BAY OF PLENTY
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TOI MOANA

Selection of ecosystem health indicators for Tauranga Moana

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Executive summary

In preparation for the eventual implementation of the National Policy Statement for Freshwater Management (NPS-FM) in the Tauranga Harbour Water Management Area (WMA), a State of the Environment (SoE) Report for the Tauranga Harbour WMA, and the Tauranga Harbour coastal and marine area, hereafter jointly referred to as Tauranga Moana, will be produced. The goal is for this SoE Report to be a concise, easy to read document which reports on a sub-set of key indicators from respective regional monitoring programmes. This report selects the indicators of condition for Tauranga Moana for use in the upcoming SoE Report and outlines methods for each of the selected indicators.

Potential indicators which could be included in the SoE Report are identified for each of five environmental domains (air, land, groundwater, freshwater and coast) and assessed against four selection criteria: linkages with key issues for Tauranga Moana; documented relationship with ecological condition; availability of national standards or guidelines; and availability of monitoring data.

Twenty indicators and seven case studies are recommended for inclusion in the Tauranga Moana SoE Report. Appropriate methods for calculating each of these indicators and associated grading bands are outlined. Selected indicators for each environmental domain are as follows:

Air	• Fine particulate matter (PM10) • TSP matter • Sulphur dioxide
Land	• Soil bulk density • Soil macroporosity • Soil C:N ratio • Soil fertility • Soil trace elements • Wetlands (case study) • Threatened ecosystems (case study)
Groundwater	• Groundwater quality • Risk of saltwater intrusion
Freshwater	• Swimming water quality • Nitrogen toxicity • Stream health • Periphyton • Benthic cyanobacteria • Freshwater fish (case study)
Coast	• Swimming water quality • Sediment mud content • Nutrient state • Sediment contaminants • Sedimentation • Dune lands (case study) • Seagrass extent (case study) • Water quality (case study) • Physical beach profiles (case study)

Contents

Part 1: **Introduction**

1.1 Background

In preparation for the eventual implementation of the National Policy Statement for Freshwater Management (NPS-FM) in the Tauranga Harbour Water Management Area (WMA), a State of the Environment (SoE) report for the Tauranga Harbour WMA, and the Tauranga Harbour coastal and marine area, hereafter jointly referred to as Tauranga Moana, will be produced. The goal is for this SoE Report to be a concise, easy to read document which reports on a sub-set of indicators[1] using a consistent grading system, rather than providing extensive information on every variable that the Bay of Plenty Regional Council (BOPRC) monitors. The intention is that these indicators will be easily understandable to the general public, but provide a scientifically defensible indication of ecosystem condition. Therefore, suitable indicators of ecosystem condition to include in a SoE Report will need to be identified and methods for each indicator will need to be outlined.

1.2 Purpose

The overall objective of the current report is to identify suitable indicators of condition for Tauranga Moana for use in the upcoming SoE Report. The specific objectives are to:

- Identify indicators of condition for SoE Reporting for Tauranga Moana; and
- Outline methods used for each of the selected indicators.

Each of these specific objectives is addressed in a separate section in this report.

1.3 Scope

This report provides the scientific basis for the selection and calculation of indicators to be used in the SoE Report. It is intended to be a companion reference to the SoE Report, which will present the indicator results in a non-technical format, with little detail of methods or scientific justification.

The scope of this report is limited to Tauranga Moana. This includes the Tauranga Harbour WMA catchment and the Tauranga Harbour coastal and marine area (Figure 1). Information is grouped into five environmental domains for ease of reading and navigation. The domains are air, land, groundwater, freshwater and coast.

Indicators of cultural health are outside the scope of this report. However, cultural health indicators are recognised as being highly subjective and just as relevant as the “science” indicators proposed in the current report. Several projects are currently in progress to develop cultural health indicators or assess the mauri of the environment both for Tauranga Moana and for the wider Bay of Plenty Region. The Tauranga Moana Iwi Management Plan also has a key action to “Develop a State of the Moana Programme” which includes monitoring cultural health. BOPRC are supporting iwi to progress this plan and are also currently looking at how to incorporate Matauranga Māori into our science work.

[1] An indicator is defined as parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value (OECD, 2003).

It is anticipated that outputs from these projects and programmes will be incorporated into SoE Reports for Tauranga Moana as they become available, in an appropriate manner and in collaboration with local iwi and hapū.

Figure 1 The catchment and coastal area referred to as Tauranga Moana.

Part 2:
Selection of indicators

2.1 Introduction

BOPRC regularly collects a wide range of monitoring data across the five environmental domains which could be included as indicators in a SoE Report for Tauranga Moana. However, in order to provide a concise summary of the state of Tauranga Moana, only a small number of indicators will be included in the SoE Report for each domain. The criteria used to select indicators to include in the SoE Report are outlined below. Potential indicators which could be included in the SoE Report are then identified and assessed against these criteria.

2.2 Selection criteria

1 Linkages with key issues for Tauranga Moana

Indicators selected should contribute towards an assessment of key environmental issues for Tauranga Moana.

Key environmental issues for the Tauranga Moana catchment include water quality, including sediment and nutrient loads and bacterial contamination; stream health; erosion; protecting native biodiversity; preventing pollution; pest plant and pest animal management; protection of water supply; and soil health and condition. These issues are identified in catchment action plans for each sub-catchment[2]. Although not specifically identified in catchment action plans, air quality and maintenance of groundwater quality and base flow are also key issues for Tauranga Moana.

The five major issues affecting New Zealand estuaries have been identified as sedimentation, eutrophication, disease risk, toxins and habitat loss (Stevens and Robertson, 2013a, 2013b). More specifically to the Bay of Plenty Region, four key environmental issues have been identified for Tauranga Harbour. The issues are water quality, sediment dynamics, habitat degradation, and decline in kaimoana.

2 Documented relationship with ecological condition

Each indicator should have a documented relationship with ecological condition. This will ensure that the indicators used will provide a scientifically defensible indication of ecosystem condition.

3 Availability of national standards or guidelines

Appropriate standards or guidelines (e.g., specific to New Zealand where possible) should be available for assessing the state of the indicator relative to ecosystem condition. This will provide appropriate context to BOPRC monitoring data and ensure that indicators included in the Tauranga Moana SoE Report are consistent with national reporting of environmental data.

[2] Catchment action plans can be downloaded at https://www.boprc.govt.nz/our-region-and-environment/land/catchment-action-plans/.

4 Availability of monitoring data

Indicators for which the necessary data is already collected as part of routine environmental monitoring undertaken by BOPRC are preferable to those for which additional data will need to be collected.

2.3 Assessment of suitability of indicators

A range of potential indicators to include in a SoE Report for Tauranga Moana were identified. These were based on indicators commonly used in SoE Reporting by other regional councils and unitary authorities, and those commonly used to assess ecological condition in New Zealand. An assessment of the suitability of each potential indicator against the four criteria outlined above is provided below for the five environmental domains: air, land, groundwater, freshwater, and coast.

2.3.1 Air

The suitability of potential indicators for the air domain for the Tauranga Moana SoE Report is assessed in Table 1.

Five national indicators of ambient air quality are outlined in the National Environmental Standards for Air Quality[3]. BOPRC currently only monitors two of these indicators in Tauranga Moana – particulate matter (PM_{10}) and sulphur dioxide (SO_2). Therefore these are recommended for inclusion in the Tauranga Moana SoE Report. Total Suspended Particulate (TSP) matter is also monitored by BOPRC. As this can be a particular issue around the Mount Maunganui industrial area, TSP matter is also recommended for inclusion in the Tauranga Moana SoE Report.

Table 1 Suitability of potential indicators for the air domain for the Tauranga Moana SoE Report.

Indicator	Suitability
Carbon monoxide	• Guidelines available in the National Environmental Standards for Air Quality. Grading bands for these guidelines have been developed by Iremonger (2012). • Carbon monoxide data monitored continuously at the Otumoetai Road site until 2012. Monitoring ceased after this time due to the non-significance of recorded results. • Carbon monoxide monitoring is not currently required in Tauranga Moana.
Particulate matter (PM_{10})	• Contributes towards the key issue of air quality. • A standard is available in the National Environmental Standards for Air Quality. Grading bands for these guidelines have been developed by Iremonger (2012). Annual guidelines available in the Ambient Air Quality Guidelines (Ministry for the Environment, 2002). These could be used as a basis to develop grading bands for this indicator in order to assess against an annual value. • PM_{10} data monitored continuously at the Otumoetai Road site in Tauranga city. • Utility of this indicator is spatially limited due to the small number of current monitoring sites. However, 5 new PM_{10} sites were installed in the Mount Maunganui area in the latter part of 2017.

[3] Resource Management (National Environmental Standards for Air Quality) Regulations 2004.

Indicator	Suitability
Total suspended particulate matter	• Contributes towards the key issue of air quality. • Guidelines available in the Good Practice Guide for Assessing and Managing Dust (Ministry for the Environment, 2016). These could be used as a basis to develop grading bands for this indicator. • TSP matter monitored continuously at the Totara Street site in Mount Maunganui. • Utility of this indicator is spatially limited due to the small number of monitoring sites. However, 5 new TSP sites are to be installed in the Mount Maunganui area in the latter part of 2017.
Nitrogen dioxide	• A standard is available in the National Environmental Standards for Air Quality. • Nitrogen dioxide monitoring is not currently required in Tauranga Moana.
Sulphur dioxide	• Contributes towards the key issue of air quality. • Standards are available in the National Environmental Standards for Air Quality. Grading bands for these guidelines have been developed by Iremonger (2012). • Sulphur dioxide data monitored continuously at a three sites in Mount Maunganui. Additional SO_2 sites were installed in the Mount Maunganui area in the latter part of 2017.
Ozone	• A standard is available in the National Environmental Standards for Air Quality. • Ozone monitoring is not currently required in Tauranga Moana.

2.3.2 Land

The suitability of potential indicators for the land domain for the Tauranga Moana SoE Report is assessed in Table 2.

Three potential indicators related to terrestrial ecosystems are available – freshwater wetlands, threatened ecosystems and pest plants and animals. The utility of a freshwater wetlands indicator is limited due to the small number of wetlands that are monitored and the infrequent timeframe for monitoring. However, given the importance of this habitat type in the terrestrial environment, freshwater wetlands are recommended for inclusion in the SoE Report as a "case study"[4]. All Terrestrial ecosystems in Tauranga Harbour WMA have been classified into ecosystem types, however threat status has not yet been determined for each ecosystem type an d data is qualitative not quantitative. Therefore, threatened ecosystems are recommended for inclusion as a case study rather than as an indicator in the SoE Report. Pest plants and animals are not monitored as part of a structured programme or over a regular timeframe and coverage of data on this topic is uneven. Therefore pest plants and animals are not suitable for inclusion in the Tauranga Moana SoE Report at this time.

Seven potential indicators related to soils are available – soil bulk density, soil macroporosity, soil organic matter, soil acidity, soil fertility, soil trace elements and soil stability. Soil stability is not currently monitored by BOPRC as part of regular NERMN monitoring and therefore is not recommended for use as an indicator. Soil acidity (pH) is actively regulated by land users and generally maintained at target levels, therefore it is also not recommended for use as an indicator.

[4] A "case study" will present summary information about a parameter of considerable importance in Tauranga Moana where the available data for that parameter is not able to be assigned into an appropriate grading framework, is not associated with a specific monitoring site or spatial location, and/or is not regularly monitored by BOPRC.

All five remaining potential indicators - soil bulk density, soil macroporosity, soil organic matter, soil fertility and soil trace elements – are recommended for inclusion in the Tauranga Moana SoE Report.

Table 2 Suitability of potential indicators for the land domain for the Tauranga Moana SoE Report.

