Waikato Regional Council Technical Report 2024/08

Whāingaroa/Raglan catchment management plan: Supporting information

ISSN 223-4363 (Online)
waikatoregion.govt.nz

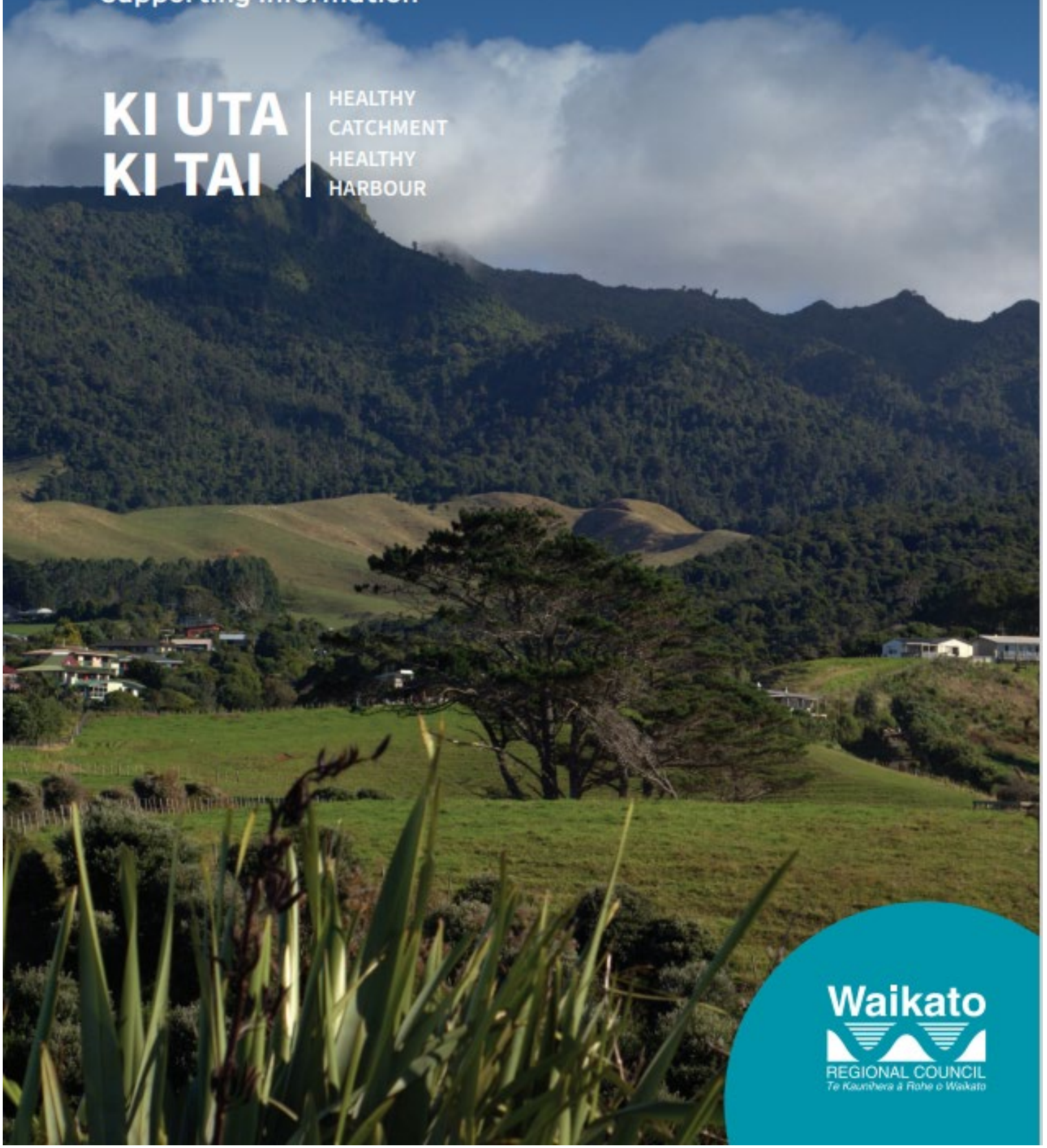
Prepared by	Tracie Dean-Speirs, Amy Taylor, Keri Neilson, Leanne Lawrence
For	Waikato Regional Council Private Bag 3038 Waikato Mail Centre HAMILTON 3240
Publication date	June 2025
Document ID	26157685

	Name	Date
Peer Reviewer	Hilke Giles	April 2024
Approving Manager	Grant Blackie	December 2024

Disclaimer

Whāingaroa/Raglan
Catchment Management Plan
Supporting information

KI UTA KI TAI | HEALTHY CATCHMENT HEALTHY HARBOUR



Waikato Regional Council
Te Kaunihera ā Rohe o Waikato

Contributors

Prepared by: Tracie Dean-Speirs, Amy Taylor, Keri Neilson, Leanne Lawrence

For: Waikato Regional Council Private Bag 3038 Waikato Mail Centre Hamilton 3240

The project team gratefully acknowledges the following people who provided significant technical input into the development of the Whāingaroa Catchment Management Plan: Supporting Information: Dan Borman and Craig Briggs – Spatial information, Callum Bourke, Taylor Scott, Lyndon Stokes, Adrian Jepson, Matt Noble (River and Catchment Management Officers – ICM), Biodiversity and Biosecurity team members, Coastal, Freshwater and Land and Soil scientists.

Peer reviewed by:

Hilke Giles Date April 2024

Approved for release by:

Grant Blackie Date December 2025

Contents

List of acronyms used in this document

CMA	Coastal Marine Area
ED	Ecological District
HCMP	Harbour Catchment Management Plan
NPS-FM	National Policy Statement for Freshwater Management
NZCPS	New Zealand Coastal Policy Statement
RMA	Resource Management Act
RPS	Regional Policy Statement
SNA	Significant Natural Areas
SOE	State of the Environment
WRC	Waikato Regional Council
WRPS	Waikato Regional Policy Statement

Executive summary

This report has been prepared to inform the development of the Whāingaroa Catchment Management Plan concurrently being prepared by Waikato Regional Council. It provides a summary of technical information held by Waikato Regional Council as well as information provided by some external sources.

Information is grouped into the following sections:

- Physical characteristics of the catchment
- Catchment land use and activities
- Erosion and sediment
- Water quality
- Biodiversity
- Biosecurity
- Hazards
- Climate change
- Prioritisation of restoration activities

The catchments of Whāingaroa cover approximately 52,595 hectares of land along the west coast of the North Island of New Zealand. The Whāingaroa catchment includes 826 kilometres of streams and has been split into five sub-catchments by Waikato Regional Council for management purposes: Kerikeri, Waingaro, Ohautira, Waitetuna, Opotoru. Whāingaroa Harbour itself extends over 3,185 hectares.

The majority of the Whāingaroa catchment is moderately steep or steeper and the underlying rocks are mostly sedimentary siltstone and sandstone. Because of the inherently unstable geology and lack of forest cover, many of the steep slopes are prone to slips, gullying and sheet erosion. Erosion reduces soil productivity and translates to problems in our waterways.

Just over half of the Whāingaroa catchment is in pasture (56%). Native woody cover (26%), and exotic forestry (13%) account for most of the remaining landcover in the catchment

The Whāingaroa catchment has changed and developed over time particularly since human settlement. Removal of native vegetation has resulted in increased area of pasture for farming and as other catchment and land use activities increased there has been a change in sediment generation, and a decline in water quality and indigenous biodiversity.

Sediment has been identified as the most important and widespread water quality issue affecting the harbours and waterways of the West Coast Harbours. The steep hills, unstable geology and high rainfall make catchments naturally vulnerable to erosion. Some land uses, including farming, which is prevalent in the Whāingaroa catchment exacerbates erosion risk, particularly along waterway margins.

Water quality in the Ohautira, Waingaro and Waitetuna Rivers has been monitored since 1995. Between 2016-2020 all three sites were considered unsuitable for contact recreation due to elevated levels of *E. coli*. Ecological health attributes varied between excellent and unsatisfactory. Trend analysis indicates an improvement in clarity and turbidity at all three sites over the monitoring period, however *E. coli* is an ongoing concern with levels either static or deteriorating for this attribute.

Water quality in Whāingaroa harbour is generally good. Highest pressures from nutrients, sediment, and microbial contaminants are observed in the eastern part of the inner harbour. These monitoring stations are closest to parts of the catchment dominated by high producing exotic grassland and may be subject to

pressures from farming activities and less well flushed than other parts of the harbour. Closer to the harbour mouth water quality improves likely due to higher seawater influence. This points towards catchment sources as the main contributor of nutrients, sediments and microbial contaminants in Whāingaroa Harbour. Water quality for contact recreation has been good most of the time with occasional exceedances of guideline values.

Sediment muddiness is variable throughout the harbour. Sediment contaminant levels are low, indicating a low risk of toxic effects on sediment dwelling organisms.

A Significant Natural Areas (SNA) project has been in operation at Waikato Regional Council since 2006, with the aim to identify, rank, and determine the management requirements of these sites of high biodiversity value in the region. A number of terrestrial and freshwater (rivers and streams) SNA have been identified in the Whāingaroa catchment.

Whāingaroa catchment margins and harbour support a diverse array of shorebirds, including several rare and threatened species. The exposed and sedimentary coastal edge environment of the harbour is not well suited for estuarine vegetation communities, but the harbour supports important areas of estuarine vegetation that are largely restricted to the sheltered arms of the harbour. The estuarine vegetation of Whāingaroa harbour includes mangroves, salt marshes, seagrass, sea meadows and weed communities.

Waikato Regional Council undertakes a range of monitoring, surveillance, enforcement and direct pest control work in conjunction with other stakeholders within the Whāingaroa catchment. Swan and Canada geese populations have been identified as being of concern for the communities in West Coast harbours, with concern over the impact of trampling and feeding on sea grass, deposition of faecal material and impact on other birds. Pest plants of concern in the most recent survey of the Whāingaroa harbour include saltwater paspalum and spartina. These two plants pose the greatest ecological risk within the harbour.

The Waikato region is prone to natural hazards like coastal erosion, sand drift, wind erosion, coastal flooding, changes in sea-level, tsunami, storms, and cyclones. As a result of climate change the West Coast harbour catchments will likely be subject to more of the high intensity rainfall and storm events that trigger short-term erosion and subsequently increase sedimentation in rivers, streams, and the coastal environment.

Prioritisation exercises undertaken by Waikato Regional Council in 2018 and 2021 have identified Kerikeri and Waitetuna sub-catchments as the highest priorities for management of soil conservation and nutrient risk (nitrogen and phosphorus). The Opotoru sub-catchment was identified as having high values for community activities such as water-based recreation, food gathering, care groups and tourism.

The data and information collated in this report has been used alongside input from iwi, landowners, community, and stakeholders to develop goals and actions for the Whāingaroa Catchment Management Plan.

Physical Characteristics of the Whāingaroa Catchment

General Description

The Whāingaroa Harbour catchment covers approximately 52,595 hectares of land along the west coast of the North Island of New Zealand (Figure 1). The Whāingaroa Harbour catchment has been subdivided into five sub-catchments for management purposes by Waikato Regional Council: Kerikeri, Waingaro, Ohautira, Waitetuna, Opotoru (Figure 2).

Figure 1. NZ Topographic map of the Whāingaroa catchment.

Whāingaroa (or Raglan) township is the main residential area in the catchment. It has a population of over 3,000 people (3,279 as per 2018 Census) but visitors in summer increase the town's population by around 300-400 per cent.

The Whāingaroa catchment sits within the Waikato Regional Council West Coast Zone, which covers an area of 425,835 hectares, or approximately 17 per cent of the Waikato region, stretching from Port Waikato in the north, to Mokau River in the south, and as far inland as Benneydale. The Whāingaroa catchment is in the Waikato District.

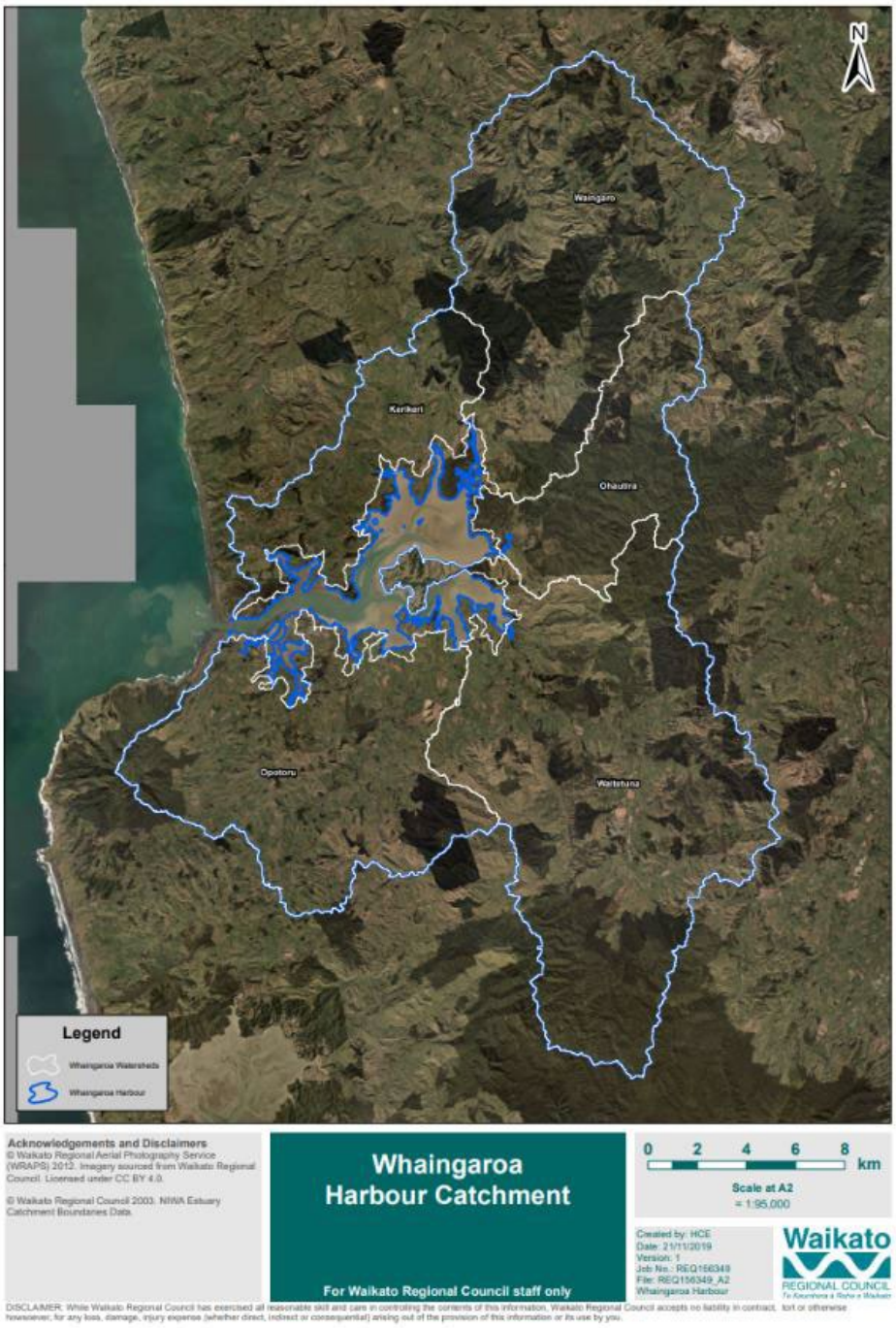


Figure 2. Whāingaroa catchment with sub catchment boundaries.

The catchment ranges in elevation from sea level to 250-350 m (above sea level) in the upper catchment but extends as high as 756m and 554m on Karioi and Pirongia mountains. Around 80% of the catchment receives 1400 -1700 mm per year, which increases to c. 2,400 mm in the areas of highest elevation.

The majority (68%) of the Whāingaroa catchment is moderately steep or steeper. The underlying rocks are mostly sedimentary siltstone (50%) and sandstone (21%), with the remainder being volcanic (14%), and small areas of other soft materials and exposed limestone. Because of the inherently unstable geology and lack of forest cover, many of the steep slopes are prone to slips, gullying and sheet erosion (Singleton, 2018).

The harbour catchment is of mixed terrain. Flat and rolling land occupies about 32% of the catchment, whilst moderately steep or steeper areas make up the remainder (68%). Only 1% of the catchment is versatile and suitable for cultivation[1]. Around 75% of the catchment is at risk of erosion[2], with the remaining 23% percent of the catchment having a slight erosion risk when cultivated (Singleton, 2018).

The Whāingaroa catchment includes 826 kilometres of streams[3]. Most of the watercourses discharging to the harbour are smaller first and second-order perennial streams, but 12 are larger waterways with catchments that extend further inland (Figure 3). Of the total catchment area, 60 per cent is drained by the Waitetuna and Waingaro Rivers which discharge into the upper harbour. The cumulative effects of naturally unstable soils, extensive and intensive farming, results in many of the rivers being silty and with high levels of harmful bacteria in their lower reaches.

The harbour is a drowned river valley that runs 12 kilometres inland from the entrance and is mostly less than 2 kilometres wide. It has an area of 3,185 hectares and is subject to a strong tidal influence with around 70% (c.2,400 hectares) of tidal estuarine flats that are exposed at low tide (Fisher, 2014).

[1] LUC classes 1-2
[2] LUC class 6 or more
[3] Based on REC2 watercourses

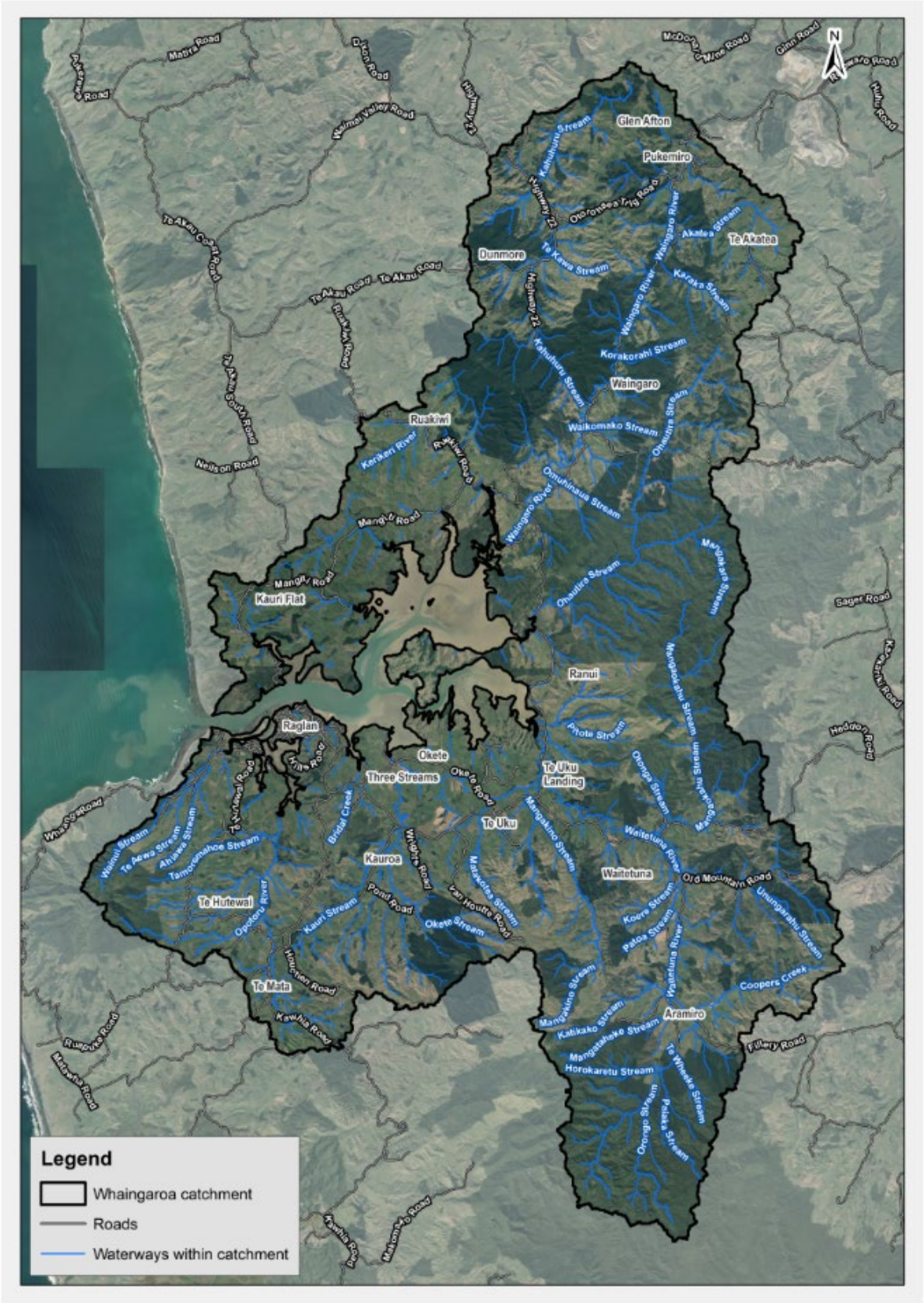


Figure 3. Aerial image of the key waterways within the Whāingaroa catchment.

Land Cover

The current land cover within the Whāingaroa Harbour Catchment is shown in Figure 4 and is summarised in Figure 5. Just over half of the catchment is in pasture (56%). Native woody cover (26%), and exotic forestry (13%) account for most of the remaining landcover with 5% described as “other”, which includes urban areas. Indigenous forest is generally found on the higher points near the outskirts of the catchment boundary.

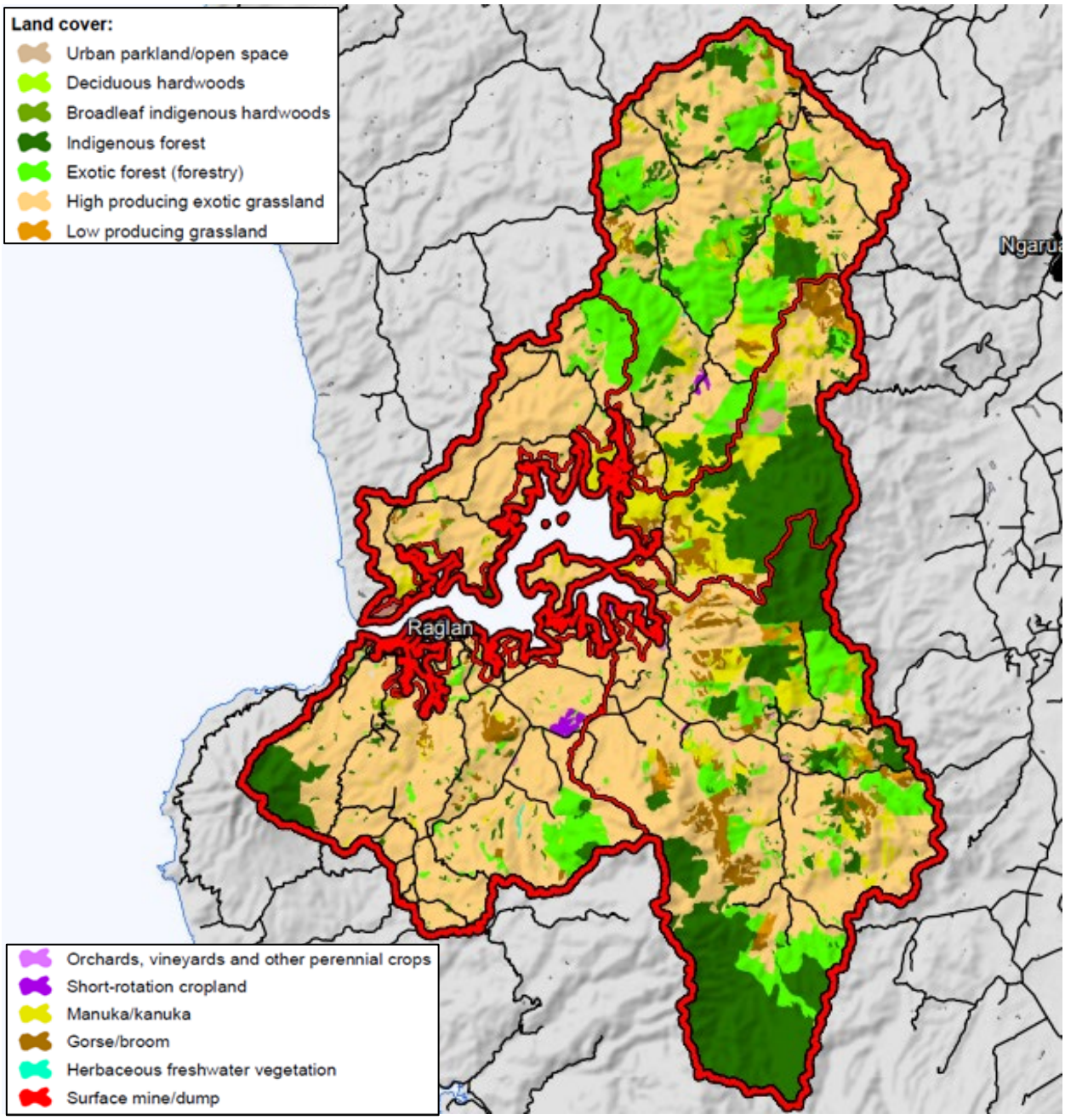


Figure 4. Overlay of land cover within the Whāingaroa catchment

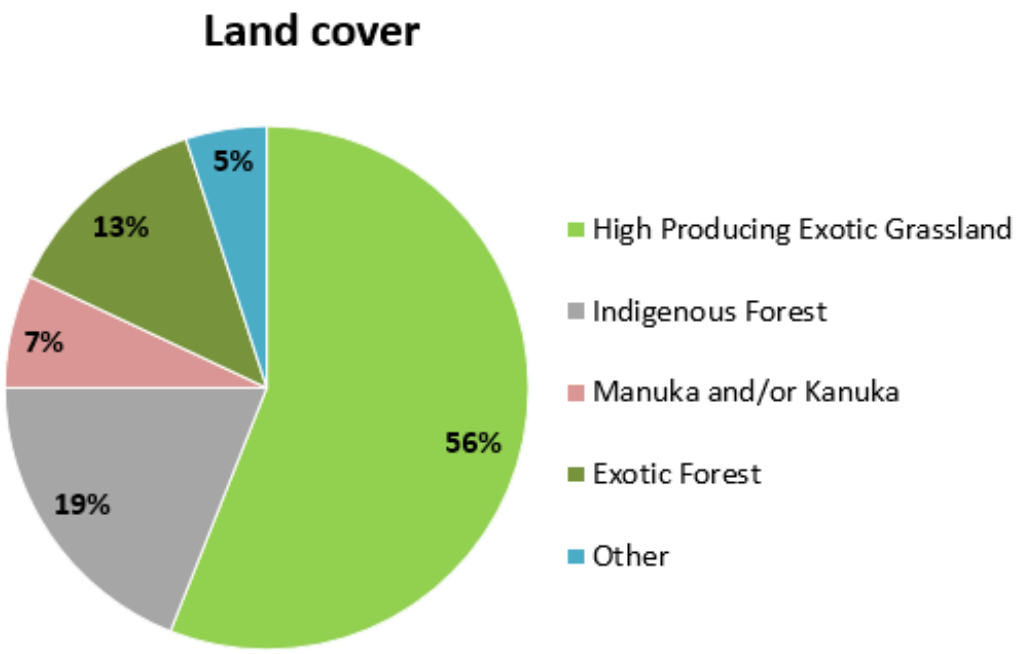


Figure 5. Summary of land cover within the Whāingaroa catchment (Singleton, 2018).

