications

As noted in Section 1.2.1, the classification of Whangarei Harbour in the Water Quality Action Plan identifies two categories:

- General Quality Standard (CA), which provides for virtually all uses, including shellfish collection and protection of marine ecosystems.
- Contact Recreation Standard (CB), which provides for contact recreation but not for marine ecosystems or aesthetic value.

These classification both have the same standards for water clarity and colour (no more than 20% reduction or change of more than 10 Munsell units, respectively). In addition, the euphotic depth shall not decrease by more than 10% in waters deeper than half the euphotic depth, and in waters shallower than half the euphotic depth the maximum reduction in light at the seabed shall not be more than 20%.

In addition, the RCP divides Northland's coastal marine area into six zones or Marine Management Areas:

- Marine 1 (Protection)
- Marine 2 (Conservation)
- Marine 3 (Marine farming)
- Marine 4 (Moorings)
- Marine 5 (Port facilities)
- Marine 6 (Wharves)

All zones other than Marine 6 are represented in Whangarei Harbour. However, other than the narrative standard that discharges to water shall not contain any contaminants that could cause "the production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials", none of these zones has associated water-quality standards relating to water clarity, turbidity or suspended solids.

3.1.2. Classification for dredging guidelines

The first stage in developing risk-based guidelines for dredging activities is to identify regions of the waterbody, based on their background water-quality (with respect to clarity, turbidity and concentrations of suspended solids), and their vulnerability to reduction in quality due to dredging.

Background water clarity and turbidity is affected by external inputs of suspended material, such as rivers, stormwater outfalls and other discharges. In addition to these, internal sources include local sediments and other seabed material that is available for resuspension by wave and current action. Both of these sources are highly dependent on weather conditions, particularly rainfall in the catchments and wind action over areas of muddy sediments, giving rise to considerable temporal variation in clarity and turbidity. This is evident in the monitoring data from Whangarei Harbour.

We have classified regions of Whangarei Harbour on the basis of background water clarity and turbidity, and the vulnerability to these stressors of features present in each region that are of particular human or ecological importance (Table 4). Because water-quality monitoring data were an important source of information for this process, the regions identified are focussed around water-quality monitoring stations. However, these are well dispersed throughout the harbour and were presumably selected to be representative of different harbour environments and uses.

Assessment of the clarity and turbidity regime in each region was based on background (median) Secchi depth and turbidity data (Table 1), and the type of sediment present (using information derived from NRC's intertidal and sub-tidal monitoring stations in NRC's Estuary Monitoring Programme: Northland Regional Council 2013 and see Figure 3). Sediment type was based on broad textural categories (*e.g.* > 75% coarse and medium sand).

Table 4. Classification or regions of Whangarei Harbour for development of water-quality guidelines for dredging.

Region	Part of harbour	WQ class	Median Secchi depth (m)	Median turbidity (NTU)	Subtidal sediment type	Values, uses and Marine Management Area classifications	Visual clarity important?	Comments
Town Basin	Upper	CB	1.0	5.0	75% med/coarse sand	Navigation, Marine 4 (Controlled Mooring)	N	Naturally turbid area and features contributing to high natural character presumably adapted.
Limeburners Creek	Upper	CB	1.0	7.7	>75% mud/fine sand	Navigation	N	Naturally turbid area and features contributing to high natural character presumably adapted.
Kissing Point	Upper	CB	1.1	6.0	>75% mud/fine sand	Navigation, Marine 4 (Controlled Mooring), 2^{o} recreation, High Natural Character (Marine 1 (Protection) Management Area)	N	Naturally turbid area and features contributing to high natural character presumably adapted.
Port Whangarei	Upper	CB	1.2	5.3	>75% mud/fine sand	Navigation, Marine 5 (Port Facilities) Marine 4 (Controlled Mooring), High Natural Character (Marine 1 (Protection)	N	Naturally turbid area and features contributing to high natural character presumably adapted.
Kaiwaka/Kioreroa Reach	Upper	CB	1.1	6.2	>75% fine sand	Major recreational area (contact), Marine 1 (Protection) Management Area	Y but see Comments	Naturally turbid area. Features contributing to high natural character presumably adapted and recreational use is secondary-contact.
Onerahi/Wellington Reach	Middle	CA	1.4	5.0	ND	Marine reserve (Waikaraka), Marine 1 (Protection) Management Area	Y but see Comments	Naturally turbid area and the mangrove forest and intertidal mudflats contributing to high natural character presumably adapted.
Otaika	Upper	CB	ND	ND	>75% mud/fine sand	Marine 1 (Protection)	N	Naturally turbid area and the mangrove forest and intertidal mudflats contributing to high natural character presumably adapted.
Portland	Upper	CA	1.1	6.7	>75% mud/fine sand	Marine 1 (Protection), Marine 2 (Conservation), Marine 5 (Port Facilities).	N	Naturally turbid area, and features contributing to high natural character presumably adapted.

Region	Part of harbour	WQ class	Median Secchi depth (m)	Median turbidity (NTU)	Subtidal sediment type	Values, uses and Marine Management Area classifications	Visual clarity important?	Comments
Mangapai Arm	Upper	CB	0.8	8.9	>75% mud/fine sand	High Natural Character with areas of Outstanding Natural Character off Hewlett Point, Marine 2 (Conservation)	N	
Tamaterau	Middle	CA	2.3	2.9	75% fine sand	High Natural Character (extensive seagrass beds) on opposite side of channel, Marine 2 (Conservation)	Y (seagrass)	
One Tree Point/Shell Cut Reach	Middle	CA	3.5	1.0	75% med/coarse sand	High Natural Character and Marine 1 (Protection) and Marine 2 (Conservation) areas to the west (extensive seagrass beds) and on opposite side of channel (shellfish banks)	Y (seagrass, shellfish)	
Snake Bank	Lower	CA	3.5	1.0	75% med/coarse sand	Area of High Natural Character and Marine 1 (Protection) (major shellfish banks). Commercial harvesting of cockles.	Y (shellfish)	
Blacksmith Creek	Lower	CA	3.8	1.0	60% med/coarse sand	Area of High Natural Character and Marine 1 (Protection) (major shellfish banks) on opposite side of channel	Y (shellfish)	
NZRC Jetty	Lower	CA	4.1	1.0	ND	Marine 5 (Port Facilities) and adjacent to Marine 1 (Protection) area (major shellfish bank on Mair Bank). Motukaroro Marine Reserve on opposite side of channel.	Y (diving, and reef assemblages in reserve)	
Mair Bank	Lower	CA	3.9	1.0	ND	High Natural Character and Marine (Protection) (major shellfish bank). Commercial harvesting of pipi.	Y (shellfish)	Marine 1 (Protection).

