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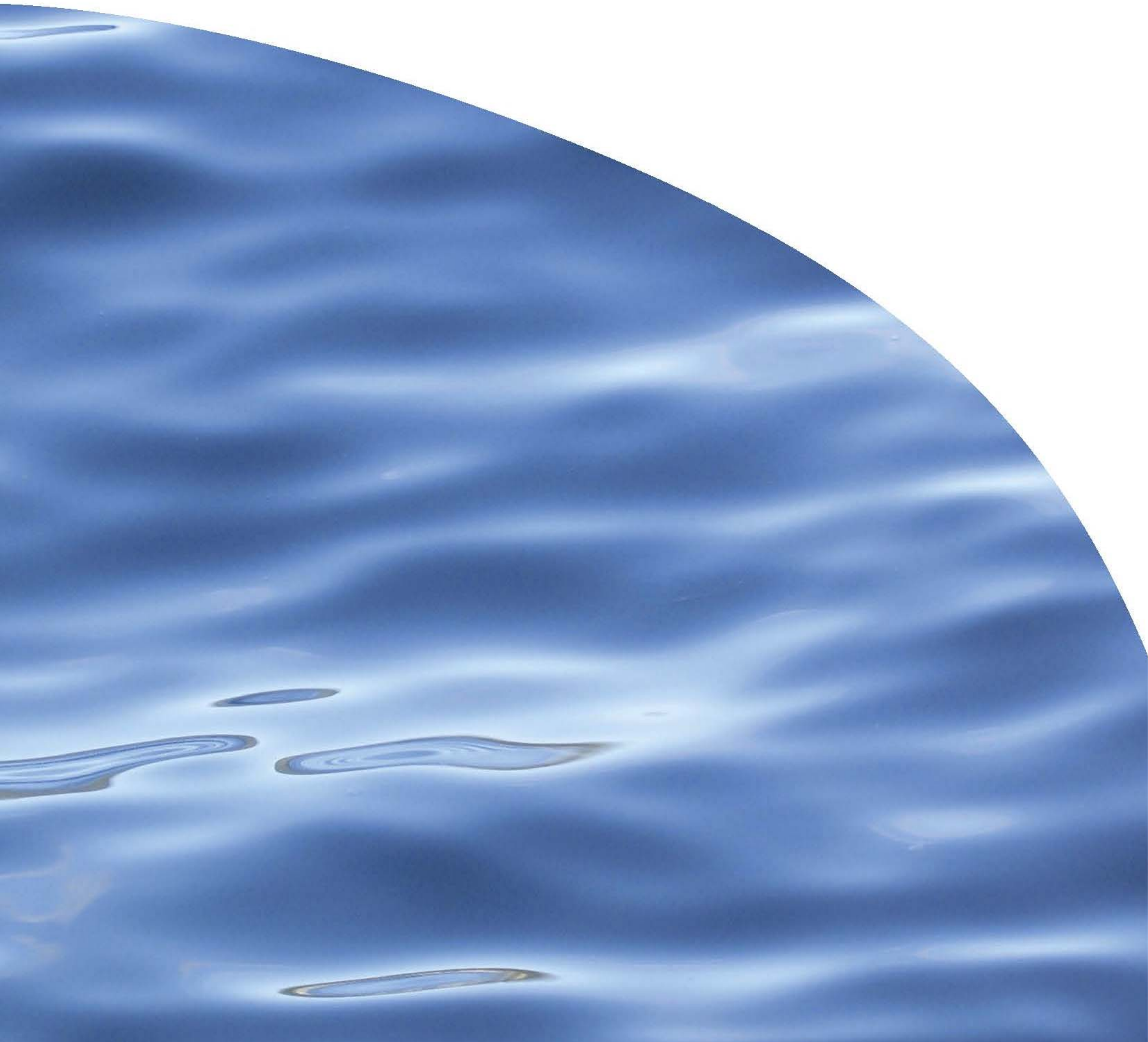
MARLBOROUGH'S COASTAL WATER QUALITY CLASSIFICATION: STANDARDS FOR SHELLFISH GATHERING AND CONTACT RECREATION CLASSES



MARLBOROUGH'S COASTAL WATER QUALITY CLASSIFICATION: STANDARDS FOR SHELLFISH GATHERING AND CONTACT RECREATION CLASSES

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EXECUTIVE SUMMARY

Marlborough District Council (MDC) is reviewing their regional plans. MDC require advice on standards appropriate for point source discharges into the marine receiving environment.

Water quality classifications are provided in Schedule 3 of the Resource Management Act 1991 (RMA), and are used in a range of ways by different councils. General requirements for the impact of discharges on water quality are defined in Sections 70 and 107 of the RMA and other requirements are stated in the New Zealand Coastal Policy Statement (NZCPS).

Under MDC's current plans, all marine waters are classified for Shellfish Gathering (SG). MDC has requested guidance on standards for the (SG) and Contact Recreation (CR) classes for the marine environment. Council recognise that the SG and CR classes do not incorporate broader requirements of the RMA and NZCPS.

Many difficulties in setting standards and monitoring impacts stem from the variability of water column characteristics in the marine environment. Our approach has been to identify standards and indicators that are relevant to the class in question, and consistent with approaches taken by other councils in New Zealand. Some commonly-used standards, such as dissolved oxygen saturation, are likely to be exceeded by background variation. Difficulty in directly attributing changes to a particular cause means that use of standards as trigger values for further investigation is often more appropriate than setting fixed points beyond which an activity is deemed non-compliant.

Suitable methods for monitoring the parameters, for which standards have been set, are also given. Often high-resolution data is required to separate impacts of an activity from background variation. Improvements in monitoring technology mean that moored instrumentation is becoming a more feasible approach to consent monitoring.

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1. INTRODUCTION

Marlborough District Council (MDC) is currently updating their Resource Management Plan. This includes combining the two existing plans (Wairau/Awatere and Marlborough Sounds) into a comprehensive Resource Management Plan for the whole district. As part of this update, there is a need to review the coastal water quality standards and how these should be measured. In the existing plan, all coastal waters are currently classified as managed for Shellfish Gathering. However, there are other uses of the coastal marine area which may have requirements for different water quality standards in different parts of the Coastal Management Area (CMA), such as for contact recreation.

This report will explore the appropriateness of the Shellfish Gathering (SR) and Contact Recreation (CR) classifications for the coastal domain. It will then review suitable methods for monitoring the standards for these classifications.

This guidance is to inform setting of operating conditions relevant to point source discharges. It is not intended to be applied to larger-scale water quality measurements (such as state of the environment assessments) or cumulative effects. Standards are given for acceptable impacts beyond a reasonable mixing zone.