Erosion Risk

1.1.1 Soil erosion

Erosion is the natural process of wearing away rocks, geologic, and soil material via water, wind, or ice. It is a natural phenomenon which results in soil losses and can lead to water quality degradation. New Zealand is geologically young and active and, as a result, the natural level of erosion is high by international standards. Changes to the vegetative cover of the land brought about by activities such as farming, introduction of pests, burning, forestry, road construction and urban development reduce protection against erosive forces and lead to accelerated erosion. Soil is a finite resource. Once erosion has occurred, the productivity of the soil rarely returns to its former level.

The susceptibility of soils to erosion is the result of a complex set of interactions between soil type, climate, vegetative cover, terrain characteristics (slope and aspect) and land management practices. Steeper land that has been cleared from native forest is generally more susceptible to accelerated erosion than other areas. Climatic or weather conditions combined with human activity can accelerate soil erosion.

Data from the Land Resource Inventory indicates that 68% of the Whāingaroa catchment is moderately steep or steeper (Figure 6). These areas, with slopes greater than 21 degrees, have slight to moderate risk of sheet and slip erosion, with the steepest areas also having gully erosion risks.

The slope of the land in the Whāingaroa catchment is a major constraint on land use development because of the risk of erosion and soil loss. In general, moderately steep land and steeper is rarely cultivated as cultivation is costly and carries a high level of erosion and soil conservation risk. Cultivation on strongly rolling areas is also limited by the number of crop rotations possible on these slopes which usually result in longer pasture rotations. Forestry is generally possible with tracked skidders on slopes up to a maximum of 26 degrees.

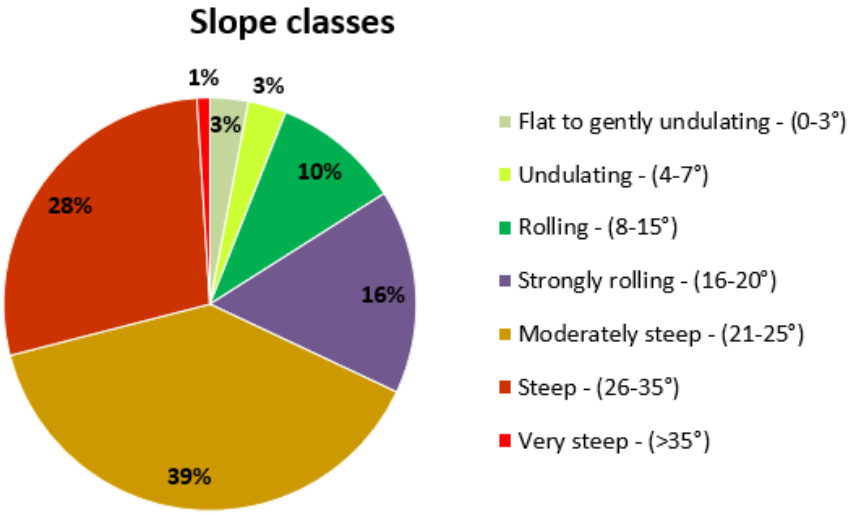


Figure 6. Slope classes within the Whāingaroa catchment derived from New Zealand Land Resource Inventory (Singleton, 2018).

Table 1. Summary of erosion risk within the Whāingaroa catchment and comparison to Kāwhia and Aotea catchments (Waikato Regional Council, 2016).

	Whāingaroa	Kāwhia	Aotea
Landslide risk for delivery to water (ha)	988	1625	351
Total area of highly erodible land (ha)	4090	2606	451
% of catchment that is highly erodible land	8	5	3
Estimated sediment yield (tonnes/km^2/yr)	233	204	197
Estimated properties with highly erodible land	176	128	29

Summary statistics regarding erosion risks within the Whāingaroa catchment (Table 1) were documented in the unpublished report to inform the West Coast Zone Plan (Waikato Regional Council, 2016). Large areas of the hill country within the Whāingaroa catchment have high erosion risk and sediment yield. In the Whāingaroa catchment there is an estimated loss of 233 tonnes/km^2/yr. The hill country has moderate to high rainfall (1,400 to over 1,700 mm) in the headwaters and is prone to shallow slip and sheet erosion, particularly where heavy livestock are grazed on steep land (Singleton, 2018).

1.1.2 River and stream bank erosion

River and stream banks are subject to the erosive force of water, which can be exacerbated by land use activities that damage or disturb the banks and beds of rivers and streams. River and stream bank erosion can damage and remove habitat and release sediment into the water.

There are still many watercourses with little or no erosion protection in place or where stock can access, accelerating stream bank erosion. The WRC Riparian Characteristics survey (Norris et al., 2020), reported that West Coast zone is the area of the region with the lowest proportion of riparian margins with effective fencing (28% of bank length), stock exclusion (16%) and the second highest incidence of stream bank erosion (23%). Climate change is expected to result in more frequent extreme rainfall events, further exacerbating erosion and sedimentation problems.

1.1.3 Coastal Erosion

Coastal erosion is a natural process that is part of natural beach behaviour. When viewed over a long period, such as a hundred years, most shorelines are simply shifting backwards and forwards. Most shorelines naturally vary between periods of sand erosion[4] and accretion[5], which can occur over long periods of time. Short-term erosion can also be caused by storms without causing a permanent change in the position of the shoreline. The area usually recovers; however, a full erosion and accretion cycle can take several decades. Climate change is expected to result in more frequent extreme rainfall events, further exacerbating erosion problems.

At Whāingaroa it is likely that significant shoreline fluctuations (up to 20-40 m) at Ocean beach occur over periods of decades in response to sediment bypassing of the entrance and offshore changes on the ebb tide delta (Tonkin and Taylor, 2008).

At the margins of the harbour entrance ongoing erosion potentially threatens a public parking area and toilet block located on the seaward side of the road. The Te Kopua shoreline further into the harbour is also very dynamic (Tonkin and Taylor, 2008). Most of the beaches around the rest of Raglan Harbour are largely thin veneers or envelopes of sand over rock, typically backed by cliffs, low banks, seawalls or rocky shorelines rather than dunes. In the harbour the erosion hazard is likely to be related to cliff instability.

The northern side of Raglan Harbour entrance is covered by extensive sheets of mobile sand. It has been reported that the dunes have migrated nearly 2 km inland from the shoreline and it is well known that there have been issues with wind erosion and sand instability due to stock grazing and destabilising the vegetation (Tonkin and Taylor, 2008).

The report by Tonkin and Taylor (2008) prioritised the following areas for erosion control:

- Raglan Township coastline (inner harbour) – The low-lying sandy area from Riria Kereopa Memorial Drive to Kopua Point is the critical area. There have been development plans for the Māori land in this area, which is Pā Zone.
- The unprotected cliffs in Raglan township, particularly some of the higher cliffs upstream of the wharf.
- The protected/seawall areas around Raglan. Many seawalls are old and there are likely to be calls for them to be replaced.

The High Risk Coastal Hazard Area (Erosion) map (Figure 7) developed by Waikato District Council identifies areas where there is already significant risk from coastal erosion with existing sea level and coastal processes in the short term. This mapping is part of a series of data relating to natural hazards which includes coastal erosion, coastal inundation, inland flooding, and land subsidence (Waikato District Council - Proposed District Plan (Stage 2 Natural Hazards), Notified 27 July 2020).

[4] gradual washing away of land along the shoreline

[5] gradual increase or acquisition of land washing up sand or silt from the sea

Figure 7. Screen shot of the High Risk Coastal Hazard Area (Erosion) map for the Whāingaroa catchment – Waikato District Council

Land suitability for production

1.1.4 The land use capability classification system

In New Zealand the land use capability (LUC) system is well established as a method to distinguish land areas according to their capacity to support long-term sustained production (Lynn et al., 2009). The LUC classification assesses five primary physical factors: rock type, soil, slope angle, erosion type and severity, and vegetation cover, which influence the long-term land use potential.

The LUC classification can be used to develop tools for land evaluation or farm planning, for example for identifying land-use configurations and/or mitigation measures that maintain or optimise profitability while minimising contaminant loss or water use.

LUC classes range from LUC Class 1 (highly versatile) to Class 8 (unsuitable for production). Land of classes 1 to 4 are versatile for a range of productive uses, including cropping, pastoral grazing or forestry. Beyond class 4, land is no longer suitable for cropping but can be used for pastoral grazing or production forestry.

LUC class 8 lands are considered to be unsuitable for any type of production but generally have important conservation and watershed protection values where indigenous vegetation has been retained.

LUC classes can be further divided into LUC subclasses that describe the main kind of physical limitation or hazard to use of the land parcel. The four limitations recognised are:

'**e**': **erodibility** (where susceptibility to erosion is the dominant limitation)

'**w**': **wetness** (where a high water table, slow internal drainage, and/or flooding constitutes the major limitation to use)

'**s**': **soil** (where the major restriction to use is a limitation within the rooting zone. This can be due to a shallow soil profile, stoniness, rock outcrops, low soil moisture holding capacity, low fertility (where this is difficult to correct), salinity or toxicity)

'**c**': **climate** (where the climate is the major limitation to use. This can be summer drought, excessive rainfall, unseasonal or frequent frost and/or snow, and exposure to strong winds or salt spray)

1.1.5 LUC classification of the Whāingaroa catchment

The LUC classes of the Whāingaroa catchment are summarised in Table 2 below. Overall, the ability to use land in the catchment for production is limited with 77% of the catchment assigned LUC classes 6,7 and 8. Twenty-two percent of the catchment falls into LUC classes 3 and 4, while one percent is classed as being highly versatile (LUC classes 1 or 2).

The areas of high producing exotic grassland in the most sensitive land classes of the Whāingaroa catchment are shown in the map in Figure 8. About half (18,081 ha) of the LUC class 6e land is in pasture (mapped in green), and 5 hectares of LUC class 8 (mapped in red). At this high level, no areas of high producing exotic grassland are identified on LUC class 7 land, although there are likely to be pockets throughout the catchment.

Table 2. Summary of the LUC classification for the Whāingaroa Harbour catchment

LUC Class	Description	Area	% Catchment
2	Very good land with slight physical limitations – ideal for crops, pasture or forestry	165 (2e) 608 (2s)	1.5
3	Moderate limitations to arable use – can be used for cultivated crops, pasture or forestry	2279 (3e) 1461 (3w)	7.1
4	Land with severe limitations to arable use. Careful management required. Usually kept in pasture for long periods	7610 (4e)	14.5
6	Mostly good, fairly stable, hill country where soil erosion can be minimised by good pasture establishment and management. Well suited to grazing and forestry.	36191 (6e)	68.8
7	This land is unsuitable for arable use and has severe limitations or hazards under perennial vegetation. Usually not suited for grazing as it requires special soil conservation practices. In some cases, it may be moderately suited to forestry.	3395 (7e) 35 (7w)	6.6
8	Predominantly very steep mountain land. Land has unfavourable characteristics and severe limitations to use. Unsuitable for forestry and grazing and best restricted to catchment protection and recreation.	412 (8e)	0.8

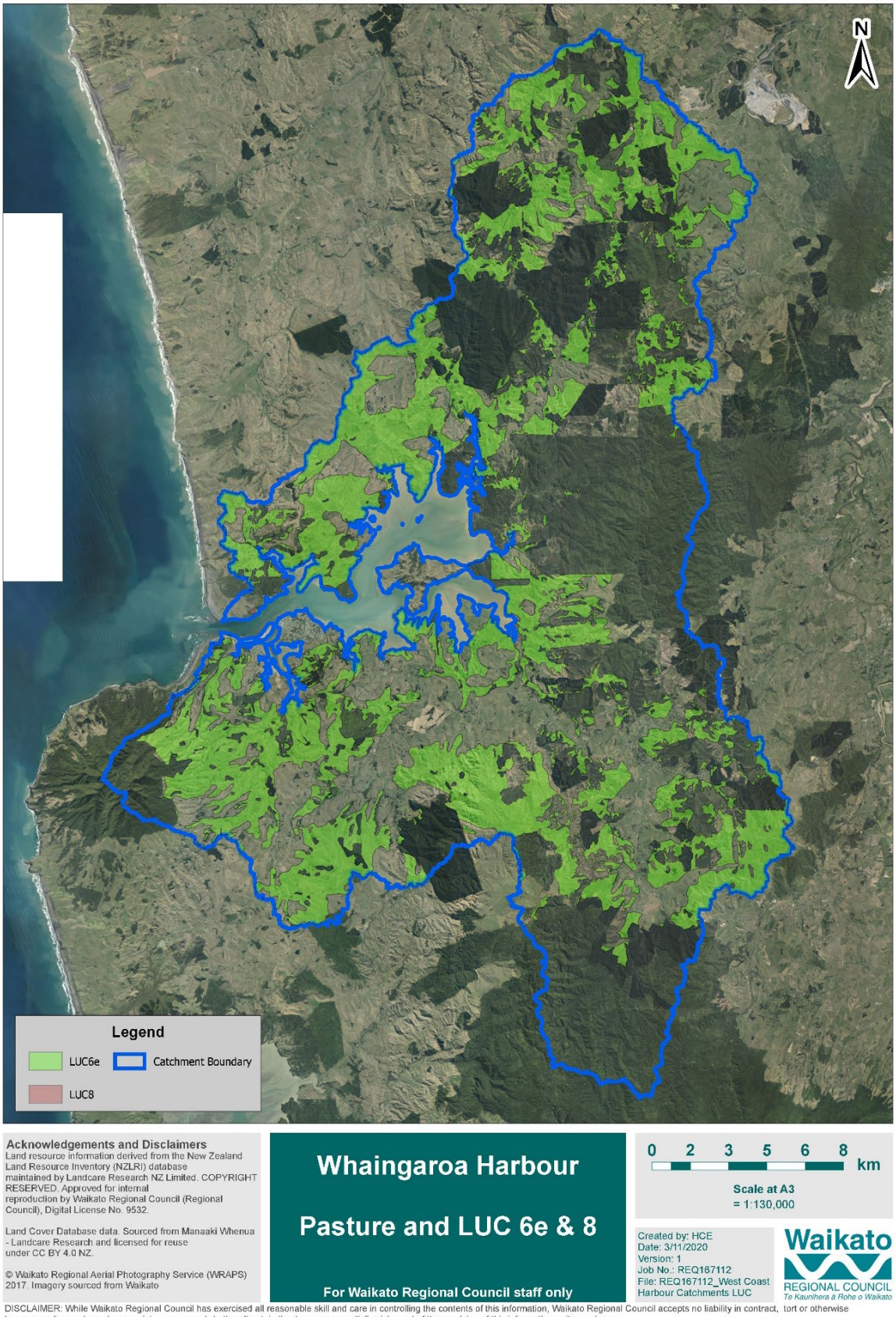


Figure 8. Map of LUC 6e and 8 class land with pastoral land use within Whāingaroa catchment.

Catchment land use and activities

Introduction

The way we use land and the activities we carry out on our land affect the environment. Some effects are clearly noticeable and easily ascribed to a specific land use, for example the effects of deforestation on land cover. However, other effects are less obvious, and it's the cumulative effects of the various land uses that contribute to environmental degradation.

There are three main land use categories in New Zealand: production, conservation, and urban and rural development. Figure 9 shows the different land uses within the Whāingaroa catchment. It is noted that there are some gaps in information regarding the exact proportions of land use in the catchment. The predominant land use within the Whāingaroa catchment is pastoral mixed sheep and beef farming (43%), with beef cattle farming making up a further 14% and dairy cattle farming a further 10% of the catchment land use (Singleton, 2018).

In the following sub-sections, we describe the main land uses and activities in the Kāwhia catchment:

- Urban and rural development (section 2.2);
- Conservation (legally protected land and conservation activities on private land, section 2.3);
- Production (plantation forestry and farming, sections 2.4 and 2.5); and
- Tourism (section 2.6).

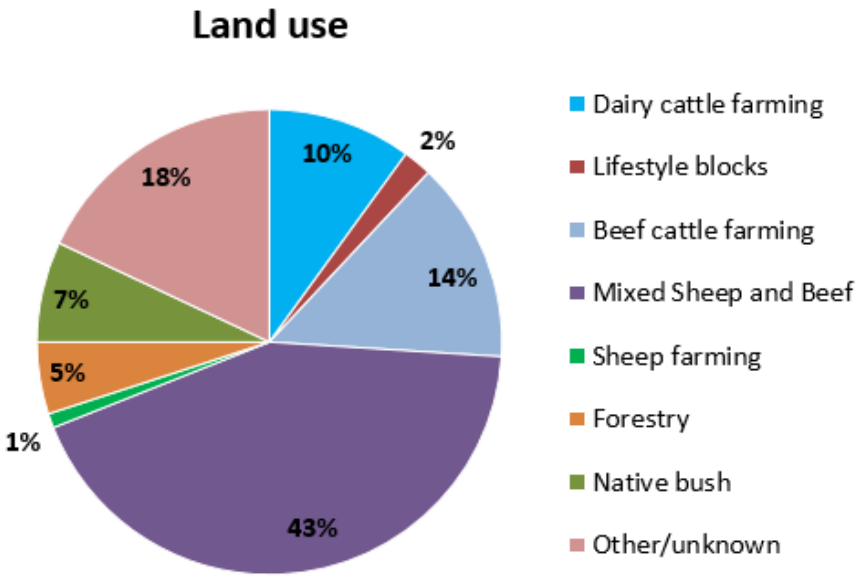


Figure 9. Land use types within the catchment (Singleton, 2018).

Urban and rural development

Raglan township is the main residential area within the wider catchment of Whāingaroa harbour. With three surf beaches, a harbour, and ready access to Hamilton, Raglan is a desirable place to live. As a result, Raglan has undergone substantial growth in the last 2 decades and had a resident population of 3,279 in the 2018 population census.

The local population expands significantly (by 300-400 percent) during summer months to accommodate seasonal visitors and holiday makers, and whānau that reside elsewhere but return regularly. The wider Raglan ward is reported to have a population of 5,870, which includes the communities of Raglan, Ruapuke, Te Mata, Makomako, Te Uku, Waitetuna and Waingaro (Raglan Naturally, 2020).

Most of the properties in the Whāingaroa catchment are privately owned. Of the total 3,646 individual properties[6] there are 185 in Crown ownership; 144 in Māori freehold land; and 3,317 in private ownership as of 2020.

The direct effects of urban development are changes to land cover, often including removal of vegetation and erosion during construction. The latter typically also applies to the construction of subdivisions. In New Zealand concerns have been raised about the loss of some of our most versatile land through expansion of urban development on highly productive land (Ministry for the Environment and Stats NZ, 2021). Considering the small proportion of developed land in the Whāingaroa catchment it is unlikely that this is a problem.

Legally protected land and conservation activities on private land

Approximately 2,900 hectares (5.5%) of the Whāingaroa catchment area is administered by DOC as public conservation land to protect its natural, scenic and recreational values[7]. Additional mechanisms for legal protection of private land include:

- QEII National Trust[8]: The Queen Elizabeth II (QEII) National Trust partners with landowners to voluntarily secure the long-term protection of natural and cultural features on private land with 'open space' covenants. Features protected include landscapes, forest remnants, wetlands, grasslands, threatened species habitats, and cultural and archaeological sites.
- Ngā Whenua Rāhui[9]: A contestable fund that is serviced by DOC and supports the protection of indigenous biodiversity on Māori-owned land, with the protection mechanism being a kawenata (covenant).

A total area of 265 hectares in the Whāingaroa catchment is protected under QEII agreements, while 6 hectares are protected by Ngā Whenua Rāhui. In total, 6% (3,160 ha) of the Whāingaroa catchment is protected by QEII, Ngā Whenua Rāhui or DOC, to protect biodiversity values.

Plantation forestry

A small portion of the Whāingaroa catchment, approximately 5%, is used for exotic forestry (Figure 10), mainly for growing and harvesting of *Pinus radiata* (radiata pine). Plantation (or exotic) forests have been established in predominately erosion prone steep hill country.

Plantation forestry can have soil conservation benefits until trees reach maturity in a 25-30 year harvest cycle. It can also however, have a potential environmental cost. Steep slopes within the Whāingaroa catchment are highly susceptible to landslides for 6 to 8 years post-harvest until new plantings have established stabilising root systems. Removal of trees can degrade streams, with loss of shade, bank destabilisation and deposition of slash and other material during rain events (Singleton, 2018).

[6] Rating units by ownership type

[7] Held under conservation legislation, e.g. the Conservation Act 1987, and Reserves Act 1977

[8] https://qeiinationaltrust.org.nz

[9] https://www.doc.govt.nz/ngawhenuarahui

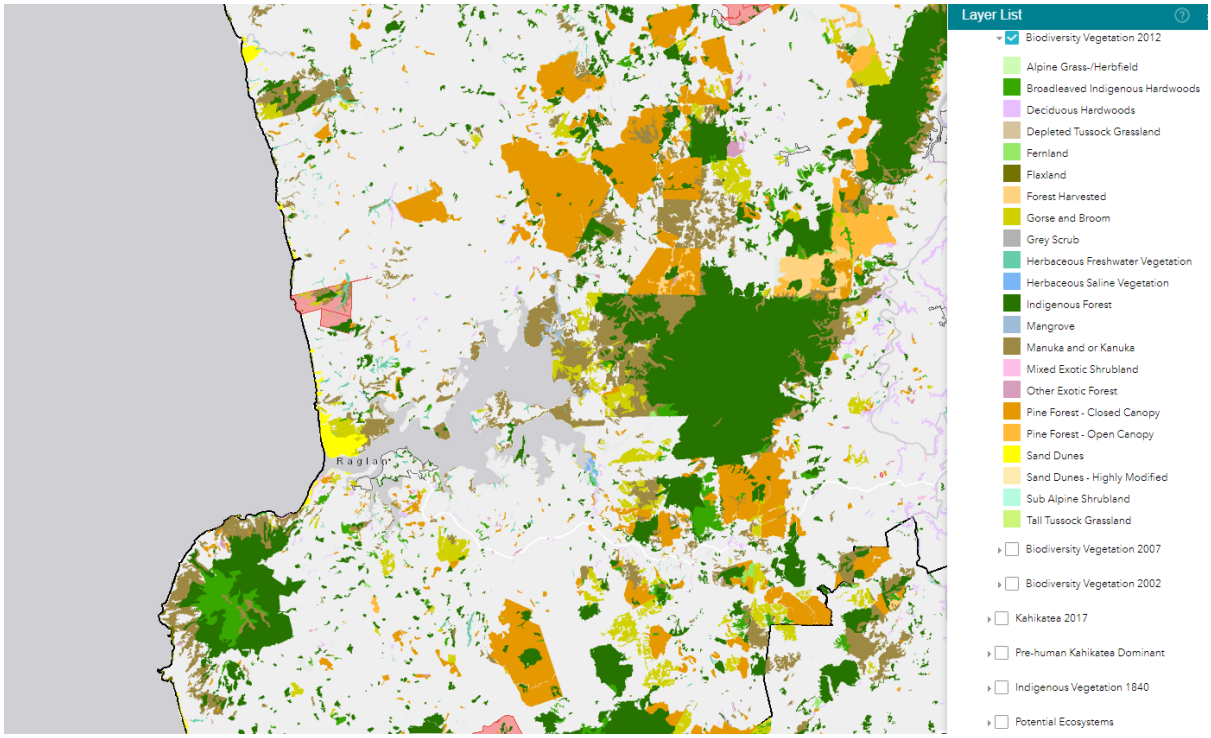


Figure 10. Snapshot of biodiversity vegetation layer 2012, with plantation forest in the Whāingaroa catchment shown in orange.

Any operations in forests are required to be conducted under the National Environmental Standard for plantation forestry (NES-PF) that came into effect in May 2018; however, local Councils will retain the ability to regulate specific areas outside the NES-PF, such as Significant Natural Areas (SNA) or Outstanding Landscapes, when more stringent rules are required to give effect to other National Policy Statements such as the NPS on Freshwater Management or the New Zealand Coastal Policy Statement.

Farming

Farming related land cover makes up approximately 70% of the Whāingaroa catchment, including high and low producing grassland used for mostly drystock and a small amount of dairy farming. Farming adversely affects the catchment if farm runoff enters adjacent rivers and streams and nutrients, sediment and pathogens are transported through the water network. Adverse effects can also arise, or be exacerbated, from farmland erosion, particularly along waterway margins. The Whāingaroa catchment has a high proportion of farmed land on class 6e land, which is prone to erosion. Farming may therefore exacerbate naturally occurring erosion rather than creating a new environmental stressor. Maintaining grass cover and identifying areas on farm prone to erosion and controlling the erosion are very important.

The effects of farming can be mitigated through good farm management. Well-managed waterway margins, grassed farm drains, seepage areas and wetlands help protect water quality. These mitigation measures filter surface runoff, remove nitrogen, and prevent stock access when fenced (reducing bank erosion from trampling, and reducing the amount of effluent reaching the water). Many of these mitigation measures are implemented in the Whāingaroa catchment with a particular focus on riparian management of pastoral waterways.

Waikato Regional Council surveyed the riparian margins of more than 300 stream reaches across the region in 2002, 2007, 2012, and 2017, to assess and track changes in the extent of fencing, vegetation and erosion

in riparian margins within pastoral land. In the 2017 survey, approximately 40% of the bank length of the region's waterways in pastoral land were unprotected from stock access at that time (Norris et al., 2020).

In the most recent regional surveys, waterways within the West Coast zone have been identified as the ones that would benefit the most from future riparian fencing efforts (Norris et al., 2020). These surveys indicate the West Coast zone has the lowest proportion of bank length with effective fencing (28%), and stock exclusion (16%), and the second highest incidence of stream bank erosion (23%). The hilly and often steep nature of the topography and the predominance of drystock farms are likely to be the main reasons for this, along with reduced access to funding (historically) compared to other parts of the Waikato Region.

Unfenced harbour margins enable stock to access the harbour which can cause physical damage to sediments, sea meadow turfs and rushes[10], and graze on mangroves, *Spartina* and saltwater paspalum. The grazing of weed species can facilitate the spread of these weeds by dislodging fragments that can be physically spread by the animals or distributed by the tide. Increased pathogens and sediment are a direct result of stock in the CMA due to stock defecation and the mobilisation of sediments.

Graeme (2012) acknowledged good progress on riparian management between 2004 and 2012 and noted a significant reduction in stock damage to the estuarine vegetation. Despite this, she identified sedimentation as a serious ongoing problem for Whāingaroa harbour and recommended implementing further fencing and soil stabilisation works within the catchment. Animal pests (goats) were also identified as a wide-ranging problem along the coastal margin, as was invasion by saltwater paspalum.

Tourism

The Whāingaroa catchment, especially the harbour and open coast, provide opportunities for surfing, boating, fishing, swimming and other activities. Over the summer months the population can become much larger than the usually resident population. This creates pressure on many aspects of the catchment, particularly on water and roading infrastructure, rubbish, navigation in the harbour and popular tourist destinations within the catchment.

Erosion and sediment

Overview of sediment-related issues in waterways

Sediment has been identified as the most important and widespread water quality issue affecting the harbours and waterways of the West Coast Harbours. The steep hills, unstable geology and high rainfall make catchments naturally vulnerable to erosion. Some land uses, including farming, which is prevalent in the Whāingaroa catchment exacerbates erosion risk, particularly along waterway margins. The eroded areas produce sediment and are slow to recover. Erosion can have a number of physical impacts on fence lines, culverts, tracks and other infrastructure (Singleton, 2018).