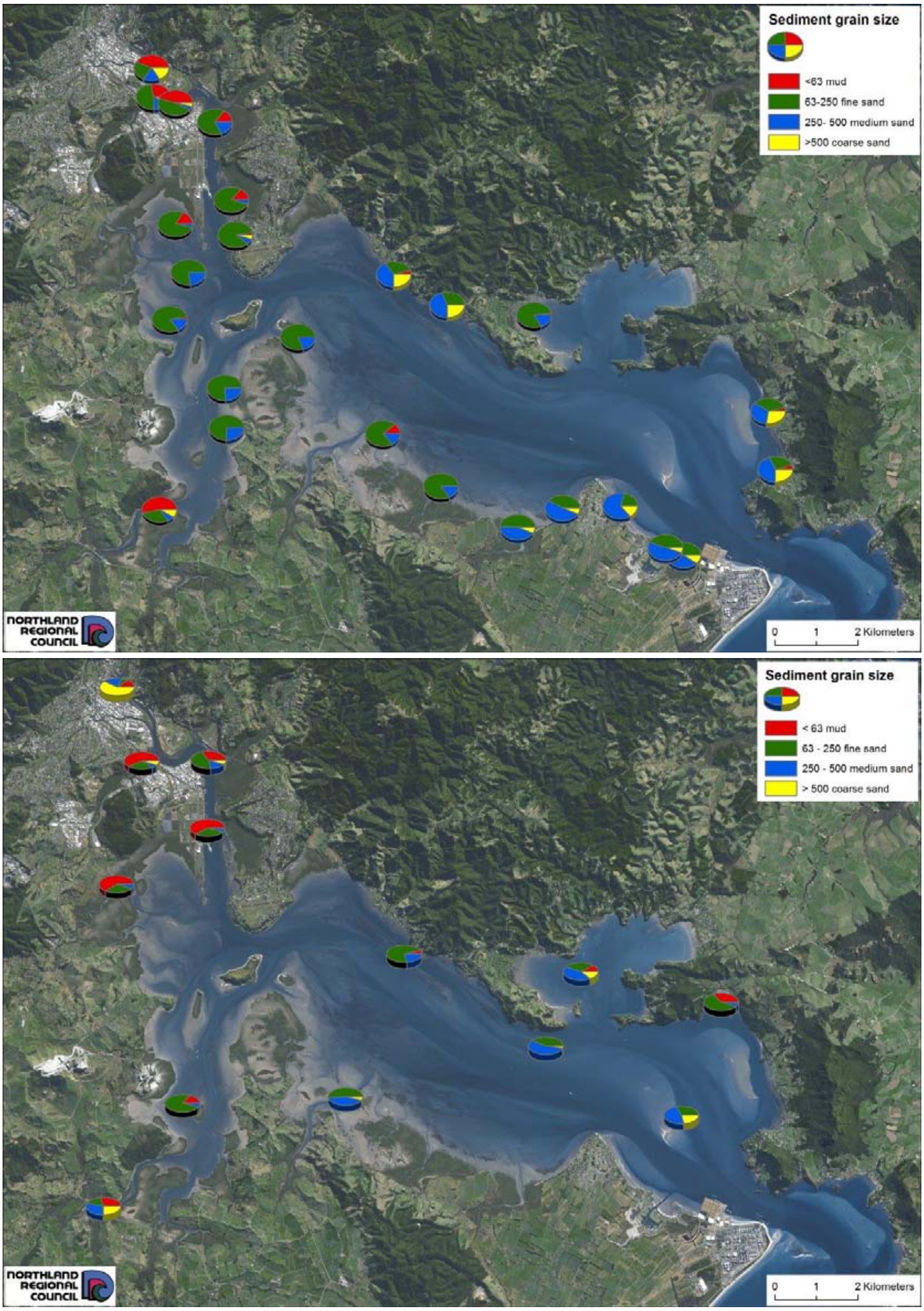


Figure 3. Intertidal (upper) and sub-tidal (lower) sediments of Whangarei Harbour.

Human and ecological values for each of the regions were identified from the maps of habitats and harbour uses contained in the Whangarei Harbour Water Quality Improvement Strategy Summary (Northland Regional Council 2012a). Northland

Regional Council also provided a map showing important areas of the harbour for recreational activities (primary and secondary contact), seagrass and shellfish beds, marine reserves and areas of 'Outstanding Natural Character' and 'High Natural Character' (Figure 4). The Marine Management Areas identified in the RCP (see Section 3.1.1) were also used to identify uses of different regions. Information on the values protected by the Waikaraka and Motukaroro Marine Reserves was obtained from the Department of Conservation website[2].

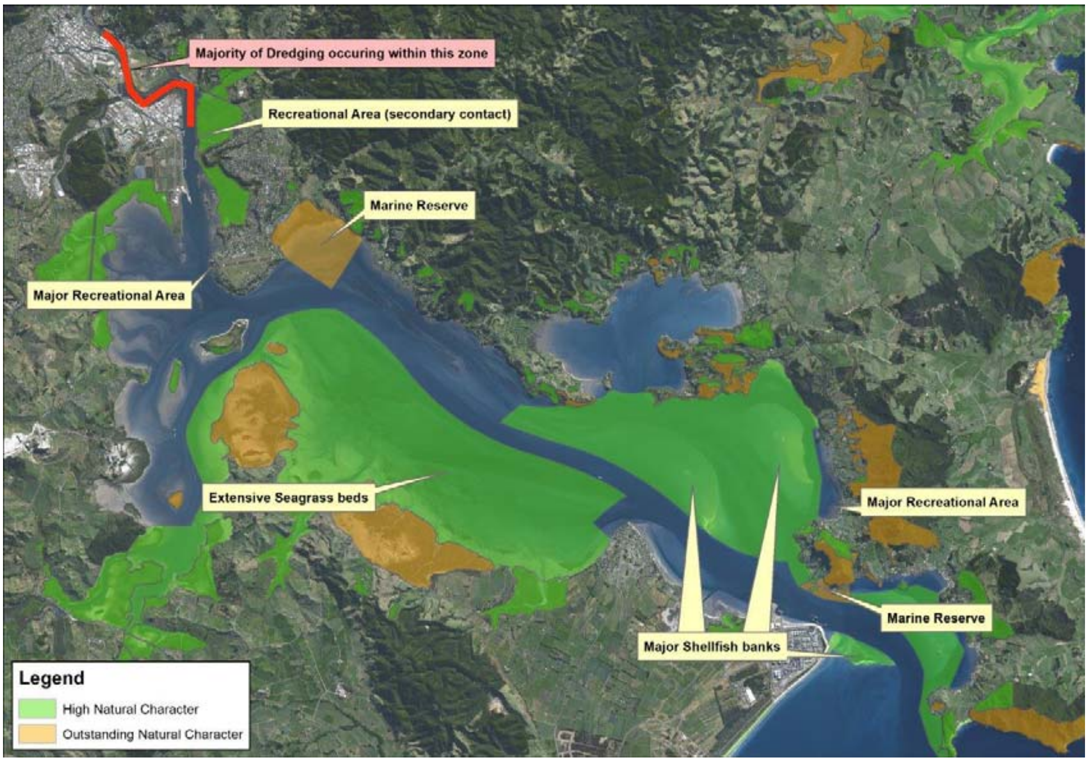


Figure 4. Important habitats and areas of recreational use in Whangarei Harbour.