1.1. Water quality classifications

The water quality classifications outlined in the third schedule of the Resource Management Act 1991 (RMA) are guidelines that are used in a variety of ways by other regional councils. For example:

- Environment Canterbury (ECan) uses a cumulative system, where Aquatic Ecosystems (AE) is the underlying classification for any water. Then Contact Recreation (CR) and Shellfish Gathering (SG) classifications are applied in addition to the requirements of the previous class (*i.e*. SG includes both CR and AE standards). These are applied in various ways to different waterbodies. Unclassified waters are considered '*largely non-degraded*' and should be maintained in their natural state. (Environment Canterbury Resource Management Plan Schedule 4).
- Similarly, Nelson City Council (NCC) has broadly classified all waters in the CMA as FEA (Fishing, Fish Spawning, Aquatic Ecosystem, Aesthetic). Additional CR, SG, and Cultural Values (CV) are applied to specified waters. (Nelson Resource Management Plan, Schedule 4).
- In the Horizons Regional Council (Horizons) One Plan, Estuarine Water Management Subzones and a single Seawater Management Zone are defined with water quality *targets* identified for each (One Plan Schedule H). Values

applied to the Seawater Management Zone are: Inanga Spawning, Whitebait Migration, CR, Amenity, Mauri, SG, Industrial Abstraction, Capacity to Assimilate Pollution, and Existing Infrastructure.

- Waikato Regional Council (WRC) provides guidelines and standards on their website. There are a range of variables assigned to estuarine Ecological Health, CR and SG. Each variable has standards for 'Excellent', 'Satisfactory', and 'Unsatisfactory' levels, and within each usage class the measures are combined into a single index.

Marlborough District Council water quality classifications are presented in Appendix H of the Marlborough Sound Resource Management Plan, and Appendix J of the Waiau/Awatere Resource Management Plan. The Council currently uses water quality classifications for all waterbodies. In the marine environment, all waters are classified as Class SG—Shellfish Gathering.

1.2. Setting standards and monitoring of impacts

Many difficulties in setting standards and monitoring impacts stem from the variability of water-column characteristics in the marine environment. Further, the resilience of a given component of the ecosystem to perturbation may vary, depending on location or time of year. For example, a reduction in saturation of dissolved oxygen (DO) is likely to have a greater impact in warmer waters, as DO concentrations are lower in warm water. Most stressors will impact on various species and life stages, differently. Additionally, the impact of many stressors will occur gradually, and when thresholds occur in nature, they are extremely hard to predict. For example, increased suspended sediment loading, pH changes, and reduction in DO can all reduce shellfish growth rates, well before they have lethal impacts. Also the levels at which lethal impacts occur can be affected by the interplay of multiple environmental variables. These issues often make the setting of precise standards unrealistic.

The use of fixed standards and indicators has appeal, due to the perceived certainty they provide. However, often it will be more realistic to identify the most important parameters, and identify standards on the basis of an assessment of the nature and values of a given site. Use of pre-defined standards may impose monitoring requirements that are unreasonably costly to a consent holder. In particular, when background water quality varies beyond the values defined in a consent. This is due largely to the limited baseline or state of the environment data available for many marine areas. A lack of such data to provide context for consent monitoring may mean that apparent breaches of consent conditions may in fact be caused by background variability. The use of metrics, such as means or percentiles, lessens the impact of background variability on assessment of standards. For example, if the 95th percentile is used to assess a given measure, the most extreme 5% of measurements of that indicator are not considered in the assessment of the standard. The use of tiered monitoring and the refinement of standards and indicators over time has the advantage of mitigating the risks associated with the lack of background information.

The approach taken by other councils in New Zealand provides some guidance regarding the appropriate approach to standard-setting for MDC. Councils tend not to incorporate metrics in the definition of standards and indicators, which can add further uncertainty to their application. Accordingly, here we have identified relevant metrics for each indicator.

1.3. Scope of the Shellfish Gathering and Contact Recreation classes

Sections 70 and 107 of the RMA limit the permissible impact of discharges[1]. Requirements not specific to the impact of discharges exist in the New Zealand Coastal Policy Statement (NZCPS), such as to ensure '*that development in the coastal environment does not make water quality unfit for aquaculture in areas approved for that purpose'* (Policy 8). Council recognise that the SG and CR classes do not incorporate these broader requirements.

In the current MDC plans, Class F—Fisheries is the underlying classification in freshwaters. As well as the standards for this class from Schedule 3 of the RMA, Class F from current plans includes most of the Section 70/107 requirements. No such class is applied in the marine environment; rather SG is currently applied to all waters.

To provide for wider protection of ecosystem functioning, development of guidelines or standards for an Aquatic Ecosystems (AC) class, relevant to the marine environment, would be of value.

1.3.1. Shellfish Gathering class

The SG class is defined as 'water managed for the gathering or cultivation of shellfish for human consumption'. The standards currently defined for SG concern both harvesting of shellfish for human consumption and environmental conditions that support shellfish survival. The standard regarding 'suitability of fish for human consumption' relates directly and specifically to human health. However, the DO and temperature requirements impact a range of ecosystem components, and are not directly related to human-health impacts.

Other aspects of water quality that can impact shellfish health or survival (therefore suitability for waters for shellfish cultivation), include:

[1] These refer to the production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials, change in the colour or visual clarity, objectionable odour, suitability for consumption by farm animals, and significant adverse effects on aquatic life.

- pH change (more specifically acidification of marine waters), which can seriously impact the survival and growth of shell-building animals such as bivalves.
- ammonia levels, which can be toxic to marine life.
- suspended sediment concentration, which may impact the feeding success of filter-feeders.

These requirements are broadly captured in section 70/107 of the RMA, stating that discharges do not have '*significant adverse effects on aquatic life'*. These requirements are not generally incorporated by councils in the SG class, as they are relevant to a wide range of ecosystem functions. They are therefore more appropriately reflected in a classification that is designed to more broadly protect ecosystem functioning.

There are two other points that support the above factors being captured in a broader ecosystem-focussed class. The identification of the level at which changes in quality cause waters to no longer be suitable for shellfish cultivation would depend on both the species of shellfish, and the life-stage being cultivated (for example, earlier life stages are more susceptible to increased acidity than older animals). Also, bivalves are less susceptible to changes in such factors than other species, for example, fish are particularly susceptible to ammonia toxicity. Inclusion of these parameters in the SG class is of limited value, as more robust protections are indicated by the requirements of other components of the ecosystem.