Sediment naturally occurs in waterways. Excess sediment can increase water turbidity (make water cloudy), infill streams and estuarine embayments, smother shellfish beds, and change sandy habitats to muddy ones. The change from sandy to muddy substrate or high turbidity reduces people's enjoyment of water. Excess sediment can also reduce the diversity and productivity of habitats. Aquatic animal (including shellfish) diversity decreases with an increase in mud. Benthic vegetation, such as seagrass, may not be able to tolerate elevated turbidity or mud deposition. Sediment is also a major carrier of contaminants, including nutrients

[10] rush root bases are particularly vulnerable to damage from livestock

(particularly phosphate) and bacteria. Erosion from farmland can thus pose health risks for people swimming in downstream waters. In urban runoff, sediment can also carry chemical and organic contaminants.

In this section we describe the main sources and exacerbators of sediment-related issues and how they impact water bodies within the Whāingaroa Harbour catchment. Additional information on suspended sediment in rivers and streams is provided in section 4.2 and suspended sediment in Whāingaroa Harbour is also discussed in section 4.3.

Sources of excess sediment

The main sediment issues for the Whāingaroa catchment and its waterways are generated in the hills of the upper catchment. Many landslips have occurred since the historic deforestation of the catchment. Studies have shown that the root systems of trees increase soil strength by 30% or more compared to pasture (described in Singleton, 2018). Deforestation has therefore reduced soil resistance to landslides. Storm events with moderate intensity can now cause erosion, while much greater storm intensities are required to cause slips in forests. Replacement of much of the forest with pasture has widened the moisture range of the soils and caused greater drying out of the surface, which increases the risk of erosion.

Large areas of the hill country have high erosion risk and sediment yield (section 1.3). Effective soil conservation is critical for maintaining the health of the catchments. The hill country has high rainfall in the headwaters and is prone to shallow slip and sheet erosion, particularly where heavy livestock are grazed on steep land.

Suspended sediment in rivers and streams

Waikato Regional Council regularly monitors the water quality of 14 streams within the West Coast Zone, between Raglan and Mokau, including 3 sites within the Whāingaroa catchment:

- Ohautira River @ Waingaro-Te Uku Road;
- Waingaro River @ Ruakiwi Road; and
- Waitetuna River @ Te Uku-Waingaro Road.

Vant (2019) describes the water quality of the Ohautira, Waingaro and Waitetuna Rivers as being reasonably good, but moderately turbid. The water quality of the Ohautira River is somewhat better than water quality of the Waingaro River, which is at least partly related to it having a greater amount of forest cover within its catchment.

Changes (or "trends") in the long-term records of water quality at all the routine monitoring sites were assessed in 2018[11]. Table 3 summarises the monitoring results for turbidity and water clarity at the monitoring stations from 1993–2017 (25 years) and 2008–2017 (10 years). Over 1993-2017 improvements were recorded at the Ohautira River site, including decreased turbidity. By comparison, clarity in the Waitetuna River declined over the same period.

Table 3. Turbidity and water clarity at the Whāingaroa catchment sites in 2017 and change (% per year) over 25 years (1993 to 2017) and the 10-year period from 2008 to 2017. The probability trends are shown in brackets. Sources: Tulagi (2018), Vant (2018).

Parameter		2017 monitoring results			Number of 2017 samples complying with WRC guidelines[12]		Annual change (%)	
		Median	Min	Max	Satisfactory	Excellent	1993-2017	2008-2017
Turbidity (NTU)	Ohautira River @ Waingaro-Te Uku Rd;	7.2	7.0	7.7	3 (of 12)	0 (of 12)	-1.3 (99)	-3.2 (94)
	Waingaro River @ Ruakiwi Rd	7.4	7.1	7.7	2 (of 12)	0 (of 12)	0.2 (64)	-1.9 (81)
	Waitetuna River @ Te Uku-Waingaro Rd.	7.3	7.0	7.7	1 (of 12)	0 (of 12)	0.8 (94)	-1.9 (93)
Baseflow water clarity (m)	Ohautira River @ Waingaro-Te Uku Rd;	0.8	0.25	1.43	0 (of 11)	0 (of 11)	1.2 (99)	2.7 (98)
	Waingaro River @ Ruakiwi Rd	0.59	0.15	1.13	0 (of 10)	0 (of 10)	-0.4 (90)	1.9 (86)
	Waitetuna River @ Te Uku-Waingaro Rd.	0.60	0.20	1.22	0 (of 10)	0 (of 10)	-0.4 (96)	3.3 (97)

Storm event monitoring over a 4-day period in the Waitetuna catchment during January 2006 indicated that bank erosion was the largest stream sediment contributor, but that most of the sediment was transported to the harbour rather than being deposited onto floodplains or stream beds. Landslips can also be important contributors of sediment, but mostly only in the most intense storms when soil is already saturated prior to the storm commencing (McKergow et al., 2010).

Generally, these rivers carry high sediment loads as a result of naturally unstable soils, and extensive and intensive farming in some areas.

Sediment yields and sedimentation in Whāingaroa Harbour

An estimate of sediment yields within the wider Waikato estuaries was published in 2005 and estimated that the sediment yield from the catchment into Whāingaroa Harbour was approximately 123,000 tonnes per year. The harbour ranking fifth highest for relative sediment yield of all 29 estuary catchments in the Waikato region. The report notes that sediment yield from the catchment is only part of the process leading to sedimentation in estuaries, as tidal flushing plays a key part in determining how much of the sediment input from the catchment is retained in the estuary (Mead and Moores, 2005).

[12] www.waikatoregion.govt.nz/environment/natural-resources/water/rivers/healthyrivers/how-we-measure-quality/

Figure 11. WRC Whāingaroa Harbour State of the Environment (SOE) Regional Estuary Monitoring Programme (REMP) monitoring sites.

Whāingaroa harbour is known to retain finer sediment particles in suspension and then discharge sediment out to the open ocean during falling tides. Because many parts of the harbour are strongly flushing, most of the harbour water is taken out on the tide. Sediment accumulation occurs in localised areas of the harbour, including the Waitetuna arm and sheltered embayments, where some extensive and deep mudbanks occur (Swales et al., 2005; Singleton, 2018).

To track patterns of contemporary intertidal sedimentation WRC has been monitoring Sediment Accumulation Rates (SAR) in Whāingaroa Harbour since 2003 as part of the State of the Environment (SOE) Regional Estuary Monitoring Programme (REMP). Five sites have been measured in the harbour, Whatitirinui Island, Ponganui Creek, Te Puna Point, Okete Bay, and Haroto Bay (Figure 11). Analysis has found that sedimentation rates are highly variable, with areas of both erosion and accretion ranging between -3.98 (erosion) and 7.04 (accretion) mm/yr in Whāingaroa Harbour. The data collected shows distinct sedimentary environments in each part of the harbour, with stability at the Ponganui plates, erosion at Whatitirinui Island and Te Puna Point in the northern arm, and accretion at Haroto Bay and Okete Bay in the southern arm (Hunt 2019).

A research study in 2005 aged and compared the sediments in Whāingaroa Harbour, to identify those sediments deposited before human settlement (when the catchment was covered in native forest), and those deposited during the main land clearance era (approximately 1880-1925; Swales et al., 2005). The study found that the sediment veneer on the rock platforms can be up to 8 metres thick, of which only the top 2 metres has been deposited in the last 6,000 years. This indicates that Whāingaroa Harbour had already substantially infilled by the time of Polynesian arrival, and that the harbour landscape of extensive mudflats and relatively narrow open-water channels at low tide was well established by then (Swales et al., 2005).

The study found major differences in the rates of sedimentation entering the harbour from different sub-catchments. The Waitetuna arm of the harbour (Figure 12) has seen large increases in sedimentation[13] associated with land clearance and most recently, plantation forestry (Swales et al., 2005). By comparison, the Waingaro arm of the harbour has had negligible sediment accumulation in the past 150 years, which is attributed to wave action maintaining sediments in suspension, and to tidal flows of water transporting sediments down-harbour. Sheltered embayments and tidal creeks have experienced continual sedimentation and appear to be the most susceptible to the effects of future changes in the quantity and type of sediment runoff associated with human activities in their land catchments (Swales et al., 2005).

[13] From a pre-human rate (average of 0.35 mm/yr) to an average of 1.1 mm/yr in the late 19th and early 20th century. The rate has further increased since 1990 to an average of 2.5 mm/yr (with a peak of 8 mm/year at a site in Okete Bay) as a result of plantation forestry land use.

Figure 12. Photograph of sediment plumes from Ohautira (top) and Waitetuna (bottom) rivers. (Source Waikato Regional Council)

The Waingaro arm of the harbour was identified as being particularly sensitive to episodic increases in suspended sediment, and sediment erosion and deposition during floods and wave events, which are likely to affect the composition of intertidal benthic macrofaunal communities. Suspension-feeding bivalves and relatively immobile shellfish species (e.g. cockles) may be under-represented in these intertidal sediments due to their sensitivity to suspended sediment. Benthic animals that are better adapted to mobile and

muddy substrates are likely to be more prevalent in these areas, e.g. crustacean and worm species (Swales et al., 2005).

In January 2006 NIWA undertook intensive monitoring of two storm events over a four-day period in the Waitetuna catchment. The purposes of the study were to:

- establish a fine sediment budget for a storm event, for a catchment and its estuary;
- examine the particle size distribution of sediment transported in the event and any spatial variation; and
- examine the timing of sediment delivery from the catchment to the estuary.

The storms involved 55 mm of rain over 14 hours and 66 mm of rain over 7 hours. The first storm delivered enough freshwater to completely displace the saltwater in the upper Waitetuna arm of the harbour, and the rain that fell in the second storm maintained the freshwater state of the arm until about 24 hours after the storm. Large quantities of sediment were transported downstream and into the harbour during the storms. The bulk of the sediment entering the harbour did so abruptly and over a short period of time during and after each storm. The state of the tide strongly influenced sediment transport when it reached the harbour. As the tide receded salinity declined, and sediment measurements increased. The finest sediments remained in suspension, coursing up and down the harbour with the tidal changes (McKergow et. al., 2010).

The main findings of the study were that:

- 3,700 tons of fine sediment left the catchment on a 10-year return period rainfall event[14];
- The Mangaokahu Stream contributed half of the fine sediment to the Waitetuna River;
- Silt-sized particles dominated suspended sediment;
- 70% of the sediment was delivered to the estuary over a 12-hour period; and
- Approximately 25% of the fine sediment was deposited on tidal flats within 3 km of the estuary head.

Sediment source identification in the Mangaokahu catchment, and an evaluation of further multiple storm events were identified as potential topics for further study (McKergow et al., 2010).

Sediment contaminants and muddiness in Whāingaroa Harbour

Sediment contaminants, such as metals and other trace elements, have both natural and man-made sources. Most of these elements are found in small amounts in the earth's crust. When volcanic rocks containing these elements are weathered and erode in the catchment, trace elements enter the marine sediments and naturally occur there.

Pressures on estuaries increase as population numbers grow and developments increase both in catchments and coastal areas. Inter-tidal flats and their associated communities are highly susceptible to changes in land use and other activities in catchments. Mining, urban and industrial activities can cause input of trace elements and organic compounds into estuaries which may be stored in the sediments. The sediments then become a potential source of trace elements and organic compounds to animals and plants both in the sediment and the overlying water.

In 2008, as part of the WRC Regional Estuary Monitoring Programme (REMP), the levels of trace elements and organic compounds in sediments of the inter-tidal sand and mudflats from five sites in Whāingaroa Harbour, were tested.

[14] An event that has a 10% probability of happening in any given year.

Rumsby (2009) reports that concentrations of most trace elements within the sediments were at the lower end of their estimated natural ranges, and that no trace elements were present in concentrations that exceed the ANZECC (2000) ISQG-low guideline values. The concentrations of trace elements were generally higher in the samples collected in the southern part of the harbour than in samples from elsewhere in the harbour. Trace quantities of some PAHs[15] were detected around Ponganui Creek, which was the closest to Raglan township of all samples collected and may indicate a minor effect from the township. No organochlorine pesticide residues were detected in Raglan Harbour (Rumsby 2009).

In 2003 and 2018, Waikato Regional council collected sediment samples to test for antimony, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, arsenic, organochlorines and total PAHs (Figure 13, maps the sampling sites). None of the samples exceeded ANZECC ISQG-low guideline values. The sediment quality in Whāingaroa Harbour (as well as Aotea and Kāwhia harbours) was assessed as "good" and indicated a low risk of toxic effects on sediment dwelling organisms.

Sediment mud content is monitored by WRC at the sites shown in Figure 11 as part of the SOE Regional Estuary Monitoring Programme (REMP). Mud content varies considerably among sites, comprising c. 14-16% mud at Ponganui Creek, Te Puna Point, and Whatitirinui Island, c. 26% at Okete Bay and c. 46% at Haroto Bay in the Waitetuna arm of the harbour (Jones, 2021).

[15] fluoranthrene, phenathrene and pyrene

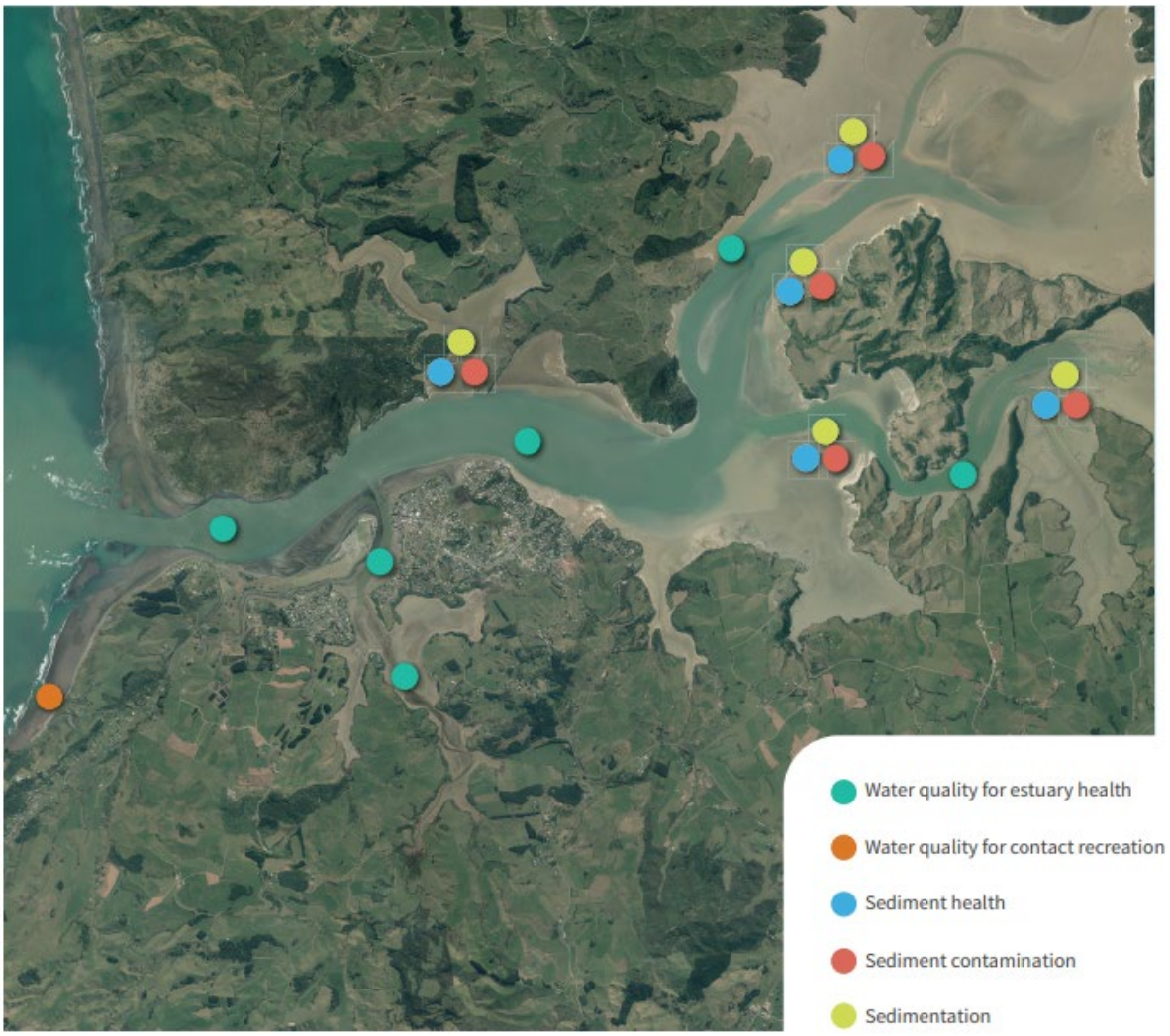


Figure 13. Map showing locations of sediment health and contamination (red and blue dots) monitoring sites in Whāingaroa Harbour.

Water quality

Introduction

Waikato Regional Council routinely monitors a representative cross-section of regional rivers and streams to assess the suitability of water quality for native water plants and animals, including three in the Whāingaroa catchment. Water quality of Whāingaroa Harbour is also monitored by WRC. The following sections provide a description of water quality in the catchment's rivers and streams as well as the harbour.

Freshwater quality within the catchment

1.1.6 River and streams

Waikato Regional Council has three routine water quality monitoring sites in the Whāingaroa catchment that have been monitored since 1993:

- Waingaro River @ Ruakiwi Road;
- Ohautira River @ Waingaro-Te Uku Road; and
- Waitetuna River @ Te Uku-Waingaro Road.

Council's Environmental Indicators website provides summary data for the 2016-2020 period (Figure 14). This information indicates that these three sites were not considered to be safe for contact recreation (swimming) over that period due to high levels of *E. coli* (100% of the time at all three sites) and unsatisfactory clarity (at baseflow) measurements (87-96% of the time). In terms of ecological health, this was assessed as excellent in respect to in-stream ammonia, dissolved oxygen, and pH most of the time. Temperature, total nitrogen, total phosphorus, and turbidity are variable with periodic (15-78% of the time) monitoring results indicating unsatisfactory ecological health.

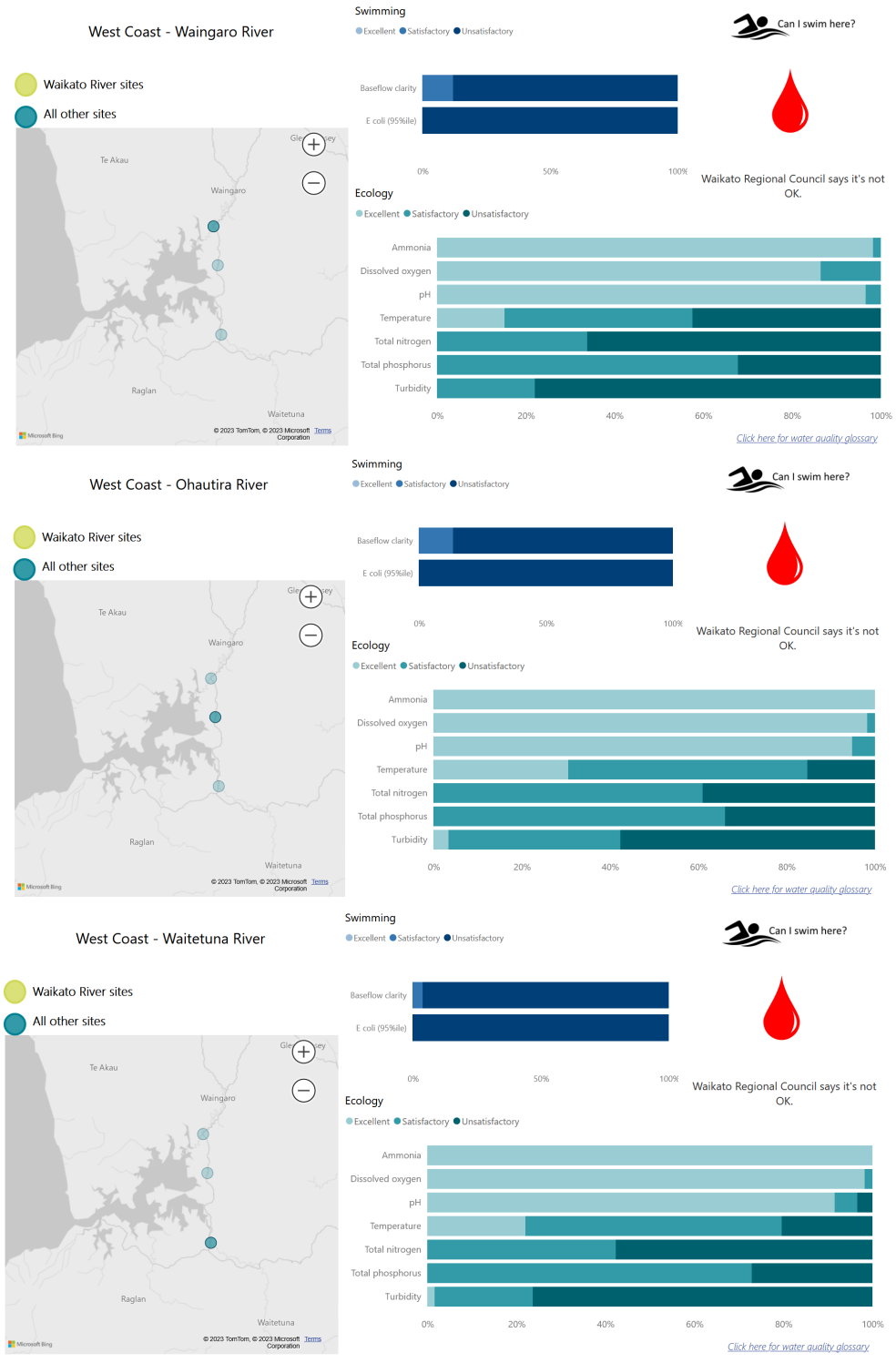


Figure 14. Average (2016-2020) results of monitoring (ecological health and suitability for swimming) at the three river and stream monitoring sites in the Whāingaroa catchment as displayed at the Waikato Regional Council Environmental Monitoring Hub website.[16]

[16] https://www.waikatoregion.govt.nz/environment/natural-resources/water/rivers/water-quality-monitoring-map/, accessed 15 April 2023.

Table 4. Median water quality measured between 2015 and 2019 in the Ohautira, Waingaro and Waitetuna Rivers. Source: Tulagi and Salu (2020).

	Ohautira R	Waingaro R	Waitetuna R
Diss oxygen (% sat)	95	94	97
pH	7.4	7.4	7.4
Turbidity (NTU)	7.4	10	9.7
Ammonia (g N/m^3)	<0.01	0.01	0.01
Total N (g/m^3)	0.48	0.82	0.62
Total P (g/m^3)	0.03	0.03	0.03
Clarity (m)	0.9	0.8	0.7
E. coli (cfu/100 mL)	380	235	410

Median water quality measured between 2015 and 2019 is shown in Table 4.

In terms of total nitrogen and total phosphorus, the water quality of all three rivers is reasonably good in comparison with other areas of the Waikato region (Figure 15). Run-off and leaching of contaminants from the land is the main source of contaminants to these streams, which is exacerbated during wet conditions (Vant, 2020).

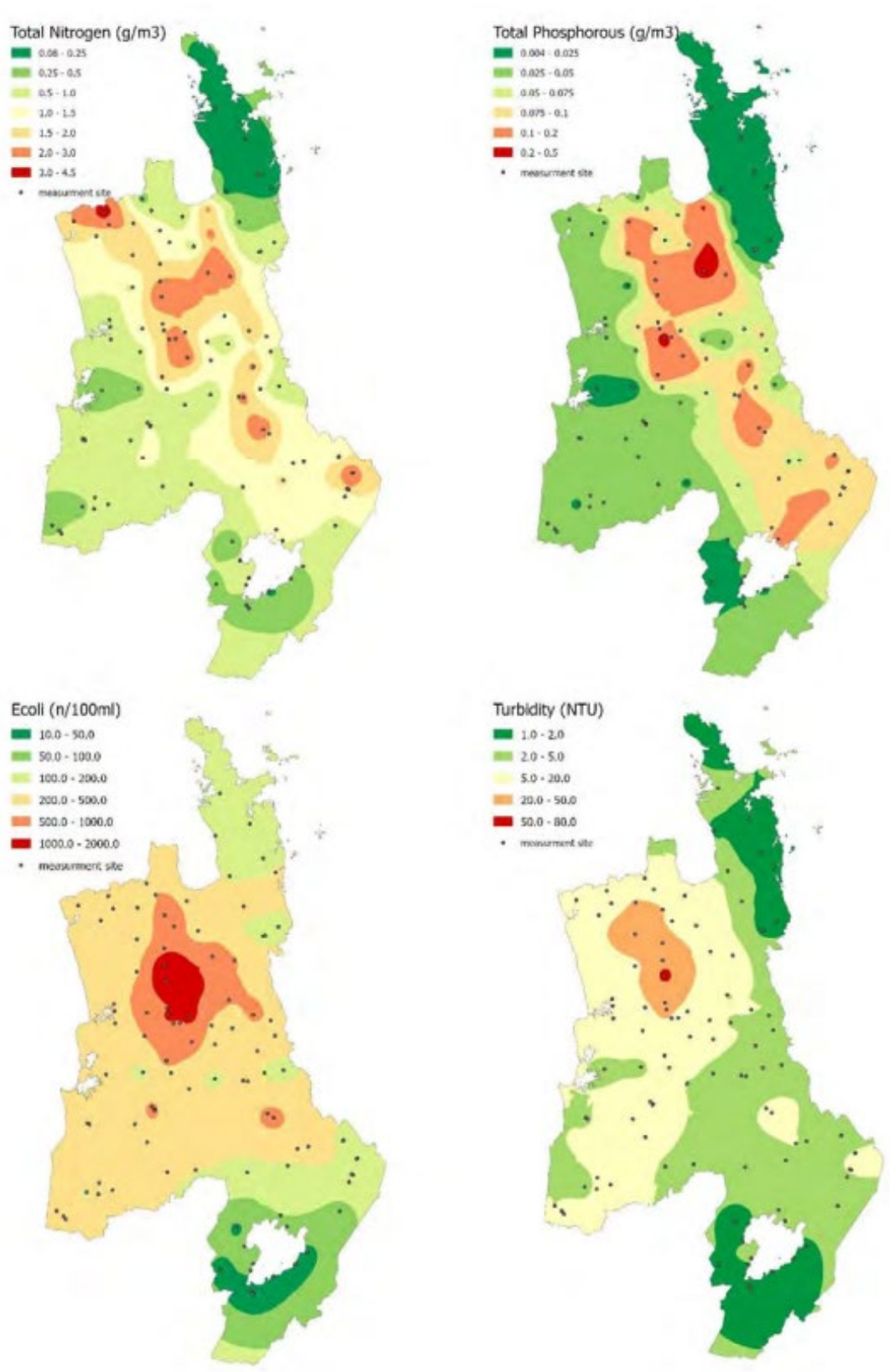


Figure 15. Spatial contour plots of four water quality parameters (based on 5-year median values, 2016-2020): Total Nitrogen, Total Phosphorus, *Escherichia coli*, Turbidity. Source: Salu (2021).

Changes (or "trends") in the long-term records of water quality at all routine monitoring sites on the Regions' rivers were assessed in 2018. Table 5. and Figure 16 summarises the trends in water quality in the three rivers in the Whāingaroa catchment over 1993–2017 (25 years; Vant, 2018).

Between 1993–2017, some improvements occurred at the Ohautira River site (decreased turbidity, increased clarity and decreased ammonia) and the Waingaro River site (decreased phosphorus). Notable decreases in ammonia concentrations also occurred at the Waingaro and Waitetuna River sites. Phosphorus concentrations also decreased slightly at the Ohautira and Waingaro sites, but there is less confidence[17] around these results.

On the other hand, there were deteriorations in total nitrogen at all three river sites in the Whāingaroa catchment, with slopes in the range 0.7–0.9% per year (as seen in Figure 16.), slightly below the value of 1% per year at which trends are considered to be 'important'. Declining trends in total nitrogen concentrations between 1993–2017 were common across the Waikato region, with deteriorations occurring at 65% of all sites. The overall rate of change averaged 0.9% per year— similar to that seen at the three Whāingaroa rivers.