Indicator	Suitability
Freshwater wetlands	• Contributes towards the key issue of protecting native biodiversity. • Indices of wetland condition and wetland pressure are assessed as part of the NERMN Biodiversity monitoring programme. These could be used as a basis to develop grading bands for this indicator. • Ecological state and trends monitored every 5 years at seven sites as part of the NERMN Biodiversity monitoring programme. • No additional data collection is necessary to enable calculation of relevant indices for this indicator. • Infrequent monitoring and small number of monitoring sites may limit the usefulness of this indicator.
Threatened ecosystems	• Contributes towards the key issue of protecting native biodiversity. • A terrestrial ecosystem classification framework has been developed for the Bay of Plenty region (Singers and Lawrence, 2014); system for assessing the status of ecosystems has been developed by the International Union for the Conservation of Nature (IUCN) (Keith *et al*. 2013). These could be used in combination to develop grading bands for this indicator. • All terrestrial ecosystems in Tauranga Harbour WMA were classified into ecosystem types in 2014. • Data only available as spatial extent and is qualitative rather than quantitative; therefore it may be difficult to develop as a site based indicator.
Pest plants and animals	• Contributes towards the key issue of protecting native biodiversity. • Numbers of pest plants and animals are not monitored as part of the NERMN programme. Only ad hoc monitoring of this occurs as part of Land Management Officer work. • Utility of indicator limited due to absence of formal monitoring programme to systematically assess pest plant and animal prevalence.
Soil bulk density	• Contributes towards the key issue of soil health and condition. • Guidelines for soil bulk density set out in Hill and Sparling (2009). These could be used as a basis to develop grading bands for this indicator. • Soil bulk density is monitored every 3 – 10 years at 12 sites as part of the NERMN Soil health monitoring programme. • The location of monitoring sites is spread across the catchment and covers a variety of land uses including: 6 forestry (3 indigenous and 3 cultivated), 2 drystock, 2 dairy, 1 deer, and 1 kiwifruit sites. • No additional data collection necessary to enable calculation of relevant indices for this indicator.

Indicator	Suitability
Soil macroporosity	• Contributes towards the key issue of soil health and condition. • Guidelines for soil macroporosity set out in Hill and Sparling (2009). These could be used as a basis to develop grading bands for this indicator. • Soil macroporosity is monitored every 3 - 10 years at 12 sites as part of the NERMN Soil health monitoring programme. • The location of monitoring sites is spread across the catchment and covers a variety of land uses including: 6 forestry (3 indigenous and 3 cultivated), 2 drystock, 2 dairy, 1 deer, and 1 kiwifruit sites. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Soil organic matter	• Contributes towards the key issue of soil health and condition. • Guidelines for soil total carbon content, total nitrogen content, anaerobic mineralisable nitrogen content and the C:N ratio set out in Hill and Sparling (2009) and Sparling *et al*. (2008). These could be used as a basis to develop grading bands for this indicator. • Soil total carbon content, total nitrogen content, anaerobic mineralisable nitrogen content and the C:N ratio is monitored every 3 - 10 years at 12 sites as part of the NERMN Soil health monitoring programme. • The location of monitoring sites is spread across the catchment and covers a variety of land uses including: 6 forestry (3 indigenous and 3 cultivated), 2 drystock, 2 dairy, 1 deer, and 1 kiwifruit sites. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Soil acidity	• Contributes towards the key issue of soil health and condition. • Guidelines for soil pH is set out in Hill and Sparling (2009). These could be used as a basis to develop grading bands for this indicator. • Soil pH is monitored every 3 - 10 years at 12 sites as part of the NERMN Soil health monitoring programme. • The location of monitoring sites is spread across the catchment and covers a variety of land uses including: 6 forestry (3 indigenous and 3 cultivated), 2 drystock, 2 dairy, 1 deer, and 1 kiwifruit sites. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Soil fertility	• Contributes towards the key issue of soil health and condition. • Guidelines for soil Olsen P is set out in Hill and Sparling (2009). These could be used as a basis to develop grading bands for this indicator. • Soil Olsen P is monitored every 3 - 10 years at 12 sites as part of the NERMN Soil health monitoring programme. • The location of monitoring sites is spread across the catchment and covers a variety of land uses including: 6 forestry (3 indigenous and 3 cultivated), 2 drystock, 2 dairy, 1 deer, and 1 kiwifruit sites. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.

Indicator	Suitability
Soil trace elements	• Contributes towards the key issue of soil health and condition. • Environmental guidelines for trace elements available from a range of sources which are set out in Kim and Taylor (2009). These could be used as a basis to develop grading bands for this indicator. Alternatively, grading bands could be based on methods used by Auckland Council to develop a pollution index, which compares concentrations of trace elements at sample sites to measured background concentrations in native bush sites. • Soil As, Cd, Cr, Cu, Hg, Ni, Pb and Zn concentrations are monitored every 3 - 10 years at 12 sites as part of the NERMN Soil health monitoring programme. • The location of monitoring sites is spread across the catchment and covers a variety of land uses including: 6 forestry (3 indigenous and 3 cultivated), 2 drystock, 2 dairy, 1 deer, and 1 kiwifruit sites. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Soil stability	• Contributes towards the key issues of soil health and condition and erosion. • Guidance for methodology to assess soil stability is provided in Burton *et al* (2009), but grading bands for this indicator require development. • Soil stability is not currently monitored by BOPRC as part of the NERMN programme. • Would need to initiate monitoring for soil stability if it was to be used as an indicator and there would be some delay in reporting on this indicator until sufficient data was collected for analysis.

2.3.3 Groundwater

The suitability of potential indicators for the groundwater domain for the Tauranga Moana SoE Report is assessed in Table 3.

Two potential indicators are available for assessing groundwater quantity – groundwater level and groundwater allocation. Groundwater allocation levels are known but the amount of this allocation that is actually used is uncertain. Groundwater level is complex to assess and BOPRC does not have a complete understanding of groundwater systems in the Tauranga Harbour catchment at this time. Therefore, neither indicator for assessing groundwater quantity can be included in the SoE Report at this time. However, there is potential to include these indicators in future SoE Reports as the BOPRC work programme around groundwater quantity in Tauranga Moana develops.

Nitrogen, risk of salt water intrusion, micro-organisms and trace elements could each be used as indicators of groundwater quality as they all have sufficient data available and relevant guidelines to assess state against. Three groundwater quality concerns for the Bay of Plenty are contamination by nutrients (nitrate and phosphate), contamination by microbial pathogens and risk of salt water intrusion (Barber and Harvey, 2013). Elevated concentrations of iron and manganese are also cited as concerns. However, as these elevated concentrations are natural rather than a result of anthropogenic influences, the use of trace elements as indicators is not recommended. Instead, risk of salt water intrusion and a composite water quality indicator that combines scores for nitrate-nitrogen and micro-organisms are recommended for inclusion in the Tauranga Moana SoE Report.

Table 3 Suitability of potential indicators for the groundwater domain for the Tauranga Moana SoE Report.

Indicator	Suitability
Groundwater level	• Contributes towards the key issues of maintenance of groundwater quality and base flow. • Guidelines do not currently exist for groundwater level and would need to be developed. • Groundwater level is measured quarterly at 10 bores and continuously at seven bores as part of the NERMN Groundwater Monitoring Programme. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Groundwater allocation	• Contributes towards the key issues of maintenance of groundwater quality and base flow. • Groundwater limits have been developed as part of the BOPRC Plan Change 9 work programme. These could be used as a basis to develop grading bands for this indicator. • Groundwater level measured quarterly at 10 bores and continuously at seven bores as part of the NERMN Groundwater Monitoring Programme. • Difficult to get accurate data as consented and permitted actual use of groundwater is estimated not directly measured. • Would provide data at an individual aquifer scale rather than for specific sites or sub-catchments, so indicator has limited ability to look at fine scale patterns across the catchment.
Nitrogen	• Contributes towards the key issues of maintenance of groundwater quality and base flow. • Guidelines available for ammonia, nitrate and nitrite in the Drinking Water Standards for New Zealand (DWSNZ)[5] and the ANZECC guidelines[6] and for nitrate only in Daughney and Reeves (2005). These could be used as a basis to develop grading bands for this indicator. • Groundwater quality measured quarterly at 9 bores as part of the NERMN Groundwater Monitoring Programme. Water is analysed for ammonia, nitrate and nitrite. • Sites are distributed across the catchment. • No additional data collection necessary to enable calculation of relevant indices for this indicator.

[5] Ministry of Health. (2008).
[6] Australian and New Zealand Environment and Conservation Council. (2000).

Indicator	Suitability
Salt water intrusion risk	• Contributes towards the key issues of maintenance of groundwater quality and base flow. • There are no health or ecosystem related guidelines for electrical conductivity or the calcium to magnesium ratio. Grading bands would need to be developed. Guidelines for chloride concentrations in groundwater are set out in the DWSNZ. Guidelines for the height of the aquifer hydraulic head above sea level are also available from Environment Canterbury[7], but would need to be modified for application in the Bay of Plenty region. These could be used as a basis to develop grading bands. • Groundwater electrical conductivity and chloride, magnesium and calcium measured quarterly at 9 bores as part of the NERMN Groundwater Monitoring Programme. • Sites are distributed across the catchment. • No additional data collection necessary to enable calculation of relevant indices for this indicator.
Micro-organisms	• Contributes towards the key issues of maintenance of groundwater quality and base flow. • Guidelines for *E. coli* concentrations in groundwater are set out in the DWSNZ and the ANZECC guidelines. These could be used as a basis to develop grading bands for this indicator. • *E. coli* and faecal coliform concentrations in groundwater measured quarterly at nine bores as part of the NERMN Groundwater Monitoring Programme. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Trace elements	• Contributes towards the key issues of maintenance of groundwater quality and base flow. • Guidelines for a range of trace elements are set out in the DWSNZ and the ANZECC guidelines. These could be used as a basis to develop grading bands for this indicator. • Groundwater trace elements measured quarterly at 9 bores as part of the NERMN Groundwater Monitoring Programme. Water is analysed for dissolved aluminium, dissolved boron, dissolved calcium, dissolved iron, dissolved magnesium, dissolved manganese, dissolved potassium, dissolved reactive silica, dissolved sodium, dissolved zinc, chloride, fluoride and sulphate. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.

[7] Aitchison-Earl et al (2003).

2.3.4 Freshwater

The suitability of potential indicators for the freshwater domain for the Tauranga Moana SoE Report is assessed in Table 4.

Swimmability is a variable of significant public interest, therefore it is recommended for inclusion in the Tauranga Moana SoE Report. It has also been selected as an indicator for the coast domain (see Section 2.3.5).

Nutrient loads, sediment loads, dissolved oxygen; pH and temperature could all be used as indicators of water quality. Some of these parameters have been selected as compulsory attributes to measure under the NPS-FM and appropriate guidelines and grading bands to assess the state of these variables are in the process of being developed (Carter *et al*. 2017). Given the public interest in freshwater quality, and the fact that ammonia toxicity and nitrate toxicity are compulsory attributes that BOPRC must report against under the NPS-FM, a composite indicator of nitrogen toxicity that combines scores for ammonia toxicity and nitrate toxicity is recommended for inclusion in the Tauranga Moana SoE Report.

Physical and chemical water quality variables give us a good indication of overall water quality. However, they only indirectly measure stream health and generally do not represent biological responses. A further challenge with monitoring water quality is that many variables are highly variable over time, yet they are only sampled once per month. Water quality monitoring also does not evaluate biological threats to ecosystem health, such as the presence of invasive species, or loss of instream habitat. The most direct way to understand stream health is to monitor biological components. The numbers and types of organisms present in a water body reflect the resultant habitat and water quality of their surroundings. Therefore, data on macroinvertebrate communities is recommended for inclusion in the Tauranga Moana SoE Report as an indicator of stream health.

One of the most important ecological values of rivers and streams for most people would undoubtedly be fish. It is not possible to include a freshwater fish indicator in the SoE Report at this time as fish communities in streams are not regularly monitored by BOPRC. However, a large number of fish surveys have been conducted throughout the Bay of Plenty region, including in Tauranga Moana, and this data has recently been collated and analysed (Suren, 2016). Therefore, given the public interest in this variable, it is recommended that information on fish communities in Tauranga Moana is still included in the SoE Report but is presented as a case study rather than as an indicator.

Periphyton is a term used to describe the slime and algae found on the bed of streams and rivers. It is a natural component of rivers and provides an important food source for invertebrates. It is also an important indicator of changes in the water quality as any increases in stream nutrient levels may result in excessive growths of periphyton (called a bloom). Periphyton blooms have detrimental impacts on not only the ecological value of rivers, but also on their recreational, aesthetic and cultural values. Therefore a periphyton indicator is recommended for inclusion in the Tauranga Moana SoE Report.

Cyanobacteria are a group of organisms that live naturally in freshwater worldwide. They are commonly referred to as blue-green algae, but in fact are bacteria. Some species of cyanobacteria produce toxins which may be harmful to humans and other animals that come into contact with the toxins. Monitoring cyanobacteria is important, as excessive amounts of this material can cause problems when cyanobacterial mats dislodge from the streambed and become stranded along the stream edge. Because of the potential health risks of cyanobacteria blooms, it is recommended for inclusion as an indicator in the Tauranga Moana SoE Report.

Table Suitability of potential indicators for the freshwater domain for the Tauranga Moana SoE Report.