Dissolved oxygen and temperature are included in Schedule 3 of the RMA SG water quality class, and are therefore included in the discussion of the SG class below.

1.3.2. Contact Recreation class

The requirements generally incorporated by councils under the CR class are limited to impacts that are visible to and valued by humans, or that could impact human health. This class therefore protects a limited set of values and does not necessarily protect ecosystem functioning. This means, as for the SG class, that standards incorporated in the CR class do not provide protection to ecosystem functioning or fulfil the broader requirements of the RMA or the NZCPS. Similarly, some parameters (e.g. pH change) could impact CR values, but only at a level at which ecosystem function would be severely degraded, therefore inclusion in the CR class is not considered appropriate.

1.4. Terminology

Use of the term 'standard' is quite broad, and would benefit from clarification. As it stands, various documents use the term 'standard' to refer to a broad parameter (*e.g.* temperature) and the nature of the change. It may assist clarity if the following terms are adopted:

- Parameter: subject of interest, *e.g.* temperature, visual clarity, suitability of a given aspect of the environment for a given purpose.
- Standard: nature of change or level of environmental quality. Standards may be:
    - a fixed requirement (which if breached, requires that action be taken to lessen the impact of concern).
    - target/aspirational (providing a framework for assessing the status of an aspect of the environment).
- Indicator: the way in which the standard is assessed. Dependent on the standard this may be straight-forward (such as a temperature change) or require definition (such as ways in which contamination may be assessed). Indicators may be:
    - fixed (indicating the standard has been breached).
    - a trigger, (which if met, requires that further investigation occur to establish the status of the standard).

We have retained the term ‘standards’ as presented by other councils as appropriate, but have used the terminology above in our recommendations in Sections 2.2 and 3.2.

1.5. Australian and New Zealand Environment and Conservation Council Guidelines

The *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC 2000), were produced by the Australian and New Zealand Environment and Conservation Council, and are widely referred to as ‘the ANZECC guidelines’.

When being used for protection of biodiversity, the ANZECC guidelines provide a range of values that depend on the status of the ecosystem in question. For example, different values are given for pristine and for moderately disturbed ecosystems, on the basis that a higher level of protection is to be afforded to pristine systems.

While values for protection of ecosystems are often taken from the ANZECC guidelines and used as absolute limits, the explicit intention of the guidelines is that they not be used in this way. Rather, values should act as triggers, and if a given level is exceeded, this should lead to further investigation.

This approach is ostensibly less straight-forward than use of absolute values at which an activity is deemed non-compliant. Nonetheless, the use of given values as triggers, rather than absolutes, may avoid activity unnecessarily being deemed non-compliant.

The adoption of tiered monitoring strategies is consistent with the application of trigger values. With a tiered approach, more intensive monitoring for impacts occurs only when trigger values (from ANZECC or otherwise) are exceeded in the primary monitoring programme.

The guidelines are currently being revised[2] and as discussed in relevant sections below, we suggest that components of the guidelines are not reproduced in the plan. Rather, the guidelines should be referred to in the plan, including a statement that the updated guidelines will be adopted when they become available. With this approach, the plan will adopt the best available information as it becomes available.

[2] www.mfe.govt.nz/fresh-water/tools-and-guidelines/anzecc-2000-guidelines
www.environment.gov.au/water/quality/national-water-quality-management-strategy

2. SHELLFISH GATHERING CLASS

Shellfish gathering and cultivation is widespread across the Marlborough region, and the Shellfish Gathering (SG) class is currently applied across all marine waters.

2.1. Current and potential standards—Shellfish Gathering

The current standards include some human health and some shellfish health components (Table 1), as discussed in Section 1.3.

Table 1. Current Marlborough District Council (MDC) standards and numeric interpretation for areas classified for Shellfish Gathering (SG)—Water managed for the gathering or cultivation of shellfish for human consumption

Standard		Numeric interpretation of standard
Temperature		Shall not be changed by more than 3°C.
Dissolved oxygen	Shall exceed 80% of saturation	N/A
Suitability of fish for human consumption	Shall not be rendered unsuitable by the presence of contaminants	Median faecal coliform concentration of not less than five samples, taken within any consecutive 30-day period, shall not exceed a most probable number (MPN) of 14 per 100 ml (or colony forming units [cfu] per 100 ml), and not more than 10% of samples taken within any consecutive 30-day period shall exceed an MPN of 43 per 100 ml (or cfu per 100ml) as a result of any discharge of a contaminant or water. Samples shall not be taken on the same or consecutive days.

2.1.1. Temperature

The avoidance of temperature change by more than 3°C (with the implication that reference information is available) is one of the most consistently applied standards across a range of councils and classifications, and this is also specified under RMA section 70. In some situations a maximum temperature is set for particular waterbodies (Table 2).

Table 2. Temperature standards from other sources.

Source	Standard
AC	No change >3°C
ECan	Shall not change by more than 3°C , shall not exceed 25°C
ECan/Bolton-Richie (2009) recommendations	Change is minimised so that 'natural water temperature is not altered by an amount likely to lead to significant ecological effects beyond the edge of a mixing zone'.
Horizons (target)	*Marine:* none *Estuarine:* The temperature of the water must not exceed 22–24°C.
NCC	No change >2°C, shall not exceed 25°C
WRC [3]	The natural temperature of the water shall not be changed by more than 3°C

Note: The following acronyms are used In Tables 2–10: ANZECC = Australian and New Zealand Environment and Conservation Council, AC = Auckland Council, ECan = Environment Canterbury Regional Council, Horizons = Horizons Regional Council, MfE= Ministry for the Environment, MoH = Ministry of Health, NCC = Nelson City Council, WRC = Waikato Regional Council

2.1.2. Dissolved oxygen

Use of a DO standard is widespread. The use of 80% across all areas and temperatures may not always be appropriate, however, as in warmer waters (which hold less oxygen) a 20% reduction in oxygen saturation may reduce the oxygen concentration to below levels that can result in undue stress for shellfish. In general, a drop to below 5.0 mg/L is considered to be detrimental to aquatic life. However, any persistent drop in DO would have implications over time. A standard of 90% of saturation is sometimes used, but this is likely to be too stringent, particularly if applied to a diverse or large area, as >10% short-term reductions could occur normally in some regions, such as in shallow waters or where upwelling of low DO bottom waters occurs. Regular or ongoing reduction in DO to < 90% saturation, however, could indicate environmental stress. Therefore, results of this magnitude could be used to trigger more detailed temporal and/or spatial sampling.

[3] Waikato Regional Coastal Plan 2011

Table 3. Dissolved oxygen (DO) standards from other sources.