Table 5. Slopes (% per year) for monthly records of flow-adjusted water quality variables in three rivers in the Raglan catchment, 1993–2017. Trends are very likely to have occurred when the slope direction probability is >95%; otherwise, they are not very likely (nvl"); slopes shown in bold type are regarded as being important. Source: Vant (2018).

	Ohautira	Waingaro	Waitetuna
Dissolved oxygen	nvl	0.1	–0.0
Turbidity	**–1.3**	nvl	nvl
Ammonia	**–2.1**	–0.9	–0.9
Total nitrogen	0.8	0.7	0.9
Total phosphorus	**–1.0**	**–1.0**	–0.6
Clarity	**1.2**	nvl	–0.4
E. coli	nvl	id	nvl

"id", insufficient data to determine trends. See WRC technical report 2018/30 for further details.

[17] Due to changes in laboratory procedures over the past 25 years.

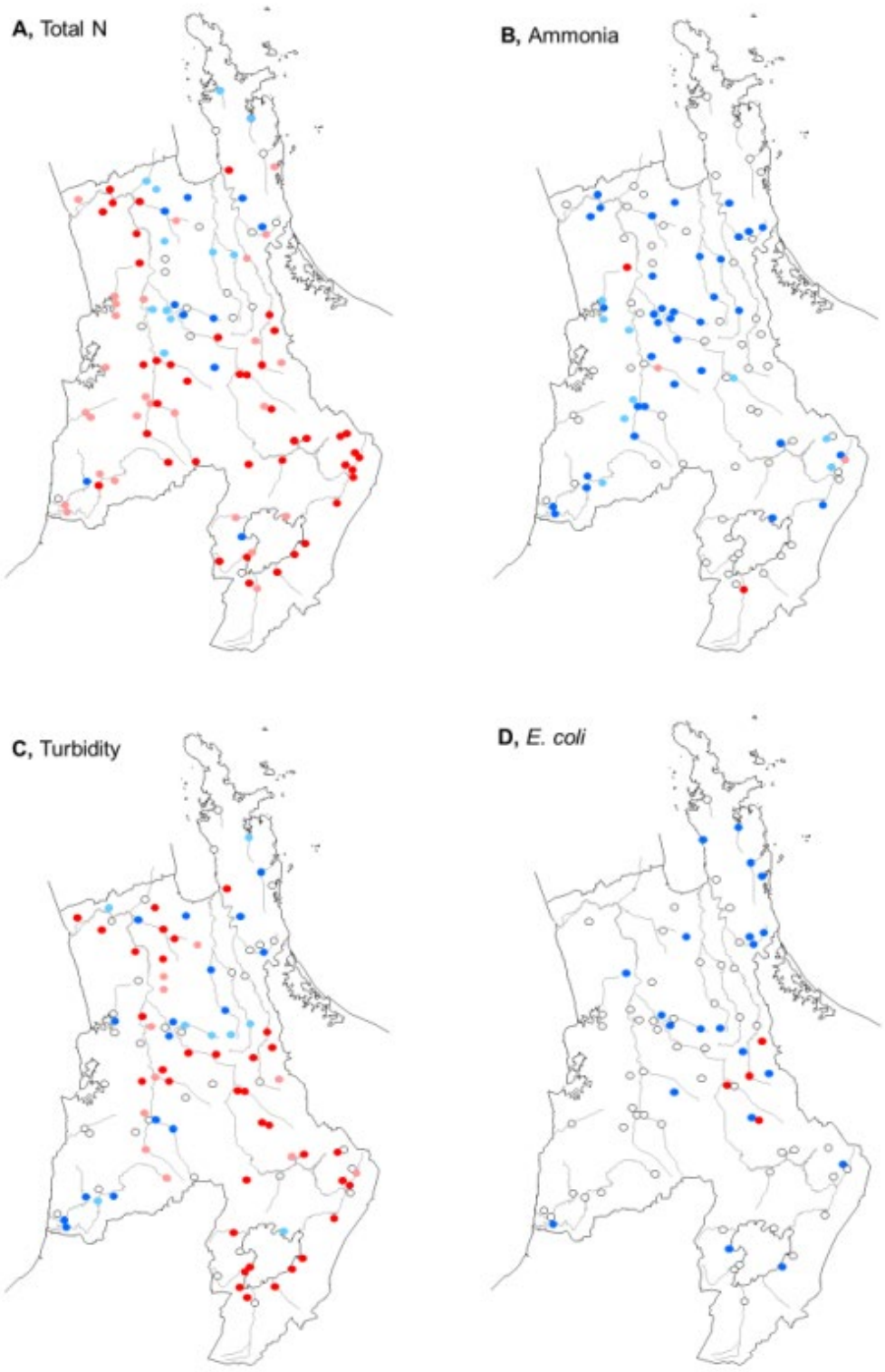


Figure 16. Nature of trends for selected water quality variables at regional river sites during 1993–2017. The symbols distinguish between records where slope probabilities were not very likely (open circles), and those showing one of the following very likely trends: important improvement (dark blue), slight improvement (pale blue); slight deterioration (pink) and important deterioration (red). A, total nitrogen; B, ammonia; C, turbidity; and D, *E. coli*. Source: Vant (2018).

The most recent information about the current state and trends of water quality indicators at these Whāingaroa river and stream monitoring sites are available from the LAWA website[18]. The website shows median values between 2019 to 2023 and provides a trend analysis for the period 2014-2023 (Table 6). For the Ohautira River, this data shows that the trend observed by Vant (2018) of improving clarity and turbidity in the river has continued. The Waingaro and Waitetuna Rivers are also now showing trends towards improvement for these factors. However potential improving trends noted in 2018 in Total Phosphorus in the Ohautira and Waingaro Rivers have not continued, and this is now considered very likely and likely degrading respectively.

Vant (2018) observed a possible deteriorating trend in Total Nitrogen in all three rivers over 1993 – 2017. However, in the trend assessment for the 10 years to 2023, the Waitetuna and Ohautira appear to be improving. *E. coli* is an issue for all three rivers, and particularly the Ohautira and Waitetuna which are in the worst 25% of all lowland rivers nationally for *E. coli* concentrations. They are both in the E band for this attribute.

Table 6. Water quality state as a five-year median (2019-2023), National Policy Statement for Freshwater Management 2020 (NPS-FM) attribute band, and comparison to other New Zealand lowland rural sites for the Ohautira, Waingaro and Waitetuna Rivers monitoring sites. Source: LAWA website, accessed 9 April 2024).

Indicator			**5-year median (2019-2023)**	**State (compared to all NZ lowland rural sites)**	**10-year trend**
Bacteria	*E. coli*	Ohautira R.	380 n/100ml	In worst 25% Attribute Band E	Very likely degrading
		Waingaro R.	220 n/100m	In worst 50% Attribute Band D	Indeterminate
		Waitetuna R.	385 n/100ml	In worst 25% Attribute Band E	Indeterminate
Clarity	Black disc	Ohautira R	1.04 metres	In worst 50% Attribute Band A	Very likely improving
		Waingaro R.	0.9 metres	In worst 25% Attribute Band B	Very likely improving
		Waitetuna R.	0.93 metres	In worst 50% Attribute Band A	Very likely improving
	Turbidity	Ohautira R	4.4 NTU	In worst 50%	Very likely improving
		Waingaro R.	7.45 NTU	In the worst 25% of all sites	Very likely improving
		Waitetuna R.	6.45 NTU	In the worst 25% of all sites	Very likely improving
Nitrogen	Total Nitrogen	Ohautira R	0.39 mg/L	In best 50%	Very likely improving
		Waingaro R.	0.58 mg/L	In worst 50%	Indeterminate
		Waitetuna R.	0.46 mg/L	In best 50%	Likely improving
		Ohautira R	0.245 mg/L	In the best 50%	Likely improving

[18] https://www.lawa.org.nz/explore-data/waikato-region/river-quality/

	Total oxidised Nitrogen	Waingaro R.	0.325 mg/L	In worst 50%	Very Likely Improving
		Waitetuna R.	0.305 mg/L	In best 50%	Likely improving
	Dissolved Inorganic Nitrogen	Ohautira R	Not assessed	Not assessed	Not assessed
		Waingaro R.	Not assessed	Not assessed	Not assessed
		Waitetuna R.	Not assessed	Not assessed	Not assessed
	Ammoniacal Nitrogen	Ohautira R	0.01 mg/L	In worst 50% Attribute Band A	Likely improving
		Waingaro R.	0.01 mg/L	In worst 50% Attribute Band A	Not assessed
		Waitetuna R.	0.01 mg/L	In worst 50% Attribute Band A	Very likely improving
	Nitrate Nitrogen	Ohautira R	0.245 mg/L	In the best 50% Attribute Band A	Likely improving
		Waingaro R.	0.325 mg/L	In the worst 50% Attribute Band A	Very likely improving
		Waitetuna R.	0.305 mg/L	In the worst 50% Attribute Band A	Likely improving
Phosphorus	Dissolved Reactive Phosphorus	Ohautira R	0.019 mg/L	In worst 50% Attribute Band D	Very likely degrading
		Waingaro R.	0.008 mg/L	In best 50% Attribute Band B	Likely improving
		Waitetuna R.	0.011 mg/L	In worst 50% Attribute Band C	Indeterminate
	Total Phosphorus	Ohautira R	0.0375 mg/L	In worst 50%	Very likely degrading
		Waingaro R.	0.0335 mg/L	In worst 50%	Likely degrading
		Waitetuna R.	0.032 mg/L	In worst 50%	Likely degrading

1.1.7 Groundwater

No information on groundwater quality in the Whāingaroa catchment is available.

1.1.8 Summary – freshwater quality

Waikato Regional Council has three long term monitoring sites in the Whāingaroa catchment, at the Waingaro, Ohautira and Waitetuna Rivers. Overall, West Coast rivers are generally of reasonable quality in comparison to other parts of the Waikato region that have more intensive land use. Run-off and leaching from pastoral land use is the likely the main source of contaminants to the harbour, which is exacerbated during wet conditions.

Between 2016-2020 all three sites were considered unsuitable for contact recreation due to elevated levels of *E. coli*. Ecological health attributes varied between excellent and unsatisfactory.

Trend analysis indicates an improvement in clarity and turbidity at all three sites over the monitoring period, however *E. coli* is an ongoing concern with levels either static or deteriorating for this attribute.

Coastal water quality within the catchment

1.1.9 Estuarine water quality

The Waikato Regional Council estuarine water quality monitoring programme has evolved over the last 20 years. The current estuarine monitoring programme in Whāingaroa Harbour started in 2017. Six monitoring stations are sampled monthly: Opotoru, Mid harbour, Whāingaroa (Raglan) Mouth, Waingaro, Wainui, Waitetuna (mapped as green dots in Figure 17). The earlier programme involved sampling surface and bottom waters at four sites (Inner Harbour North, Inner Harbour South, Mid Harbour and Outer Harbour) during the following periods:

- August 2002 to April 2003 on a bi-monthly basis;
- April 2003 until June 2003 on a monthly basis; and
- July 2013 to May 2014 on a bimonthly basis (and also included June 2014)

In a 2020 summary[19] of monitoring data from Whāingaroa Harbour, two (Waingaro and Waitetuna) of the six monitoring sites were reported as having marginal water quality, meaning the conditions often depart from desirable levels. The remaining four sites were considered to have fair water quality. All sites were reported as regularly exceeding ANZECC guidelines for nitrogen and phosphorus.

Since 2017, slight dissolved oxygen depletion was recorded in summer months (January to March) for all currently monitored stations, but this was more pronounced at the freshwater influenced stations at Opotoru, Waingaro, and Waitetuna (Kamke, 2021). Oxygen depletion was not to a critical level and dissolved oxygen concentrations remained within ANZECC guideline levels at all stations. Oxygen reductions coincided with increased chlorophyll *a* concentrations[20] from November – January, which exceeded ANZECC guideline values for Waitetuna and Waingaro. To prevent critical oxygen levels in future at these stations, Kamke (2021) recommended minimising and or reducing nutrient inputs.

Water clarity parameters have been poorest at the inner harbour and best at the stations closest to the outer harbour and mouth. During the 2002/03 monitoring period, turbidity values often exceeded ANZECC guidelines at the inner harbour stations and in 2013/14 median turbidity at Mid Harbour also exceeded the guideline.

[19] Whāingaroa Harbour marine report card 2020, https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/6661-Whaingaroa-Report-Card.pdf

[20] that are likely to be related to Spring algal growth

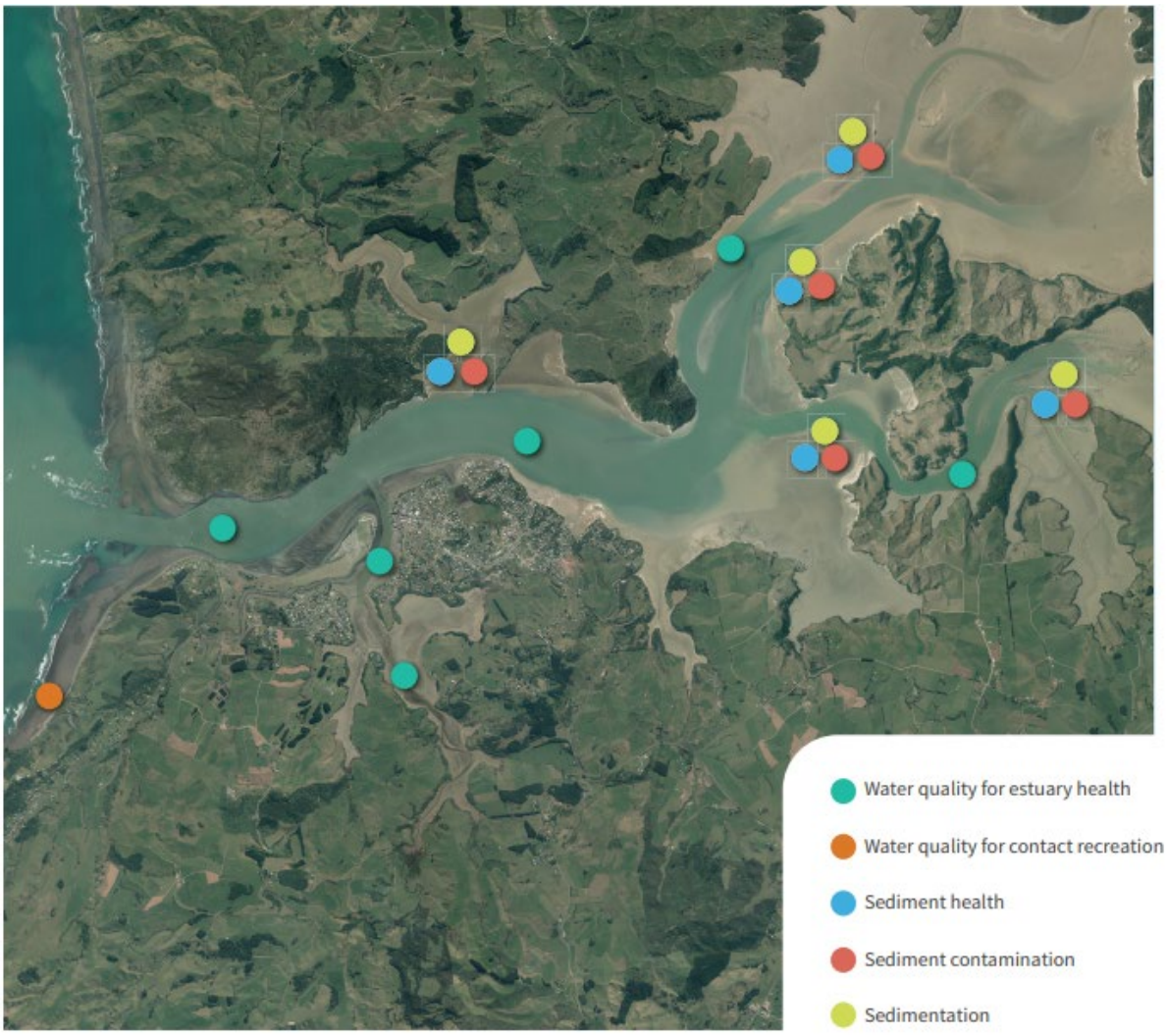


Figure 17. Map showing locations of estuarine (green dots) and recreational (orange dots) water quality monitoring stations at Whāingaroa Harbour (https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/6661-Whaingaroa-Report-Card.pdf)

Temperature data shows a broad range in Whāingaroa harbour over time. Kamke (2021) describes maximum temperatures in 2002/03 and 2013/14 over all stations ranged between 19 and 23 °C compared to a maximum temperature range between 24 and 26 °C since 2017. At the same time minimum temperatures in 2002/03 and 2013/14 ranged between 12 and 14 °C while temperature minimums since 2017 ranged between 10 and 12°C.

Total nitrogen values (Figure 18) occasionally exceeded guidelines values in 2013/14 and less frequently since 2017. However, median ammoniacal nitrogen values for all sites have exceeded the ANZECC guidelines during this monitoring period. In previous monitoring periods (2002/03), median ammoniacal nitrogen values exceeded guideline values mainly at inner and mid harbour stations.

Median total phosphorus values consistently exceeded ANZECC guideline values in 2002/03 except at the outer harbour surface station. In the following monitoring periods median values remained at or under guidelines values (Figure 18). Dissolved reactive phosphorus guidelines were exceeded at almost all stations and monitoring periods more than 75% of the time. Because of inconsistent methodologies and short monitoring timeframes, it is not possible to analyse this data statistically (Kamke, 2021).

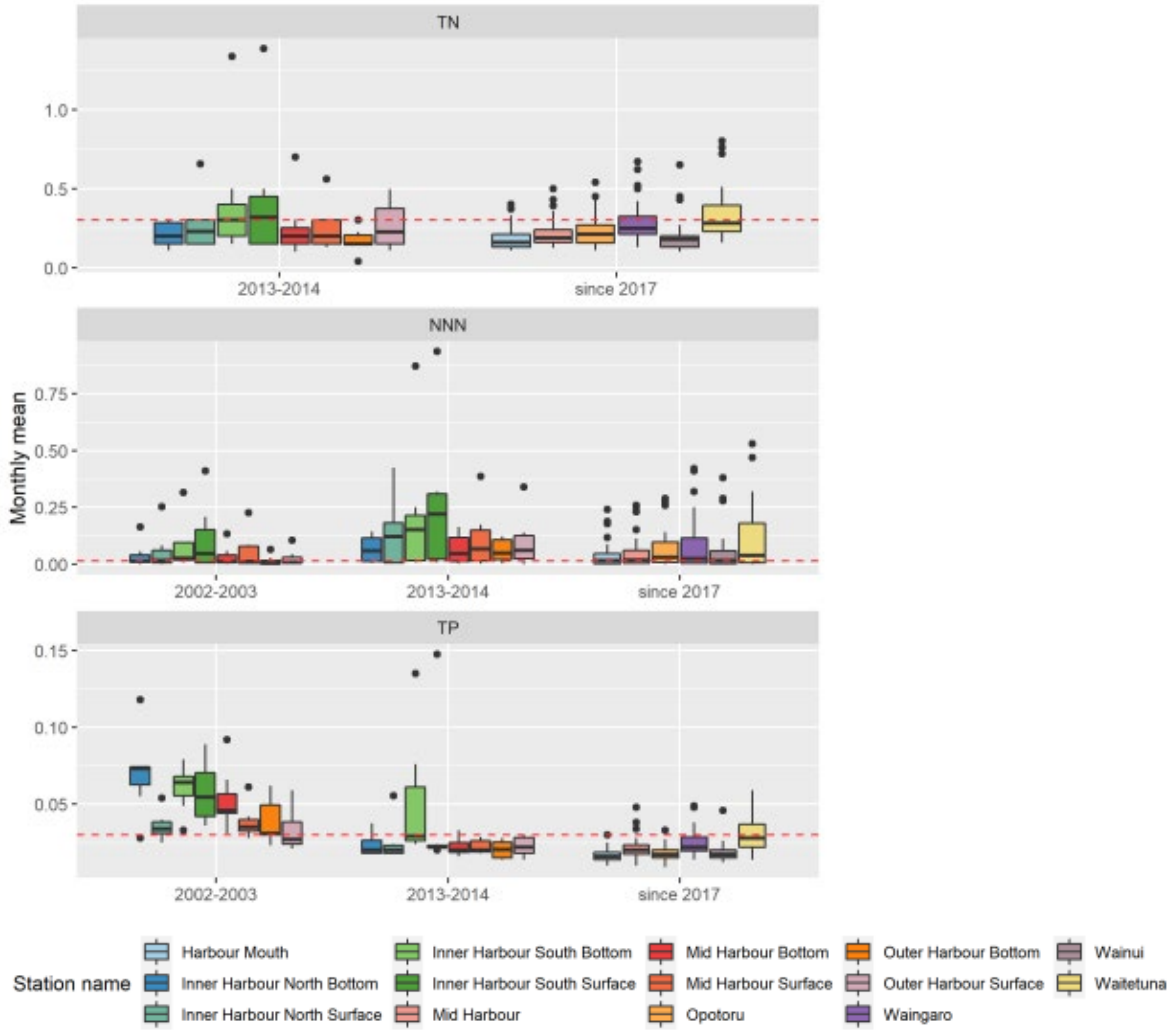


Figure 18. Distribution of chemical estuarine water quality monitoring data per monitoring period for Whāingaroa Harbour. The box represents interquartile range between the 25th percentile (lower boarder) and the 75th (upper boarder), the bold line inside the box represents the median. Vertical lines (whiskers) below and above show the data range. Outliers (calculated at 1.5 interquartile range) are shown as black circles. Dashed red lines represent ANZECC guideline limits for the respective parameter (from Kamke, 2021).

Water clarity measures, including secchi disc, total suspended solids and turbidity, from the three sampling periods showed decreased water clarity at stations in the inner harbour and best visibility at the Harbour Mouth and Outer Harbour stations.

Nutrient and sediment were often elevated at inner harbour monitoring stations in particular, Inner Harbour South and Waitetuna, which often had the highest concentrations of all monitoring stations. Inner Harbour North and Waingaro showed elevated concentrations as well but not as prominent as at the southern monitoring stations.

Water quality at the harbour mouth or outer harbour was usually better, with less sediment and lower nutrient concentrations. This points towards the catchment being the primary source for sediments and nutrients. The majority of the Waitetuna catchment which discharges into the southeast of Whāingaroa Harbour is composed of high producing exotic grassland, which may explain the increased nutrient and sediment contaminants inputs (Kamke, 2021).

1.1.10 Recreational water quality

Since 2017, microbial parameters indicated good water quality throughout the estuary. *E. coli* and enterococci concentrations remained below guidelines values with few exceptions (Figure 19). However, the 90th percentile guideline value for faecal coliforms has been exceeded at nearly all stations for all monitoring periods except for Mid Harbour, Mouth and Wainui stations since 2017. Inner harbour south stations exceeded the guideline value more than 70-fold[21] in 2013/14. The closest monitoring station in the last monitoring period (Waitetuna) exceeded the guideline value 10-fold[22]. Shellfish gathering water quality monitoring may be advisable in these areas if shellfish gathering sites are close (Kamke, 2021).

As with nutrients and sediment, microbial contaminants were often elevated at inner harbour monitoring stations in particular, Inner Harbour South and Waitetuna, which often had the highest concentrations of all monitoring stations. Inner Harbour North and Waingaro showed elevated concentrations as well but not as prominent as at the southern monitoring stations. Microbial concentrations at the harbour mouth or outer harbour were usually lower and visibility was improved compared to inner harbour sites (Kamke, 2021).

In addition to the microbial parameters measured through the estuarine water quality monitoring programme, recreational water quality has previously been monitored at four stations in the Whāingaroa (Raglan) area including Manu Bay, Motor Camp North of Bridge, Ngarunui Beach and Whale Bay. Of these sites, Ngarunui Beach is the only monitoring site still sampled. It has been monitored weekly each swimming season (Nov-March) since 2015/16 for enterococci. Recreational monitoring before 2015 was not regular for all stations and parameters (Kamke, 2021).

Recreational water quality monitoring data from Whāingaroa was generally below alert level values for swimming for enterococci at all stations and *E. coli* at Ngarunui Beach (Figure 20). The LAWA[23] website indicates that over the past 5-years (2019-2023) the Ngarunui Beach site was suitable for swimming 98% of the time.

Kamke (2021) summarises previous microbial water quality data (Figure 20) from sites within Whāingaroa harbour. At Motor Camp North of Bridge from 1994-1997 the 95th percentile *E. coli* value was 367 cfu/ 100ml. Under LAWA assessment criteria this would grade the station at a 3-yearly amber level with a moderate infection risk. Between 2000-2009 the sampling switched to enterococci and is now no longer monitored. Faecal coliform concentrations at Motor Camp North of Bridge also exceeded the median (16.5 cfu/100ml) and the 90th percentile (127 cfu/100ml) limits for shellfish gathering waters in the 1994-1997 monitoring period. During the 2000-2009 monitoring period, the 90th percentile (47 cfu/100ml) value also exceeded the guidelines.

[21] 90th percentile bottom = 3088 cfu/100ml, surface= 3570 cfu/100ml

[22] (90th percentile = 424 cfu / 100ml).

[23] Land, Air, Water Aotearoa (LAWA) - Ngarunui Beach at Raglan Harbour

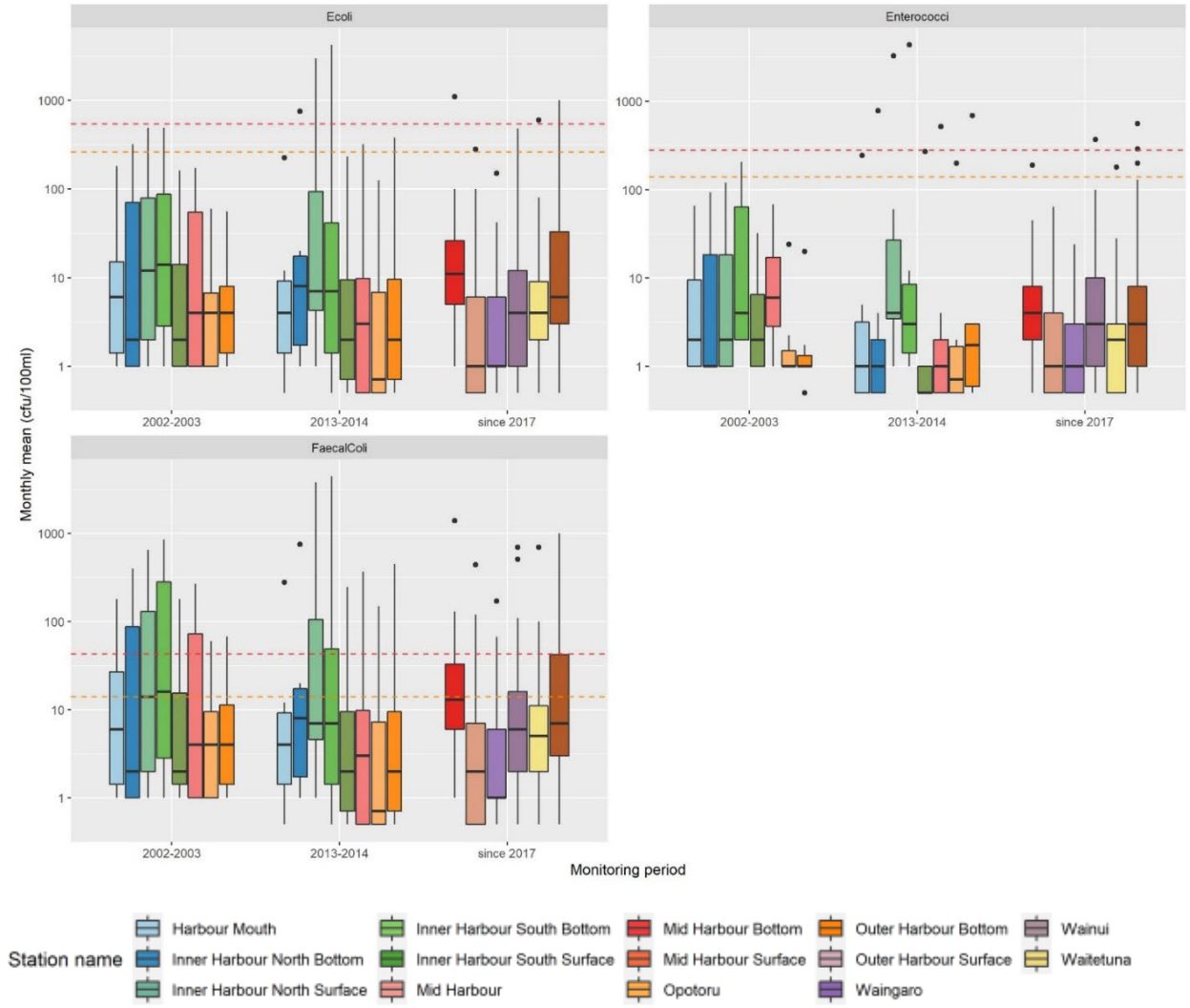


Figure 19. Distribution of microbial estuarine water quality monitoring data per monitoring period for Whāingaroa (Raglan) Harbour. The box represents in interquartile range between the 25th percentile (lower boarder) and the 75th (upper boarder), the bold line inside the box represents the median. Vertical lines (whiskers) below and above show the data range. Outliers (calculated at 1.5 interquartile range) are shown as black circles. Dashed red lines represent the red alert and dashed amber lines the amber alert limit for *E. coli* and Enterococci according to the recreational water quality guidelines for marine and freshwater. For faecal coliforms, the dashed red line denotes limit for the 90%th percentile and the dashed amber line the median limit for shellfish gathering waters (from Kamke, 2021).