Indicator	Suitability
Swimming water quality (swimmability)	• Contributes towards the key issues of bacterial contamination and water quality. • Guidelines available to assess health risk for swimming based on indicator bacteria concentrations (Ministry of Health/Ministry for the Environment, 2003). • Indicator bacteria data is collected weekly from October – March each year for approximately five sites (exact number may vary from year to year) as part of NERMN Recreational Water Quality Monitoring Programme, and monthly at a further 18 sites as part of the NERMN Surface Water Quality monitoring programme. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Water quality - nutrient concentrations	• Contributes towards the key issue of water quality. • Guidelines available on ecosystem health for nitrate and ammonia under the NPS-FM National Objectives Framework (NOF). Several other indices are in use by other regional councils and could be adapted for Tauranga Moana. ANZECC trigger values exist for all the nutrient variables we monitor, but some development of grading bands based on these trigger values would be required. Guidelines not currently available for any measures of phosphorus. • Five water quality nutrient variables measured monthly at 18 sites in Tauranga Harbour as part of the NERMN Surface Water Quality monitoring programme. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Water quality – turbidity and total suspended solids	• Contributes towards the key issue of water quality. • ANZECC trigger values exist for turbidity, but some development of grading bands based on these trigger values would be required. • Turbidity and total suspended solids measured monthly at 18 sites in Tauranga Moana as part of the NERMN Surface Water Quality monitoring programme. • Sites are distributed across the catchment. • Issues with sampling programme not capturing events, which is when the majority of sediment comes down a river. Only provides indication of background rates of suspended solids.

Indicator	Suitability
Water quality - dissolved oxygen	• Contributes towards the key issue of water quality. • Guidelines available for dissolved oxygen on ecosystem health under the NPS-FM National Objectives Framework (NOF). • Dissolved oxygen measured monthly at 18 sites in Tauranga Moana as part of the NERMN Surface Water Quality monitoring programme. • Sites are distributed across the catchment. • Dissolved oxygen can be highly variable over a 24 hour period. One-off monthly monitoring does not capture this variation and therefore is not a true reflection of the state of this variable. Continuous measurement of dissolved oxygen is required to enable assessment of state across relevant timeframes.
Water quality – pH	• Contributes towards the key issue of water quality. • ANZECC trigger values exist for pH, but some development of grading bands based on these trigger values would be required. Numeric attribute state bands for continuous pH measurements have been developed for the NPS-FM and could be used. • pH measured monthly at 18 sites in Tauranga Moana as part of the NERMN Surface Water Quality monitoring programme Sites are distributed across the catchment. • pH can be highly variable over a 24 hour period. One-off monthly monitoring does not capture this variation and therefore is not a true reflection of the state of this variable. Continuous measurement of pH is required to enable assessment of state across relevant timeframes.
Water quality – temperature	• Contributes towards the key issue of water quality. • ANZECC trigger values exist for temperature, but some development of grading bands based on these trigger values would be required. Numeric attribute state bands for continuous temperature measurements have been developed for the NPS-FM and could be used. • Temperature measured monthly at 18 sites in Tauranga Moana as part of the NERMN Surface Water Quality monitoring programme. • Sites are distributed across the catchment. • Water temperature can be highly variable over a range of timescales (e.g. daily, seasonally). One-off monthly monitoring does not capture this variation and therefore is not a true reflection of the state of this variable. Continuous measurement of water temperature is required to enable assessment of state across relevant timeframes.
Macroinvertebrate communities	• Contributes towards the key issue of stream health. • Appropriate guidelines have been developed specifically for the Bay of Plenty Region (Suren, 2017) and region specific numeric attribute state bands for the macroinvertebrate community index (MCI) have been developed for the NPS-FM and could be used. • Macroinvertebrate communities surveyed annually at 32 sites as part of the NERMN Freshwater Ecology monitoring programme. • Sites are distributed across the catchment. • No additional data collection necessary to enable calculation of relevant indices for this indicator.

Indicator	Suitability
Fish communities	• Contributes towards the key issue of stream health. • Appropriate guidelines have been developed specifically for the Bay of Plenty Region (Suren, 2016). • Fish communities are not surveyed in Tauranga Harbour by BOPRC; however, some one-off survey data is available from the NIWA fish database. • Sites are distributed across the catchment. • Regular surveys of fish communities would need to be undertaken if this was to be used as an indicator.
Periphyton	• Contributes towards the key issue of stream health. • BOPRC specific guidelines have been developed for periphyton communities as part of the NPS-FM implementation process and could be used. • Periphyton communities monitored monthly at five sites in Tauranga Moana as part of the NERMN Freshwater Ecology monitoring programme. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Benthic cyanobacteria	• Contributes towards the key issue of stream health. • Guidelines available to assess health risk from cyanobacteria (Wood et al., 2009). • Benthic cyanobacteria monitored monthly at five sites in Tauranga Moana as part of the NERMN Freshwater Ecology monitoring programme. • Sites are distributed across the catchment. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.

2.3.5 Coast

The suitability of potential indicators for the coast domain for the Tauranga Moana SoE Report is assessed in Table 5.

Two potential indicators can be used to assess the health of the terrestrial coastal zone –physical beach profile and dune lands. Information of the physical profile of beaches is important as it can indicate the occurrence of erosion. However, erosion or accretion of beach profiles can be a natural part of coastal sediment processes and is not necessarily “good” or “bad”. Therefore it is recommended that this indicator is only included in a case study in the SoE Report. Dunes in the Bay of Plenty are a significant part of the region’s character and are identified in the New Zealand Coastal Policy Statement as a national priority ecosystem (Willems, 2010). However, data on dune lands is qualitative not quantitative and may be difficult to develop as an indicator. Therefore, dune lands are recommended for inclusion in the SoE Report as a case study rather than an indicator.

Swimmability is a variable of significant public interest, therefore it is recommended for inclusion in the Tauranga Moana SoE Report. It has also been selected as an indicator for the freshwater domain (see Section 2.3.4).

Seagrass cover is also a variable of significant public interest. It is affected by a range of factors, such as sedimentation, light and water quality, and can therefore provide an integrated measure of estuarine health. However, as outlined in Table 5, there are a number of potential issues that could make it difficult to use seagrass cover as an indicator. But given its importance as an ecosystem component in Tauranga Harbour, and the fact that it is a measure which is easily understood by the public, it is recommended that seagrass extent is included in the SoE Report as a case study. Data is available on the extent of seagrass cover in defined areas of Tauranga Harbour for 1959, 1996 and 2011 and information on the percentage decline in seagrass cover between 1959 and 2011 in each region of the harbour could therefore be reported on.

A range of variables could be used as indicators to assess the health of the estuarine environment. Several of these are not suitable due to the absence of appropriate guidelines to assess state (water quality), the limited number spatial availability of data (water quality, benthic macrofauna); or a requirement to collect additional data (Estuarine Trophic Index (ETI) score). However, given the importance of water quality as a determinant of estuarine health, it is recommended for inclusion in the Tauranga Moana SoE Report as a case study.

The remaining indicators could be used for SoE Reporting in Tauranga Moana without the need to collect any further data. These are sedimentation, sediment contaminants, sediment mud content, sediment total organic carbon (TOC) content, sediment total N and total P content and macroalgal cover. Macroalgal cover is not recommended for use as an indicator as large drifting blooms of macroalgae can accumulate in parts of the harbour as a result of prevailing currents and winds and do not necessary reflect specific conditions at sites where they accumulate. All remaining indicators are recommended for inclusion in the Tauranga Moana SoE Report. As outlined in Section 3.6.5, it is recommended that data on sediment TOC, sediment total N and total P concentrations is combined to produce a composite indicator called “nutrient state”.

Table 4 Suitability of potential indicators for the coast domain for the Tauranga Moana SoE Report.

Indicator	Suitability
Physical beach profile	• Contributes towards the key issue of coastal health. Can indicate occurrence of coastal erosion. • Beach profiles classified as eroding, accreting or stable, but grading bands for this indicator would need to be developed. • Physical beach profiles are surveyed annually at 21 sites as part of the NERMN beach profile monitoring programme. • Sites are distributed across the catchment. • Utility of this indicator may be limited as erosion or accretion of beach profiles can be a natural part of coastal sediment processes and are not necessarily “good” or “bad”. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Dune lands	• Contributes towards the key issue of coastal health. • Guidelines to assess state of dune lands do not currently exist and would need to be developed. • Coastal dune lands are mapped every five years as part of the NERMN Biodiversity monitoring programme. Vegetation, threatened and significant plants, cover of exotic species and factors impacting on dune vegetation are mapped. • Sites are distributed across the catchment. • Data is qualitative not quantitative and therefore may be difficult to develop as an indicator.

Indicator	Suitability
Swimming water quality (swimmability)	• Contributes towards the assessment of the key issues of disease risk and water quality. • Guidelines available to assess health risk for swimming based on indicator bacteria concentrations (Ministry of Health/Ministry for the Environment, 2003). • Indicator bacteria data is collected weekly from October – March each year for approximately 15 sites in Tauranga Harbour (exact number may vary from year to year) as part of NERMN Recreational Water Quality Monitoring Programme, and monthly at a further eight sites as part of the NERMN Estuary Water Quality monitoring programme. • Sites are distributed across the harbour. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Seagrass cover	• Contributes towards the assessment of the key issues of habitat loss/habitat degradation. • Guidelines on changes in seagrass extent is available in the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Extent of seagrass in Tauranga Harbour mapped infrequently (1959, 1996 and 2011). • Seagrass extent data is available for the entire harbour. • Seagrass cover can vary considerably over short time scales in Tauranga Harbour, most appropriate to analyse changes over five plus year periods rather than annually. • Swans can cause significant declines in seagrass cover so could be a confounding variable in understanding trends in the data. • More frequent mapping would be required than is currently undertaken for this to be a useful indicator.
Water quality	• Contributes towards assessment of the key issues of water quality and eutrophication. • No appropriate guidelines are available to assess the state of the indicator. • Water quality nutrient variables are measured monthly at eight sites in Tauranga Harbour as part of the NERMN Estuary Water Quality monitoring programme. • Sites are distributed across the harbour. • Limited ability to look at fine scale patterns of water quality in the harbour or analyse water quality data for sub-catchments due to small number of monitoring sites.

Indicator	Suitability
Sedimentation rate	• Contributes towards assessment of the key issues of sediment dynamics/sedimentation. • Guidelines on sedimentation rates available in the New Zealand Estuary Vulnerability Assessment[8] (Stevens and Robertson, 2013a, 2013b) • Sediment accumulation rate data collected quarterly for 14 sites and annually for 45 sites in Tauranga Harbour as part of the NERMN Benthic Health Monitoring Programme. • Sites are distributed across the harbour. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Sediment contaminants	• Contributes towards assessment of the key issues of sediment dynamics and toxins. • Guidelines on heavy metal sediment contaminant data is available in the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Sediment concentrations of heavy metals As, Cd, Cr, Cu, Hg, Pb, Ni and Zn are collected annually for 59 sites in Tauranga Harbour as part of the NERMN Benthic Health Monitoring Programme and at a further seven sites as part of the NERMN Coastal and Estuarine Ecology programme. Data are also collected every three years at 31 sites as part of the NERMN Sediment Contaminant monitoring programme. • Sites are distributed across the harbour. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Sediment mud content	• Contributes towards assessment of the key issues of sediment dynamics/sedimentation. • Guidelines on mud content available in the Estuarine Trophic Index (ETI) Toolkit (Robertson *et al.,* 2016) and the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Sediment grain size data is collected annually for 59 sites in Tauranga Harbour as part of NERMN Benthic Health Monitoring Programme and at a further 7 sites as part of the NERMN Benthic Health Monitoring programme. • Sites are distributed across the harbour. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.

[8] The Estuary Vulnerability Assessment is a comprehensive evaluation of New Zealand estuarine condition and likely response to stressors developed by Wriggle Coastal Management. The methodology is based on the National Estuary monitoring protocol (Robertson *et al*., 2002).