Source	Standard			
ANZECC 2000 (trigger)	*Marine*: 90 < 110% saturation *Estuarine*: 80 < 110%			
ECan	> 80% saturation (SG waters)			
Horizons (target)	*Marine*: The concentration of DO must exceed 90% of saturation. *Estuarine*: The concentration of DO must exceed 70% of saturation.			
NCC	The concentration of dissolved oxygen shall exceed the higher of 6mg/l or 80% saturation.			
WRC[4] (estuarine)		**Categories**		
		Excellent	Satisfactory	Unsatisfactory
	DO (% of saturation)	> 90	80–90	< 80

2.1.3. Suitability of fish for human consumption

The standard that shellfish '*shall not be rendered unsuitable by the presence of contaminants'* does not specify the type of contaminants which may be present. Contaminants may be pathogenic or toxic. Faecal indicator bacteria (FIB) levels are the only indicator of contamination identified in the current plan. While the standards adopted are widely used, there is substantial uncertainty regarding how well they reflect real health risks of consuming shellfish. There are two main components of uncertainty. Firstly, water column measures are not always a reliable indicator of FIB contamination of shellfish. This may be for a number of reasons: the water sample may not be taken from the same level of the water column that the shellfish are filtering; the water column measurements are a single point in time, while shellfish contamination represents an integrated measure of FIB levels over several days; and water column measurements are likely to be very patchy in both space and time. The second component of uncertainty is the extent to which FIB represent the risk of disease, as FIB in themselves are not necessarily disease-causing, and do not provide an exact indication of the presence of pathogens. Direct measurement of contamination in shellfish flesh overcomes the first issue, but not the second. Collection of shellfish for analysis is more time-consuming than collection of water samples, and councils nation-wide rely substantially on water column testing to indicate suitability of shellfish for human consumption (Table 4).

[4] http://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Coasts/Coastal-water-quality/Estuarine-water-quality-techinfo/

Table 4. Faecal indicator bacteria (FIB) standards from other sources: general, or specific to shellfish gathering.

<table>
<tr><th>Source</th><th colspan="4">Standard</th></tr>
<tr><td>ECan</td><td colspan="4">The median faecal coliform concentration of not less than five samples taken within any consecutive 30 day period, shall not exceed 14 colony-forming units per 100 ml, and no more than 10% of samples taken within any consecutive 30 day period shall exceed 43 colony-forming units per 100 ml as a result of any discharge of a contaminant or water.
Samples shall not be taken on the same or consecutive days.</td></tr>
<tr><td>Horizons (target)</td><td colspan="4">Marine:
The concentration of enterococci must not exceed 140 per 100 mL 1 November–30 April (inclusive).
The concentration of enterococci must not exceed 280 per 100 mL 1 May–31 October (inclusive).
The median concentration of faecal coliforms must not exceed 14 per 100 mL.
The 90^{th} percentile concentration of faecal coliforms must not exceed 43 per 100 mL.

Estuarine:
The concentration of Escherichia coli must not exceed 260 per 100 mL 1 November–30 April (inclusive) when the river flow is at or below the 50^{th} flow exceedance percentile.
The concentration of Escherichia coli must not exceed 550 per 100 mL year round when the river flow is at or below the 20^{th} flow exceedance percentile.</td></tr>
<tr><td>MfE/MoH 2003</td><td colspan="4">The median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a most probable number (MPN) of 14/100 mL, and not more than 10% of samples should exceed an MPN of 43/100 mL (using a 5-tube dilution test).
These guidelines should be applied in conjunction with a sanitary survey (see MfE 2004 for details).</td></tr>
<tr><td>MoH 1995</td><td colspan="4">Shellfish flesh—suitability for human consumption
Acceptable: < 230 faecal coliforms/100 g flesh
Marginally acceptable: 230 to < 330 faecal coliforms/100 g flesh
Unacceptable: > 330 faecal coliforms/100 g flesh</td></tr>
<tr><td>WRC[5]</td><td></td><td colspan="3">Categories</td></tr>
<tr><td></td><td></td><td>Excellent</td><td>Satisfactory</td><td>Unsatisfactory</td></tr>
<tr><td></td><td>Shellfish-gathering</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Faecal coliforms, median (no./100 mL)</td><td>< 2</td><td>2–14</td><td>> 14</td></tr>
<tr><td></td><td>Faecal coliforms, 90 percentile (no./100 mL)</td><td>< 6</td><td>6–43</td><td>> 43</td></tr>
</table>

No indicators regarding chemical contamination are included in the current MDC plan, and a component of toxicity is likely appropriate. Heavy metal contamination of shellfish in New Zealand is rare, and most likely to occur in association with obvious impacts such as slipways [6]. Toxic contamination such as heavy metal concentration tends to be measured in the environment (from sediments) rather than in shellfish

[5] http://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Coasts/Coastal-water-quality/Estuarine-water-quality-techinfo/

[6] MPI. www.foodsmart.govt.nz/elibrary/food_safety_seafood.pdf

flesh. The Marlborough Shellfish Quality Programme (MSQP) programme monitors biotoxins, bacteria, and heavy metals in water and shellfish[7]. This data is not made publically available, but is used by the Ministry of Primary Industries to provide a warning system for the possibility of toxic impacts of harmful algal blooms.

The ANZECC guidelines refer to ANZFA standards, which are now managed by Food Standards Australia New Zealand[8]. Current standards for contaminants and natural toxicants are given in Australia New Zealand Food Standards Code—Standard 1.4.1[9].

Standards from other sources presented in Table 5 are all based on ANZECC guidelines.

Table 5. Non-faecal indicator bacteria (FIB) contaminant standards from other sources.

Source	Standard
ANZECC	Ref to ANZFA standards—see text
Horizons (target)	*Marine*: For toxicants not otherwise defined in these targets, the concentration of toxicants in the water must not exceed the trigger values for coastal waters defined in the 2000 ANZECC guidelines Table 3.4.1 for the level of protection of 99 % of species. For metals the trigger value must be adjusted for hardness and apply to the dissolved fraction as directed in the table. *Estuarine:* For toxicants not otherwise defined in these targets, the concentration of toxicants in the water must not exceed the trigger values for coastal waters defined in the 2000 ANZECC guidelines Table 3.4.1 as the level of protection for 95 % of species. For metals the trigger value must be adjusted for hardness and apply to the dissolved fraction as directed in the table.
ECan	Other than in the operational area of a port, concentrations of the dissolved fractions of the following metals, measured after filtering a sample through an acid-washed 0.45 micron filter, shall not exceed the concentrations set out below as the result of any discharge of a contaminant or water: • Arsenic 50 mg per cubic metre • Cadmium 2 mg per cubic metre • Chromium 50 mg per cubic metre • Copper 5 mg per cubic metre • Lead 5 mg per cubic metre • Nickel 15 mg per cubic metre • Zinc 50 mg per cubic metre

7 www.marinefarming.co.nz/quality.asp
8 www.foodstandards.govt.nz
9 www.comlaw.gov.au/Details/F2015C00052

2.2. Recommended standards—Shellfish Gathering

Table 6. Recommended standard for areas classified for Shellfish Gathering.