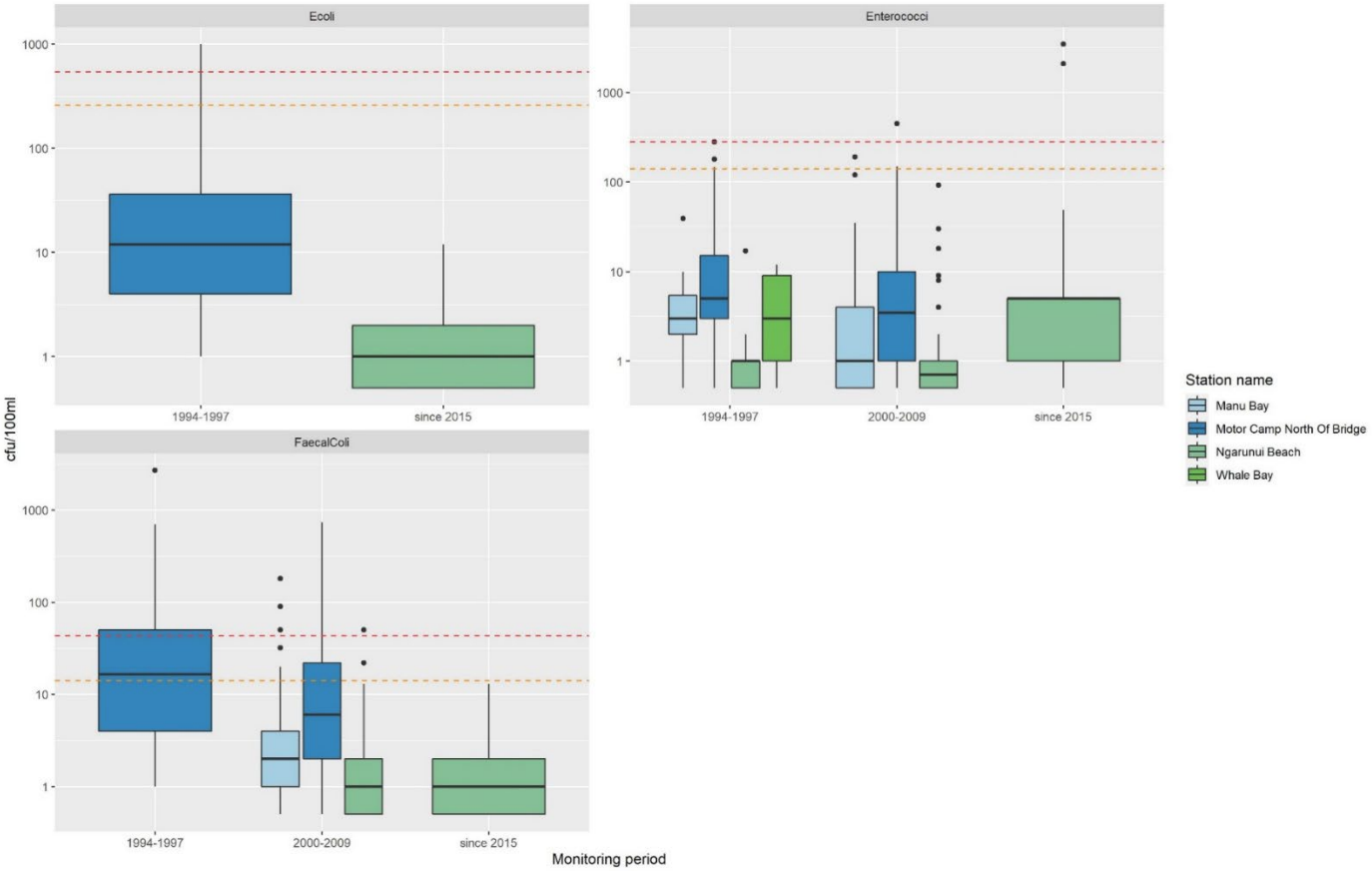


Figure 20. Distribution of microbial recreational water quality monitoring data per monitoring period for Whāingaroa (Raglan) Harbour. The box represents the interquartile range between the 25th percentile (lower boarder) and the 75th (upper boarder), the bold line inside the box represents the median. Vertical lines (whiskers) below and above show the data range. Outliers (calculated at 1.5 interquartile range) are shown as black circles. Dashed red lines represent the red alert and dashed amber lines the amber alert limit for *E. coli* and Enterococci according to the recreational water quality guidelines for marine and freshwater. For faecal coliforms, the dashed red line denotes limit for the 90%th percentile and the dashed amber line the median limit for shellfish gathering waters (from Kamke, 2021).

1.1.11 Tide gauge monitoring

Waikato Regional Council currently operates a tide gauge network to measure tidal and extreme sea levels in the Waikato region. Water levels are also continuously monitored at the Raglan Wharf (tidally influenced) and reported via the WRC website. In addition to water levels, other data such as wind speed, wind direction, atmospheric pressure and water temperature (or a subset) are monitored at each location (Hunt, 2021).

Hunt (2021) reported annual analysis of the tidal record showed no long-term inter-annual variability in tidal constituents and therefore although the tidal signal is modified compared to the open coast the tidal signal has been broadly consistent at this location over the duration of the record. Despite the historical stability of the tidal signal, there may be future changes in tidal characteristics from morphological changes in the estuary and rising sea level.

1.1.12 Summary – Coastal Water Quality

Water quality monitoring has been carried out in Whāingaroa sporadically since 2002 and regularly (monthly) since 2017. All monitoring periods showed the highest pressures from nutrients, sediment, and microbial contaminants in the eastern part of the inner harbour. Phytoplankton growth was higher at these stations and dissolved oxygen concentrations were lower in summer compared to other stations. These stations are

closest to parts of the catchment dominated by high producing exotic grassland and may be subject to pressures from farming activities and less well flushed than other parts of the harbour. Closer to the harbour mouth water quality improved likely due to higher seawater influence. This points towards catchment sources as the main contributor of nutrients, sediments and microbial contaminants in Whāingaroa Harbour. Overall, the harbour experiences some pressures from catchment sources that currently do not show major eutrophication issues but have the potential to cause these in future particularly at inner harbour locations.

Water quality for contact recreation appeared good most of the time with occasional exceedances of guideline values.

The three waters: drinking water, wastewater, and stormwater

Associated with rural and urban settlements and infrastructure development are the three waters: drinking water, wastewater, and stormwater. During the summer period demand on water infrastructure is at its highest, but the catchment also can experience fluctuating demands. This can present challenges for the provision of water infrastructure, both in terms of providing services to people and in regard to environmental effects.

Waikato District Council (WDC) owns the three water assets within their territorial boundary with Watercare Services Limited being responsible for managing and delivering these services, including capital works. An independent body, the Waters Governance Board is responsible for managing the performance for Waikato District's water services. Since 2023, Taumata Arowai has responsibility for monitoring and reporting on the environmental performance of wastewater and stormwater networks.

The WDC Three Waters Asset Management Plan 2021 – 2031 outlines a 10-year programme for the management of the Three Waters assets within the Waikato District, including an asset profile and description of each of the three water schemes. Information from this document has been used to inform the following sections on three water assets within the Whāingaroa catchment (Waikato District Council, 2021).

1.1.13 Drinking water

A fenced spring at the upper reaches of the Omahina Creek at Te Hutewai Road supplies Raglan township with its water. The catchment is predominantly farmland with small native bush remnants that backs onto Mount Karioi. The spring is open but within a fenced compound to keep out large animals and provides good quality raw water. The water that is abstracted is well protected from contamination by the collection piping structure which consists of a pipe that has been inserted deep into the spring to collect water from several meters before it emerges into the spring pond. The spring produces a relatively constant output of approximately 4,500 m^3 per day. The water is collected by two pipes drilled into the spring which discharge into a chamber before being pumped through UV and chlorination treatment. The water is then pumped to a high-level reservoir allowing it to be gravity fed to the town reticulation (piped network) and to two further storage reservoirs.

The Raglan water collection area must cope with a large increase in population over the summer period (Smart Water, n.d.). In 2001, a bore was drilled 20 metres away from the spring, intended as a supplementary source to meet the summer demand and a new reservoir was built at the quarry at the end of Cornwall Road to feed the eastern part of Raglan. The bore has never been used as the quality of water from it is poor.

The treatment process for the supply was upgraded in 2014 with a new treatment plant constructed adjacent to the existing chlorination plant. The pump activity at the treatment plant, reservoir levels, turbidity and

(free available chlorine (FAC) levels are continuously monitored and transmitted by telemetry to the operations base depot at WDC which is fully staffed (Opus, 2015).

1.1.14 Wastewater

Wastewater within the Whāingaroa Catchment is collected and conveyed to the Raglan Wastewater Treatment Plant (WWTP) which is located to the southwest of Raglan and operated by Waikato District Council (WDC). The current discharge point for treated wastewater from the WWTP is at the mouth of the Whāingaroa Harbour.

WDC have a consent to discharge up to 2600 cubic metres of treated wastewater per day into the Raglan Harbour. This consent expired in February 2020 with a short-term discharge consent application lodged to allow the WTP to continue to operate, whilst WDC assess long-term options for the WWTP.

An audit undertaken by the Waikato Regional Council on the WWTP in 2018/2019 (Waikato Regional Council 2019) concluded that suspended solids levels continue to be the most significant non-compliance issue at this site. The exceedances are not major however they are high enough to be non-compliant with the consents median and 90 percentile limits. This issue has been ongoing for several years now and the significance of this continued non-compliance has raised this issue to a serious level. The consent holder has stated that a new membrane plant will be installed to treat suspended solids and reduce them to a compliant level. This has been delayed as the discharge consent for the plant is currently due for replacement and an application has been lodged. The new resource consent may include more stringent limits, and the consent holder wants to ensure that any major capital outlay at this site is suitable to achieve any new compliance limits for the new discharge consent

1.1.15 Stormwater

Stormwater is the rainwater that drains off the land. Stormwater needs to be managed properly as it otherwise can flood roads, pose risks to public health and safety, property, or the ecological health of waterways. The Raglan stormwater scheme operates under comprehensive resource consent 105646 which expires September 2028. Stormwater is collected via catchpits and channels and is directed to the receiving water of the Whāingaroa harbour. Some treatment is undertaken within the stormwater system in the form of Enviropods fitted into some catchpits that filter out gross debris from the stormwater flows. As part of its consent conditions, WDC collects first-flush samples from three sites in Bow St and one in Wainui Rd. One Bow St discharge is sampled monthly, with the remainder sampled quarterly. This sampling has shown typical results for untreated urban stormwater runoff.

In some parts of the community, there is not a lot of formal stormwater infrastructure, with drainage occurring as overland flow before being collected in swales. WDC has counted three detention and treatment devices within the Raglan.

Biodiversity

Introduction

New Zealand's indigenous biodiversity has declined over time, particularly since human settlement. More than 200 indigenous plant and animal species are now under threat of extinction in the Waikato. Threats to our biodiversity include introduced predators and pest species, conversion of land to farmland and degradation or loss of wetlands, dunelands, river and lake systems, and coastal areas. For more information about pests see section 6.

This section provides an overview on the state of biodiversity within the Whāingaroa catchment including terrestrial, freshwater, and estuarine.

Significant natural areas (SNA)

New Zealand still contains many natural areas that provide habitats for indigenous plant and animal species and provide important ecosystem services. Some of these natural areas contain threatened species or rare types of habitats that make them more important relative to other natural areas without these features. In the Waikato region these areas are called significant natural areas (SNAs).

A Significant Natural Areas (SNA) project has been in operation at Waikato Regional Council since 2006, with the aim to identify, rank, and determine the management requirements of sites of high biodiversity value in the region, largely focussing on terrestrial areas. SNA are given a significance ranking of "international, national, regional or local" by assessing against 11 criteria defined in the Waikato Regional Policy Statement. Table 7 shows the extent of area identified in each of these categories within the Whāingaroa catchment, and this is mapped in Figure 21.

Waikato Regional Council identifies and prioritises[24] Significant Natural Areas (SNA) to:

- protect natural heritage for future generations;
- protect sufficient habitats to provide habitat for threatened species and prevent extinction;
- link up or re-connect SNAs to improve their health; and
- fulfil its obligations under the Resource Management Act 1991[25].

Table 7. Area and proportion of the Whāingaroa catchment identified as a SNA.

Level of Significance	Area (ha)	% of total catchment[26]
Likely	290.1	0.6
Local	3222.5	6.1
National	3461.1	6.6
Regional	4784.3	9.1
Total	12904.7	24.6

[24] according to its level of significance (international, national, regional or local)

[25] The Resource Management Act (RMA) 1991 requires regional and district councils to protect "areas of significant indigenous vegetation and significant habitats of indigenous fauna"

[26] 52595 ha Whaingaroa catchment

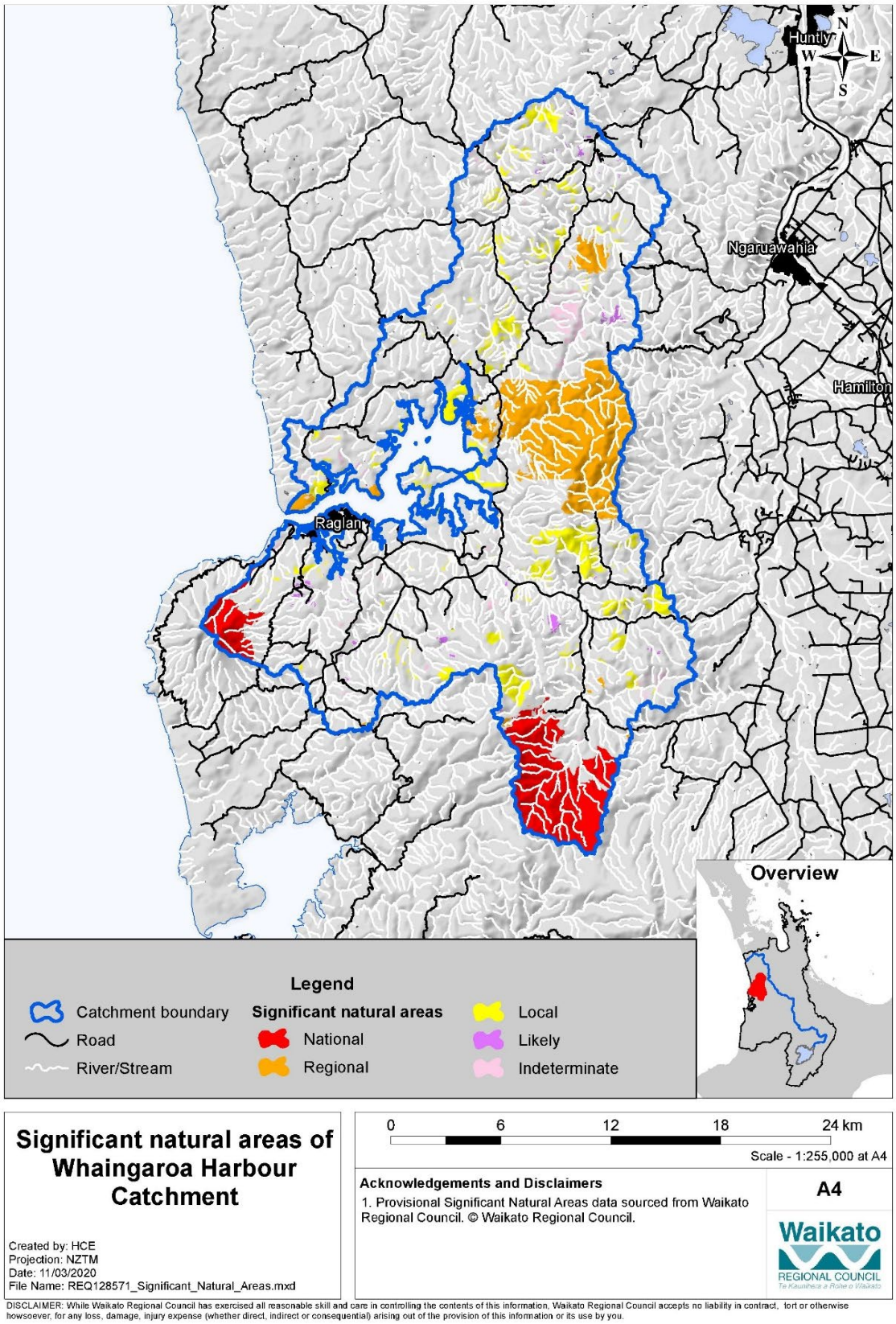


Figure 21. Significant natural areas in the Whāingaroa catchment (Singleton, 2018).

Terrestrial vegetation

The original vegetation of the Whāingaroa ecological district and the extent of change that has occurred since human settlement is described in Harding (1997) and van der Zwan and Kessels (2017).

The Whāingaroa Ecological District (ED) covers the broken hill country and low ranges and includes the drowned valley system that forms Raglan Harbour. It stretches from Port Waikato in the north to the southern side of Raglan Harbour in the south, and from the coast in the west to the Waikato River Basin in the east. It is bordered by Meremere ED in the north and east, Hamilton ED in the southeast, and Kawhia ED in the south. Ecological Districts are subdivided based on geological, pedological, topographical and botanical features.

The Whāingaroa catchment would originally have been covered in indigenous forest that extended through mature indigenous coastal forest with saltmarshes at the coastal fringe and small raupō or sedge wetlands in the narrow, entrenched gullies. The ridgelines and streams of the catchment fall to the harbour edge relatively steeply. There are (and were originally) few low-lying floodplain areas (Boffa Miskell, 2016).

Historically, in the north of the ED associations of kauri forest dominated the vegetation, with kauri-taraire-conifer-broadleaved forest dominant in the northwest, and kauri-conifer broadleaved forest dominant in the northeast. Rimu-tawa forest was dominant in the south and smaller areas of rimu-taraire-tawa forest were present. At low altitudes dense podocarp forest was relatively common and included stands of kahikatea in the flat, flood prone areas. Wetland and duneland vegetation were almost absent from the ED and only small areas of estuary vegetation existed in Whāingaroa Harbour (van der Zwan and Kessels, 2017).

The Whāingaroa catchment is now dominated by pastoral farming with small pockets of indigenous forest remaining. Exotic forest can also be found on steeper parts of the catchment. Most natural areas within the Whāingaroa ED are surrounded by farmland and therefore are potentially at risk of clearance and stock incursions. Pest animals such as possums, goats, deer, and pigs are present, and pest plants such as grey willow and wilding radiata pine are also known. Over the last 25 years, there have been substantial efforts from the community to replant the riparian margins of the catchment with over two million native plants planted.

Karst sites

Karst is a limestone landscape with sinkholes, fluted rocky outcrops, disappearing streams, underground rivers, caves, natural bridges and springs that develops because limestones made of calcium carbonate dissolve by rainfall over time[27].

Initial work has been undertaken to identify significant natural karst areas (Figure 22) and features within the Waikato region and collate information on their values. Work is underway to ground truth these sites and document their current condition.

The Whāingaroa catchment contains several significant surface and cave karst features (Hayward, 2022; Waikato Regional Council, 2022), including:

- **The Karamu Cave (308)** is a small privately owned cave karst site with 3km of passages. It has two naturally uncommon ecosystems: cave entrances; and caves and cracks. It is associated with a small

[27] See storymap about the management of karst landscapes in the Waikato region at https://storymaps.arcgis.com/stories/54ccf093bef8446badd0f3fe47adf096.

wetland and contains Myrtaceae species. The site is considered highly degraded and is surrounded mostly by pasture.

- **The Tomac Tomo (340)** is a 12.4 ha cave karst site composed of a single area, at Karamu Caves. The surface is entirely exotic pasture, with visible limestone banding/outcrop sand. It has two naturally uncommon ecosystems: cave entrances; and caves and cracks.
- **The Old Mountain Road karst (325)** is a moderately sized (54.2 ha), privately owned, surface karst site composed of vegetated limestone bluffs, and numerous small caves. It has three types of naturally uncommon karst ecosystem: cave entrances; caves and cracks; cliffs, scarps, and tors. Much of the site is pasture, but a lake and areas of wetland are also present.
- **The Raglan coastal karst (330)** is a small (10.9 ha), well-known example of coastal karst. It is mostly located on the northern side of Whāingaroa harbour, with one area further up the harbour to the east. A small area of wetland habitat is present, providing habitat for indigenous flora and fauna species. Naturally uncommon cliffs, cracks are present.

Most of these areas occur on private land and support a wide range of rare and threatened species. These sites are vulnerable to pest animals and weeds, and human visitation, as well as further impacts arising from grazing and other agricultural impact associated with rural land use.

Changes in terrestrial ecosystems within the Whāingaroa catchment

As in many parts of New Zealand, the indigenous flora and fauna of Whāingaroa catchment has been greatly reduced relative to its former extent (Golder Associates, 2007). Despite this, the Whāingaroa catchment contains a number of significant natural areas that contain important threatened species or rare habitat types and perform important ecosystem services.

In 1840, the area around Raglan was relatively isolated, so intensive deforestation did not occur in the area until 1879 when the first Waipa-Raglan road was completed (Swales et al., 2005). A summary of vegetation cover for the Raglan ED in 1995 (Leathwick et al., 1995) shows that only 13.3% of forest (primary, secondary and cutover), and 53.3% of freshwater and wetland habitat remained, with only 0.1% being wetland. There has been an almost three-fold increase from the original extent of secondary scrub/shrubland (Leathwick et al., 1995).

Coastal and lowland vegetation has been significantly affected as a result of clearance and development. Vegetation occurring at lower elevations and particularly floodplain vegetation has been largely removed for pastoral land development. Higher elevation areas, which are unsuitable for farming, have retained their indigenous character but have been modified by the removal (i.e. logging) of larger podocarp species. Several blocks of indigenous forest remain. Coastal forest species include kohekohe, nikau, puriri and tawa.

To identify the remaining extent of land cover for different ecosystem types it is necessary to have an accurate inventory of both current indigenous vegetation and original coverage (the latter known as the Potential Ecosystem (PE) Layer developed by Singers and Rogers (2014)). The average accuracy of the current biodiversity inventory data is ~60%[28], but will increase to >80% with work that is currently underway to verify the terrestrial vegetation data that WRC holds. A map of potential ecosystems in the Whāingaroa catchment is shown in Figure 22 and the codes used to identify ecosystem are explained in Table 8. A draft map of estimated[29] current ecosystems in the catchment is shown in Figure 23.

[28] *Based on the WRC biodiversity inventory layer*

[29] The draft biodiversity inventory has not been ground-truthed and is therefore indicative only.

The area of coverage of each ecosystem type in the potential and estimated current ecosystems maps are also shown in Table 8, alongside the calculated percentage remaining, indicating the reduction or increase in all ecosystem types.

Comparing potential and current ecosystems highlights substantial reduction or loss of valuable ecosystems in the catchment. There has been a complete loss of kauri-podocarp-tawa forest and totara-kanuka-broadleaved (dune) forest. Only 13% of the original Hall's totara-pahautea-kamahi forest remains today.

Table 8 suggests there has been a significant increase in wetland ecosystems, but this is largely due to re classification of vegetation types from the warm forest categories WF13 and WF8 to wetland categories.

Almost 70 % of all saline ecosystems, such as seagrass herbfields, mangrove forest and saltmarsh, have been lost. Seagrass herbfields have seen the greatest depletion with only 0.3% remaining.

However overall, the Whāingaroa catchment still contains large areas of high biodiversity value, most notably the indigenous forests in the upper catchment and areas of scrubby manuka and kanuka, which can support further forest regeneration.