Indicator	Suitability
Estuarine trophic index (ETI) score	• Contributes towards assessment of the key issues of eutrophication, water quality and sediment dynamics. • Framework available to calculate ETI scores (Robertson *et al.,* 2016). • All required data except detailed macroalgae abundance and distribution data is collected annually for 59 sites in Tauranga Harbour as part of the NERMN Benthic Health Monitoring Programme. • Sites are distributed across the harbour. • Additional data collection required for macroalgae across the harbour to enable calculation of this indicator. • Calculation of ETI would be more appropriate at the scale of individual sub-estuaries, rather than the scale the entire harbour, but this would be complex as hydrodynamic models for each sub-estuary will need to be developed within the tool to enable accurate assessments of trophic state.
Sediment total organic carbon (TOC) content	• Contributes towards assessment of the key issues of sediment dynamics and eutrophication. • Guidelines on sediment TOC data are available in the ETI Toolkit (Robertson *et al,* 2016) and the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Sediment TOC data is collected annually for 59 sites in Tauranga Harbour as part of NERMN Benthic Health Monitoring Programme and at a further seven sites as part of the NERMN Benthic Health Monitoring programme. • Sites are distributed across the harbour. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.
Sediment total nitrogen and phosphorus content	• Contributes towards assessment of the key issues of sediment dynamics and eutrophication. • Guidelines on sediment total nitrogen and phosphorus content are available in the ETI Toolkit (Robertson *et al.,* 2016) and the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Sediment total nitrogen and phosphorus content are collected annually for 59 sites in Tauranga Harbour as part of NERMN Benthic Health Monitoring Programme and at a further 7 sites as part of the NERMN Benthic Health Monitoring programme. Sites are distributed across the harbour. • No additional data collection is necessary to enable calculation of relevant indices for this indicator.

Indicator	Suitability
Macroalgal cover	• Contributes towards assessment of the key issues of habitat loss/habitat degradation and eutrophication. • Guidelines on changes in macroalgal cover are available in the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Sea lettuce abundance is monitored every two months at three sites in Tauranga Harbour. • Macroalgal cover is monitored annually at 59 sites around Tauranga Harbour as part of NERMN Benthic Health Monitoring Programme. • Bi-monthly sea lettuce abundance data has limited utility as an indicator due to small number of monitoring sites. • Annual macroalgal cover data does not always provide a good indication of eutrophication state in Tauranga Harbour as large drifting blooms of macroalgae can accumulate in parts of the harbour as a result of prevailing currents and winds and do not necessary reflect specific conditions at sites where they accumulate.
Benthic macrofauna	• Contributes towards assessment of the key issues of habitat loss/habitat degradation, toxins, eutrophication and sedimentation. • Guidelines on composition and abundance of benthic macrofauna available in the ETI Toolkit (Robertson *et al.,* 2016) and the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Benthic macrofauna monitored annually at seven sites in Tauranga Harbour. • Limited ability to look at fine scale patterns or analyse data for sub-catchments due to small number of monitoring sites.
Redox profile	• Contributes towards assessment of the key issue of eutrophication. • Guidelines on redox potential discontinuity data available in the ETI Toolkit (Robertson *et al*, 2016) and the New Zealand Estuary Vulnerability Assessment (Stevens and Robertson, 2013a, 2013b). • Redox discontinuity depth is monitored annually for 59 sites in Tauranga Harbour. • Visual methods of assessment are used and these are not calibrated with a meter, therefore data are not reliable enough to use as an indicator.

Part 3: Methods of calculation

3.1 Introduction

Indicators have been selected for the air, land, groundwater, freshwater and coast domains for use in SoE Reporting for Tauranga Moana as outlined in Part 2. A range of methods have been developed or are currently in use to assess the state of these indicators. This section outlines the methods recommended for calculation of each of these indicators and associated grading bands.

The final metric for each indicator should be a single numerical value which is then assigned into a grade with a word descriptor. The use of word descriptors for each grade will provide a simple and easy to understand way of communicating often complex scientific data to the general public. It will provide context to the results, which may otherwise be meaningless to the general public without the inclusion of reference or guideline values. The numerical values assigned to each grade will differ among indicators, but where possible and appropriate, a four band grading system with the following four word descriptions should be used for each indicator: “very good”, “good”, “fair” and “poor”. However, it is recognised that it may not be appropriate to use this four band grading system for all indicators or environmental domains (e.g. soils, Section 3.3).

Data for variables which are to be included as case studies, rather than as indicators, in the SoE Report can be presented in any format depending on the type of data that is available. Therefore a description of calculation methods for these variables is not included in this section.

3.2 Air

3.2.1 Particulate matter

The National Environmental Standards for Air Quality set the minimum requirements that ambient air quality should meet for a range of air pollutants, including particulate matter (PM_{10}), in order to protect human health and the environment. Ministry for the Environment, 2002)PM_{10}A grading framework for air quality guidelines and standards has been developed by Iremonger (2012) and can be applied to the guideline values specified in the Ambient Air Quality Guidelines for PM_{10} concentrations. This framework has four bands, which can be directly converted to the four grading bands that will be used for the SoE Report, where the grades of ”excellent”, “good”, “acceptable” and “alert” in Iremonger (2012) become grades of “very good”, “good”, “fair” and “poor” respectively in the SoE Report. Iremonger (2012) also has an additional grade of “action” for any measured values which exceed the guideline values. It is recommended that this grade is retained in the SoE Report but is renamed “exceeds guideline values”.

A summary of the recommended calculation of the particulate matter indicator and grading bands is provided in Table 6.

Particulate matter data is collected by BOPRC as per the Good Practice Guide for air quality monitoring and data management (Ministry for the Environment, 2009) as part of the NERMN Air Quality Monitoring Programme. This data should be used for calculation of the particulate matter indicator. A full description of the NERMN Air Quality Monitoring Programme is provided in Iremonger (2012).

Table 5 Data requirements, recommended method of calculation and grading bands for particulate matter indicator.

Data required	Calculation method	Grading
Average recorded.	Sites assigned a grade based on	• Very good: average is <10% of

Data required	Calculation method	Grading
PM_{10} concentration over the previous 12 months. Use data collected as part of the NERMN Air Quality Monitoring Programme.	the average PM_{10} concentration recorded over the last 12 months relative to the 20 µg per m^3 threshold concentration specified in the Ambient Air Quality Guidelines.	the guideline value. • Good: average is ≥10 - 33% of the guideline value. • Fair: average is ≥33 - 66% of the guideline value. • Poor: average is ≥66 - <100% of the guideline value. • Exceeds guideline value: >100% of the guideline value.

3.2.2 Total suspended particulate matter

New Zealand trigger levels for TSP matter are provided in the Dust Good Practice Guide (Ministry for the Environment, 2016). This guide outlines both short-term (5 minutes and 1 hour) and daily trigger levels for high, moderate and low sensitivity receiving environments. Annual trigger levels are not specified in the Dust Good Practice Guide and guidance is not currently available around how measured values of TSP matter correspond to assessments of state such as "good" or "poor". Therefore, measures of TSP matter are not directly convertible to the to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3). Instead, an alternative grading system is proposed where the TSP matter of a site is graded as being either "within trigger levels at all times" or "exceeds trigger levels at least once". TSP matter monitoring data from the previous 12 months will be analysed with reference to trigger levels for all three averaging periods (5 minutes, 1 hour and daily). If a measured value at a site exceeds a trigger level for any one of these averaging periods then that site will automatically be graded as "exceeds trigger levels at least once", even if measured values don't exceed trigger levels for the other two averaging periods. Similarly, all measured values at a site must be within trigger levels for each of the 5 minute, 1 hour and daily averaging periods to be assigned a grade of "within trigger levels at all times".

A summary of the recommended calculation of the TSP matter indicator and grading bands is provided in Table 7.

TSP matter data is collected by BOPRC as per the Good practice guide for air quality monitoring and data management (Ministry for the Environment, 2009) as part of the NERMN Air Quality Monitoring Programme. This data should be used for calculation of the TSP matter indicator. A full description of the NERMN Air Quality Monitoring Programme is provided in Iremonger (2012).

Table 6 Data requirements, recommended method of calculation and grading bands for TSP matter indicator.

Data required	Calculation method	Grading
Continuous TSP matter measurements recorded over the previous 12 months. Use data collected as part of the NERMN Air Quality Monitoring Programme.	Sites assigned a grade based on whether they exceed the trigger levels for 5 minute, 1 hour and daily averaging periods for TSP matter specified in the Dust Good Practice Guide (Ministry for the Environment, 2016). TSP matter is defined as any particles <100 µm in diameter.	• Within trigger levels at all times: all measured values are within trigger levels for each of the 5 minute, 1 hour and daily averaging periods at all times. • Exceeds trigger levels at least once: measured values exceed trigger levels for any one of the averaging periods at least once.

3.2.3 Sulphur dioxide

The New Zealand National Environmental Standards for Air Quality set the minimum requirements that should be met by ambient air quality for a range of air pollutants, including sulphur dioxide, in order to protect human health and the environment. Two threshold concentrations are specified in the Standards – 350 and 570 µg sulphur dioxide per m^3 expressed as a 1-hour mean, with different permissible excesses for each value. Annual threshold concentrations are not specified in the Standards and guidance is not currently available around how measured values of sulphur dioxide correspond to assessments of state such as “good” or “poor”. Therefore, measures of sulphur dioxide are not directly convertible to the to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3). Instead, an alternative grading system is proposed where the sulphur dioxide concentration of a site is graded as being either “within national standards at all times” or “exceeds national standards at least once”. Sulphur dioxide monitoring data from the previous 12 months will be analysed with reference to both the 350 and 570 µg per m^3 threshold concentrations. If a measured value at a site exceeds either of these threshold concentrations and associated permissible excesses then that site will automatically be graded as “exceeds national standards at least once”. Similarly, all measured values at a site must be within both 350 and 570 µg per m^3 threshold concentrations and permissible excesses to be assigned a grade of “within national standards at all times”.

A summary of the recommended calculation of the sulphur dioxide indicator and grading bands is provided in Table 8.

Sulphur dioxide data is collected as per the Good practice guide for air quality monitoring and data management (Ministry for the Environment, 2009) as part of the NERMN Air Quality Monitoring Programme. This data should be used for calculation of the sulphur dioxide indicator. A full description of the NERMN Air Quality Monitoring Programme is provided in Iremonger (2012).

Table 7 Data requirements, recommended method of calculation and grading bands for sulphur dioxide indicator.

Data required	Calculation method	Grading
Average hourly recorded sulphur dioxide concentration over the previous 12 months. Use data collected as part of the NERMN Air Quality Monitoring Programme.	Sites assigned a grade based on the average hourly sulphur dioxide concentration recorded over the last 12 months relative to the 350 and 570 µg per m^3 threshold concentrations and permissible excesses specified in the New Zealand National Environmental Standards for Air Quality.	• Within national standards at all times: all measured values at a site are within 350 and 570 µg per m^3 threshold concentrations and permissible excesses at all times. • Exceeds national standards at least once: measured values exceed either of 350 and 570 µg per m^3 threshold concentrations and associated permissible excesses at least once.

3.3 Land

3.3.1 Soil bulk density

Guidelines specific to New Zealand soils have been developed for soil bulk density (Sparling *et al*. 2008; Hill and Sparling, 2009). However, these guidelines are not directly convertible to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3) as soil characteristics are either within or outside of a target range, rather than being "good", "poor" etc. Therefore, an alternative grading system is proposed where the soil bulk density of sites is graded as either being "within target range", "very loose" or "very compact", based on the bands outlined in Hill and Sparling (2009). Such an approach has also been used by Greater Wellington Regional Council (Sorenson, 2012).

A summary of the recommended calculation of the soil bulk density indicator and grading bands is provided in Table 9.

Data collected as part of the NERMN Soils Monitoring Programme should be used for calculation of the soil bulk density indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Rijkse and Bloor (2014).

Table 8 Data requirements, recommended method of calculation and grading bands for soil bulk density indicator.

Data required	Calculation method	Grading
Measurements of soil bulk density. Use data collected as part of the NERMN Soils Monitoring Programme.	Sites assigned a grade based on soil bulk density rankings in Hill and Sparling (2009) for individual soil orders.	**Semi-arid, pallic and recent soils:** • Very loose: <0.4 Mg/m^3 • Within target range: ≥0.4 to ≤1.4 Mg/m^3 • Very compact: ≥1.4 Mg/m^3 **Allophanic soils:** • Very loose: <0.3 Mg/m^3 • Within target range: ≥0.3 to ≤1.3 Mg/m^3 • Very compact: ≥1.3 Mg/m^3 **Organic soils:** • Very loose: <0.2 Mg/m^3 • Within target range: ≥0.2 to ≤1.0 Mg/m^3 • Very compact: ≥1.0 Mg/m^3 **All other soils:** • Very loose: <0.7 Mg/m^3 • Within target range: ≥0.7 to ≤1.4 Mg/m^3 • Very compact: ≥1.4 Mg/m^3

3.3.2 Soil macroporosity

Guidelines specific to New Zealand soils have been developed for soil macroporosity (Sparling *et al*. 2008; Hill and Sparling, 2009). However, these guidelines are not directly convertible to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3) as soil characteristics are either within or outside of a target range, rather than being ”good”, “poor” etc. Therefore, an alternative grading system is proposed where the macroporosity of sites is graded as either being “within target range”, “very low” or “high”, based on the bands outlined in Hill and Sparling (2009). Such an approach has also been used by Greater Wellington Regional Council (Sorenson, 2012).