Upper-harbour locations, and also Portland and the Mangapai Arm, experience low water clarity because of run-off from land and resuspension of the fine, muddy sediments present in these areas. Muddy intertidal flats and restricted public access limit the amount of primary-contact recreation in the upper harbour (Northland Regional Council and Whangarei District Council 2012b). Consequently, human expectations of visual clarity are likely to be low and clarity is therefore not an important characteristic of the waterbody in these areas. Biological assemblages will be adapted to low visual clarity, high turbidity and relatively high rates of sediment deposition. Many of these areas are fringed by mangrove forests, which are generally highly depositional environments. The Waikaraka Marine Reserve protects

[2] http://www.doc.govt.nz/parks-and-recreation/places-to-visit/northland/whangarei-area/whangarei-harbour-marine-reserve/features/: accessed 15 January 2015

representative mangrove habitats and their associated biota, including birds. High turbidity and sediment deposition therefore contributes to the natural character of these parts of the harbour. Temporary increases in turbidity and reductions in clarity caused by dredging may not exceed background variation and are relatively unlikely to have adverse effects.

Water clarity in the middle and lower harbour is markedly higher (median Secchi depths of 2–4 m rather than ca 1 m) and turbidity lower (1–3 NTU rather than 5–9 NTU) than in the upper harbour. Sediments in these areas are generally fine–coarse sands and therefore require stronger wave or water movement to resuspend them and, once resuspended, settle out again more rapidly. Consequently, human expectations of water clarity are likely to be higher for these areas and several locations, such as McLeod and Taurikura bays, are valued for contact recreation. Natural habitats and their biota are also dependent on high water clarity and low turbidity, notably seagrass and shellfish beds. About a quarter of New Zealand’s total commercial harvest of cockles comes from Snake Bank. In the past, almost the entire commercial pipi harvest comes from Mair Bank (Morrison 2005) but the current stock is less than 1% of that in 2005 and commercial harvesting stopped in 2011–2012 (pers. comm. Ricky Eyre, NRC). Visual clarity is therefore an important characteristic for these areas of the harbour. Because of the relatively coarse sediments, however, dredging activities are likely to have less severe effects on clarity and turbidity.

3.2. Water-quality guidelines for different harbour regions

Having characterised the different harbour regions on the basis of background water quality and their vulnerability to decreased quality caused by dredging, the next step is to determine appropriate water-quality guidelines for each region. Although this discussion focusses on Whangarei Harbour, the process is applicable to other harbours and estuaries in Northland.

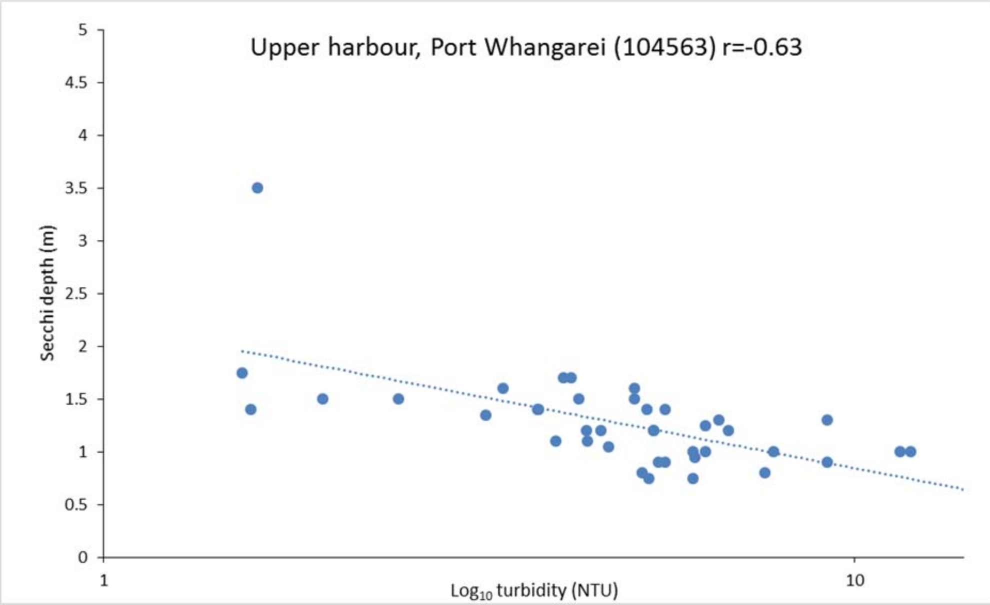
3.2.1. Water-quality indicator for guidelines

Following the recommendations of MfE (1994), ANZECC (2000) and Clement and Barter (2011), we suggest that water clarity should be the primary guideline variable. Clarity guidelines should be based on aesthetic considerations, partly because water clarity is an important characteristic for parts of the harbour used for contact recreation. Equally importantly, however, in the absence of information on which to base clarity criteria to protect aquatic life, protection of aesthetic values is also likely to protect the habitat of sighted aquatic animals and the photosynthetic requirements of plants (MfE 1994, Clement & Barter 2011). In other words, “[p]rotection of the visual clarity of waters will usually ensure that colour and light penetration are not degraded” and also has practical advantages in terms of ease of measurement (MfE 1994).

Strictly speaking, this justification for the use of water clarity applies only to optical effects of suspended solids, not physical effects of suspended solids (such as clogging of respiratory organs) or the effects of their subsequent deposition. The former are likely to occur at very high concentrations (MfE 1994, Clement & Barter 2011). The latter depends on the characteristics of the suspended material in terms of how long it remains in suspension (*e.g.* particle size and density), and on water movements that maintain it in suspension, disperse it, or allow it to settle. These factors are site specific and variable over a wide range of time scales and, therefore, not amenable to the development of numerical guidelines. Again, these concentrations are likely to be significantly greater than those causing conspicuous visual effects (Clement & Barter 2011) and so protection of the latter is likely to provide protection against non-optical effects.

3.2.2. Other indicators

Visual clarity is proposed as the guideline variable rather than turbidity because of the "…varied values [of turbidity] associated with natural perturbations…" (ANZECC 2000). The relatively large variability compared with that observed with visual clarity is illustrated by the Whangarei Harbour monitoring data (Table 1). The difference between the median and 95%ile values for turbidity ranged from 111–1,009% of the median among the 15 monitoring stations, while the equivalent range for the 5%ile for Secchi depth was 30–62%. There was a significant correlation between Secchi depth and $\log_{10}$ turbidity at all but two (Blacksmiths Creek and Mair Bank) of the monitoring stations, but the spread of data was too wide to provide a useful predictive relationship (example plots are shown in Figure 5).