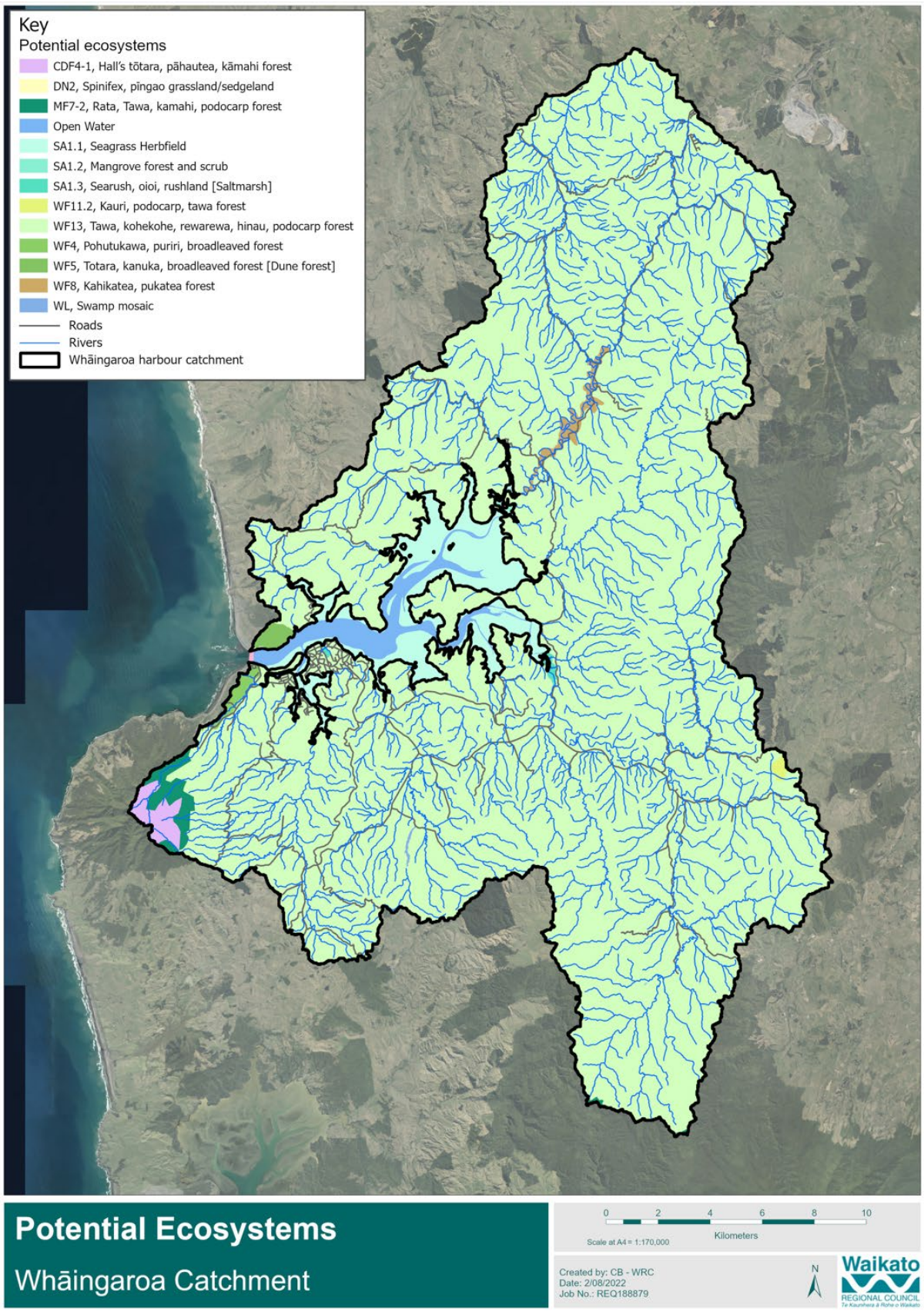


Figure 22. Potential ecosystems in the Whāingaroa catchment

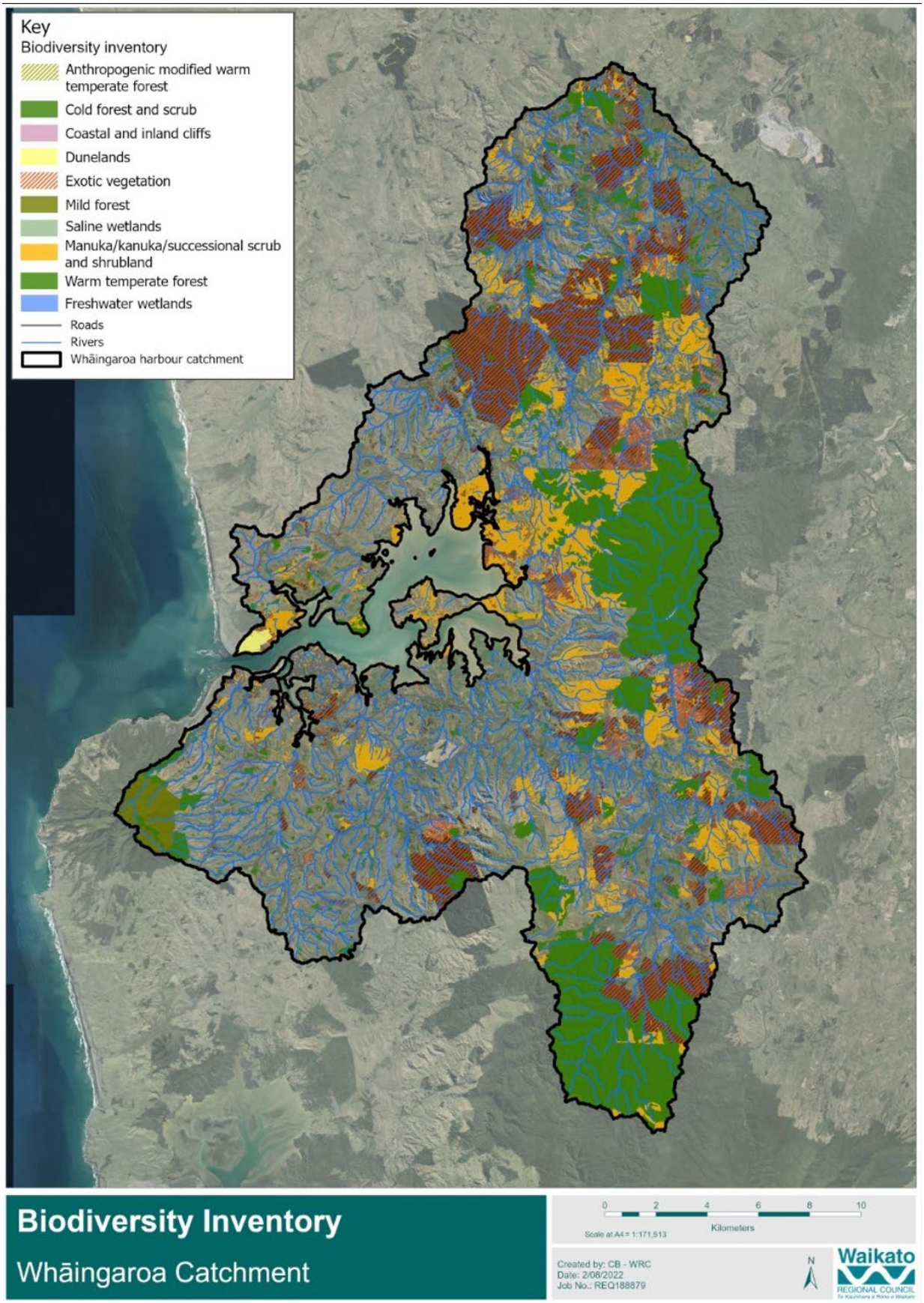


Figure 23. Draft biodiversity inventory for the Whāingaroa catchment.

Table 8. Ecosystem types used to map potential ecosystems and the draft biodiversity inventory. The estimated potential and current area of each ecosystem type is shown as well as the percentage remaining today compared to the potential coverage. Colour codes are explained below the table.

Code	Ecosystem type	Potential Area (ha)	Current Area (ha)	Remaining (%)
Anthropogenic (A)				
AVS1	Anthropogenic totara forest		24.05	
AWF1	Anthropogenic kahikatea forest		20.25	
AWF3	Riparian Forest – Adv Sec Riparian Forest – totara, kanuka, kahikatea		6.69	
Cold forest and scrub (CDF)				
CDF4-1	Hall's totara, pahautea, kamahi forest	259.14	33.71	13.01
Cliffs (CL)				
CL2	Ngaio, taupata treeland/herbfield/rockland		3.20	
Active coastal sand dunes (DN)				
DN2	Spinifex, pingao grassland/sedgeland	1.37	1.35	98.69
DN2/5	Coastal Sand Dunes Mosaic		61.26	
Exotic (E)				
EF-FH	Forest Harvested		591.37	
EF-OEF	Other Exotic Forest		263.80	
EF-PFCC	Pine Fore–t - Closed Canopy		5712.03	
EF-PFOC	Pine Fore–t - Open Canopy		548.69	
EF-WIL	Willow		13.19	
ES-DHW	Deciduous Hardwoods		38.47	
ES-EGH	Exotic grassland, herbfield, rushland		110.25	
ES-GB	Gorse, Broom, pampas and woolly nightshade		779.43	
ES-MES	Mixed Exotic Shrubland		17.46	
Mild Forest (MF)				
MF4	Kahikatea forest		1.11	
MF7-2	Rata, Tawa, kamahi, podocarp forest	320.09	252.82	78.99
MF8-1	Kamahi, broadleaved, podocarp forest		216.55	
Saline (SA)				
SA1.1	Seagrass herbfield	124.18	0.40	0.32
SA1.2	Mangrove forest and scrub	10.40	6.29	60.47
SA1.3	Searush, oioi, rushland [Saltmarsh]	56.65	46.84	82.67
SA1.6	Saltmarsh, ribbonwood, ngaio, akeake scrub		4.92	
SA1.7	Saline herbfield (sea meadow) – glasswort, sea primrose, half star, shore celery, sea rush, etc		0.55	
Vegetation Succession (VS)				
VS15	Conifer-rich regenerating scrub-forest – rimu, totara, matai, miro and kahikatea		15.69	
VS15.1	Conifer-rich Adv Sec Fore–t - rimu, totara, matai, miro and kahikatea		60.82	
VS16	Restoration/Revegetation – mixed native plantings		81.29	
VS17	Mixed native and exotic shrubland		1102.62	
VS2	Kanuka scrub/forest		1707.56	
VS2.1	Advanced regenerating podocarp with kanuka		385.94	
VS3	Manuka-Kanuka		1659.64	
VS3.1	Adv sec with regen conifers through Manuka-kanuka mosaic		30.40	
VS4	Manuka		10.04	

VS5	Broadleaved species scrub/forest mosaic/treefern scrub		418.39	
VS5.1	Adv sec broadleaved fore–t - most kamahi-dominated		121.01	
VS5.2	Tree fernland		142.07	
Warm Forests (WF)				
WF11.2	Kauri, podocarp, tawa forest	43.30		0.00
WF13	Tawa, kohekohe, rewarewa, hinau, podocarp forest	51240.80	8346.98	16.29
WF13.1	Lowland, semi coastal, increasing puriri		19.84	
WF4	Pohutukawa, puriri, broadleaved forest	131.95	3.91	2.96
WF4.1	Coastal/semi coastal, little or no Pohutukawa		115.10	
WF5	Totara, kanuka, broadleaved forest [Dune forest]	105.37		0.00
WF7-3	Kahikatea, puriri forest		0.37	
WF8	Kahikatea, pukatea forest	240.47	255.13	106.10
WF8/WL	Kahikatea, pukatea forest and Swamp mosaic		14.64	
Wetlands (WL)				
WL-FM	Fen mosaic		7.15	
WL-SFM	Swamp/Fen mosaic		2.34	
WL-SM	Swamp mosaic	51.59	284.04	550.61
WL18	Flaxland		0.31	
WL19	Raupō reedland		0.86	
Other	Other		13.99	
Strand	Strand		0.35	

Absent

<20% remaining (underrepresented in catchment)

>20% remaining

>Expected

Rivers and Streams

Biodiversity river prioritisation for the Waikato identified the highest value rivers most representative of a particular river type in the region based on stream geology, associated species, climate and a range of other factors. The approach also included combining physical information with cost-benefit aspects of restoration. For example, sites that have DOC estate in headwaters are more likely to benefit from restoration than those with highly developed upstream environments (Leathwick and Julian, 2009).

As part of the SNA analysis of streams and rivers a total of 12.72% of the Whāingaroa catchment had areas which had been identified within the top 20% of sites identified as SNAs within the region (Waikato Regional Council, 2016). Areas of the following catchments were identified:

- Ohautira River
- Oruawha Creek
- Opotoru River
- Wainui Stream

- Maunurima Stream
- Waitetuna River
- Korere Stream
- Otonga Stream
- Mangaokahu Stream
- Mangakirikiri stream

Rivers identified through this method are in principle the best candidates for restoration/conservation. However, the prioritisation approach is mainly a desktop exercise and there will be features in the riverscape that were not considered but that affect outcomes. For this reason, sites and their upstream environments would need to be visited and assessed before any results shown here can be used to inform restoration/conservation activities.

Lakes

The Waikato Regional Council has more than 70 shallow lakes that provide for a wide range of values including wildlife habitats, water supply, flood control, commercial and traditional fisheries, and recreation. These lakes also perform nutrient cycling and other ecosystem processes that contribute to the life supporting capacity of the wider environment.

The only recorded lake near the Whāingaroa catchment is Lake Waitamoumou, which is located on the northern head of the Whāingaroa harbour mouth, just outside of the mapped catchment boundary. Dean-Speirs and Neilson (2014) identified that there was insufficient information about Lake Waitamoumou to inform future management recommendations. As a result, it was categorised in WRC's Shallow Lakes Management Plan as "data deficient" and a priority to visit to assess condition and future management requirements.

Whāingaroa Harbour

Whāingaroa Harbour is a drowned river valley that runs 12 kilometres inland from the entrance and is mostly less than two kilometres wide. The harbour has an area of 3,185 hectares and is subject to a strong tidal influence with around 70% (c.2,400 hectares) of tidal estuarine flats that are exposed at low tide (Fisher 2014). Estuaries provide essential ecosystem services and contribute to critical processes that influence ecosystem health and water quality, including clarity, nutrient cycling and sediment stability. Estuaries also provide habitat for species that are important food resources for humans, fish, birds and other species (Hillock and Rohan, 2011).

The coastal waters and margins of Whāingaroa Harbour have been assessed to have high amenity natural features and landscapes (Boffa Miskell Limited, 2016). Whāingaroa Harbour is also identified as an Area of Significant Conservation Value in the Waikato Regional Coastal Plan for a range of reasons including (but not limited to):

- Site of cultural significance to Tainui;
- Resident and frequenting rare and threatened wading and coastal bird fauna;
- Hectors (Maui) dolphin area;
- Recognised southern limit of mangroves.

Whāingaroa harbour extends a long distance inland and has a largely unmodified landform with a narrow neck and mouth relative to the harbour size. The surrounding watercourses drain into the harbour and as

a result, the margins are highly indented. The harbour itself has area of indigenous vegetation, and numerous rivers that form channels across the extensive inter-tidal flats.

Shorebirds in Whāingaroa Harbour

Whāingaroa catchment margins and harbour supports a diverse array of birds, including several rare and threatened species.

Graeme (2012) described banded rail presence amongst mangroves in the Waingaro River arm, and bittern and fernbird associated with the ribbonwood and freshwater wetland vegetation that occurs in the Waitetuna River arm. She also compiled the following list of birds that were observed during a survey of estuarine vegetation:

- Banded rail
- Barnyard goose
- Australasian bittern
- Black-backed gulls
- Canadian goose
- Fernbird
- Little black shag
- Mallard duck
- Paradise duck
- Pied oystercatcher
- Pied shag
- Pied stilt
- Spur-winged plover
- Red-billed gull
- Welcome swallow
- Bar-tailed godwit
- Kingfisher
- Kōtoku

Fifty-one sites of importance to shorebirds and/or seabirds have been identified in the Waikato region, 11 on the west coast, and Raglan Harbour has been identified by Dowding (2019) as a priority two site. Priority two sites contain Threatened or At-Risk species, but not at the 1% level[30]. Dowding (2019) also notes that the west coast of the Waikato Region is highly important as the entire western coastal strip of the region has very high ecological value as the primary north-south shorebird migration route in the country.

Dowding (2019) reports that the main short-term threats to resident species are predation, disturbance during breeding, and natural factors, such as flooding of nests. In the longer term, loss and degradation of habitat (from both natural and human-induced causes) will affect both resident and migratory species.

Whāingaroa harbour provides important feeding and roosting grounds for large (and increasing) populations of waterfowl, including black swan and Canada geese, that utilise the harbours during moulting. There is widespread concern about their impacts on the ecology of the harbour because of their grazing pressure on seagrass communities. There is also some concern about their indirect impacts on sea grass and wider harbour ecology through trampling, increased turbidity, eutrophication via deposition of faecal matter, and wider ecological effects including impacts on indigenous birds[31], and dispersal of undesirable plants and animals (Smith, 2019).

Aquatic fauna in the Whāingaroa catchment

1.1.16 Shellfish in Whāingaroa Harbour

Shellfish perform important ecosystem services in estuaries. They form a key component of shorebird and fish diets and are a significant source of mahinga kai for mana whenua. The presence of shellfish can have a profound impact on water quality as they feed by pumping water across their gills and filtering out food particles. The removal of organic particles from the water column is likely to improve water clarity and provide for greater light availability and increased primary production.

[30] Containing at least 1% of the global population
[31] including disease risk and competition

Monitoring of cockle and pipi populations in Whāingaroa harbour by MPI between 1999 - 2018 indicated that total population of both species had been relatively stable over the previous five to ten years, but that the proportion of the population made up by large individuals was relatively small (Berkenbusch and Neubauer, 2018).

The WRC Regional Estuary Monitoring Programme (REMP) focuses on monitoring intertidal benthic macroinvertebrates (i.e., animals such as shellfish that live in estuarine sediments) and sediment properties as indicators of ecological health in the Waikato region (Jones, 2021). This monitoring programme has been carried out in the harbour since 2001 and Whāingaroa is one of two sites where WRC has a long-term monitoring programme. Sampling involves collection of sediment cores from five sites in Whāingaroa harbour – Ponganui Creek, Whatititrinui Island, Te Puna Point, Haroto Bay, and Okete Bay (Figure 11).

Summaries of monitoring results for each monitoring site in Whāingaroa Harbour, as presented in Jones (2021), are provided below. Summarised estuarine health results up to 2020 are provided in the Whāingaroa Harbour Marine Report Card (Appendix 1).

Haroto Bay

Estuarine health indices suggest this site is in poor health. High rates of sedimentation (c. 2.3 mm/year), a significant increasing trend in organic matter, and indicator species trends suggest health is declining at this site. Of note there was a significant decreasing trend in cockle numbers.

Okete Bay

Estuarine health indices suggest this site is moderately healthy, although with relatively high mud content (c. 26%). Sedimentation rates were highly variable but averaged c. 1.4 mm/year. A significant increasing trend in organic matter, and several trends in indicator species suggest health is declining at this site.

Te Puna Point

Estuarine health indices suggest this site is in good health, with c. 14% mud. Sedimentation rates suggest net erosion (c. -1.3 mm/year) and one trend in indicator species suggests health is improving at this site.

Whatitirinui Island

Estuarine health indices suggest this site is in moderate to good health, with c. 16% mud. Sedimentation rates suggest net erosion (c. -2.1 mm/year), and three out of four indicator species trends also suggest health is improving at this site, however, there has been a decreasing trend in wedge shells between 2012-2018.

Ponganui Creek

Estuarine health indices suggest this site is in good health, with c. 14% mud. There is little net sedimentation (c. 0.8 mm/year), but a possible increase in mud content and trends in indicator species suggest health is declining at this site.

The long-term information on sediment characteristics and shellfish abundance and distribution in Whāingaroa Harbour has generated robust knowledge and is a good baseline for future comparisons. This is particularly important for assessing impacts from sedimentation and suspended sediment input into the harbour. Studies have shown that cockles and wedge shells may tolerate short term exposure to pulses of suspended sediment, but that sustained exposure is problematic. Terrigenous sediment (eroded from the land) is known to be more difficult for cockles to process than re-suspended marine sediments (Bouma, 2016).

1.1.17 Freshwater fish and macroinvertebrates

Waikato Regional Council monitors the ecological health of 3 waterways within the Whāingaroa catchment as part of its River Ecological Monitoring of Streams (REMS) Programme. In this programme, macroinvertebrate and stream habitat is assessed at sites in the Waitetuna River catchment (on the Mangaokau and Parawai Streams) and the Wainui Stream. The results are summarised in Table 9 and are available from the LAWA website https://www.lawa.org.nz.

Table 9. Results from ecological health monitoring undertaken within the Whāingaroa Catchment between 2014-2022 (www.lawa.org.nz)

Site	**Macroinvertebrate Community Index (MCI)***			**Taxonomic Richness**	**%EPT*****
	5 yr median	**National Objective Framework (NOF)** attribute band**	**Trend**	**5 yr median**	**5 yr median**
Mangaokau Stream @ Cogswell Rd	129.2	Band B (mild organic pollution or nutrient enrichment)	Very likely improving	24	64
Parawai Stream @ Ohautira Rd	98.1	Band C (moderate organic pollution or nutrient enrichment)	Indeterminate	29	31
Wainui Stream	103.4	Band C (moderate organic pollution or nutrient enrichment)	Likely improving	29	39

* Higher MCI score indicates better stream conditions.
** As per the National Policy Statement for Freshwater 2020 Appendix 2B Table 14 National-Policy-Statement-for-Freshwater-Management-2020.pdf (environment.govt.nz)
*** EPT are macroinvertebrates that are sensitive to water pollution. These are Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly).

Most of New Zealand's native freshwater fish require unimpeded migratory access to the sea and back to complete their lifecycle. As a result, they are extremely sensitive to catchment changes, and most species have suffered substantial population declines as a result of habitat modification and loss. Habitat modification can substantially limit instream habitats, for example:

- Sedimentation can reduce water quality, the amount of available habitat[32], and smother spawning sites and fish eggs. Good sediment management within the catchment to minimise sediment loads into rivers and streams is thus important for supporting our freshwater fish biodiversity.
- Fish passage through the catchment can be severely restricted by inappropriate structures (including culverts and fords). National guidelines have been developed for the design of instream infrastructure to provide for fish passage[33]. In the Whāingaroa catchment 194 culverts were previously surveyed. Under low flow conditions, 14% were considered to pose a barrier to natural

[32] Including by filling interstitial spaces on the stream bed
[33] www.niwa.co.nz/static/web/freshwater-and-estuaries/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf

fish passage. An additional 42% of culverts were considered to be a barrier regardless of flow conditions. Only 41% of the culverts surveyed provided adequate fish passage (Speirs and Kelly, 2001).

- Fish are very sensitive to changes in river and stream water quality, including temperature[34]. Instream temperatures are directly related to the amount of riparian vegetation/shading that is available. Riparian vegetation is a key component of restoration projects that have considerable benefits for freshwater fish and invertebrates

To monitor the state of freshwater fish populations in the region, Waikato Regional Council developed a standardised fisheries sampling programme in wadable streams in 2009 and added routine fisheries sampling to the Councils existing Regional Ecological Monitoring of Streams (REMS) programme in 2011/12 (David et al., 2016). This has involved establishing a network of 160 sites across the region that are fished at least once every 3 years[35].

The data that has been collected provides a baseline of information to monitor 'state' (and any changes over time) to better inform policy development and management decisions. It is likely that the data from the REMS invertebrate and fish monitoring programmes will be amalgamated, and that metrics will be developed in future to provide a much more comprehensive and holistic assessment of the state and health of the Waikato wadable river network.

1.1.18 Freshwater mussels (kākahi or kāeo) in wadable streams and rivers

New Zealand has three species of native (and endemic) freshwater mussel (kākahi or kāeo), *Echyridella menziesii*, *Echyridella aucklandica* and *Echyridella onekaka* that play an important functional role within ecosystems and are recognised as a cultural keystone species[36]. However, all three species have been classified as "Nationally Vulnerable" or "At Risk" under New Zealand's threat classification system (Grainger et al. 2014).

Two of these mussel species *(Echyridella menziesii*, *E. aucklandica)* are known to occur within the Whāingaroa catchment. To monitor freshwater mussel populations, Waikato Regional Council has developed a standardised protocol for monitoring in wadable streams and rivers (Melchior et al., 2023), which has been applied in five catchments of the Waikato region between 2013-2017. The result of this work indicates that freshwater mussels generally occur in low densities, with a few exceptions where dense populations occur. The Whāingaroa catchment had the highest presence of both species compared to the other catchments surveyed, followed by Kāwhia.

Work so far suggests that the main factors that influence the presence of freshwater mussels are the presence of silt, runs, and bank habitat. Size structure was investigated and appears to show ageing populations for both species with little sign of juvenile recruitment.

Aquatic flora in the Whāingaroa Catchment

1.1.19 Wetland Vegetation

Wetlands are biologically rich and important features and are important transition zones between land and water. They are characterised by local conditions (hydrology, soils and vegetation). Wetlands provide a number of beneficial services for people and for fish and wildlife which include protecting and improving

[34] which directly affects oxygen saturation levels, and the toxicity of a range of contaminants
[35] With the exception of 15 reference sites that are visited annually.
[36] because of their cultural importance (as a taonga species and a source of mahinga kai) for Maori

water quality; providing fish and wildlife habitats; storing floodwaters and maintaining surface water flow during dry periods.

As in the rest of NZ, many wetlands have been reduced and lost from the Whāingaroa catchment as a result of drainage and historical land use changes. Consequently, very few wetlands remain in the catchment, and any remaining natural wetlands are considered highly significant. A freshwater wetland on Pond Rd is described as the largest freshwater wetland (>2ha) within the Whāingaroa catchment.

Significant and under-represented freshwater wetland vegetation was identified within the Whāingaroa catchment by Graeme (2012) at the Waitetuna River mouth and within the Opotoru River arm. The Waitetuna River mouth supports bittern, fernbird and banded rail. Graeme (2012) has recommended protection of the remaining freshwater wetland communities and restoration of degraded wetland areas within the harbour catchment.

1.1.20 Estuarine Vegetation

Estuarine vegetation, such as salt marsh, mangroves and seagrass provide shelter, food, breeding and nursery grounds for animals such as fish, birds and shellfish. These habitats also act as filters, trapping sediment, nutrients and other contaminants, which improves estuarine water quality. Estuarine vegetation can also stabilise sediments and acts as a natural buffer between the land and ocean, absorbing floodwaters from land and storm surges from the ocean. Estuaries are characterised by very high biodiversity which is a function of their productivity, and the variety of habitat types they contain.

The exposed and sedimentary coastal edge environment of Whāingaroa harbour is not well suited for estuarine vegetation communities but the harbour supports important areas of estuarine vegetation that are largely restricted to the sheltered arms of the harbour (Graeme, 2012). The largest and most diverse areas of estuarine vegetation occur in the Waingaro, Ohautira, and Waitetuna River arms as shown in Figure 24.

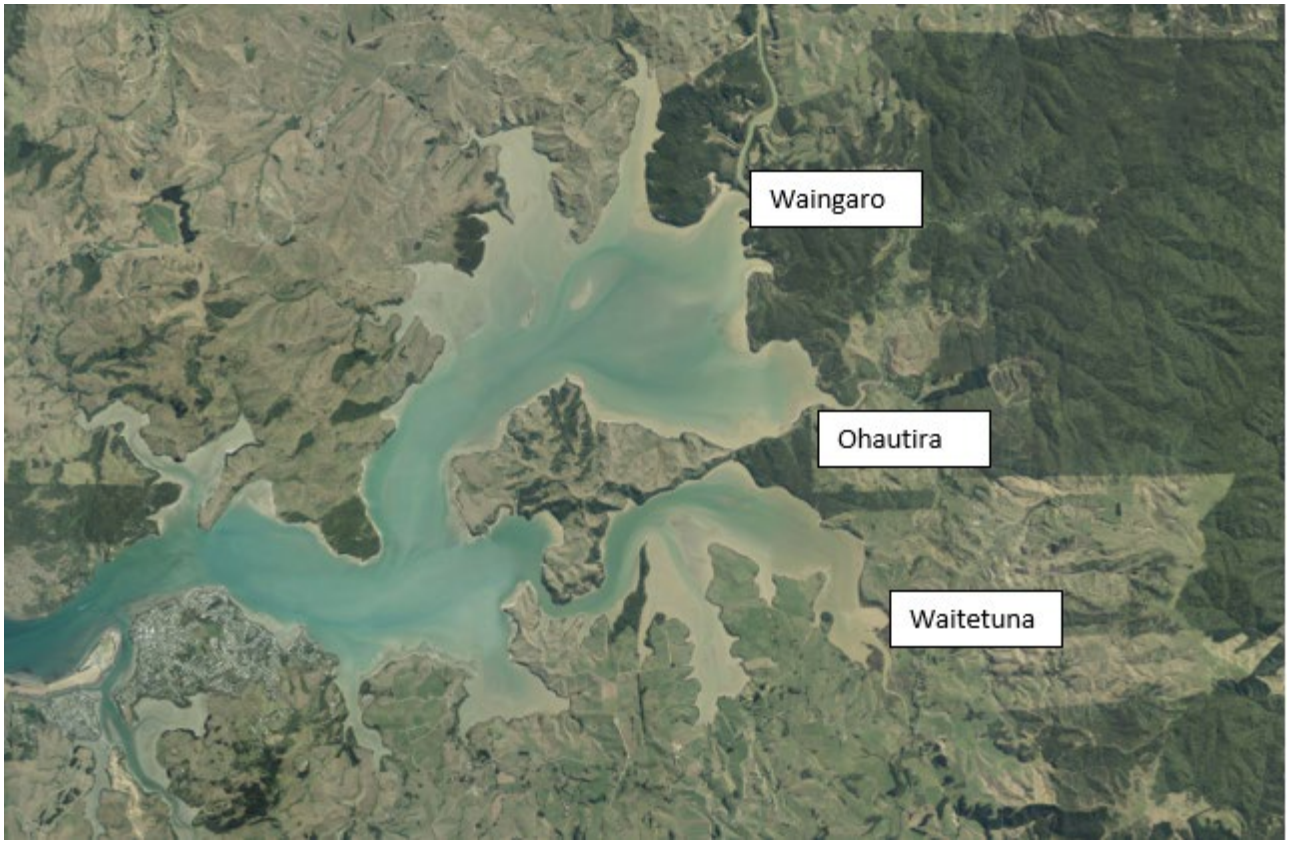


Figure 24. Map of Whāingaroa harbour and marked river arms with most diverse estuarine vegetation.