Parameter	Standard	Indicator	Metric	Likelihood of background variation exceeding this standard	Comparison to Section 70/107 requirements
Temperature	Shall not be changed by more than 3°C.	Temperature change compared to reference sites	Absolute (at all times)	N/A (standard is relative to background levels)	Identical
Dissolved oxygen	Shall exceed 80% of saturation or 6 mg/l, whichever is greater	DO saturation. Compared to reference sites if necessary to establish that any apparent breach of standard is due to background variation.	95th percentile	High—particularly likely that DO will fall below 80% saturation under a range of natural conditions (such as upwelling in some locations)	Consistent with RMA requirement to avoid '*significant adverse effects on aquatic life*'
Suitability of fish for human consumption	Shall not be rendered unsuitable by the presence of contaminants	Median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a most probable number (MPN) of 14 per 100 ml, and not more than 10% of samples should exceed an MPN of 43 per 100 ml[10,11,12].	as per 'indicator' detail	High	Unrelated

[10] or colony forming units per 100 ml
[11] MfE state that these guidelines should be applied in conjunction with a sanitary survey to better assess health risks.
[12] In estuarine waters use of freshwater standards may also be appropriate.

While some councils have adopted more stringent requirements for temperature, the use of 3°C of change is most widely used, and in the absence of reference to specific organisms, it is reasonable to retain this standard. It may be appropriate to add a maximum temperature dependent on the characteristics of the site of a given discharge.

The reduction to 80% DO is more flexible than many standards for marine waters. The use of the 95th percentile allows for minor variation beyond the standard/indicator values. However, the use of a minimum level (6mg/L) ensures that impacts are particularly limited when shellfish are more vulnerable to relative changes in DO (*i.e.* when water temperatures are higher). Application of the 95th percentile requires relatively high-resolution data-collection: in any methodology producing fewer than 21 measurements over a monitoring period, a single measurement over the indicator value would result in a breach of the standard.

Due to current levels of contamination (as identified at swimming spots, Henkel 2014), an expectation that the standards/indicators of SG classification are to be met in all waters may be unrealistic in the short term. Background levels already exceed standards in the SG class, which would complicate assessment of the impact of discharges. Moreover, if applied to all waters, the SG class may need to be aspirational at some sites.

It should also be noted that substantial measurement and reporting takes place with respect to recreational water quality (Henkel 2014), which is less rigorous than requirements for the SG standard.

In future it would be preferable if more representative measures were employed by councils across New Zealand to assess shellfish contamination. The first step for improving analyses would be to assess FIB contamination of shellfish flesh rather than, or in conjunction with, water samples. In areas where shellfish are not readily accessible due to depth or scarcity, it may be appropriate to test sentinel bivalves (most likely green-lipped mussels, *Perna canaliculus*). These can be deployed in baskets suspended in mid-water, and collected after 3-5 days in the field. As genetic techniques develop, it is likely that direct monitoring of specific pathogens will become possible. However, despite their limitations, the FIB indicators as currently used by MDC, are widely used by other councils. Therefore, continuing with this approach is reasonable at this time.

Standards for contamination are for human health, and do not adequately capture Māori perspectives on faecal contamination. While degradation at high-impact sites may be considered acceptable by some sectors of the population, iwi aspirations for kaimoana populations may be more ambitious. Any faecal contamination of kaimoana is considered by many Māori to be offensive or unacceptable, and this is particularly the case for contamination from humans. To address Māori cultural concerns, different standards may be appropriate, as may relevant further study such as microbial source tracking (use of genetic indicators to distinguish between various sources of faecal contamination, such as cattle, birds, or humans).

Metals (or metalloids) currently included for shellfish contamination in the Australia New Zealand Food Standards Code are arsenic, cadmium, lead, and mercury[13]. The purpose of the standard includes the statement that, '*This Standard sets out the maximum levels (MLs) of specified metal and non-metal contaminants and natural toxicants in nominated foods. As a general principle, regardless of whether or not an ML exists, the levels of contaminants and natural toxicants in all foods should be kept As Low As Reasonably Achievable*.'

Councils tend not to set contaminant levels in the SG class, and toxicant levels are more commonly defined in relation to ecosystem function. It is likely more appropriate to use indicator trigger values for ecological change from ANZECC (2000) guidelines[14], or in an updated version of those guidelines. These are employed by a number of councils, and if trigger values for contaminants that impact food safety were exceeded, then testing of shellfish flesh as per the Australia New Zealand Food Standards Code may be appropriate.

2.2.1. Indicators/monitoring methods—Shellfish Gathering

Temperature: Temperature measurements are part of state of the environment monitoring in Queen Charlotte and Pelorus sounds. The Marlborough Shellfish Quality Programme (MSQP) data (collected weekly) from Pelorus Sound, and other monitoring associated with aquaculture, are also suitable data sources. The MSQP data has been used to model temperature (and other water quality components) for both sounds. Accordingly there is a substantial existent baseline data set for water temperature in subtidal waters of the sounds. Data on surface water temperature in outer areas of the CMA could be captured from satellite image collections.

The extent and degree of expected temperature change would determine the appropriate scale of measurement. Moored temperature loggers at impact and control sites would be expected to be the best method of assessing change on small scales as discrete measurements are unlikely to reliably eliminate background variability unless the temperature change is consistent or extreme.

Dissolved oxygen: The concentration of DO in mg/L at 100% saturation is dependent on the temperature and salinity of the water. A DO standard of 80% saturation is an absolute rather than relative standard, as it is compared to the ability of water at the current temperature and salinity to hold oxygen, rather than a comparison to background levels. Dissolved oxygen measurements are part of state

[13] www.comlaw.gov.au/Details/F2015C00052
[14] Current trigger values for toxicants at alternative levels of protection are in Table 3.4.1

of the environment monitoring in Queen Charlotte and Pelorus sounds. This information would provide context for the frequency of DO reduction below that of the standard levels. If localised data is required, it may be that moored DO sensors would be the best method of assessing background deviation from set standards (as is done for temperature).