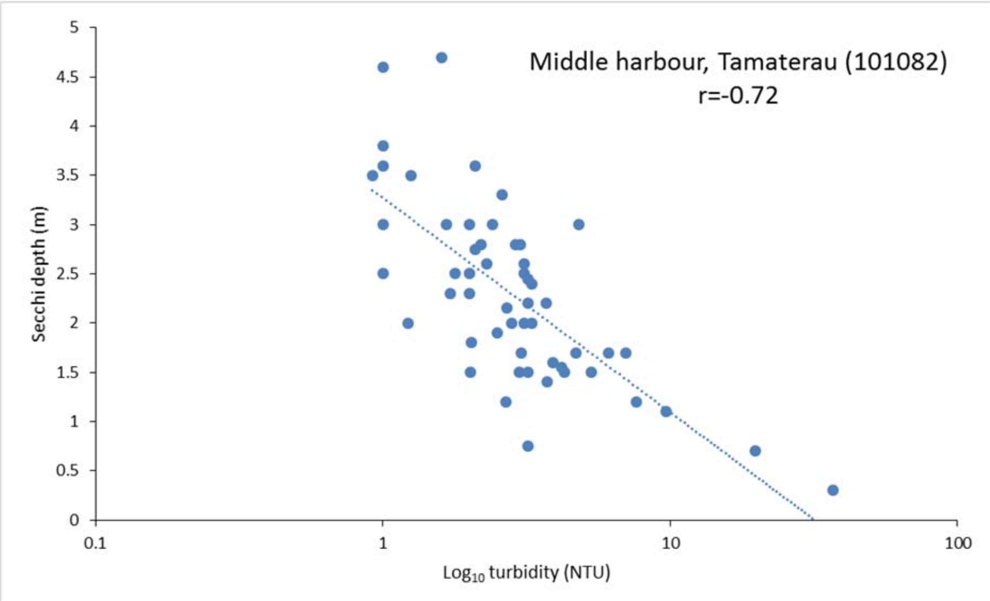


Figure 5. Correlation between Secchi depth and $\log_{10}$ of turbidity for two of the water-quality monitoring sites in Whangarei Harbour.

MfE (1994) and Barter and Deas (2003) argued against the use of turbidity and suspended solid concentrations as indicators of optical water quality because measurements are less accurate than black disk measurements. Coefficients of variation were only acceptably small and similar to those of black-disk measurements when testing relatively large concentrations. The comparisons of black-disk, turbidity and suspended solids measurements reported in MfE (1994) were based on studies in freshwater. Secchi disk measurements are generally recommended for estuarine and marine waters (NZWERF 2002), provide a direct measure of clarity and have also been found to be more precise for measuring water clarity than turbidity measurements (MfE 1994).

Although we do not recommend guidelines based on turbidity or TSS, for the reasons given by MfE (1994) and Clement and Barter (2011), they can be developed as appropriate site-specific surrogates with cross-calibration with visual effects methods (although relationships among these variables are not simple). ANZECC (2000) advocates inclusion of continuous turbidity monitoring in local or national water-quality monitoring programmes. This will result in improved turbidity databases, allowing variability in turbidity to be better defined and providing the basis for better defining statistically-based guidelines. Clement and Barter (2011) further suggest that collection of other data, such as TSS, will help determine how different aspects of water quality are related and aid future interpretation of turbidity records.

Guidelines for water colour are contained in the RCP (see Section 1.2.1) and in dredging consents but colour is not monitored either as part of the Whangarei Harbour Water Quality Monitoring Programme or for consent compliance (pers. comm. Ricky Eyre, NRC). Consequently, we have not made any recommendations on guidelines for this indicator.

3.2.3. Guidelines for water clarity

As noted in Sections 2.2.2 and 2.2.3, MfE (1994) and ANZECC (2000) advocate a maximum change of 20% for waters where visual clarity is an important characteristic, and that are managed specifically to protect this feature. This is not the case for any waters in Whangarei Harbour, with the possible exception of the area around the Motukaroro Marine Reserve This area is popular for diving and has relatively high, but variable, natural visual clarity.

For other waters, "the visual clarity should not be changed by more than 33–50% *depending on the site conditions*" (MfE 1994). Site conditions include the background variability in water quality and the values associated with the waterbody. ANZECC (2000) advises that selection of water clarity guidelines needs to consider inherent variability within the waterbody and use site-specific information to develop appropriate local limits.

Following this guidance, and following the characterisation of different parts of the harbour described in Section 3.1.2, we have applied the upper and lower bounds of MfE's (1994) suggested range (33% and 50% change) to different parts of harbour (Table 5).

- We suggest a guideline of **no more than 50% reduction relative to background clarity at the time of monitoring for upper parts of the harbour** (Town Basin to Kaiwaka Point and also Portland and the Mangapai Arm), where water clarity is naturally lower, turbidity higher, public expectations of water clarity are low and the biota is adapted to these conditions.

- The suggested **guideline for the middle and lower harbour is no more than 33% reduction relative to background clarity at the time of monitoring** to protect aesthetic values, water quality for contact recreation, and habitats and organisms sensitive to elevated suspended solids and reduced clarity (seagrass and shellfish beds, encrusting biota of rocky reefs). Because these areas are not managed specifically for their visual clarity, we consider that the 20% criterion would be unnecessarily restrictive.
- The possible exception to the previous guideline for the lower harbour is the Motukaroro Marine Reserve. This area protects a diverse and abundant fish fauna, macroalgal beds and assemblages of filter-feeding organisms (including anemones, sponges and ascidians). These organisms are likely to be sensitive to suspended solids and the site is popular with divers, for whom water clarity is an important feature. For this area, a maximum reduction in clarity of 20% relative to background clarity at the time of monitoring may be appropriate.
- We also suggest that **exceedances of the 33% and 50% guidelines are acceptable providing that the absolute Secchi depth is not less than the 20th percentile of the long-term Secchi depth monitoring data for the upper or middle/lower parts of the harbour, as appropriate** (these values are 0.8 m and 2.3 m, respectively). This condition allows for situations where background clarity is unusually good at the time of dredging and a reduction to < 50% does not represent a value that is unusual in terms of long-term background water clarity. Local biota are likely to be able to tolerate conditions that occur naturally for 20% of the time, and public expectations of water clarity are also likely to be tolerant.
- Breaching of these guidelines will trigger more intensive monitoring of Secchi depth, turbidity and TSS to determine whether this is a sustained event (more than, say, one day's duration). If so, dredging should be stopped or mitigation measures put in place.
- Turbidity and TSS should continue to be monitored to allow variability in turbidity to be better defined and provide the basis for better defining statistically-based guidelines. Turbidity measurements may be useful in situations where measuring Secchi depth is not practical, for example where remote or continuous monitoring is required. In these cases, a location-specific relationship between clarity (Secchi depth) and turbidity or TSS should be established.

We have not incorporated the guideline proposed by MfE (1994) for waterbodies managed for contact recreation (*i.e.* minimum black disk distance > 1.6 m). This guideline was developed for freshwater and the authors recognised that this would not necessarily be appropriate for marine waters, where bathing areas often have naturally lower clarity (*e.g.* Kaiwaka in Whangarei Harbour).

Table 5. Proposed water-clarity guidelines (percentage reduction in Secchi depth) for different parts of Whangarei Harbour.