A summary of the recommended calculation of the soil macroporosity indicator and grading bands is provided in Table 10.

Data collected as part of the NERMN Soils Monitoring Programme should be used for calculation of the soil macroporosity indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Rijkse and Bloor (2014).

Table 9 Data requirements, recommended method of calculation and grading bands for soil macroporosity indicator.

Data required	Calculation method	Grading
Measurements of soil macroporosity. Use data collected as part of the NERMN Soils Monitoring Programme.	Sites assigned a grade based on soil macroporosity rankings in Hill and Sparling (2009) for individual land uses.	**Pastures, cropping and horticulture:** • Very low: <6% (-10kPa) • Within target range: ≥6% to ≤30% (-10kPa) • High: ≥30% (-10kPa) **Forestry:** • Very low: <8% (-10kPa) • Within target range: ≥8% to ≤30% (-10kPa) • High: ≥30% (-10kPa)

3.3.3 Soil organic matter

Four potential variables are available for assessing soil organic matter: soil total carbon content, total nitrogen content, anaerobic mineralisable nitrogen content and the C:N ratio. There are a number of recognised issues around the use of soil total nitrogen content and anaerobic mineralisable nitrogen content as indicators of soil organic matter (Mackay *et al*. 2013). The soil carbon content could be used, however, the soil carbon to nitrogen (C:N) ratio is regarded as a better descriptor of soil organic matter quality than the actual carbon content (Mackay *et al*. 2013). Therefore, the C:N ratio is recommended as an indicator of soil organic matter for SoE Reporting.

Guidance on appropriate C:N ratios for New Zealand soils is provided in Sparling *et al*. (2008). However, these guidelines are not directly convertible to the to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3) as soil characteristics are either within or outside of a target range, rather than being good, poor etc. Therefore, an alternative grading system is proposed where the C:N ratio of soils is graded as either being “within target range”, “low” or “high”, based on the provisional targets outlined in out in Sparling *et al*. (2008) for environmental criteria. Under these targets, a C:N ratio of less than 7 indicates a possible risk of excess N mineralisation and N leaching, while a C:N ratio greater than 30 indicates possible N limitation and poor ecosystem health.

A summary of the recommended calculation of the soil organic matter indicator and grading bands is provided in Table 11.

Data collected as part of the NERMN Soils Monitoring Programme should be used for calculation of the soil organic matter indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Rijkse and Bloor (2014).

Table 10 Data requirements, recommended method of calculation and grading bands for soil organic matter indicator.

Data required	Calculation method	Grading
C:N ratio measurements in soils. Use data collected as part of the NERMN Soil Monitoring Programme.	Sites assigned a grade based on soil C:N provisional targets outlined in Sparling *et al*. (2008) for individual land uses and soil orders.	• Low: C:N ratio <7 • Within target range: C:N ratio ≥7 to ≤30 • High: C:N ratio >30

3.3.4 Soil fertility

Soil fertility is determined by the Olsen P concentration of the soil. Olsen P provides a measure of the plant available phosphate in the soil. Guidelines specific to New Zealand soils have been developed for soil Olsen P (Sparling *et al.* 2008; Hill and Sparling, 2009). However, these guidelines are not directly convertible to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3) as soil characteristics are either within or outside of a target range, rather than being "good", "poor" etc. Therefore, an alternative grading system is proposed where the Olsen P concentration of sites is graded as either being "within target range", "very low" or "high", based on the bands outlined in Hill and Sparling (2009). Such an approach has also been used by Greater Wellington Regional Council (Sorenson, 2012).

A summary of the recommended calculation of the soil fertility indicator and grading bands is provided in Table 12.

Data collected as part of the NERMN Soils Monitoring Programme should be used for calculation of the soil fertility indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Rijkse and Bloor (2014).

Table 11 Data requirements, recommended method of calculation and grading bands for soil fertility indicator.

Data required	Calculation method	Grading
Measurements of soil Oslen P concentrations. Use data collected as part of the NERMN Soils Monitoring Programme.	Sites assigned a grade based on soil Olsen P concentrations C:N provisional targets outlined in Hill and Sparling (2009) for individual land uses and soil orders.	**Pasture on all soil orders:** • Very low: <15 mg/kg • Within target range: ≥15 to ≤100 mg/kg • High: ≥100 mg/kg **Cropping and horticulture on sedimentary and allophanic soils:** • Very low: <20 mg/kg • Within target range: ≥20 to ≤100 mg/kg • High: ≥100 mg/kg **Cropping and horticulture on pumice and organic soils:** • Very low: <25 mg/kg • Within target range: ≥25 to ≤100 mg/kg • High: ≥100 mg/kg

Data required	Calculation method	Grading
		Forestry on all soil orders: • Very low: <5 mg/kg • Within target range: ≥5 to ≤100 mg/kg • High: ≥100 mg/kg

3.3.5 Soil trace elements

A range of guidelines are available for assessing the concentrations of various trace elements in New Zealand soils. These are outlined in Table 5.12 of Kim and Taylor (2009). Of these, the New Zealand Water and Wastes Association Guidelines for the Safe Application of Biosolids to Land in New Zealand – the “Biosolids Guidelines” (NZWWA, 2003) are recommended as they have been specifically developed for New Zealand soils. These guidelines contain limits for trace element concentrations in soils which will minimise the risks of adverse effects on human health and the environment (NZWWA, 2003). Although the biosolids guidelines have been specifically developed in relation to the application of biosolids to land, the limits specified in the guidelines provide a more general indication of trace element concentrations which are likely to impact the environment. Consequently, they are transferable to other situations and activities and are appropriate to use in the current context.

BOPRC currently monitors the concentration of eight trace elements (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) in soils. As exceedance of the limits specified in the biosolids guidelines for any one of these eight trace elements can have significant adverse effects on the environment, it will be difficult to develop the same four band grading system for this indicator that will be used for other indicators in the SoE Reporting (see Section 2.3). Instead, an alternative grading system is proposed in which sites are classified into one of two grading bands based on the limits for trace element concentrations specified in the biosolids guidelines. The two grading bands are “good” for sites where all trace element concentrations are within guideline limits and “poor” for sites where the concentration of one or more trace elements exceeds guideline limits.

A summary of the recommended calculation of the soil trace elements indicator and grading bands is provided in Table 13.

Data collected as part of the NERMN Soils Monitoring Programme should be used for calculation of the soil trace elements indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Rijkse and Bloor (2014).

Table 12 Data requirements, recommended method of calculation and grading bands for soil trace elements indicator.

Data required	Calculation method	Grading
Measurements of concentrations of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn in soils. Use data collected as part of the NERMN Soils Monitoring Programme.	Concentrations of each trace element compared to limits for the concentrations of trace elements in soils specified in the biosolids guidelines (NZWWA, 2003).	• Good: Concentrations of all trace elements are within the biosolids guidelines limits. • Poor: Concentrations of at least one trace element exceeds the biosolids guidelines limits.

3.4 Groundwater

3.4.1 Groundwater quality

A composite water quality indicator that combines scores for micro-organisms (*E. coli*) and nitrate-N (NO_3-N) is proposed. *Escherichia coli* (*E.coli*) in groundwater can indicate the presence of pathogens (disease-causing organisms) from animal or human faeces. These pathogens can cause illness for anyone who ingests them. Nitrate-N is routinely monitored for health and environmental reasons. Excessive nitrate concentrations are linked to a blood disorder in bottle-fed babies known as 'blue baby syndrome' (methaemoglobinaemia). Too much nitrate-N can also lead to excessive plant and algae growth where groundwater flows (springs and seeps) into surface water. However, note that some of the aquifers in Tauranga Harbour are confined aquifers with a long residence time (~200 – 250 years). Consequently, groundwater from these aquifers is unlikely to impact on water quality of marine or surface waters.

The Drinking Water Standards for New Zealand (Ministry of Health, 2005) set the health-related maximum acceptable values of substances or organisms or contaminants or residues that may be present in drinking-water. Although the standards are not strictly applicable to ambient groundwater quality, they serve as a reference for comparison and indicators of change and are used by BOPRC to assess the levels of *E. coli* and nitrate-N in groundwater (Barber and Harvey 2013). Therefore, it is recommended that the Drinking Water Standards for New Zealand are used as the basis of the groundwater quality indicator.

The Drinking Water Standards for New Zealand are not directly convertible to the four band grading system that will be used for other indicators in the SoE Reporting (see Section 2.3) as measurements of *E. coli* and nitrate-N are either within or above maximum acceptable values, rather than being "good", "poor" etc. Therefore, an alternative grading system is proposed where the groundwater quality of sites is graded as either being "within national standards" or "exceeds national standards".

The Drinking Water Standards for New Zealand specify maximum acceptable values of one colony forming unit (cfu) per 100 mL for *E. coli* and 50 mg/L for nitrate-N. Groundwater quality is monitored quarterly in Tauranga Harbour. If measured values at a site exceed maximum acceptable values for either parameter (nitrate-N or *E. coli*) for any one of the quarterly monitoring points in the most recent year, then that site will automatically be graded as "exceeds national standards at least once". If measured values are below the maximum acceptable values for both parameters at all monitoring points in the last year then the site will be graded as "within national standards at all times".

A summary of the recommended calculation of the groundwater quality indicator and grading bands is provided in Table 14.

Data collected as part of the NERMN Groundwater Monitoring Programme should be used for calculation of the groundwater quality indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Barber and Harvey (2013).

Table 13 Data requirements, recommended method of calculation and grading bands for groundwater quality indicator.

Data required	Calculation method	Grading
Mean concentrations of nitrate-N and *E. coli* in groundwater samples from the previous 12 months. Use data collected as part of the NERMN Groundwater Monitoring Programme.	Sites assigned a grade based on whether they exceed national standards for n *E. coli* and nitrate-N concentrations specified in the Drinking Water Standards for New Zealand (Ministry of Health, 2005).	• Within standards at all times: all measured values for both *E. coli* and nitrate-N are below maximum acceptable values at all times. • Exceeds national standards at least once: at least one measured values *E. coli* and nitrate-N exceed maximum acceptable values at least once.

3.4.2 Saltwater intrusion risk

Saltwater intrusion is the migration of saltwater into a freshwater aquifer. It occurs when there is a reduction in the freshwater head and flow at the sea water interface. A range of variables can be used as indicators of saltwater intrusion, including aquifer water level, electrical conductivity, chloride ion (Cl^-) concentration, and the ratio of calcium to magnesium (Ca:Mg ratio). Saltwater intrusion commonly occurs when there is over pumping or insufficient groundwater recharge of an aquifer in the coastal zone. In these situations, aquifer pressure and water level can decrease, allowing salt water to intrude. For this reason, aquifer water level is an important determinant of salt water intrusion risk. Electrical conductivity provides a general indicator of increasing dissolved solid concentrations as saltwater intrusion occurs in groundwater. Chloride ion concentrations are much higher in sea water (~20,000 mg/m^3) compared to fresh groundwater (typically <30 mg/m^3) (Callander *et al*., 2011) and therefore elevated chloride concentrations can indicate saltwater intrusion. Similarly, the Ca:Mg ratio is typically high in fresh groundwater (>1) and lower in sea water (<1), and the ratio decreases as saltwater intrusion occurs (Callander *et al.,* 2011).

As a range of factors can affect groundwater quality, it is necessary to use multiple variables to investigate saltwater intrusion risk in groundwater wells. Information is not available at present on the level before which saline intrusion can occur for specific aquifers in Tauranga Moana, or for the Bay of Plenty region. Therefore, a composite indicator of saltwater intrusion risk which combines electrical conductivity, chloride ion (Cl^-) concentration, and the Ca:Mg ratio is proposed. However, it is intended that an aquifer water level component will be added to this indicator as and when data are available. In the interim, a composite indicator of saltwater intrusion risk which combines electrical conductivity, chloride ion (Cl^-) concentration, and the Ca:Mg ratio is proposed.