The estuarine vegetation of Whāingaroa harbour includes mangroves, salt marshes, seagrass, sea meadows and weed communities. Figure 24 provides an indication of the location of vegetation within an estuarine environment. The distribution of mangroves, saltmarsh and seagrass within the Whāingaroa Harbour are provided in Figure 25, Figure 26 and Figure 27 respectively, with further detail provided below:

Mangroves (*Avicennia marina* var. *resinifera*)

Graeme (2005) reported that scattered young mangroves existed up the heads of some of the south-southwestern bays/arms of the harbour. Larger mangroves were found to the north-northeast of the harbour especially up the Waingaro arm where the trees reached 3-4m in height. Graeme (2005) observed that mangrove establishment may assist in stabilising (i.e. reducing wave erosion) of the harbour edges, although they are unlikely to establish on the open wave-prone coastlines (e.g. Pairere Point).

Saltmarshes

Saltmarshes are composed of mixtures of low-growing herbs (sea meadows)[37], rushes[38] and sedges[39]. Sea meadows generally occur as thin bands (0.5-1.0m wide) or mixed with rushland along the upper tidal zone. Silver tussock occurs on headlands and exposed areas, as well as in patches behind other sea meadow species.

[37] e.g. glasswort, sea primrose
[38] e.g. sea rush
[39] e.g. oioi, knobby clubrush

Graeme (2005) observed that saltmarsh is extremely limited in extent in Whāingaroa harbour, partly as a consequence of the geology and past infilling. As a result, all remaining areas of saltmarsh are considered to be highly significant. Despite their significance and rarity, remaining saltmarsh ribbonwood communities have also been modified for farming (through grazing or infilling). The Ohautira River arm was described as supporting extensive and important rushland and saltmarsh ribbonwood communities (Graeme, 2012). Graeme (2012) observed signs of saltmarsh receding at various places around the harbour but also saw signs of active growth in other areas.

Seagrass

Seagrass has a far more restricted distribution in Whāingaroa harbour (compared with Aotea and Kawhia harbours). Graeme (2012) reports that seagrass beds are a major feature along the town foreshore up past Lorenzen Bay and past the one lane bridge up into the Opotoru River arm. They are also a feature up the freshwater landing side arm of the Waingaro River.

Figure 25. Mangrove distribution in Whāingaroa Harbour. Source: Bouma (2016).

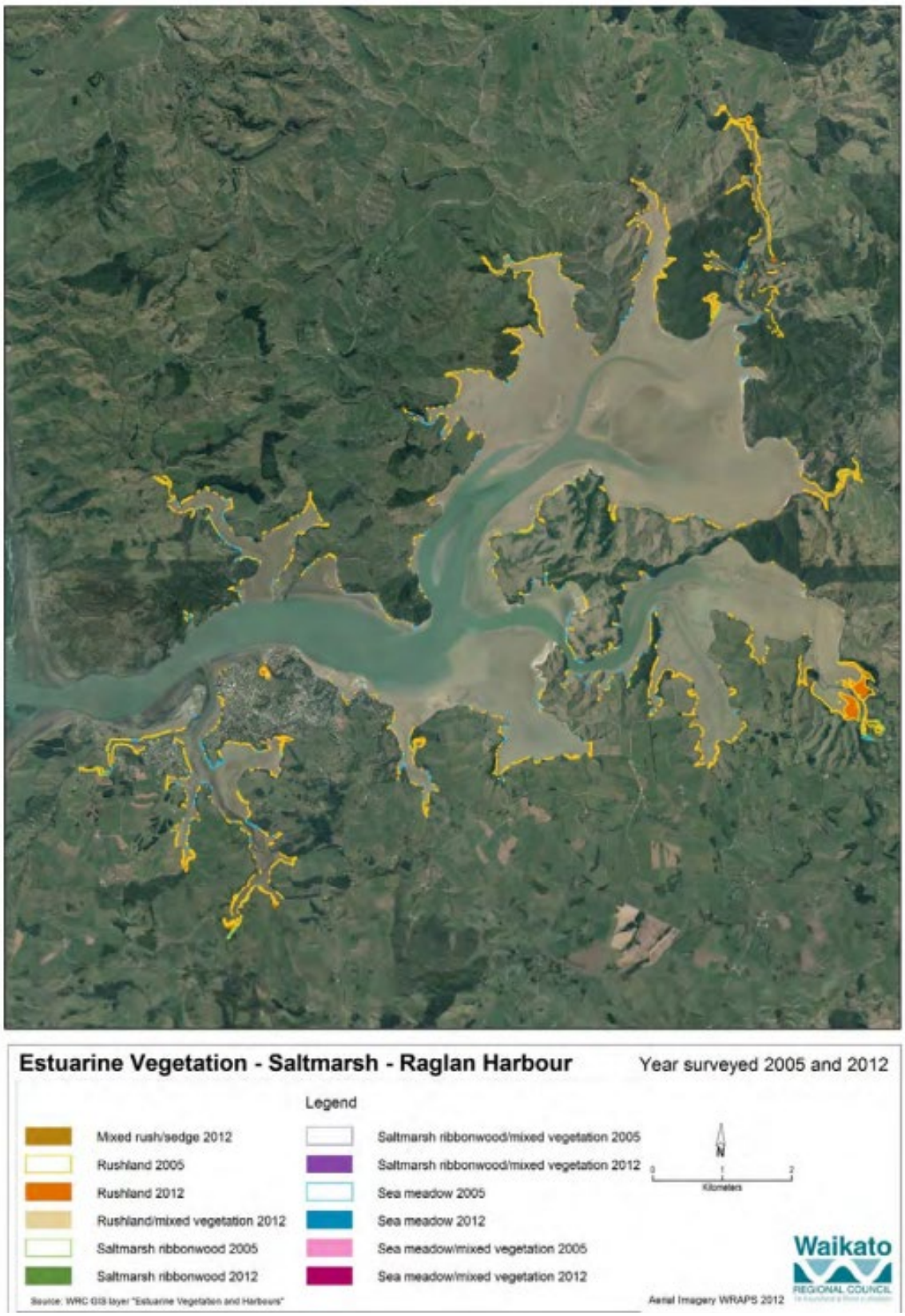


Figure 26. Saltmarsh distribution in Whāingaroa Harbour. Source: Bouma (2016).

Figure 27. Seagrass distribution in Whāingaroa Harbour. Source: Bouma (2016).

Biosecurity

Introduction

Many of New Zealand's indigenous species evolved and once thrived without any native predators. However, many introduced pests arrived with humans, and threaten the survival of our indigenous species. Biosecurity helps to prevent or reduce any damage caused by plant or animal pests.

Waikato Regional Council also undertakes a range of monitoring, surveillance, enforcement and direct pest control work. Staff also offer advice and information and organise larger scale control programmes.

Pest management is undertaken and prioritised according to a range of considerations, including:

- Protection of sites with high biodiversity values.
- Excluding pests from areas they do not yet occur.
- Rapid eradication of pests that are a high threat but low occurrence.
- Ongoing maintenance and surveillance to achieve and maintain eradication. This often includes long term commitments from private landowners' and other stakeholders.

In this section, information on a range of pest plants and animals that threaten the Whāingaroa Harbour catchment is provided.

1.1.21 Pest Animals

Goats are a wide-ranging problem along the coastal edge of the Whāingaroa harbour. They are having a detrimental effect on the regeneration of the riparian coastal forest, and trampling and browsing of estuarine vegetation communities by goats has been noted in a number of areas. They are also a possible vector for the further spread of saltwater paspalum (Graeme, 2012).

Swan and Canada geese populations have been identified as being of particular concern for the West Coast harbours as the birds occur in large numbers and are perceived to have a negative impact on the harbours via:

- Impacts on seagrass beds - via feeding and trampling
- deposition of faecal matter- leading to nutrient enrichment, turbidity and microbial contamination
- changes to other estuarine vegetation,
- vectors for disease transmission,
- distribution of weed propagules
- impacts on other birds

Smith (2019) summarises available information about geese and swans in the West Coast harbours. Moult season surveys in the western Waikato show that swan populations have declined substantially since 1984 to about 5,000 birds (c. one third of the 1984 swan population), and that populations fluctuate but appear to be relatively stable at this level. Approximately 80% of this population now resides in estuarine habitats during moult season, which may be due to the deterioration of lake and wetland habitats within the region.

By comparison, surveys show that goose numbers have increased over the past 30 years by a factor of 20, to approximately 10,000 birds. Geese began appearing in estuaries in moult season in 2006 and numbers fluctuate between years but are increasing overall. Approximately 25% of the population was using Aotea, Whāingaroa and Kāwhia estuaries during the 2018 moult season survey. To understand the impacts of goose feeding behaviour in estuaries, diet studies were undertaken by the University of Waikato and Waikato Regional Council. Geese were observed during summer months foraging in seagrass beds utilising several

destructive methods, however gut sample analysis indicated that this was not a major part of their diet over winter and spring (Ferries, 2021).

Smith (2019) suggests that these birds could be managed via an integrated approach focused primarily on reducing the adult population. Humane moult season culls applied in conjunction with other methods, such as reproductive control and scaring techniques, are likely to have the greatest impact on population sizes of these birds. Given the mobile nature of these species, management would need to be nationally coordinated. Without effective coordination, vacated habitats would probably quickly be recolonised by remaining populations.

1.1.22 Pest Plants

Saltwater paspalum and spartina have been identified as the weeds in Whāingaroa harbour that pose the greatest ecological risks. The distribution of these species was surveyed in 2004 and 2012 and is shown in the map in Figure 28 (Bouma, 2016).

Saltwater paspalum has become widespread in Whāingaroa and has been identified as the most pressing threat to the ongoing health of estuarine vegetation communities within the harbour. Graeme (2012) recommended that the priority management focus for Whāingaroa should be to prevent saltwater paspalum from invading biodiversity hotspots (e.g. Waingaro River, Ohautira River, Waitetuna River and Pokohui Creek arms).

The biology and weed characteristics of saltwater paspalum in New Zealand were reviewed by Graeme and Kendal (2001). Saltwater paspalum is of particular concern in estuaries because of its smothering habit and its wide habitat range. It will grow amongst and compete with all estuarine vegetation communities except sea grass and will colonise open mudflats. It can climb over vegetation and form dense beds, easily smothering sea meadow, saltmarsh ribbonwood, rushland and even short mangrove communities. At the upstream saltwater limit, saltwater paspalum grows amongst freshwater riparian vegetation and often meets its freshwater invasive relative, Mercer grass (*Paspalum distichum*).

Field observations suggest that saltwater paspalum generally excludes burrowing fauna, reduces access to bird feeding and roosting sites, alters fish spawning and feeding grounds, and alters estuarine hydrology by accumulating sediments. Due to its competitiveness and wide-ranging effect on estuarine biodiversity, saltwater paspalum is considered a greater threat than spartina to the ongoing health of the native estuarine communities.

Graeme (2012) observed that the disturbance of estuarine vegetation by stock, feral animals, drainage works, tracking, and roading increases the vulnerability of these areas to weed invasion and persistence and also exacerbates the spread of saltwater paspalum by breaking off fragments which can then float away to infest new sites.

Graeme and Kendal (2014) ranked[40] the West Coast estuaries in priority order for control of saltwater paspalum. Whāingaroa harbour was ranked lower priority than Kāwhia and Aotea estuaries because it contains a higher abundance of saltwater paspalum. The arms of the Kerikeri/Waingaro Rivers, Ohautira Stream and Waitetuna River have been identified as important "within estuary" areas for saltwater paspalum control in Whāingaroa (Graeme and Kendal, 2014). Spartina has decreased significantly in Whāingaroa due

[40] Based on the ecological value of the site, the degree of saltwater paspalum infestation, and the site's vulnerability to invasion

to the control programme undertaken by the Department of Conservation. As of 2024, eradication has not yet been achieved (D. Embling, WRC, pers. comm).

Waikato Regional Council has undertaken the following weed control work within the West Coast zone in recent years (D. Embling, WRC, pers. comm):

- Eradication of alligator weed from the mouth of the Kāwhia harbour
- Control and management of yellow flag iris, which is identified as a threat to the harbours
- Control and management of Old Man's beard and climbing spindleberry
- Management of boneseed on the cliffs in Raglan
- Biocontrol programmes for thistles, woolly nightshade, ragwort, gorse, tradescantia, moth plant, tutsan
- Collaborative project with Ministry Primary Industries (MPI) and Department of Conservation (DOC) to eradicate Sea spurge from the west coast.
- General pest plant surveillance.
- Managing pest plant threats from outside the catchment to protect the catchment

Figure 28. Spartina and saltwater paspalum distribution in Whāingaroa Harbour 2015. Source: Bouma (2016).

1.1.23 Pathogenic Pests

Kauri dieback disease[41] was discovered in 2009 and is threatening the well-being of kauri within New Zealand. Kauri trees need protection from kauri dieback disease, which is spread through the movement of contaminated soil, and will cause most infected trees to die prematurely. There is no known cure for kauri dieback, so the best way to protect kauri is by stopping the spread of the disease.

Naturally occurring kauri are found throughout the warmer regions of the upper North Island as far south as Kāwhia, which is the southern limit of its distribution.

People, stock and feral animals are the main vectors for spread (via contaminated soil), so landowners can protect kauri by:

- fencing out stock
- maintaining good hygiene (i.e. clean equipment)
- managing feral animals

Practical information[42] is available for rural landowners regarding kauri protection, which establishes guidelines and hygiene standards for activities on land where kauri occur. These guidelines focus on reducing the risk of soil transfer and limiting soil and root disturbance around trees (O'Toole and Parker, 2020). As kauri have a sensitive network of feeder roots through the litter and soil surface, well beyond the canopy drip line, fences must be placed beyond the kauri root zone. The root zone is defined as a distance three times the radius of the outermost canopy dripline.

Hazards

Introduction

New Zealand consists of a range of geographical and geological features that contribute to the occurrence of natural hazards. The country lies across two tectonic plates that are pushing against each other, creating the many mountains and volcanos that occur down the centre of the country as well as frequent earthquake events. The mountains also intensify rain events and flooding is generally the most frequent natural disaster that occurs in New Zealand. Natural hazard risk in the region is increasing, mainly because development is still occurring in hazard prone areas.

The coastal environment is one of the most active environments in the Waikato Region and is subject to regular and sometimes instantaneous changes due to erosion and inundation. In the coastal environment, natural hazards may include coastal erosion, sand drift, wind erosion, coastal flooding, changes in sea-level, tsunami, storms and cyclones.

The WRPS recognises that natural hazards are natural events that only really pose a problem when people, or development, are put at risk. As a result, Waikato Regional Council seeks to manage activities to reduce the risks from natural hazards and co-ordinate its work with the range of organisations that are involved in responding to natural hazard.

[41] *Phytophthora agathidicida* is a pathogen that causes kauri dieback disease

[42] Protecting Kauri: A rural landowners guide - https://www.kauridieback.co.nz/media/2050/6617-kauri-dieback-guide-booklet-a5_3_wr_final.pdf)

This section outlines the Whāingaroa catchment's vulnerability to natural hazards as well as identification of known and potential natural hazards that the catchment may be susceptible to.

Vulnerability to natural hazards

As a result of climate change West Coast harbour catchments will be subject to more of the high intensity rainfall and storm events that trigger short-term erosion and subsequently increase sedimentation in rivers, streams and the coastal environment. The presence of karst in the Waikato District is particularly relevant to the management of natural hazards, as the creation of underground karst formations often (eventually) results in localised subsidence.

The coastline around harbour entrances is likely to be dynamic due to the presence of highly mobile material (e.g. sand, gravel and mud) and coastal features such as sand spits and bars that are sensitive to natural fluctuations. This dynamic environment also extends into the lower harbours, where there is evidence of shoreline fluctuations (Ryan, 2009).

Tsunamis are a threat to people and property in coastal and low-lying estuarine areas. The waves travel quickly, rapidly flooding and damaging coastal communities, picking up debris as they go (Ryan, 2009). The coastal areas of the Whāingaroa catchment have less risk of tsunami due to the sheltering effect of New Zealand from the most likely sources of tsunami.

Identifying natural hazards

Natural hazards can cause disruption, damage properties and take lives. To improve access to hazard information, and help the public, local authorities and others to make informed decisions, Waikato Regional Council has developed a Waikato Regional Hazards Portal (Figure 29)[43]. The Portal contains all available (suitably robust) spatial hazard information that is held by Waikato Regional Council, as well as some data from other organisations.

For the Whāingaroa catchment, the portal identifies known and potential hazards relating to:

- Flooding
- Coastal hazards
- Coastal inundation
- Earthquakes and landslides

As a result of climate change West Coast harbour catchments will be subject to more high intensity rainfall and storm events. The predicted influence of this is displayed in the Waikato Regional Hazards Portal.

The Waikato District also maps a High-Risk Coastal Hazard Area (Erosion) which identifies areas where there is already significant risk from coastal erosion with existing sea level and coastal processes in the short term[44].

[43] www.waikatoregion.govt.nz/regional-hazards-portal

[44] High Risk Coastal Hazard (Erosion) Area (Notified) | WDC Data Service (waikatodistrict.govt.nz)

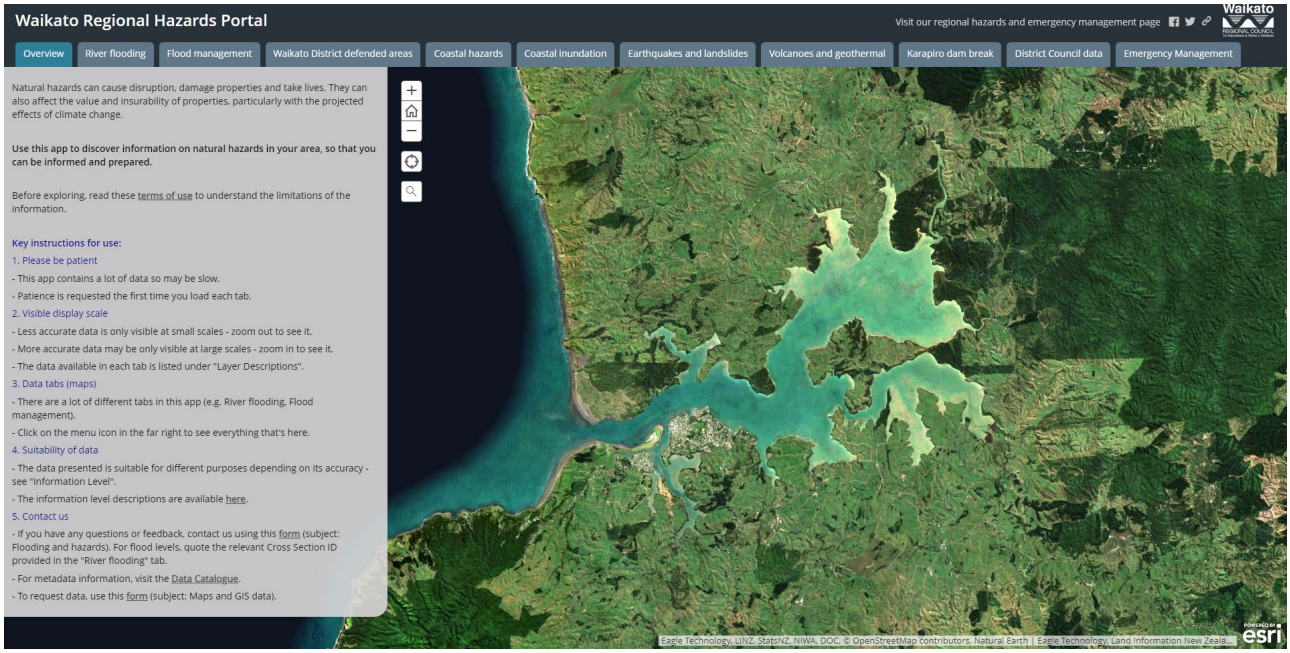


Figure 29. Screenshot of the Waikato Regional Council Hazards Portal. Source: WRC Hazard Portal.

Climate Change

Introduction

Climate change is predicted to affect rivers and streams through changes to base flows, flow patterns[45], increased flooding, increased water temperatures, declining water quality; increased erosion and sediment transport; increased salinity of river mouths (due to sea level rise); reduced freshwater habitats and disruption of migrations. Human responses to climate change are likely to add further pressure with increased demand for water abstraction, dam and irrigation schemes, and engineering for flood prevention to protect human life, infrastructure and the economy. These impacts are likely to vary amongst catchments depending on flow source and so are difficult to predict with confidence.

As greenhouse gases increase in our atmosphere, New Zealand is experiencing the impact of a changing climate. A recent Ministry for the Environment report gave an increase in the average annual temperature by 1.13 degrees Celsius from 1909 to 2019 and we are seeing sea levels rise, changes in drought and extreme rainfall (Ministry for the Environment, 2021).

Water temperature and acidity of coastal waters are predicted to increase with climate change, which may change the suitability of coastal waters for marine species and make coastal waters more susceptible to undesirable consequences, such as algal blooms.

Climate change projections for the Waikato region

The Ministry for the Environment (MfE) has provided an overview of how the climate in the Waikato region is likely to change into the future and what implications this has for the region.[46]

These predictions are not certain. As explained by the MfE, projections of climate change depend on future greenhouse gas emissions, which are uncertain. Predictions are based on four main global emissions scenarios ranging from low to high greenhouse gas concentrations. These were used to calculate regional projections for a transition from a low emission to a high emission future. The projected changes are calculated for 2031–2050 (referred to as 2040) and 2081–2100 (2090) compared to the climate of 1986–2005 (1995).

Climate change projections for the Waikato region are summarised in Table 10. In summary, the changes likely to be experienced in the Whāingaroa catchment over the coming 20 to 70 years are:

- Increased temperatures, including:
  - increased daily average temperatures;
  - increased days with high temperatures (over 25 ˚C); and
  - less frosts.
- Increased winter rainfall and reduced spring rainfall but there will be local variation and projections are uncertain.
- Potential increase in westerly wind flow during winter, and north-easterly wind flow during summer.
- Some increase in storm intensity, local wind extremes and thunderstorms. Ex-tropical cyclones will likely be stronger and cause more damage as a result of heavy rain and strong winds.

[45] and altered frequency and timing of ecologically important flow events

[46] www.mfe.govt.nz/climate-change/likely-impacts-of-climate-change/how-could-climate-change-affect-my-region/waikato

- Over the 20th century there has been an average rise in relative mean sea level of 1.7 mm per year. Further rise is expected in the future.

Table 10. Climate change projections for the Waikato region provided by the Ministry for the Environment. Source: www.mfe.govt.nz/climate-change/likely-impacts-of-climate-change/how-could-climate-change-affect-my-region/waikato.

 **Temperature**
Compared to 1995, temperatures are likely to be 0.7˚C to 1.1˚C warmer by 2040 and 0.7˚C to 3.1˚C warmer by 2090. By 2090, the Waikato is projected to have from 10 to 60 extra days per year where maximum temperatures exceed 25˚C. The number of frosts could decrease by around 5 to 13 days per year in Waikato, with frosts becoming rare in the Coromandel.
 **Rainfall**
Rainfall will vary locally within the region. The largest changes will be for particular seasons rather than annually. Winter rainfall in Ruakura is projected to increase by 4 to 8 per cent by 2090. In Taupo, winter rainfall is projected to increase by 4 to 7 per cent by 2090. Spring rainfall is projected to decrease by up to 6 per cent in both locations. According to the most recent projections, the Waikato is not expected to experience a significant change in the frequency of extreme rain days as a result of climate change.
 **Wind**
The frequency of extremely windy days is likely to decrease by 2 to 3 per cent. There may be an increase in westerly wind flow during winter, and north-easterly wind flow during summer.
 **Storms**
Future changes in the frequency of storms are likely to be small compared to natural inter-annual variability. Some increase in storm intensity, local wind extremes and thunderstorms is likely to occur. The frequency of ex-tropical cyclones is projected to either decrease or remain unchanged over the 21st century; however, the ex-tropical cyclones will likely be stronger and cause more damage as a result of heavy rain and strong winds.
 **Sea-level rise**
New Zealand tide records show an average rise in relative mean sea level of 1.7 mm per year over the 20th century. Globally, the rate of rise has increased, and further rise is expected in the future. The Ministry for the Environment provides guidance on coastal hazards and climate change, including recommendations for sea level rise.

Likely effects of climate change in the Whāingaroa catchment

The most likely climate-induced changes identified for the Whāingaroa community are droughts, sea level rise and river flooding events. The Whāingaroa community are likely to experience similar impacts to those identified in a study in Mania - Examining community risk, vulnerability and endurance at Manaia Settlement, Hauraki-Waikato, Aotearoa-New Zealand (King et al., 2012):

- Increased coastal erosion and destabilisation of coastal slopes from rising sea-levels and storms.
- Increased risk of coastal flooding from rising sea-levels and extreme weather events.
- Permanent inundation of low-lying coastal areas including saltwater intrusion (salinisation) into freshwater resources and farm paddocks.
- Structural damage to privately owned buildings and key infrastructure such as local roads from higher water levels and periodic storms.
- Degradation of sacred places and sites resulting in loss of identity and whakapapa.
- Adverse impacts on ecology from erosion, sedimentation and pollution from destruction of septic tanks and sewer lines.
- Danger of injury and loss of life in the case of extreme flooding events; and
- Rising costs surrounding the maintenance, repair and re-design of whānau homes and vital infrastructure to cope with such changes.

Prioritisation of conservation and restoration activities

Prioritisation of conservation and restoration activities is necessary to ensure resources are utilised in the most effective way. In other parts of the region catchments and sub-catchments have been prioritised in the past to guide catchment management activities.

This section outlines the prioritisation process that have been used in the Whāingaroa catchment.

Sub-catchment prioritisation process for the West Coast harbour catchments

To support the implementation of the West Coast Zone Plan and help direct resources to activities and areas of greatest environmental and community benefit within the harbours, Singleton (2018) undertook a prioritisation process that involved:

- Subdividing the Whāingaroa catchment into seven sub-catchments;
- Identifying features, issues and uses of each sub-catchment using a range of information[47];
- Scoring each sub-catchment (and its downstream harbour area) on the basis of a several categories including:
    - Land instability (poor vegetation protection, sediment and erosion risk) – scored as the % sub catchment with moderate or higher risk;
    - Water quality risks (*E. coli,* N, P, stream bank erosion and stocking risk) – scored as the % sub catchment with moderate or higher risk
    - Biodiversity values of the land (priority streams, priority areas on private land, SNAs) - scored as the km of high-risk stream, % of priority native cover on private land, and % of vegetation that is regionally, nationally or internationally significant;
    - Importance of harbour features (presence of salt marsh or seagrass, shellfish beds, coastal flushing) – scoring based on the relative abundance of shellfish or habitat near the catchment discharge
    - Relative importance for community activities (tourism and visitors, water based commercial activities, swimming, food gathering, schools and marae, care groups) – scoring based on the relative use of the sub catchment for a range of community activities.