Area	Part of harbour	Guideline	Temporal restrictions on dredging
Town Basin	Upper	< 50%	Closed season: 16 December–7 February, public holidays, weekends [1]
Limeburners Creek	Upper	< 50%	Closed season:16 December–7 February, public holidays, weekends [1]
Kissing Point	Upper	< 50%	Closed season:16 December–7 February, public holidays, weekends [1]
Port Whangarei	Upper	< 50%	Closed season:16 December–7 February, public holidays, weekends [1]
Kaiwaka/Kioreroa Reach	Upper	< 33%	Closed season:16 December–7 February, public holidays, weekends [1]
Onerahi/Wellington Reach	Middle	< 33%	
Otaika	Upper	< 33%	Shellfish habitat value: closed season for wedge shell and cockle spawning October–December, settlement December–January [1]
Portland	Upper	< 50%	Shellfish habitat value: closed season for wedge shell and cockle spawning October–December, settlement December–January [1]
Mangapai Arm	Upper	< 50%	
Tamaterau	Middle	< 33%	Fish habitat value: closed season November–March for settlement and occurrence of juvenile snapper (and other species) [1, 2]
One Tree Point/Shell Cut Reach	Middle	< 33%	Fish habitat value: closed season November–March for settlement and occurrence of juvenile snapper (and other species). Shellfish habitat value: closed season for cockle and pipi spawning October–December, settlement December–January [1, 2, 3]
Snake Bank	Lower	< 33%	Shellfish habitat value—closed season for cockle and pipi spawning October–December, settlement December–January [1, 3]
Blacksmith Creek	Lower	< 33%	Shellfish habitat value:closed season for cockle and pipi spawning October–December, settlement December–January [1, 3]
NZRC Jetty	Lower	< 20% (?)	Shellfish habitat value: closed season for cockle and pipi spawning October–December, settlement December–January [1, 3]
Mair Bank	Lower	< 33%	Shellfish habitat value: closed season for cockle and pipi spawning October–December, settlement December–January [1, 3]

[1] Proposed in NRC dredging risk matrix (NRC unpublished), based on recreational use and presence of fish (snapper) at this time of year.
[2] Morrison *et al*. 2014.
[3] Morrison 2005.

It should be noted that, although the guidelines developed by the MfE (1994) and ANZECC (2000) are intended for use in both marine and fresh waters (subject to consideration of site conditions) they were developed from studies conducted in fresh waters. Clement and Barter (2011) point out that, while the effects are expected to be generally similar, "it is still unclear what a 20% or 50% change in visual clarity of marine and estuarine waters represents empirically from an aesthetic viewpoint". NZWERF (2002) suggest that these guidelines are not necessarily inappropriate for use in coastal or estuarine waters, but that site-specific considerations should be taken into account when applying them.

3.3. Temporal restrictions on dredging activities

Temporal restrictions on dredging activities in some parts of Whangarei Harbour are suggested in Table 5. The current consent for maintenance dredging of the Hatea River channel, the Town Basin and the Kissing Point mooring area specifies that dredging should only occur between 1 April and 15 December, presumably because of recreational use of the area (sailing and other secondary-contact activities) outside this period. The closed period between December and April also corresponds roughly to the periods of settlement and occurrence of juveniles of various species of fish (November–March: Morrison *et al.* 2014) and the spawning and settlement (October–January) of cockles and pipis (Morrison 2005 and as indicated in an unpublished risk-assessment matrix for dredging developed by NRC).

We suggest that the following temporal restrictions be imposed:

- **Closed season in the upper harbour (Hatea River arm) during the time of peak recreational use** (16 December–7 February, public holidays and weekends).
- **Closed season from November–March (inclusive) at Tamaterau** to protect juvenile fish, including snapper.
- **Closed season from October–March (inclusive) at One Tree Point/Shell Cut Reach** to protect juvenile fish and shellfish beds.
- **Closed season from October–January (inclusive) in the lower Harbour and at Portland/Otaika** to protect shellfish beds.

Temporal restrictions on dredging should correspond to ecologically sensitive periods in addition to recreational use. The restrictions proposed in Table 5 are intended to address this.

3.4. Summary

We make the following recommendations.

- The consent conditions for dredging should focus on visual clarity (measured as Secchi depth), rather than turbidity or TSS. Water clarity is strongly linked to optical water quality, is more precise, and is easier to measure.
- The consent conditions for dredging should be based on aesthetic considerations. Water clarity is an important characteristic for parts of the harbour used for contact recreation. The protection of aesthetic values is also likely to protect the habitat of sighted aquatic animals and the photosynthetic requirements of plants.
- Reduction in visual clarity due to dredging should be no more than 50% in the upper harbour and no more than 33% in the middle and lower parts of the harbour.
- Exceedances of the 33% and 50% criteria are acceptable providing that the absolute Secchi depth is not less than the 20th percentile of the long-term Secchi depth monitoring data for the upper or middle/lower parts of the harbour, as appropriate.
- Turbidity and TSS should continue to be monitored to allow variability in turbidity to be better defined and provide the basis for better defining statistically-based guidelines.
- Breaches of these guidelines should trigger more intense monitoring of Secchi depth, turbidity and TSS to determine whether the breach is a sustained event (more than, say, one day's duration). If so, dredging should be stopped or mitigation measures put in place.
- Temporal restrictions on dredging activities are also proposed to avoid the period of peak recreational use of parts of the harbour (December–March) and periods of spawning and settlement of fish and shellfish (October–March), dependent on the location and resources to be protected.

This approach to development of guidelines can be applied to other harbours and estuaries in Northland.