Interpretation can be facilitated by expressing DO as both concentration and percent saturation. Recent developments of optical DO sensors have significantly improved long-term data-logging capability.

Contamination of shellfish: Because it is an absolute indicator, baseline or reference data is not required for the assessment of faecal contamination in shellfish. It would be expected that reference sites away from the impacted area would be sampled to ensure that any impact can be attributed to the discharge. A substantial data set exists from past MDC monitoring and from MSQP data,[15] and this provides a good indication of historical levels of faecal contamination in water samples.

At a site where background contamination levels exceed the indicator levels for consumption of shellfish, it may be more appropriate to set maximum FIB levels in the discharge, rather than the environment. Microbial source tracking may be a useful tool for attribution of faecal contamination to a given source, thereby isolating results of a given discharge from other factors.

Monitoring for chemical contamination, such as heavy metals, tends to occur at source as part of relevant consent monitoring. For example, metals have been monitored in association with surveys in target areas such as the outfall site at Shakespeare Bay and the Waikawa Marina, and zinc and copper are measured as part of NZ King Salmon annual monitoring (where control sites were tested on three or four occasions between 2005 and 2012 at one control site in each of Pelorus and Queen Charlotte sounds). Heavy metals are also likely to be elevated around ports and in stormwater run-off.

Contaminants such as heavy metals are generally tested in sediments, and compared with trigger levels in the ANZECC guidelines, rather than assessed as a proportional change from background levels. However, control sites are normally used in consent monitoring, to place potentially impacted sites in the context of background concentrations of the substance of interest.

[15] This is not generally publically available

3. CONTACT RECREATION STANDARD

3.1. Current and potential standards

Contact Recreation (CR) is also widespread across the Marlborough region, therefore broad classification of waters as suitable for CR is appropriate. In general, however, the interpretation of the standards for the CR classification is specific to freshwater (Table 7). Moreover, the CR value as applied in freshwater environments has as an underlying classification of F—Water managed for fisheries purposes.

Table 7. Current Marlborough District Council (MDC) standards and numeric interpretation for areas classified for Contact Recreation (CR).

CR—Water managed for Contact Recreation purposes*		
Visual clarity	Shall not be so low as to be unsuitable for bathing	Horizontal sighting range of 200 mm black disk shall exceed 1.6 m during low flows.
Contaminants	Shall not render water unsuitable for bathing	Median concentration of enterococci of at least 20 samples taken throughout the bathing season shall not exceed 33 / 100 mL, nor shall any sample exceed 107 enterococci per 100 mL. The bathing season is defined as the period of 1 November to 1 April inclusive.
Biological growths	Shall be no undesirable growths	Bacterial and/or fungal slime growths shall not be visible to the naked eye as obvious plumose growths or mats. The daily average carbonaceous BOD5[16] due to dissolved organic compounds (*i.e*. those passing a GF/C filter) shall not exceed 2 g/m^3. The median concentration of dissolved reactive phosphorus (DRP) shall be less than 15 mg/m^3 at low flows, unless other physical and/or biological factors prevent undesirable biological growths developing at higher DRP concentrations Seasonal maximum cover of stream or river beds by periphyton as filamentous growths or mats (more than 3 mm thick) shall not exceed 40%, and the biomass on the bed shall not exceed 100 mg chlorophyll-a/m^2

3.1.1. Visual clarity

While visual clarity is valued by the public in terms of suitability for bathing, the nature of coastal environments is such that due to natural conditions coastal waters are often cloudy[17]. Loss of water clarity caused by suspended solids can be associated with an increased risk of exposure to pathogens. However the reduction in water quality associated with natural phenomena would be expected on occasion in any case. For

[16] Biochemical oxygen demand over a 5-day incubation period.

[17] The term ‘turbidity’ is used in general language to refer to low water clarity generally, however these aspects of water quality are not synonymous: Turbidity refers to the relative tendency of water to scatter light, and is measured in nephelometric turbidity units (NTU). Water clarity refers to the transmission of light through water. It has two aspects; visual clarity (measured by Secchi or black disk) and photic depth (depth of penetration by diffuse sunlight). (MfE 1994)

example, clarity on surf beaches is often near zero due to wave action re-suspending sediments and producing small bubbles. Visual clarity is an example of an attribute that is likely to be highly spatially and temporally variable, and is therefore more realistically measured relative to long-term and spatially-diverse data.

Table 8. Water clarity standards from other sources.

<table>
<tr><th>Source</th><th colspan="4">Standard</th></tr>
<tr><td>ANZECC</td><td colspan="4">Visual clarity & colour: To protect the aesthetic quality of a waterbody:
• the natural visual clarity should not be reduced by more than 20%.
• the natural hue of the water should not be changed by more than 10 points on the Munsell Scale.
• the natural reflectance of the water should not be changed by more than 50%.
To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter black disk should exceed 1.6 m.</td></tr>
<tr><td>Clement and Barter (2011) recommendations to ECan</td><td colspan="4">Recommend continued use of water clarity (visual clarity) and colour (hue) indicators, based on aesthetic perspective as these are more robust when it comes to protecting all other optical values and are relatively easily adjusted to different impact scenarios. (but further investigation is required before implementation).
Suspended solids or turbidity for general visual effects not recommended.</td></tr>
<tr><td>Horizons (target)</td><td colspan="4">Marine:
The visual clarity of the water measured as the horizontal sighting range of a black disk must not be reduced by more than 20 %.
The visual clarity of the water measured as the horizontal sighting range of a black disk must equal or exceed 1.6 metres.
Estuarine:
The euphotic depth must not be reduced by more than 10%.
The visual clarity of the water measured as the horizontal sighting range of a black disk must not be reduced by more than 20%.
The visual clarity of the water measured as the horizontal sighting range of a black disk must equal or exceed 1.2 m when the river is at or below the 50^{th} flow exceedance percentile.</td></tr>
<tr><td>MfE 1994</td><td colspan="4">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.</td></tr>
<tr><td rowspan="4">WRC</td><td colspan="4">Any visible change in water quality shall not be detectable 12 hours after discharge. The discharge shall not contain any material which will cause the production of conspicuous oil or grease films, scums or foams, or floatable suspended materials outside a 5 m radius of the point of discharge [18].</td></tr>
<tr><td rowspan="2">Estuarine[19]</td><td colspan="3">Categories</td></tr>
<tr><td>Excellent</td><td>Satisfactory</td><td>Unsatisfactory</td></tr>
<tr><td>Turbidity (NTU)</td><td>< 2</td><td>2–10</td><td>> 10</td></tr>
</table>

[18] Waikato Regional Coastal Plan 2011
[19] http://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Coasts/Coastal-water-quality/Estuarine-water-quality-techinfo/, ANZECC and MfE guidelines

3.1.2. Contaminants

As for the contaminants attribute of the SG classification, faecal indicator bacteria levels are the only indicator of contamination identified in the current plan, *i.e.* there is no chemical/toxic component. Bacterial standards from other sources are presented below (Table 9), while chemical standards can be found in Table 5.