There are no human health or ecosystem-related standards for electrical conductivity specified in the Drinking Water Standards for New Zealand or ANZECC Guidelines. However, guidance around electrical conductivity measurements that are indicative of saltwater intrusion are provided in Callander *et al*. (2011) and Klassen *et al.* (2014) and are used as a basis to develop grading bands. Callander *et al.* (2011) propose that groundwater with an electrical conductivity between 25 to 50 mS/m provide a slight indication of saltwater intrusion, while an electrical conductivity greater than 100 mS/m indicates likely saltwater intrusion effects. Similarly, Klassen *et al*. (2014) propose that groundwater samples with an electrical conductivity exceeding 100 mS/m are most likely influenced by saltwater intrusion, and samples that have an electrical conductivity between 60 and 200 mS/m represent a mixing between freshwater and saltwater. Therefore, a maximum electrical conductivity of <25 mS/m is proposed as the cut off value for the “very low risk” grade, a maximum electrical conductivity of 50 mS/m is proposed as the cut off value for the “low risk” grade, and a maximum electrical conductivity of 200 mS/m is proposed as the cut off value for the “moderate risk” grade (Table 15).

Guidelines for chloride concentrations in groundwater are provided in the DWSNZ. These provide an aesthetic guideline value of 250 g/m^3. Similar aesthetic guidelines are also provided by the World Health Organisation, which states that water begins to taste salty when chloride concentrations exceed an upper limit 250 g/m^3 (equivalent to 2% seawater) (Klassen *et al.,* 2014). If saltwater content exceeds 500 g/m^3 (equivalent to 4% seawater), then the water becomes unusable for many uses, and if saltwater content exceeds 750 g/m^3 (equivalent to 6% seawater) then the water is unusable except for cooling and flushing purposes (Klassen *et al.,* 2014). Data analysed by Klassen *et al.* (2014) also provides some guidance around chloride concentrations indicative of saltwater intrusion. Klassen *et al.* (2014) propose that groundwater samples with a chloride concentration exceeding 200 g/m^3 are most likely influenced by saltwater intrusion, and samples that have a chloride concentration between 100 to 200 g/m^3 represent a mixing between freshwater and saltwater. Finally, Callander *et al*. (2011) note that fresh groundwater typically has a chloride concentration between 10 - 30 g/m^3. A combination of these values is used as a basis to develop grading bands. A maximum chloride concentration of <30 g/m^3 is proposed as the cut off value for the “very low risk” grade, a maximum chloride concentration of <200 g/m^3 is proposed as the cut off value for the “low risk” grade, and a maximum chloride concentration of <500 g/m^3 is proposed as the cut off value for the “moderate risk” grade (Table 15).

There are no specific guidelines around the Ca:Mg ratio in groundwater. However, a Ca:Mg ratio greater than 1 is accepted as indicative of the onset of saltwater intrusion (Callander *et al.*, 2011; Klassen *et al*., 2014). Therefore instead of developing grading bands for this variable, it is proposed that a maximum Ca:Mg ratio greater than 1 be assigned a score of 0, and a maximum Ca:Mg ratio less than 1 be assigned a score of 2.

For each variable (electrical conductivity, chloride ion concentrations and Ca:Mg ratio), the maximum value recorded in monitoring data from the previous 12 months at each site should be compared against the grading bands to obtain a grade for that site. Use a maximum value rather than a median or percentile is recommended as any increase in the value of measured variables indicates an increased risk of salt water intrusion.

To provide an overall indicator grade for saltwater intrusion risk, it is recommended that each of the grading bands is assigned a number ranging from 1 for the "very low risk" grade through to 4 for the "high risk" grade. An individual grade, and associated number, should be calculated for both electrical conductivity and chloride concentration as described above and a score should be assigned for the Ca:Mg ratio as described above. The resultant numbers for each variable should then be averaged to provide an overall score ranging from 1 to 4. This score provides the overall grade for the saltwater intrusion risk indicator, as outlined in the grading column of Table 15.

A summary of the recommended calculation of the saltwater intrusion risk indicator and grading bands is provided in Table 15.

Data collected as part of the NERMN Groundwater Monitoring Programme should be used for calculation of the saltwater intrusion risk indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Barber and Harvey (2013).

Table 14 Data requirements, recommended method of calculation and grading bands for saltwater intrusion risk indicator.

Data required	Calculation method	Grading
Maximum recorded values for electrical conductivity, chloride ion concentrations, and the Ca:Mg ratio in groundwater samples from the previous 12 months. Use data collected as part of the NERMN Groundwater Monitoring Programme.	It is intended that scoring for this indicator will include a component assessing aquifer water level. However, until data on aquifer water level is available in Tauranga Harbour, sites will be assigned a grade based on maximum electrical conductivity, chloride ion concentrations and the Ca:Mg ratio as follows: **Electrical conductivity:** • Very low risk: <25 mS/m • Low risk: 25 to ≤50 mS/m • Moderate risk: >50 to ≤200 mS/m • High risk: >200 mS/m **Chloride:** • Very low risk: <30 g/m^3 • Low risk: 30 to ≤200 g/m^3 • Moderate risk: >200 to ≤500 g/m^3 • High risk: >500 g/m^3	• Very low risk: overall score ≤1 • Low risk: overall score >1 to <2 • Moderate risk: overall score 2 to <3 • High risk: overall score ≥3

Data required	Calculation method	Grading
	A number is assigned to each grade calculated for each variable above as follows: • Very low risk = 1 • Low risk = 2 • Moderate risk = 3 • High risk = 4 The Ca:Mg ratio is assigned score as follows: • If ratio <1 then score = 2 • If ratio >1: score = 0 The resultant numbers for electrical conductivity and chloride ion concentrations and the score for the Ca:Mg ratio are then averaged to provide an overall score ranging from 1 to 4. This score is used to assign an overall grade.	

3.5 Freshwater

3.5.1 Swimming water quality

Guidelines specific to New Zealand for assessing the health risk in recreational waters associated with faecal contamination are provided by the Ministry of Health/Ministry for the Environment (2003). There are two tiers to the guidelines. The first tier is used to compare concentrations of indicator bacteria in weekly monitoring results with the microbiological guidelines. This framework only provides a grade for individual/single samples. The second tier guidelines use a combination of information from microbial bathing survey results over the past five years and catchment characteristics, as land use, discharges and climate, to calculate a grade assessing swimmability over time. This grade is called the Suitability for Recreational Grading (SFRG) and is reported annually for all monitored sites in the Bay of Plenty region in the Recreational Water Quality Surveillance Reports (Scholes *et al.,* 2016). Attribute states and numeric values for concentrations of indicator bacteria in streams and rivers are also set out in the National Objectives Framework (NOF) as part of the NPS-FM (Ministry for the Environment, 2014). However, to maintain consistency in the reporting of swimming water quality by the BOPRC, and to enable comparison between freshwater and marine sites, it is recommended that the SFRG is used as an indicator of swimming water quality in the Tauranga Moana SoE Report.

Full details of how the SFRG is calculated are provided in Scholes *et al.,* (2016). This framework has five grading bands – “very good”, “good”, “fair”, “poor”, “very poor”. To maintain consistency, the same word descriptors and grading system will be reported in the Tauranga Moana SoE Report.

A summary of the recommended calculation of the swimming water quality indicator and grading bands is provided in Table 16.

Data collected as part of the NERMN Recreational Water Quality Monitoring Programme should be used for calculation of the nitrogen toxicity indicator A full description of the methods used to obtain data collected as part of this programme is provided in Scholes *et al*., (2016).

Table 15 Data requirements, recommended method of calculation and grading bands for swimming water quality indicator.

Data required	Calculation method	Grading
Concentrations of *E. coli* bacteria in water samples collected weekly from popular swimming sites from the last sampling season. Use data collected as part of the NERMN Recreational Water Quality Monitoring Programme.	Sites assigned a grade based on the Suitability for Recreation Grading as outlined in Scholes *et al.*, (2016).	• Grades ranging from very good to very poor are assigned to each site.

3.5.2 Nitrogen toxicity

Under the NPS-FM, the National Objectives Framework (NOF) sets out attribute states and numeric values for ammonia toxicity and nitrate toxicity (Ministry for the Environment, 2014). The numeric values are ranked into four bands (Attribute states A – D) following the numeric attribute states specified in Appendix 2 of the NPS-FM (Ministry for the Environment, 2014). It is recommended that these bands are used to assign grades for a nitrogen toxicity indicator for the SoE Report. Sites should be assigned into one of these numeric state bands for each attribute (ammonia toxicity and nitrate toxicity). Note that two statistics are used to assess the numeric attribute state for each attribute under the NOF. The lowest band ranking out of these two statistics should be used to assign a numeric attribute state for each attribute. The lowest band ranking out of the two attributes (ammonia toxicity and nitrate toxicity) should then be used as the overall grade for that site. As there are four bands under the NOF, these can be directly converted to the four grading bands that will be used for the SoE Report, where A band becomes a grade of "very good", B band becomes a grade of "good", C band becomes a grade of "fair" and D band becomes a grade of "poor".

A summary of the recommended calculation of the nitrogen toxicity indicator and grading bands is provided in Table 17.

Data collected as part of the NERMN River Water Quality Monitoring Programme should be used for calculation of the nitrogen toxicity indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Scholes and McIntosh (2009).

Table 16 Data requirements, recommended method of calculation and grading bands for nitrogen toxicity indicator.

Data required	Calculation method	Grading
Monthly concentrations of ammonia and nitrate in river and stream water samples for the last 12 months. Use data collected as part of the NERMN River Water Quality Monitoring Programme.	Sites assigned into one of four attribute state bands for each of ammonia toxicity and nitrate toxicity as outlined in Appendix 2 of the NPS-FM. The lowest band ranking across both attributes is then taken as the overall grade.	• Very good: NOF band A • Good: NOF band B • Fair: NOF band C • Poor: NOF band D

3.5.3 Stream health

As outlined in Section 2.3.4, data on macroinvertebrate communities is recommended as an indicator of overall stream health for SoE Reporting. A number of biotic metrics are commonly used to analyse stream macroinvertebrate communities to provide an indication of stream health. These include the Macroinvertebrate Community Index (MCI) and its quantitative variant (QMCI), taxonomic richness (r), the number of Ephemeroptera, Plecoptera and Trichoptera (EPT_r), the % of EPT to taxonomic richness (%EPT_r), and the % of EPT to total density (%EPT_n). The MCI is the most commonly used biotic index in New Zealand and is also used on the LAWA website as an index of stream health. For these reasons, it is recommended that the MCI is used to assign grades for a stream health indicator.

Water quality classes based on MCI scores have been developed by Stark and Maxted (2007). However, as these classes were based on MCI scores for hard/stony bottomed streams, they can provide erroneous classifications of water quality if applied to soft bottom streams. An assessment of stream health in the Bay of Plenty region found that ecological communities naturally differed between streams assigned to one of three biophysical classes (non-volcanic steep, volcanic low gradient, and volcanic steep-gradient) (Suren, 2017). Based on this assessment, Carter *et al.* (2017) have developed separate numerical state bands for MCI scores for each stream biophysical classification. These numeric state bands are to be used region-wide by BOPRC as part of the NPS-FM implementation. Therefore, it is recommended that these bands are used to assign grades for a stream health indicator. As these numerical state bands have four bands they can be directly converted to the four grading bands that will be used for the SoE Report, where A band becomes a grade of ”very good”, B band becomes a grade of “good”, C band becomes a grade of “fair” and D band becomes a grade of “poor”.

A summary of the recommended calculation of the stream health indicator and grading bands is provided in Table 18.

Data collected as part of the NERMN Freshwater Ecology Monitoring Programme should be used for calculation of the stream health indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Suren (2017).

Table 17 Data requirements, recommended method of calculation and grading bands for stream health indicator.

Data required	Calculation method	Grading
Stream macroinvertebrate community survey data. Use data collected as part of the NERMN Freshwater Ecology Monitoring Programme.	Sites assigned a grade based on their MCI score and stream biophysical classification (Carter *et al*., 2017).	**Non-volcanic steep-gradient streams:** • Very good: MCI score ≥120 • Good: MCI score ≥110 - 120 • Fair: MCI score ≥100 - 110 • Poor: MCI score <100 **Volcanic low-gradient streams:** • Very good: MCI score ≥124 • Good: MCI score ≥106 - 124 • Fair: MCI score ≥88 - 106 • Poor: MCI score <88 **Volcanic steep-gradient streams:** • Very good: MCI score ≥115 • Good: MCI score ≥100 - 115 • Fair: MCI score ≥87 - 100 • Poor: MCI score <87

3.5.4 Periphyton

Under the NPS-FM, the National Objectives Framework (NOF) sets out attribute states and numeric values for periphyton (Ministry for the Environment, 2014). The numeric values are ranked into four bands (Attribute states A – D) based on the numeric attribute states specified in Appendix 2 of the NPS-FM (Ministry for the Environment, 2014). It is recommended that these bands are used to assign grades for a periphyton indicator for the SoE Report. As there are four bands under the NOF, these can be directly converted to the four grading bands that will be used for the SoE Report, where A band becomes a grade of “very good”, B band becomes a grade of “good”, C band becomes a grade of “fair” and D band becomes a grade of “poor”.