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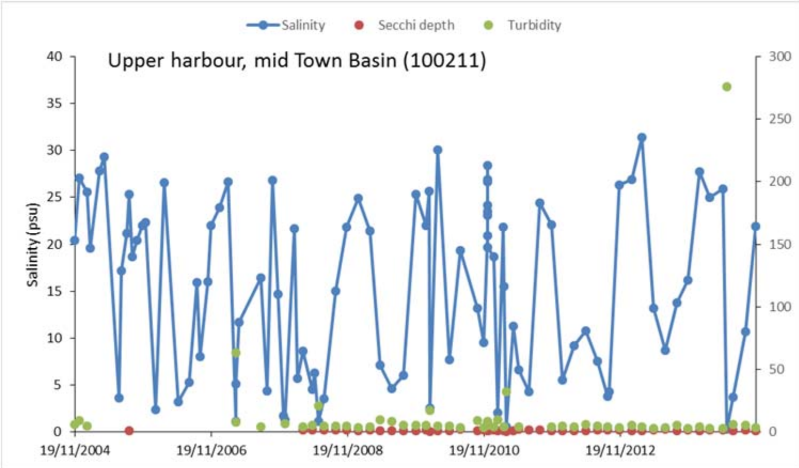
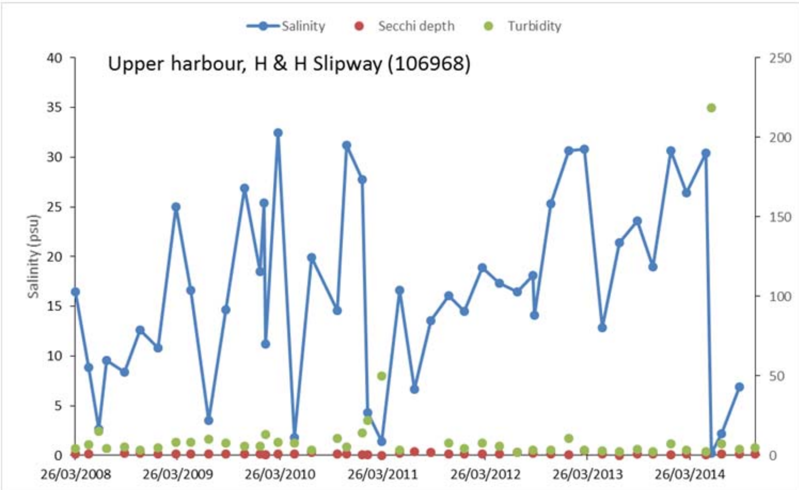
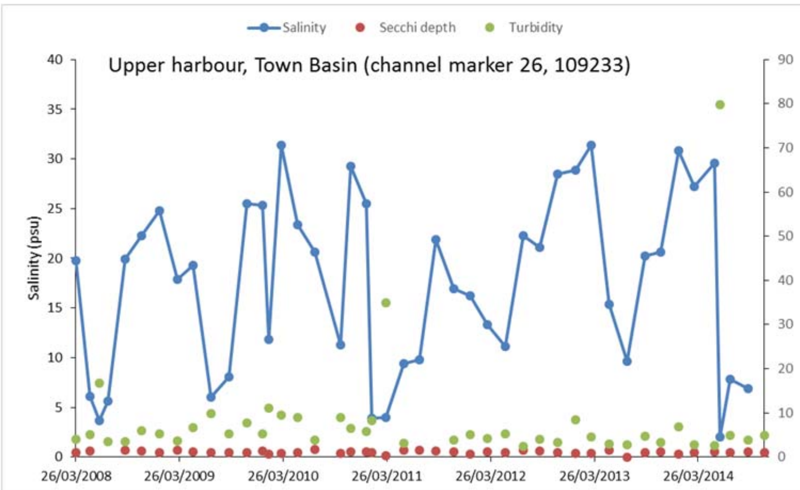
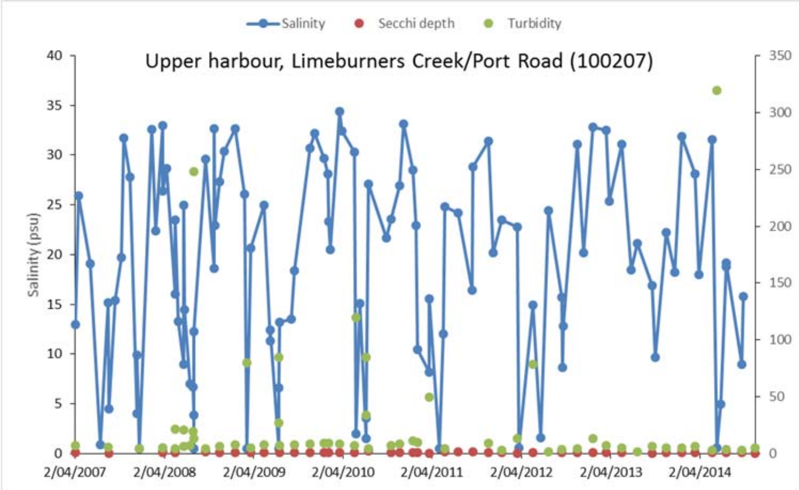
5. APPENDIX

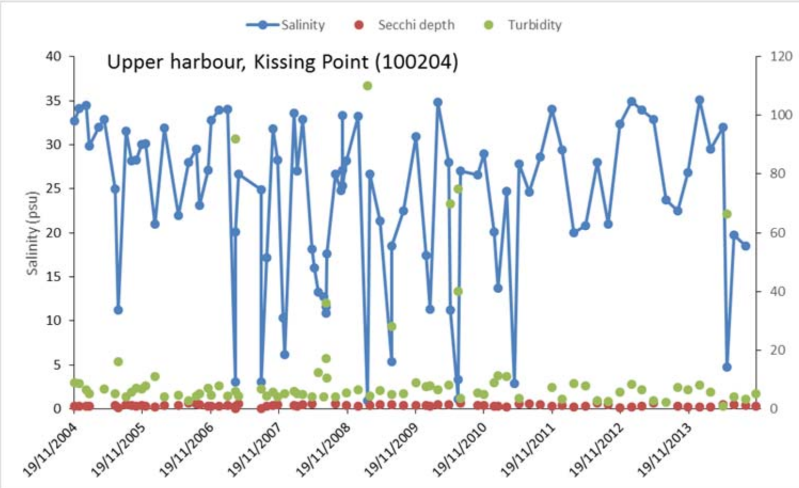
Appendix 1. Plots of salinity, Secchi depth, turbidity and total suspended solids (TSS) data from the Whangarei Harbour water-quality monitoring programme.