Table 9. Faecal indicator bacteria (FIB) standards from other sources: general, or specific to contact recreation.

Source	**Standard**
ANZECC	*Primary contact:* The median bacterial content in samples of fresh or marine waters taken over the bathing season should not exceed: • 150 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 600 organisms/100 mL). • 35 enterococci organisms/100 mL (maximum number in any one sample 60–100 organisms/100 mL). *Secondary contact:* The median bacterial content in fresh and marine waters should not exceed: • 1,000 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 4000 organisms/100 mL). • 230 enterococci organisms/100 mL (maximum number in any one sample: 450–700 organisms/100 mL).
ECan	Between 1 November in any year and 31 March in the following year, all running medians of concentrations of enterococci from any series of five consecutive samples collected at intervals of between five and nine days shall not exceed 35 colony-forming units per 100 mL of water as a result of any discharge of a contaminant or water, with no single sample exceeding 277 colony-forming units per 100 mL of water.
MfE/MoH 2003	Coastal Enterococci Surveillance/Green mode: no single sample < 140/100 mL Alert/Amber mode: single sample >1 40/100 mL Action/Red mode: two consecutive samples > 280/100 mL
NCC	The median of samples taken over the bathing season shall not exceed 35 enterococci/100 mL No sample shall exceed: Designated bathing beach: 104/100 mL Moderate use: 153/100 mL Light use: 275/100 mL

Source	Standard			
WRC[20]		Categories		
	Contact recreation	Excellent	Satisfactory	Unsatisfactory
	Enterococci, single sample (no./100 mL)	< 28	28–280	> 280

3.1.3. Biological growths

The various components of the interpretation of the standard '*[there] shall be no undesirable [biological] growths*' are more specifically relevant to freshwater rather than marine systems. Benthic microalgal mats that indicate over-enrichment can occur in the marine environment (*e.g.* diatoms, euglenoids, cyanobacteria including *Beggiatoa* and similar genera of colourless sulphur-oxidising cyanobacteria). However opportunistic green seaweeds (such as *Ulva* spp.) and planktonic microalgae, which can cause nuisance blooms, are more common concerns in marine systems. While phosphorus is identified as a nutrient contributing to undesirable biological growths in the current plan (and is generally the limiting nutrient in fresh waters), nitrogen is likely to be the limiting nutrient in the marine environment. Periphyton are by definition freshwater organisms.

Table 10. Biological growth standards from other sources.

Source	Standard
Horizons (target)	*Marine:* Average algal biomass must not exceed 3 mg chlorophyll-a / m^3 The annual average concentration of total phosphorus must not exceed 0.01 grams / m^3. The average annual concentration of total nitrogen must not exceed 0.060 grams / m^3 The average concentration of ammonical nitrogen must not exceed 0.060 grams / m^3 *Estuarine:* The maximum cover of visible shore surface by macro-algae must not exceed 5%. The annual average algal biomass must not exceed 4 milligrams of chlorophyll-a / m^3. The annual average concentration of dissolved reactive phosphorus (DRP) when the river flow is at or below the 20th flow exceedance percentile must not exceed 0.015 grams / m^3. The annual average concentration of soluble inorganic nitrogen when the river flow is at or below the 20th flow exceedance percentile must not exceed 0.167 grams / m^3. The average concentration of ammoniacal nitrogen must not exceed 0.4 grams per m^3.

[20] http://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Coasts/Coastal-water-quality/Estuarine-water-quality-techinfo/

Source	Standard			
ANZECC 2000	Marine 120 µg nitrogen/L Estuaries 300 µg nitrogen/L			
ECan/ Bolton-Richie (2009) recommendations	Bacterial or cyanobacterial (blue-green algae) or fungal or slime mould growths shall not be visible to the naked eye as plumose growths or mats as a result of any discharge of a contaminant or water.			
WRC[21] (estuarine)		**Categories**		
		Excellent	Satisfactory	Unsatisfactory
	Nitrate (g N/ m^3)	< 0.005	0.005–0.015	> 0.015
	Total phosphorus (g/ m^3)	< 0.01	0.01–0.03	> 0.03
	Chlorophyll-a (g/ m^3)	< 0.002	0.002–0.004	> 0.004

3.2. Recommended standards—Contact Recreation

Nutrient inputs can cause nuisance blooms of macroalgae. Most commonly these are caused by excessive growth of the green sea lettuce, *Ulva* sp. Quantification of these blooms are problematic because the macroalgal growth varies enormously over normal seasonal cycles and wave action can cause large volumes of drift algae to deposit in small areas of the intertidal. The approach Horizons uses, where a target of < 5% cover is stated, can be problematic. The reason is because the calculated proportional coverage depends on the area being considered, *i.e*. a patch of 100% cover at the head of a bay, may constitute only a small proportion of the intertidal area of the entire bay. Accordingly, whether the algal cover should be considered less than or greater than 5% depends on the scale being used.

A broadly applicable, easily measurable indicator of change in macroalgal cover is not apparent, and standards/indicators for macroalgal growth tend not to be set in water quality classes by other councils. Accordingly, no such indicator is recommended here. A relevant indicator could be developed specifically for a given consent. In such a case, regular (*e.g.* fortnightly) photography of macroalgal beds over summer growth periods would be required, probably in conjunction with biomass calibration measurements.

Other parameters and standards are presented in Table 11.

[21] http://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Coasts/Coastal-water-quality/Estuarine-water-quality-techinfo/

Table 11. Recommended standard for areas classified for Contact Recreation.

Parameter	Standard	Indicator	Metric	Likelihood of background variation exceeding this standard	Comparison to Section 70/107 requirements
Visual clarity	Shall not be so low as to be unsuitable for bathing	The visual clarity of the water measured must not be reduced by more than 20%	95th percentile	None (standard is relative to background levels)	'*no conspicuous change in the colour or visual clarity*'
Biological growths	Shall be no undesirable growths	Bacterial or cyanobacterial or fungal or slime mould growths shall not be visible to the naked eye as obvious plumose growths or mat	Absolute (at all times)	Low (in areas away from other consented discharges)	Not related
		Chlorophyll-a < 5 mg/L	95th percentile	High probability of infrequent breaches	'*no conspicuous change in the colour*'
Contaminants	Shall not render water unsuitable for bathing	Enterococci: No single sample > 140 enterococci/100 mL Median concentration of enterococci of at least 20 samples shall not exceed 33 per 100 mL, nor shall any sample exceed 107 enterococci per 100 mL. [22]	as per 'indicator' detail	High (in areas already identified by MDC in FIB monitoring)	Not related

[22] In estuaries both freshwater and marine standards should be used.