A summary of the recommended calculation of the benthic cyanobacteria indicator and grading bands is provided in Table 19.

Data collected as part of the NERMN Freshwater Ecology Monitoring Programme should be used for calculation of the periphyton indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Suren and Carter (2016).

Table 18 Data requirements, recommended method of calculation and grading bands for periphyton indicator.

Data required	Calculation method	Grading
Measurements of algal biomass (as chlorophyll-a biomass per unit area) data collected as part of the NERMN Freshwater Ecology Monitoring Programme.	Sites assigned a grade based on the mean chlorophyll-a biomass per unit area as outlined in Appendix 2 of the NPS-FM.	**Exceeded no more than 8% of samples (default class):** • Very good: $\leq$50 mg chl-a/m^2 • Good: >50 to $\leq$120 mg chl-a/m^2 • Fair: >120 to $\leq$200 mg chl-a/m^2 • Poor: $\geq$200 mg chl-a/m^2 **Exceeded no more than 17% of samples (productive class):** • Very good: $\leq$50 mg chl-a/m^2 • Good: >50 to $\leq$120 mg chl-a/m^2 • Fair: >120 to $\leq$200 mg chl-a/m^2 • Poor: $\geq$200 mg chl-a/m^2

3.5.5 Benthic cyanobacteria

The Ministry of Health and Ministry for the Environment (MoH/MfE) have developed guidelines to assess the public health risks from cyanobacteria associated with contact recreation (Wood *et al*., 2009). These guidelines are currently being used by BOPRC. The MoH/MfE guidelines have been used by Carter *et al*. (2017) as a basis to develop numeric attribute state bands for a benthic cyanobacteria attribute. These numeric state bands are to be used region-wide by BOPRC as part of the NPS-FM implementation. Therefore, it is recommended that these bands are used to assign grades for a benthic cyanobacteria indicator for the SoE Report. As these numerical state bands have four bands they can be directly converted to the four grading bands that will be used for the SoE Report, where A band becomes a grade of “very good”, B band becomes a grade of “good”, C band becomes a grade of “fair” and D band becomes a grade of “poor”.

A summary of the recommended calculation of the benthic cyanobacteria indicator and grading bands is provided in Table 20.

Data collected as part of the NERMN Freshwater Ecology Monitoring Programme should be used for calculation of the periphyton indicator. A full description of the methods used to obtain data collected as part of this programme is provided in Suren and Carter (2016).

Table 19 Data requirements, recommended method of calculation and grading bands for benthic cyanobacteria indicator.

Data required	Calculation method	Grading
Benthic cyanobacteria percentage cover data collected as part of the NERMN Freshwater Ecology Monitoring Programme.	Sites assigned a grade based on the percentage cover of the stream bed by cyanobacteria as outlined in Carter *et al*., (2017).	• Very good: cover <20% • Good: N/A • Fair: cover 20 – 50% • Poor: cover >50% or max dislodging and accumulating along river's edge.

3.6 Coast

3.6.1 Swimming water quality

Guidelines specific to New Zealand for assessing the health risk in recreational waters associated with faecal contamination are provided by the Ministry of Health/Ministry for the Environment (2003). There are two tiers to the guidelines. The first tier is used to compare concentrations of indicator bacteria weekly monitoring results with the microbiological guidelines. This framework only provides a grade for individual/single samples. The second tier guidelines use a combination of information from microbial bathing survey results over the past five years and catchment characteristics, as land use, discharges and climate, to calculate a grade assessing swimmability over time. This grade is called the Suitability for Recreational Grading (SFRG) and is reported annually for all monitored sites in the Bay of Plenty region in the Recreational Water Quality Surveillance Reports (Scholes *et al.,* 2016). To maintain consistency in the reporting of swimming water quality by the BOPRC, and to enable comparison between freshwater and marine sites, it is recommended that the SFRG is used as an indicator of swimming water quality in the Tauranga Moana SoE Report.

Full details of how the SFRG is calculated are provided in Scholes *et al.,* (2016). This framework has five grading bands – "very good", "good", "fair", "poor", "very poor". To maintain consistency, the same word descriptors and grading system will be reported in the Tauranga Moana SoE Report.

A summary of the recommended calculation of the swimming water quality indicator and grading bands is provided in Table 21.

Data collected as part of the NERMN Recreational Water Quality Monitoring Programme should be used for calculation of the nitrogen toxicity indicator A full description of the methods used to obtain data collected as part of this programme is provided in Scholes *et al*., (2016).

Table 20 Data requirements, recommended method of calculation and grading bands for swimming water quality indicator.

Data required	Calculation method	Grading
Concentrations of *Enterococci* bacteria in water samples collected weekly from popular swimming sites from the last sampling season. Use data collected as part of the NERMN Recreational Water Quality Monitoring Programme.	Sites assigned a grade based on the Suitability for Recreation Grading as outlined in Scholes *et al*., (2016).	• Grades ranging from very good to very poor are assigned to each site.

3.6.2 Sedimentation rate

Condition ratings specific to New Zealand estuaries for sedimentation rates are provided in the Estuarine Vulnerability Assessment developed by Wriggle Coastal Management and have been applied to estuaries in Southland, Tasman and Wellington (e.g., Robertson and Stevens 2006, 2007, 2009, Stevens and Robertson 2013a, 2013b, Robertson and Robertson 2014). The ratings are based on a review of estuary monitoring data, guideline criteria and expert opinion. The condition ratings assign a grade for each site based on the mean annual sedimentation rates measured using sedimentation plates. It is recommended that these ratings are used to assign grades for the sedimentation rate indicator. The Estuarine Vulnerability Assessment grading system has five bands – risk ratings of very low, low, moderate, high and very high. To maintain a consistent grading system across all indicators used in SoE Reporting (see Section 3.1) it is recommended that the high and very high bands be combined to give a total of four grading bands. These bands are outlined under the grading column of Table 23.

Sedimentation rates are estimated quarterly for 14 sites and annually for 45 sites around Tauranga Harbour as part of the NERMN Estuarine Benthic Health monitoring programme. To calculate a mean annual sedimentation rate to compare against the grading system, a long-term average annual sedimentation rate should be calculated for each site. This is done by calculating the overall change in sediment plate depth at each site since sediment pates were established and stabilised and then converting this change into an average annual rate (e.g. change in sediment depth per year). A long term average annual sedimentation rate is recommended rather than using an annual rate for the most recent year as there can be significant short term variation in sedimentation rates as a result of climatic variation (e.g., heavy rainfall) which can mask overall trends. This long-term average annual sedimentation rate should then be compared against the grading bands to obtain a grade for the sedimentation indicator for each site. Sedimentation plates require at least a “settling in” period of at least five years. Therefore, because of the recent establishment of the plates in 2013/2014, it will be necessary to interpret the early results for this indicator with caution.

A summary of the recommended calculation of the sedimentation indicator and grading bands are provided in Table 22.

A full description of the methods used to obtain data collected as part of the NERMN Estuarine Benthic Health Monitoring Programme is provided in Appendix 1.

Table 21 Data requirements, recommended method of calculation and grading bands for sedimentation indicator.

Data required	Calculation method	Grading
Overall change in sediment plate depth at sites since sediment plates were established and had stabilised. Use data collected as part of the NERMN Estuarine Benthic Health monitoring programme.	Sites assigned a grade based on long term average annual sedimentation rates measured using sedimentation plates.	• Very good: mean annual sedimentation rate <1 mm/yr. • Good: mean annual sedimentation rate >1 mm/yr to 2 mm/yr. • Fair: mean annual sedimentation rate >2 mm/yr to 5 mm/yr. • Poor: mean annual sedimentation rate >5 mm/yr.

3.6.3 Sediment mud content

Condition ratings specific to New Zealand estuaries for sediment mud content are outlined in the Estuarine Vulnerability Assessment developed by Wriggle Coastal Management and have been applied to estuaries in Southland, Tasman and Wellington (e.g. Robertson and Stevens 2006, 2007, 2009, Stevens and Robertson 2013a, 2013b, Robertson and Robertson 2014). Based on research conducted across 25 unmodified to highly disturbed, shallow New Zealand estuaries that developed an ecologically relevant model of the responses of benthic macrofauna to sediment mud content (Robertson *et al*., 2015), these ratings were refined and an updated version was published as part of the ETI Toolkit (Robertson *et al*., 2016). The condition ratings included in ETI Toolkit are therefore the most up to date and appropriate ratings for New Zealand estuaries. As such, it is recommended that these ratings are used to assign grades for the sedimentation mud content indicator.

The condition ratings in the ETI Toolkit assign a grade for each site based on the percent mud content in sediment samples, where mud is defined as any particle with a size of <63 µm. The ETI condition ratings have four bands, therefore these bands can be directly converted to the four grading bands that will be used for the SoE Report, where Band A becomes a grade of "very good", Band B becomes a grade of "good", Band C becomes a grade of "fair" and Band D becomes a grade of "poor".

A summary of the recommended calculation of the sediment mud content indicator and grading bands are provided in Table 23.

Table 22 Data requirements, recommended method of calculation and grading bands for sediment mud content indicator.

Data required	Calculation method	Grading
Percent mud content in sediment samples. Use data collected as part of the NERMN Estuarine Benthic Health monitoring programme.	Sites are assigned a grade based on the percent mud content in sediment samples. Mud is defined as any particle <63 µm.	• Very good: % mud content <5% • Good: % mud content 5% to 15% • Fair: % mud content >15 to 25% • Poor: % mud content >25%

3.6.4 Sediment contaminants

Condition ratings specific to New Zealand estuaries for heavy metal contaminants in sediments are outlined in the Estuarine Vulnerability Assessment developed by Wriggle Coastal Management and have been applied to estuaries in Southland, Tasman and Wellington (e.g. Robertson and Stevens 2006, 2007, 2009, Stevens and Robertson 2013a, 2013b, Robertson and Robertson 2014). These ratings are broadly based on the Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 guidelines. The ANZECC guidelines are referred to as the interim sediment quality guidelines (ISQG). There are two guideline values (low and high) which are intended to be used to guide decision making and management actions. The low value is a level at which sub-lethal effects may occur for sensitive species. The high value is a trigger level indicating that there is a need for further investigation and action to remediate the contaminant(s) due to potential toxicity.

The condition ratings in the Estuarine Vulnerability Assessment assign a grade for each site based on the concentration of heavy metals in sediment samples in comparison to the ANZECC ISQG low and high guideline values. It is recommended that these ratings are used to assign grades for each of these variables. The Estuarine Vulnerability Assessment grading system has five bands – risk ratings of very low, low, moderate, high and very high. To maintain a consistent grading system across all indicators used in SoE Reporting (see Section 3.1) it is recommended that the high and very high bands be combined to give a total of four grading bands. These bands are outlined under the calculation method column of Table 24.

The Estuarine Vulnerability Assessment System condition grades provide a framework for assessing the concentration of individual heavy metals. However, BOPRC routinely measures concentrations of eight heavy metals in sediment samples (As, Cd, Cr, Cu, Hg, Pb, Ni and Zn). Therefore, to provide an overall indicator grade for sediment heavy metal contaminants, it is recommended that each of the grading bands is assigned a number ranging from 1 for the very good grade through to 4 for the poor grade. An individual grade, and associated number, should be calculated for each of the eight heavy metals BOPRC measures. The resultant numbers for all eight heavy metals should then be averaged to provide an overall score ranging from 1 to 4. This score then provides the overall grade for the sediment contaminant indicator, as outlined in the grading column of Table 24. It is recognised that assigning an overall measure of sediment contamination in this way may result in a loss of data for individual heavy metals. However, this situation is judged to be acceptable as the intent is to develop a measure to provide an indication of overall state.

A summary of the recommended calculation of the sediment contaminants indicator and grading bands are provided in Table 24.

Data collected as part of the NERMN Estuarine Benthic Health Monitoring Programme should be used for calculation of the sediment mud content indicator.

Table 23 Data requirements, recommended method of calculation and grading bands for sediment contaminants indicator.