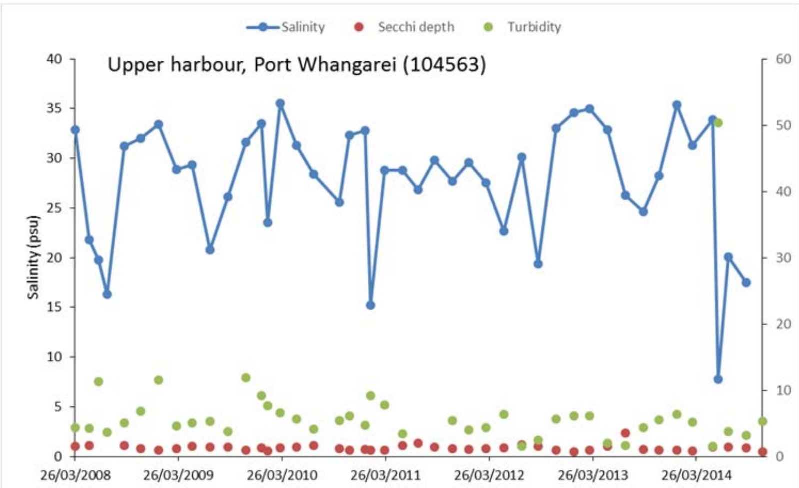


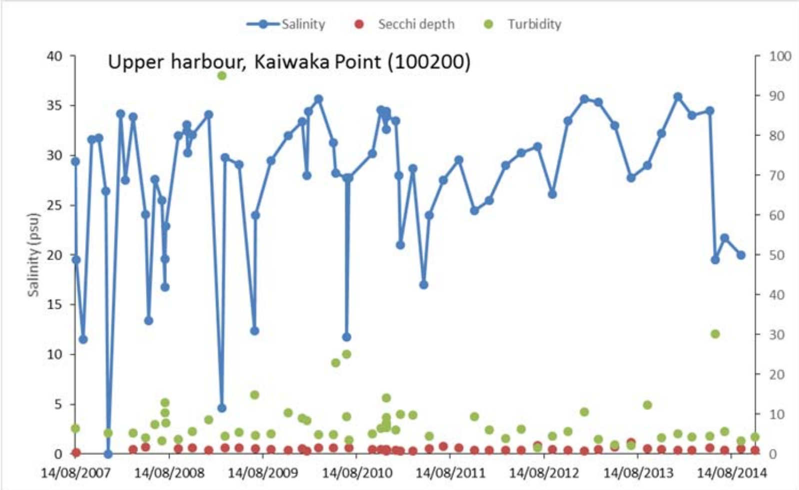


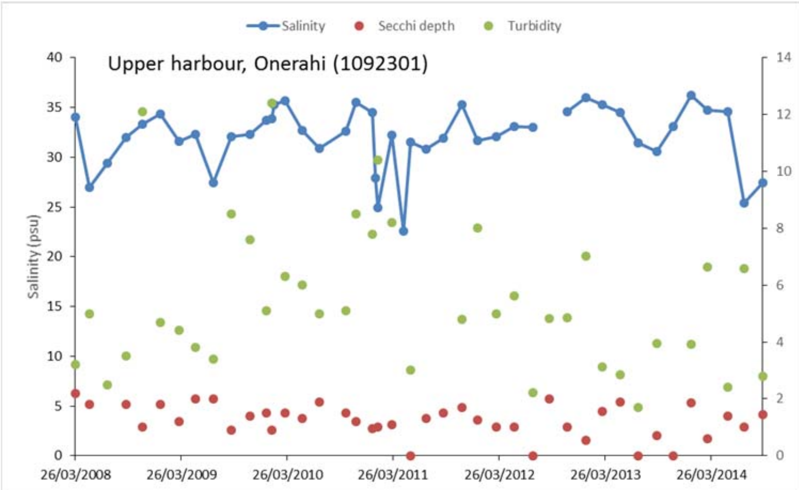


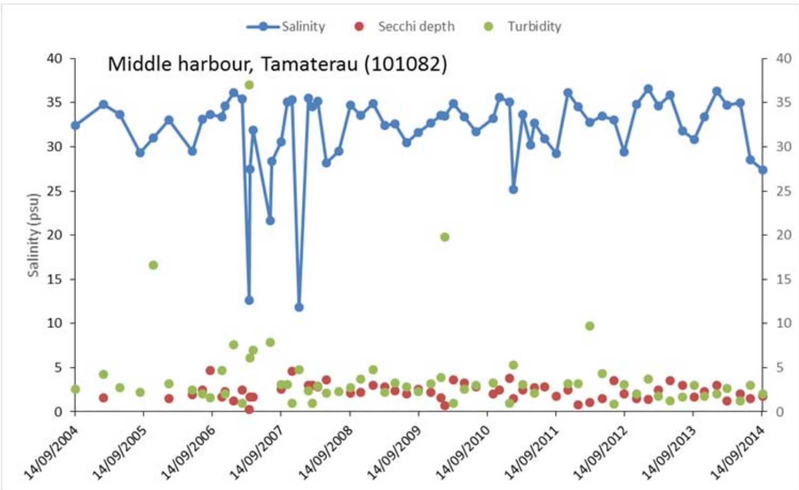

Salinity
Secchi depth
Turbidity
Upper harbour, Limeburners Creek/Port Road (100207)
Salinity (psu)
2/04/2007
2/04/2008
2/04/2009
2/04/2010
2/04/2011
2/04/2012
2/04/2013
2/04/2014

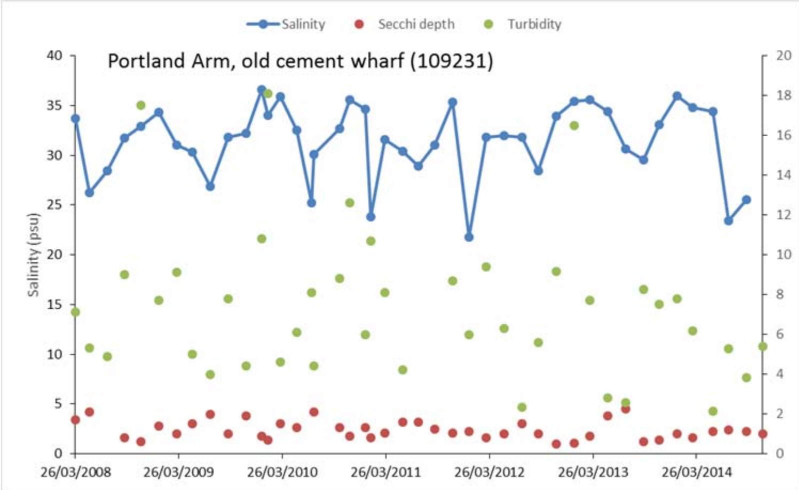

Salinity
Secchi depth
Turbidity
Upper harbour, Kissing Point (100204)
Salinity (psu)
19/11/2004
19/11/2005
19/11/2006
19/11/2007
19/11/2008
19/11/2009
19/11/2010
19/11/2011
19/11/2012
19/11/2013

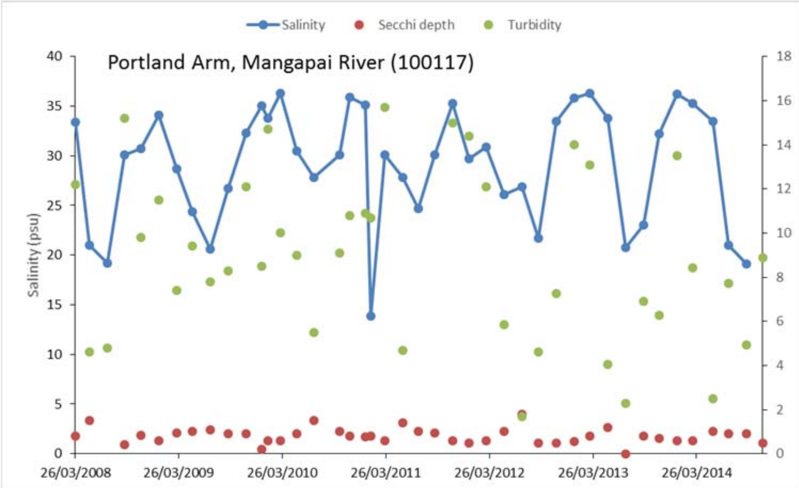

Salinity
Secchi depth
Turbidity
Upper harbour, Port Whangarei (104563)
Salinity (psu)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014

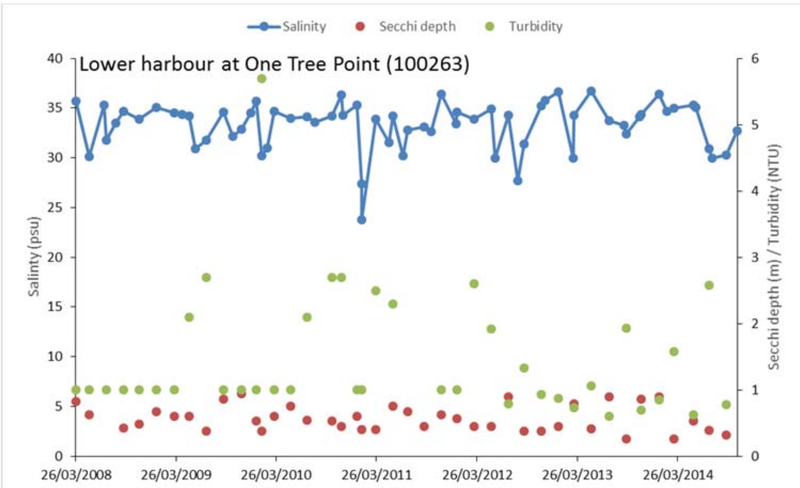

Salinity
Secchi depth
Turbidity
Upper harbour, Kaiwaka Point (100200)
Salinity (psu)
14/08/2007
14/08/2008
14/08/2009
14/08/2010
14/08/2011
14/08/2012
14/08/2013
14/08/2014