A set maximum clarity is not recommended. This is because at many sites in Marlborough coastal waters visual clarity is substantially below the commonly-used 1.6 m due to background variability. The 20% reduction in clarity would remain in place at low visibilities, for example, by limiting reduction in waters with a background visibility of 1 m to 0.8 m. The application of the 95th percentile allow for occasional variability beyond indicator levels, yet that frequent reductions in visual clarity are unlikely to be considered acceptable in waters used for contact recreation. Application of the 95th percentile requires relatively high-resolution data-collection: in any methodology producing fewer than 21 measurements over a monitoring period, a single measurement over the indicator value would result in a breach of the standard.

Visibility of slime growths generally indicates high enrichment therefore no acceptable level of cover by such growths outside of a mixing zone is required.

The development of indicators for nuisance planktonic growths from a point-source discharge is complex. This is due to factors such as:

- water movement and patchy dilution.
- the lag between nutrient supply and subsequent phytoplankton growth.
- background variability.

Chlorophyll-a is used as a proxy for phytoplankton growth. The appropriate level at which to consider phytoplankton ‘nuisance’, in the context of the CR classification, is 5 mg chl-a/L. This is the point at which it is visually apparent. As for the general clarity measurement, the application of the 95th percentile allow for occasional variability beyond indicator levels, but calculation of this metric is dependent on relatively high-resolution data-collection.

To ensure alignment with recreational water quality reporting for microbial contamination (*e.g.* Henkel 2013) it seems reasonable to adopt numerical definitions from current MfE) classifications. Accordingly, a minor change to the enterococci single measurement indicator from 107/100 mL to the surveillance/green mode limit of 140/100 mL is suggested. Regarding the adoption of a seasonal metric (*e.g.* median or percentile) the microbial assessment category (MAC) category A (upper 95 percentile < 41/100 mL) seems overly restrictive compared to other council guidelines. Retaining the current median value of 33/100mL seems reasonable given the range adopted by other councils.

If SG is used as an underlying class for CR, then the standards/indicators for bacterial contamination are redundant as more stringent requirements exist as part of the SG class.

Indicators for toxic contamination are not generally included in the CR class. Many types of contamination could be present without impacting CR values. In many cases ecosystem function would be likely to be impacted before CR values were compromised. Nonetheless, guideline values for general chemical and pesticides[23], are available in the ANZECC (2000) guidelines, and could be employed as indicators if appropriate.

3.2.1. Indicators/monitoring methods: Contact Recreation

Visual clarity: While a methodology is sometimes identified for the water clarity standard (Secchi or black disk), no method of assessment is identified here. Secchi and black disks have some limitations. For example, Secchi can only be used where water depth is greater than visual depth. Variability under different conditions and with different observers is also possible. Furthermore, point measurements may not reliably detect an impact where background variability is high. Dependent on the nature of monitoring, these limitations may be acceptable or able to be mitigated. However, often it may be more appropriate to use other technology. Electronic meters, such as a transmissiometer, allow for high frequency measurement of visual clarity. These can be used at a point, or towed along a transect. This is a useful approach, for example, for measuring the extent of a plume. Moored sensors are able to collect much higher frequency data. This would be an appropriate approach where impact may vary over time, for example, where the nature of the discharge varies, or where impacts may substantially change over the tidal cycle.

Biological growths: The indicator for benthic biological growths is descriptive but easily measured. For example, a series of randomly-positioned photo-quadrats might be placed within the impacted zone and at a suitable reference site. Percent cover of biological growths can be calculated with dedicated computer programs, and a difference in cover of biological growths tested with standard statistical measures.

In many coastal areas, attribution of chlorophyll-a at a given site to discharges from a single point, would be difficult if only field measurements were used. Modelled data would likely be a more feasible option. Models require ground-truthing to confirm that they are effectively representing the real environment. This typically requires high-frequency data captured with moored instrumentation.

Contaminants: Standards/indicators and monitoring protocols for bacterial contamination in the context of contact recreation are detailed in the widely-used Ministry of Health guidelines (MfE 2003). In these it states that at least 20 microbiological samples should be collected '*over the period of greatest recreational use'*.

[23] Current contamination guidelines for recreational waters are in tables 5.2.3 and 5.2.4

Set indicator values (absolute or guideline/trigger) exist for monitoring of FIB and other contaminants. However, control sites are still necessary in consent monitoring, as reference values are needed to place potentially impacted sites in the context of background concentrations.

4. ADDITIONAL CONSIDERATIONS

4.1. Temporal limitations

4.1.1. Limits on application of standards

It may be that the standards for CR are only applied during summer months, an approach used by a number of councils.

4.1.2. Limits on permissible impacts

Changes to aspects of water quality such as temperature, dissolved oxygen concentration, and visual clarity are likely to have environmental impacts if they occur for sufficiently long periods of time. To prevent breaching the requirements of sections 70 and 107, avoiding "significant adverse effects on aquatic life", it may be appropriate to limit the time frame over which measurable change is acceptable. Alternatively, more rigorous standards may be applied for part of the time. The nature of any such temporal limitations would be dependent on the nature and scale of the expected impact.

4.2. Mixing zones

Definition of mixing zones is dependent on a range of factors, which have been well-considered elsewhere (Clapcott & Hay 2014, Rutherford 1994). Some councils have defined standard mixing zones, for example:

- In Environment Canterbury's Coastal Plan, discharges of water shall not give rise to certain changes (in water colour, odour, DO, and temperature) further than 20 m from the point of discharge (Rule 7.1 a). Stormwater impacts are limited to a given distance, either absolute, or relative to pipe diameter (7.1 b and c). Effects of antifouling materials and activity are limited to 5 m outside port areas, and 20 m within port areas.
- Waikato Regional Council define (on their website) a 5 m radius from a discharge point as the acceptable limit for conspicuous oil or grease films, scums or foams, or floatable suspended materials.

The Tasman Resource Management Plan requires that the mixing zone does not include intertidal areas '*unless the discharge has no more than a minor adverse effect on the inter-tidal area*'.

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