Data required	Calculation method	Grading
Concentrations of heavy metals in sediment samples. Use data collected as part of the NERMN Estuarine Benthic Health monitoring programme.	Sites assigned a grade based on the concentration of heavy metals in sediment samples. Each heavy metal is assigned a grade based on the Wriggle Coastal Management condition ratings as follows: • Very good: <0.2 x ISQGLow • Good: 0.2 x ISQGLow to 0.5 x ISQGLow • Fair: >0.5 x ISQGLow to ISQGLow • Poor: >ISQGLow A number is assigned to each grade calculated for each heavy metal as follows: • Very good = 1 • Good = 2 • Fair = 3 • Poor = 4	• Very good: overall score ≤1 • Good: overall score >1 to ≤2 • Fair: overall score >2 to ≤3 • Poor: overall score >3, at least 1 heavy metal is assigned a score of 4.
	The resultant numbers for all eight heavy metals are then averaged to provide an overall score ranging	

Data required	Calculation method	Grading
	from 1 to 4. This score is used to assign an overall grade.	

3.6.5 Nutrient state

The recently developed New Zealand ETI Toolkit (Robertson *et al*., 2016) provides a framework to assess the nutrient enrichment (eutrophication) state of an estuary. Ideally, an ETI score would be calculated for each sub-estuary in Tauranga Harbour and used as an indicator of nutrient state. However, additional macroalgae distribution and abundance data will need to be collected before this score can be calculated. Additionally, calculation of the ETI score is unlikely to be straightforward for individual sub-estuaries in Tauranga Harbour due to the need to develop hydrodynamic models for each sub-estuary within the tool to enable accurate assessments of trophic state. Therefore, in the interim, until additional required data are collected and sub-estuary models are developed, a composite nutrient state indicator that combines scores for sediment TOC, sediment total N and sediment total P concentrations is proposed. These variables are all key indicators of nutrient state for New Zealand estuaries (Robertson *et al*., 2016). Generally, increasing sediment TOC, total N, and total indicate an increasing degree of eutrophication (and therefore poorer nutrient state) in an estuary.

Condition ratings specific to New Zealand estuaries for sediment TOC, and sediment total N and sediment total P concentrations are outlined in the Estuarine Vulnerability Assessment developed by Wriggle Coastal Management (e.g. Robertson and Robertson 2014). Condition ratings for sediment TOC and sediment total N are also outlined in the ETI Toolkit (Robertson *et al*., 2016). Both sets of ratings are based on a review of estuary monitoring data, guideline criteria and expert opinion. The ETI Toolkit ratings are identical to those in the Estuarine Vulnerability Assessment, with the exception that the ETI ratings have only four bands and have condensed the “very low” and “low” ratings of the Estuarine Vulnerability Assessment into a single grade. It is recommended that the ETI condition ratings are used to assign grades for sediment TOC and sediment total N concentrations. As these ratings have four bands they can be directly converted to the four grading bands that will be used for the SoE Report where Band A becomes a grade of “very good”, Band B becomes a grade of “good”, Band C becomes a grade of “fair” and Band D becomes a grade of “poor”. It is recommended that the Estuarine Vulnerability Assessment ratings are used to assign a grade for sediment total P concentrations, with the five band grading system used for these ratings converted to a four band system by combining the high and very high bands to maintain consistency with the 4 band grading system used for the ETI Toolkit. These bands are outlined under the grading column of Table 25.

To provide an overall indicator grade for nutrient state, it is recommended that each of the grading bands is assigned a number ranging from 1 for the very good grade through to 4 for the poor grade. An individual grade, and associated number, should be calculated for each of the three variables as described above (sediment TOC, sediment total N, and sediment total P). The resultant numbers for all three variables should then be averaged to provide an overall score ranging from 1 to 4. This score provides the overall grade for the nutrient state indicator, as outlined in the grading column of Table 26.

A summary of the recommended calculation of the nutrient state indicator and grading bands are provided in Table 25.

Data collected as part of the NERMN Estuarine Benthic Health Monitoring Programme should be used for calculation of the sediment nutrient state indicator.

Table 24 Data requirements, recommended method of calculation and grading bands for nutrient state indicator.

Data required	Calculation method	Grading
Percent TOC and total N and total P concentrations in sediment samples, percent	Sites assigned a grade based on % TOC and total N and total P concentrations in sediment samples.	• Very good: overall score $\leq$1

Data required	Calculation method	Grading
macroalgal cover. Use data collected as part of the NERMN Estuarine Benthic Health monitoring programme.	Grades based on Estuarine Vulnerability Assessment condition ratings or ETI Toolkit bands as follows: **% TOC** • Very good: <0.5% • Good: 0.5 to 1% • Fair: >1 to 2% • Poor: >2% **Total N** • Very good: <250 mg/kg • Good: 250 – 1000 mg/kg • Fair: >1000 – 2000 mg/kg • Poor: >2000 mg/kg **Total P** • Very good: <100 mg/kg • Good: 100 – 300 mg/kg • Fair: >300 – 500 mg/kg • Poor: >500 mg/kg A number is assigned to each grade calculated for each variable above as follows: • Very good = 1 • Good = 2 • Fair = 3 • Poor = 4 The resultant numbers for all three variables are then averaged to provide an overall score ranging from 1 to 4. This score is used to assign an overall grade.	• Good: overall score >1 to ≤2 • Fair: overall score >2 to ≤3 • Poor: overall score >3. At least one variable assigned a score of 4.

Part 4: **Conclusions**

Twenty indicators and seven case studies are recommended for inclusion in the Tauranga Moana SoE Report. These are outlined in Table 26. Three indicators have been selected for the air domain; five indicators and two case studies have been selected for the land domain; two indicators have been selected for the groundwater domain; five indicators and one case study has been selected for the freshwater domain; and five indicators and four case studies have been selected for the coast domain. Appropriate methods for calculating each of these indicators and grading bands are outlined in Part 3.

Table 25 Indicators and case studies recommended for inclusion in the Tauranga Moana SoE Report.

Air	• Fine particulate matter (PM10) • TSP matter • Sulphur dioxide
Land	• Soil bulk density • Soil macroporosity • Soil C:N ratio • Soil fertility • Soil trace elements • Wetlands (case study) • Threatened ecosystems (case study)
Groundwater	• Groundwater quality • Risk of saltwater intrusion
Freshwater	• Swimming water quality • Nitrogen toxicity • Stream health • Periphyton • Benthic cyanobacteria • Freshwater fish (case study)
Coast	• Swimming water quality • Sediment mud content • Nutrient state • Sediment contaminants • Sedimentation • Dune lands (case study) • Seagrass extent (case study) • Water quality (case study) • Physical beach profiles (case study)

Part 5: References

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Appendices

Appendix 1:

NERMN Estuarine Benthic Health Monitoring Programme Methods and Protocols

Bay of Plenty Regional Council undertakes regular monitoring of 59 sites across Tauranga Harbour as part of the NERMN Estuarine Benthic Health Monitoring Programme (Fig. 2). A range of variables are monitored annually at each site during the summer period (November to February). Methods for the variables which are to be used as indicators for the Tauranga Moana SoE Report are outlined below.

Sedimentation rate

At each site a 300 x 300 mm ceramic floor tile was buried at approximately 200 mm depth in the intertidal zone in the 2013/2014 summer period. These floor tiles are referred to as sediment plates. Each buried sediment plate was located in stable substrate beneath the sediment surface. The position of each sediment plate was marked with wooden stakes driven into the sediment and their GPS locations were logged. Sedimentation rate is calculated at each site by a simple method of measuring the amount of sediment over the buried sediment plate. The GPS locations, marker stakes and a probe are used to relocate each sediment plate without disturbing the overlying sediments. Ten probes are then pushed into the sediment until they hit the plate and the penetration depth is measured. The probes are spread across the estimated surface area of the sediment plate, avoiding any obvious large holes (e.g., crab burrows) or raised mounds (e.g. sediment excavated from burrows). These measurements are then averaged to take into account irregular sediment surfaces. An annual sedimentation rate is calculated for each site by multiplying the difference in average sediment plate depth since the last measurement by the number of days since the last measurement was taken divided by 365.

Sediment mud content, nutrients and contaminants

The mud content and the concentration of total organic carbon (TOC), total N, total P and heavy metals are measured at each site in at least 15 replicate sediment core samples from the top 20 mm of sediment from the marked site location using a disposable plastic syringe. Replicate samples are combined into a single composite sample for each site and stored frozen in labelled plastic bags prior to analysis. Grain size of sediment particles is analysed using a "Malvern" laser particle size analyser at the University of Waikato. Mud is defined as any particle with a grain size of <63 µm. Concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn), nutrients (total nitrogen and total phosphorus) and total organic carbon (TOC) in the sediment samples are analysed at Hills Laboratories following standard methods conducted by IANZ accredited laboratories.

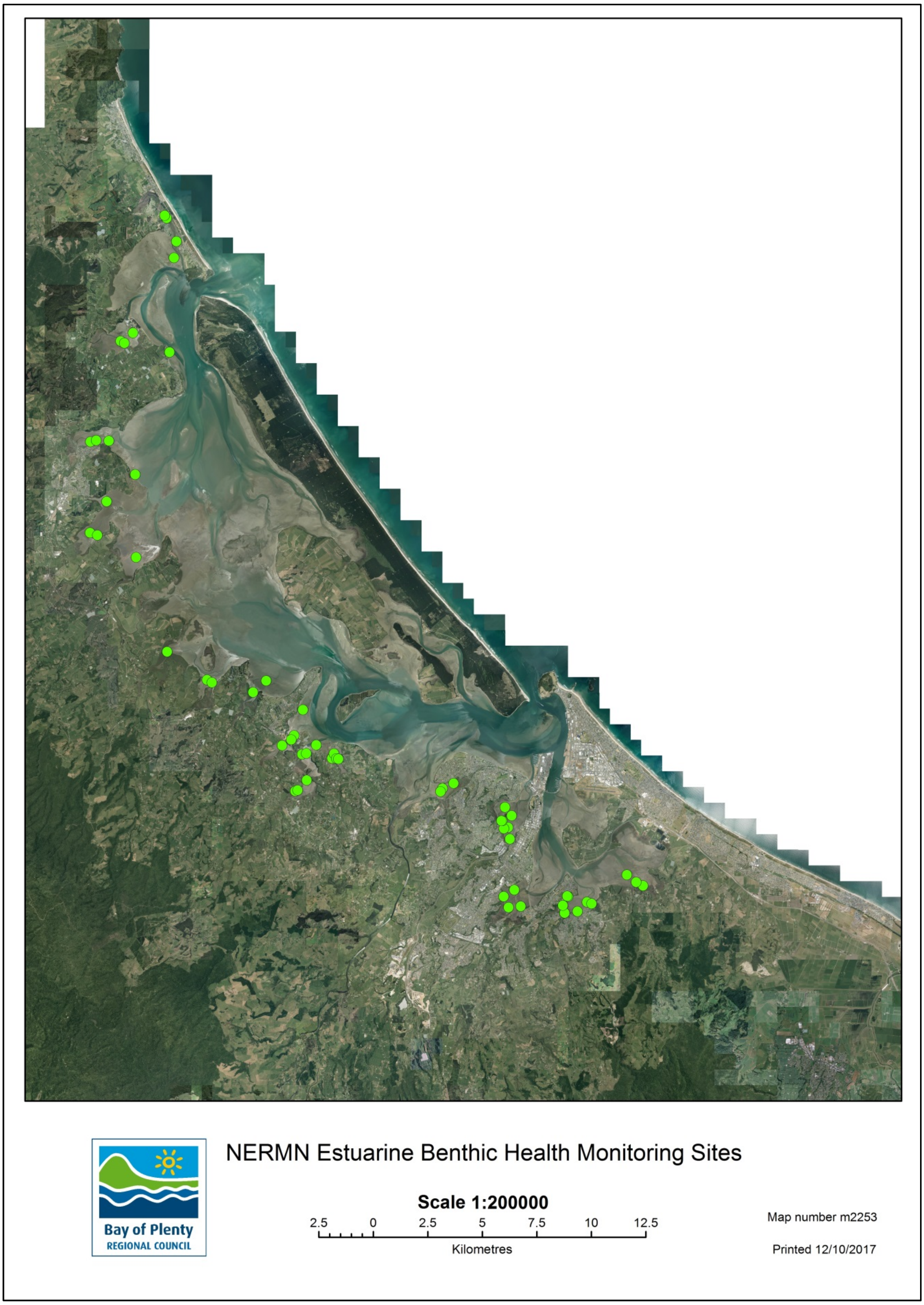

Figure 2 Location of NERMN Estuarine Benthic Health monitoring sites in Tauranga Harbour.