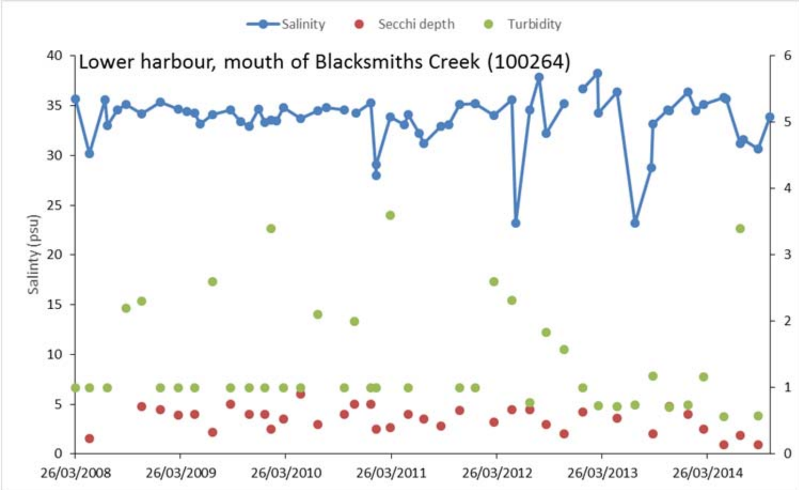

Salinity
Secchi depth
Turbidity
Upper harbour, Onerahi (1092301)
Salinity (psu)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014

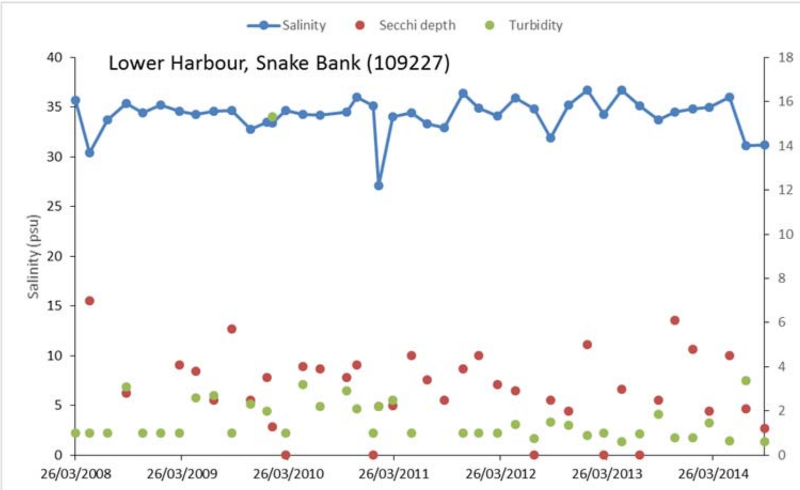

Salinity
Secchi depth
Turbidity
Middle harbour, Tamaterau (101082)
Salinity (psu)
14/09/2004
14/09/2005
14/09/2006
14/09/2007
14/09/2008
14/09/2009
14/09/2010
14/09/2011
14/09/2012
14/09/2013
14/09/2014

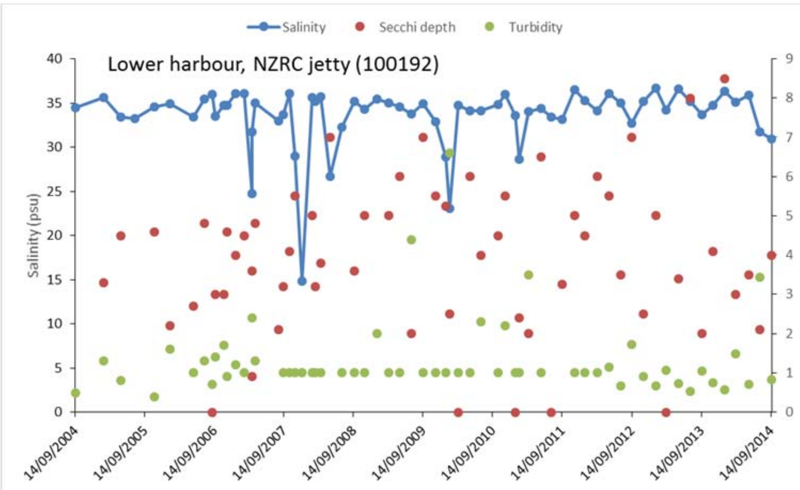

Salinity
Secchi depth
Turbidity
Portland Arm, old cement wharf (109231)
Salinity (psu)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014

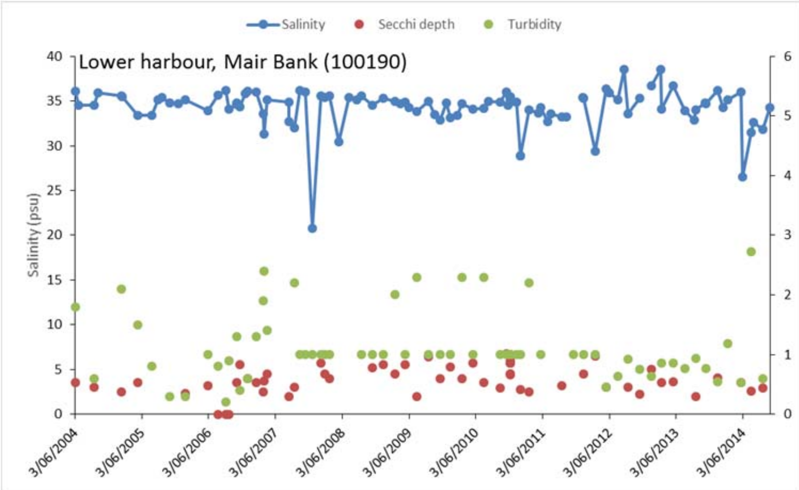

Salinity
Secchi depth
Turbidity
Portland Arm, Mangapai River (100117)
Salinity (psu)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014


Salinity
Secchi depth
Turbidity
Lower harbour at One Tree Point (100263)
Salinty (psu)
Secchi depth (m) / Turbidity (NTU)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014


Salinity
Secchi depth
Turbidity
Lower harbour, mouth of Blacksmiths Creek (100264)
Salinty (psu)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014


Salinity
Secchi depth
Turbidity
Lower Harbour, Snake Bank (109227)
Salinity (psu)
26/03/2008
26/03/2009
26/03/2010
26/03/2011
26/03/2012
26/03/2013
26/03/2014


Salinity
Secchi depth
Turbidity
Lower harbour, NZRC jetty (100192)
Salinity (psu)
14/09/2004
14/09/2005
14/09/2006
14/09/2007
14/09/2008
14/09/2009
14/09/2010
14/09/2011
14/09/2012
14/09/2013
14/09/2014


Salinity
Secchi depth
Turbidity
Lower harbour, Mair Bank (100190)
Salinity (psu)
40
35
30
25
20
15
10
5
0
6
5
4
3
2
1
0
3/06/2004
3/06/2005
3/06/2006
3/06/2007
3/06/2008
3/06/2009
3/06/2010
3/06/2011
3/06/2012
3/06/2013
3/06/2014