Using this process, Singleton (2018) sought to identify the sub-catchments with the highest land and water quality risks, the most important biodiversity values, and the most community use and engagement. In this way, he hoped to maximise the biodiversity and community benefits from land and water improvements.

Whilst the prioritisation was intended to be impartial, it was limited by the quality and availability of information and required judgement to determine final priorities. It also relied on Iwi environmental management plans and other documents to determine community aspirations and would have benefited from further iwi and community input. Nevertheless, it provided useful initial guidance on areas of risk and opportunity for the zone plan.

Table 11. shows the final category scores and overall priority rankings for each of the sub-catchments of Whāingaroa Harbour (from Singleton, 2018).

[47] including reports, plans and planning doc

Table 11. Outcome of the prioritisation process in Whāingaroa Harbour catchment by Singleton (2018)

Sub-catchment	Land Instability Risk Score	Water Quality Risk Score	Biodiversity Score	Harbour Score	Community Score	TOTAL Score	Rank within Harbour
Kerikeri	96	57	50	7	13	223	2
Waingaro	51	33	6	19	25	134	5
Ohautira	32	20	55	20	10	137	4
Waitetuna	58	39	27	16	31	171	3
Opotoru	46	36	50	14	80	226	1

The Opotoru sub catchment scored significantly higher than any other in the community score and this drove it being identified as the highest priority sub catchment overall for Whāingaroa. However, the Kerikeri sub catchment and was identified as having the highest scores for land instability and water quality risk. Ohautira had the highest score for biodiversity.

Waikato Regional Prioritisation Project (WRPP)

In 2013 the Waikato Regional Council Land and Water Forum identified a need to better prioritise incentivised catchment management works regionally and within Zones. As a result, a prioritisation framework was developed internally and used to support the preparation of the Waipā Catchment Plan (Waikato Regional Council, 2014). Following this the Waikato Prioritisation Framework (WPF) was developed for the whole of region in 2015 (Hill and Borman, 2016). A 2018 revision supported the identification of priority locations and mitigations for the Waikato and Waipā River Restoration Strategy (Neilson et al., 2018). Further revisions and updates have been completed periodically, with the most recent revision undertaken in 2021 (Norris et al., 2021).

The WPF is a spatial framework that utilises spatial model data from multiple sources and applies geospatial techniques for determining priorities based on risk. It provides a decision support tool for prioritisation across catchments, identifying locations with the greatest potential for water quality improvement, and with the likely greatest cost benefit in implementing soil conservation mitigations (Norris et al., 2021). Although the outputs of the project were intended primarily to be used by the Waikato Regional Council, they can also be of benefit to mana whenua, Co-governance partners, and land managers, funding agencies and communities within the wider Waikato region (Hill and Borman, 2016).

As part of the 2021 revision of the WPF, a detailed assessment of risks, mitigations, costs and potential outcomes was undertaken for the West Coast Zone, including for the harbour catchments. The outcomes of this assessment have been used to refine and confirm priority Waikato Regional Council sub catchments for management of soil conservation and erosion in the Whāingaroa harbour catchment.

The results of the WPF identify the Kerikeri and Waitetuna sub-catchments as the first and second highest priorities respectively for management of both soil conservation and nutrient risk (nitrogen and phosphorus). It is therefore likely that catchment management works in these locations will lead to more positive sediment reduction and water quality improvements for the harbour than similar work at other locations.

Table 12. Summarised Waikato Regional Prioritisation Project mitigation estimates for Aotea harbour catchment (Norris et al., 2021).

	Whāingaroa
Total area of combined sub catchments (ha)	50,536
Mean sub catchment area (ha)	10,107
Ranking for soil conservation	Kerikeri Waitetuna Waingaro Ohautira Opotoru
Ranking for water quality	Kerikeri Waitetuna Opotoru Waingaro Ohautira
Hill slope mitigation costs ($)	$12,154,318
Riparian mitigation costs ($)	$14,711,505
Total mitigation costs ($)	**$26,865,823**
Mitigation sediment reductions (%)	49%
Mitigation nitrogen reductions (%)	16%
Mitigation phosphorus reductions (%)	27%
Mitigation *E. coli* reductions (%)	23%

In terms of potential outcomes for the Whāingaroa harbour catchment, the WPF model estimated relative reductions in sediment and other contaminant generation before and after a range of mitigations for hill slope and streambank protection. It also enabled an estimate of costs to achieve these reductions. A summary of estimated mitigation costs and reductions for the Whāingaroa catchment is displayed in Table 12. This assumes management actions including retirement and revegetation of very steep land, stabilising other steep areas with open spaced pole planting, and undertaking riparian fencing and planting (Norris et al., 2021). The total cost of this work as of 2021 was estimated to be approximately $26.9m. Modelling predicted that if this work was undertaken it would achieve a 49% reduction in sediment to waterways and a 24% reduction in *E. coli*.

A detailed summary of the WPF and results for the West Coast can be found in Norris et al. (2021)). This work has informed the priorities and actions identified in the Whāingaroa Catchment Management Plan, scheduled for publication in 2024. The priorities have also been incorporated into work programmes across the rest of the West Coast Zone from 2023/24 and an update of the West Coast Zone Plan (*in prep*).

Catchment works

Waikato Regional Council has an active programme of catchment works within the Whāingaroa catchment, working with landowners, community groups and other stakeholders. Figure 30 shows the properties (shaded in yellow) where WRC and landowners have entered into an agreement for funding, support and maintenance for catchment management projects.

The Whāingaroa harbour catchment has been the focus of a long-standing community planting programme with a goal on improving the ecological health of the harbour. Whāingaroa HarbourCare, with support from others, has planted 2 million trees and fenced more than 500km of streams, wetlands and natural areas within the catchment (F. Edwards *pers. comm.).* Waikato Regional Council has had some involvement in these works over the last 20 years and has a growing programme of wider work within the catchment. Funding priorities to date have been driven by priority catchments, sites and actions identified within the West Coast Zone Plan (Addenbrooke et al., 2016).

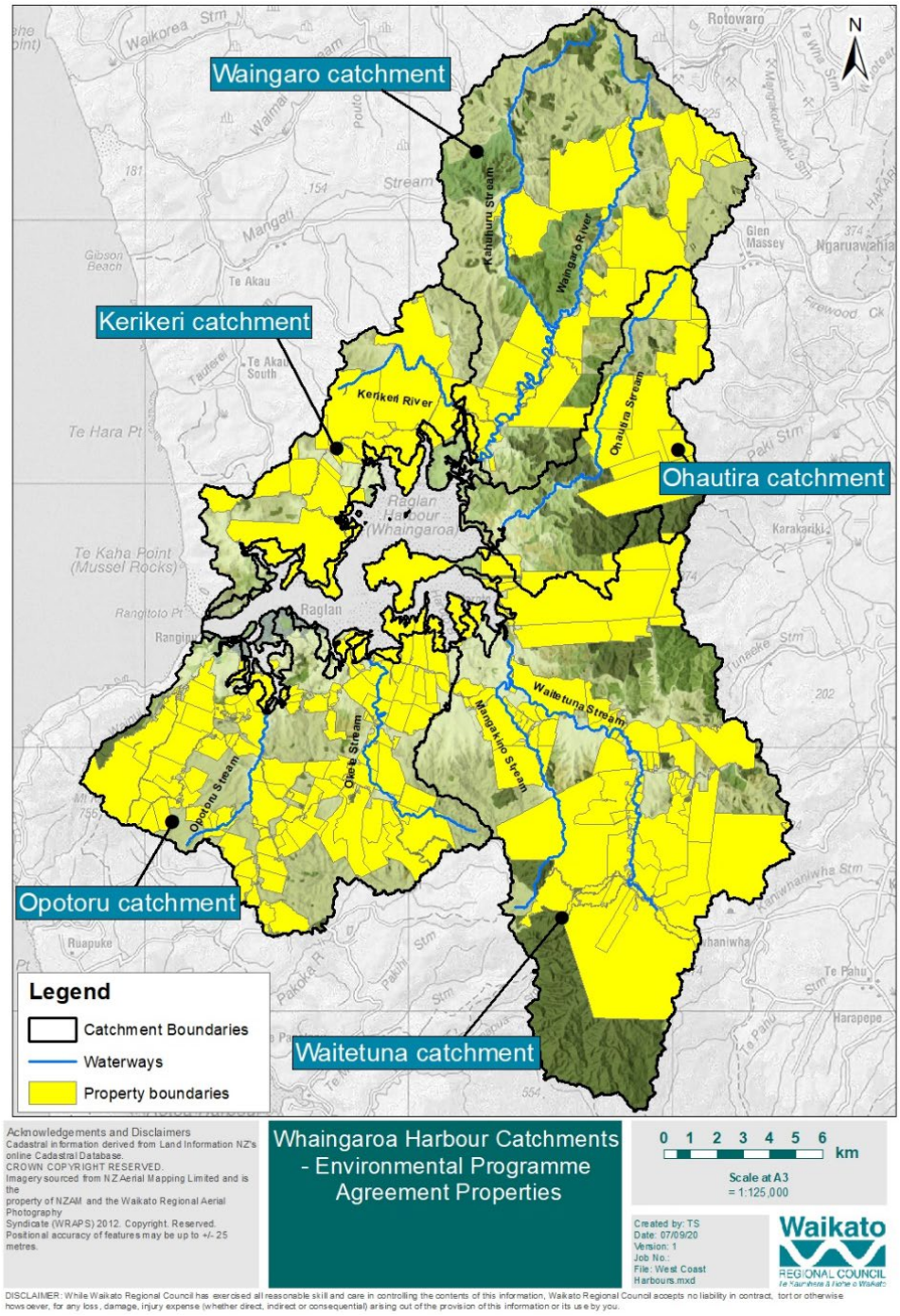


Figure 30. Extent of properties that have Environmental Programme Agreements with the Waikato Regional Council within the Whāingaroa Catchment

References

Addenbrooke J, McKenzie A, Lawrence L. 2016. West Coast Zone Plan – Te Mahere o te Rohe Taihauāuru. Waikato Regional Council Technical Report 2016/08. Hamilton, Waikato Regional Council.

Berkenbusch K, Neubauer P. 2018. Intertidal shellfish monitoring in the northern North Island region, 2017-18. New Zealand Fisheries Assessment Report 2018/28. Wellington, Fisheries New Zealand.

Boffa Miskell. 2016. Natural Character study of the Waikato coastal environment. Waikato Regional Council Technical Report 2016/05. Hamilton, Waikato Regional Council.

Bouma S. 2016. Marine biodiversity stocktake of the Waikato Region 2015. Waikato Regional Council Technical Report 2015/48. Hamilton, Waikato Regional Council.

David B, Bourke C, Hamer M, Scothern S, Pingram M, and Lake M. 2016. Incorporating fish monitoring into the Waikato Regional Councils' Regional Ecological Monitoring of Streams (REMS) – preliminary results for wadeable streams 2009-2015. Waikato Regional Council Technical Report 2016/29. Hamilton, Waikato Regional Council.

Dean-Speirs T, and Neilson K. 2014. Waikato Regional Shallow Lakes Management Plan (Volumes 1 & 2) Waikato Regional Council Technical Reports 2014/58 and 2014/59. Hamilton, Waikato Regional Council.

Dowding JE. 2019. Sites of importance to shorebirds and seabirds in the Waikato Region. Waikato Regional Council Technical Report 2019/20. Hamilton, Waikato Regional Council.

Ferries M. 2021. The use of seagrass (*Zostera muelleri*) habitat by Canada geese (*Branta canadensis*) in Waikato estuaries. Unpublished MSc thesis. Hamilton, University of Waikato.

Fisher M. 2014. The environmental management of Whāingaroa/Raglan Harbour with a focus on the period since 1970. Case-study commissioned by the Waitangi Tribunal for the Wai 898 Te Rohe Potae Inquiry.

Gibbs M, Hewitt J. 2004. Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. Auckland Regional Council Technical Publication 264. Auckland, Auckland Regional Council.

Golder Associates. 2007. West Coast Natural Character and Landscape Assessment (Kawhia and Aotea Catchments). Report Number ENVWAWKT002. Commissioned by Environment Waikato. Auckland, Golder Associates.

Graeme M. 2005. Estuarine Vegetation Survey – Raglan Harbour. Environment Waikato Technical Report 2005/44. Hamilton, Waikato Regional Council (Environment Waikato).

Graeme M. 2012. Estuarine Vegetation Survey – Raglan (Whāingaroa) Harbour. Waikato Regional Council Technical Report 2012/35. Hamilton, Waikato Regional Council.

Graeme M, Kendal H. 2001. Saltwater Paspalum (Paspalum vaginatum) – a weed review. Environment Waikato Technical Report 2001/18. Hamilton, Waikato Regional Council (Environment Waikato).

Graeme M, Kendal H. 2014. Ecological prioritisation for saltwater paspalum control in the Waikato region. Waikato Regional Council Internal Report 2015/46. Hamilton, Waikato Regional Council.

Grainger N, Collier KJ, Hitchmough R, Harding JS, Smith BJ, and Sutherland DL. 2014. Conservation status of New Zealand freshwater invertebrates, 2013. New Zealand Threat Classification Series 8. Wellington, Department of Conservation.

Harding M. 1997. Waikato Protection Strategy. A report to the Heritage Fund Committee. Wellington, Forest Heritage Fund.

Hayward BW. 2022. Mapping significant natural areas of the Waikato region: the physical basis for the identification of karst ecosystem sites: updated methodology report. Waikato Regional Council Technical Report 2022/03. Hamilton, Waikato Regional Council.

Hill R and Borman D. 2016. Waikato Regional Prioritisation Project: Phase 2 Overview. Waikato Regional Council Internal Report Series 2016/22. Hamilton, Waikato Regional Council.

Hunt S. 2019. Regional estuary monitoring programme (REMP) intertidal sedimentation measurements, results and review of methodologies. Waikato Regional Council Technical Report 2019/04. Hamilton, Waikato Regional Council.

Hunt S. 2021. Optimisation of the Waikato Regional Council tide gauge network. Waikato Regional Council Technical Report 2021/25. Hamilton, Waikato Regional Council.

Jones H. 2021. Regional Estuary Monitoring Programme trend report: 2001 to 2018. Waikato Regional Council Technical Report 2021/05. Hamilton, Waikato Regional Council.

Kamke J. 2021. State of coastal water quality for the west coast of the Waikato region 1994-2021. Waikato Regional Council Internal Series 2021/17. Hamilton, Waikato Regional Council.

King D, Dalton W, Bind J, Srinivasan M, Duncan M, Skipper A, Ashford-Hosking D, Williams B, Renata H, Baker M. 2012. Coastal adaptation to climate variability and change : examining community risk, vulnerability and endurance at Manaia Settlement, Hauraki-Waikato, Aotearoa-New Zealand. NIWA Report No: AKL2012-029. Auckland, National Institute of Water and Atmospheric Research (NIWA).

Leathwick JR, Clarkson BD, Whaley PT. 1995. Vegetation of the Waikato Region: current and historical perspectives. Landcare Research Contract Report LC9596/022. Hamilton, Manaaki Whenua - Landcare Research.

Leathwick J, Julian K. 2009. Identification of high value rivers and streams in the Waikato Region: final report. Environment Waikato Technical Report 2009/05. Hamilton, Waikato Regional Council (Environment Waikato).

Lynn I, Manderson A, Page M, Harmsworth G, Eyles G, Douglas G, Mackay A. 2009. Land use capability survey handbook: a New Zealand handbook for the classification of land. Hamilton, AgResearch Ltd.

Mead S and Moores A. 2005. Estuary sedimentation: a review of estuarine sedimentation in the Waikato Region. Environment Waikato Technical Report 2005/13. Hamilton, Waikato Regional Council (Environment Waikato).

Melchior M, Williams A, Hamer M, Pingram M, Collier K. 2023. The state of Freshwater Mussels (Kākahi, Kāeo) in Waikato wadeable streams. Waikato Regional Council Technical Report 2022/01. Hamilton, Waikato Regional Council.

McKergow LA, Pritchard M, Elliott AH, Duncan MJ, Senior AK. 2010. Storm fine sediment flux from catchment to estuary, Waitetuna – Raglan Harbour, New Zealand. New Zealand Journal of Marine and Freshwater Research 44(1): 53-76.

Ministry for the Environment. 2021. He kupu ārahi mō te aromatawai tūraru huringa āhuarangi ā-rohe / A guide to local climate change risk assessments. Wellington, Ministry for the Environment.

Ministry for the Environment and Stats NZ. 2021. Our land 2021. New Zealand's environmental reporting series/ME 1555. Wellington, Ministry for the Environment.

Neilson K, Hodges M, Williams J and Bradly N. 2018. Waikato and Waipā River Restoration Strategy – Te Rautiki Tāmata i ngā Awa o Waikato me Waipā. Waikato Regional Council, DairyNZ and Waikato River Authority. Hamilton, Waikato Regional Council.

Norris M, Jones H, Kimberley M, Borman D. 2020. Riparian characteristics of pastoral waterways in the Waikato region, 2002–2017. Waikato Regional Council Technical Report 2020/12. Hamilton, Waikato Regional Council.

Norris M, Borman D, Hill R. 2021. Waikato Prioritisation Framework and its use for soil conservation - development and methods. Waikato Regional Council Technical Report 2021/06. Hamilton, Waikato Regional Council.

Opus. 2015. Raglan Water Supply Safety Plan. A report prepared by Opus International Consultants and Waikato District Council staff., Ngāruawāhia, Waikato District Council.

O'Toole K, Parker K. 2020. Protecting kauri: Preventing the spread of kauri dieback on rural properties. Wellington, Ministry for Primary Industries. https://www.kauriprotection.co.nz/assets/Documents-PDFs/Best-Practice-Guides/Guide_protect

Raglan Naturally. 2020. Our community plan, February 2020. Raglan, Raglan Naturally. https://www.raglannaturally.co.nz/raglan-naturally-draft-plan/

Rumsby A. 2009. Trace elements in the sediment of Waikato West Coast Estuaries. Waikato Regional Council Technical Report 2009/08. Hamilton, Waikato Regional Council.

Ryan G. 2009. Natural Hazard Risk Assessment Ōtorohanga District. Waikato Regional Council Technical Report 2009/34. Hamilton, Waikato Regional Council.

Salu A. 2021. Regional rivers water quality monitoring programme data report 2020. Waikato Regional Council Technical Report 2021/19. Hamilton, Waikato Regional Council.

Singers N, Rogers M. 2014. A classification of New Zealand's terrestrial ecosystems. Science for Conservation 325. Wellington, Department of Conservation.

Singleton P. 2018. Priority West Coast Harbour Catchments. sub-catchment prioritisation. Natural Knowledge Ltd report prepared for Waikato Regional Council.

Smart Water. N.d. Section Three: How Water gets to our Taps. https://www.smartwater.org.nz/assets/Curriculum-Resource-Files/section-3.pdf [accessed 17 March 2022].

Smith B. 2019. Use of West Coast Waikato estuaries by Canada geese and black swans. Waikato Regional Council Technical Report 2019/16. Hamilton, Waikato Regional Council.

Speirs D, Kelly J. 2001. Fish Passage at Culverts – A Survey of the Coromandel Peninsula and Whāingaroa Catchment. Waikato Regional Council Technical Report 2001/08. Hamilton, Waikato Regional Council.

Swales A, Ovenden R, Budd R, Hawken J, McGlone MS, Hermanspahn N, Okey MJ. 2005. Whāingaroa (Raglan) Harbour: sedimentation and the effects of historical catchment landcover changes. Environment Waikato Technical Report 2005/36. Hamilton, Waikato Regional Council (Environment Waikato).

Tonkin and Taylor Ltd. 2008. West Coast Hazard Project. Waikato Regional Council Technical Report 2008/14. Hamilton, Waikato Regional Council.

Tulagi A. 2018. Regional rivers water quality monitoring programme: data report 2017. Waikato Regional Council Technical Report 2018/25. Hamilton, Waikato Regional Council.

Tulagi A, Salu A. 2020. Regional rivers water quality monitoring programme: data report 2019. Waikato Regional Council Technical Report 2020/20. Hamilton, Waikato Regional Council.

Vant W. 2018. Trends in river water quality in the Waikato region, 1993-2017. Waikato Regional Council Technical Report TR2018/30. Hamilton, Waikato Regional Council.

Vant W. 2019. Internal WRC memo - Water quality in streams in the catchments of Aotea and Kāwhia Harbours. (WRC document reference 15119510). Hamilton, Waikato Regional Council.

Vant W. 2020. Internal WRC memo – Water quality in streams in the catchment of Raglan harbour. (WRC document reference 16171593). Hamilton, Waikato Regional Council.

van der Zwan W and Kessels G. 2017. Significant Natural Areas of the Waikato District: terrestrial and wetland ecosystems. Waikato Regional Council Technical Report 2017/36. Hamilton, Waikato Regional Council.

Waikato District Council. 2021. Three Waters 2021-2031 Asset Management Plan. Ngāruawāhia, Waikato District Council.

Waikato Regional Council. 2014. Waipā Catchment Plan. Waikato Regional Council Technical Report 2014/33. Hamilton, Waikato Regional Council.

Waikato Regional Council. 2016. West Coast Zone Plan Supporting Information. Unpublished report. Waikato Regional Council. (WRC document reference 4089579). Hamilton, Waikato Regional Council.

Waikato Regional Council. 2019. Site Compliance Report: Raglan WWTP: Wainui Rd, Raglan. Raglan Urban Area Stormwater. (WRC document reference 15374917). Hamilton, Waikato Regional Council. https://www.waikatodistrict.govt.nz/docs/default-source/services-and-facilities/water/wastewater/raglan-wastewater-discharge-consent/studies-and-key-documents/raglan-wwtp-2018-2019-wrc-audit-report.pdf?sfvrsn=1d0690c9_2 [accessed 17 March 2022].

Waikato Regional Council. 2022. Significant Natural Areas (SNA) of the Waikato Region – Karst Ecosystems: Methodologies for ranking the top 58 karst SNA sites for biodiversity management in the Waikato. Waikato Regional Council Technical Report 2022/43. Hamilton, Waikato Regional Council.

Appendix 1

WHĀINGAROA HARBOUR MARINE REPORT CARD

Includes water quality, ecological health and sedimentation.

Summary of Whāingaroa Harbour 2020

Waikato Regional Council monitors a number of sites in Whāingaroa (Raglan), including its harbour and open coast beach during the summer months (November to March), to assess the suitability of water quality for recreational activities, estuarine water quality, ecological health and sediment contamination.

Quick facts

3185ha
Whāingaroa Harbour is 3185ha in area with a catchment size of 52,585ha

70%
of the harbour is exposed at low tide

Monitoring since 2001
WRC has been monitoring ecological health in the harbour since 2001.

133km coastline
Whāingaroa Harbour has 133km of coastline

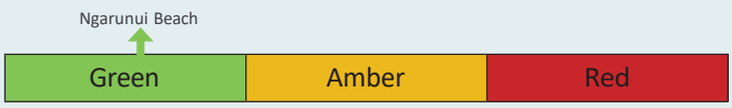
Raglan
The town of Raglan is situated on the southern side of Whāingaroa Harbour. It's a popular tourist town, with its population growing by 300-400% during summer.

At a glance

The following grades represent a summary of results from monitoring sites within the Whāingaroa harbour and nearby beach.

Results from each sampling event are published on our website as soon as practicable. Recreational water quality results are also published on the national environmental data platform, Land and Water Aotearoa (LAWA).

Recreational water quality



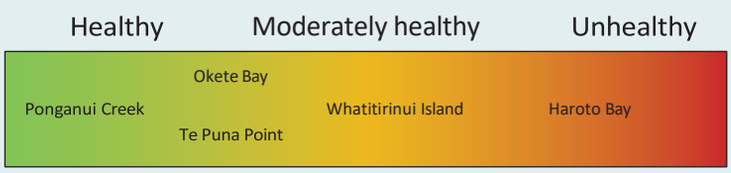
LAWA Rating

Estuarine water quality

WQI	95-100	80-94	65-79	45-64	0-44
Rating	Excellent	Good	Fair	Marginal	Poor

Opotoru (73)
Waingaro (59)
Mid Harbour (68)
Waitetuna (56)
Mouth (69)
Wainui (74)

Estuarine ecological health



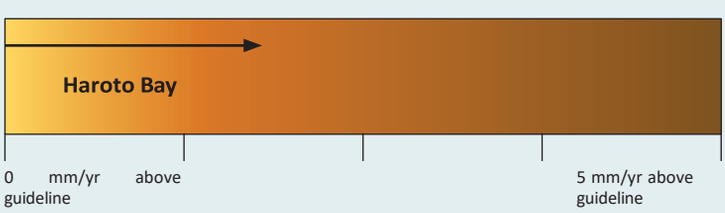
Ecological Health of intertidal fauna – Traits Based Index (TBI)

Estuarine Sediment contamination

Antimony	Cadmium	Copper	Mercury	Silver
Arsenic	Chromium	Lead	Nickel	Zinc

Concentrations are below ANZECC interim sediment quality guidelines at all 5 monitoring sites.

Estuarine Sedimentation



Sites below sedimentation guideline:
Whatitirinui Island, Ponganui Creek, Te Puna Point, Okete Bay

What does this tell us?

Recreational water quality

The water quality of Ngarunui beach is nearly always suitable for recreational activities.

Estuarine water quality

Two out of the six sites have marginal water quality meaning the conditions often depart from desirable levels. Sites regularly exceed ANZECC guidelines for nitrogen and phosphorus. Investigation is required to determine if there are impacts on community values.

Estuarine ecological health

Three sites are considered healthy, one site is moderately healthy, and another site is unhealthy.

Estuarine sediment contamination

Sediment contamination from heavy metals is low.

Estuarine sedimentation

Sedimentation rates at four sites in the harbour are within acceptable guidelines. Rates at Haroto Bay are slightly elevated (1.4mm yr^{-1} above sedimentation guidelines).

Monitoring approach

Recreational water quality

Suitability of the water for recreational activities such as swimming and surfing is monitored weekly between November and March. We do this by measuring a faecal indicator bacteria (enterococci) in the water. The number of faecal indicator bacteria inform the likelihood of contracting a disease from pathogens. We compare our results to national water quality guidelines to determine suitability.

Estuarine water quality

Some aquatic plants and animals are sensitive and will not persist or prosper if water quality is poor, and nuisance species can take over. We monitor the water quality in Whāingaroa Harbour every month. We do this by collecting samples from six sites and test them in a laboratory to measure dissolved oxygen, nutrients (nitrogen and phosphorous), chlorophyll a as an indicator of alga growth, pH levels, temperature and turbidity. To summarise the results in context of ecological health, we use a Water Quality Index (WQI) which is based on performance relative to regional and national target values to understand the ecological health of the harbour. The WQI method is based on Foley (2018) with modifications and is currently under review for WRC. Results are indicative only. See Foley (2018) Auckland Technical Report TR2018/015.

Estuarine ecological health

Estuarine animals, including shellfish, crustaceans and marine worms, are affected by the surrounding conditions and so are useful indicators of ecosystem health. We monitor the diversity and types of species living in or on the intertidal flats by collecting cores of sediment, sieving these over a 0.5mm mesh, and identifying and counting the retained animals. The results are classified according to a Traits-Based Index which uses information on the diversity of taxa in seven biological trait categories.

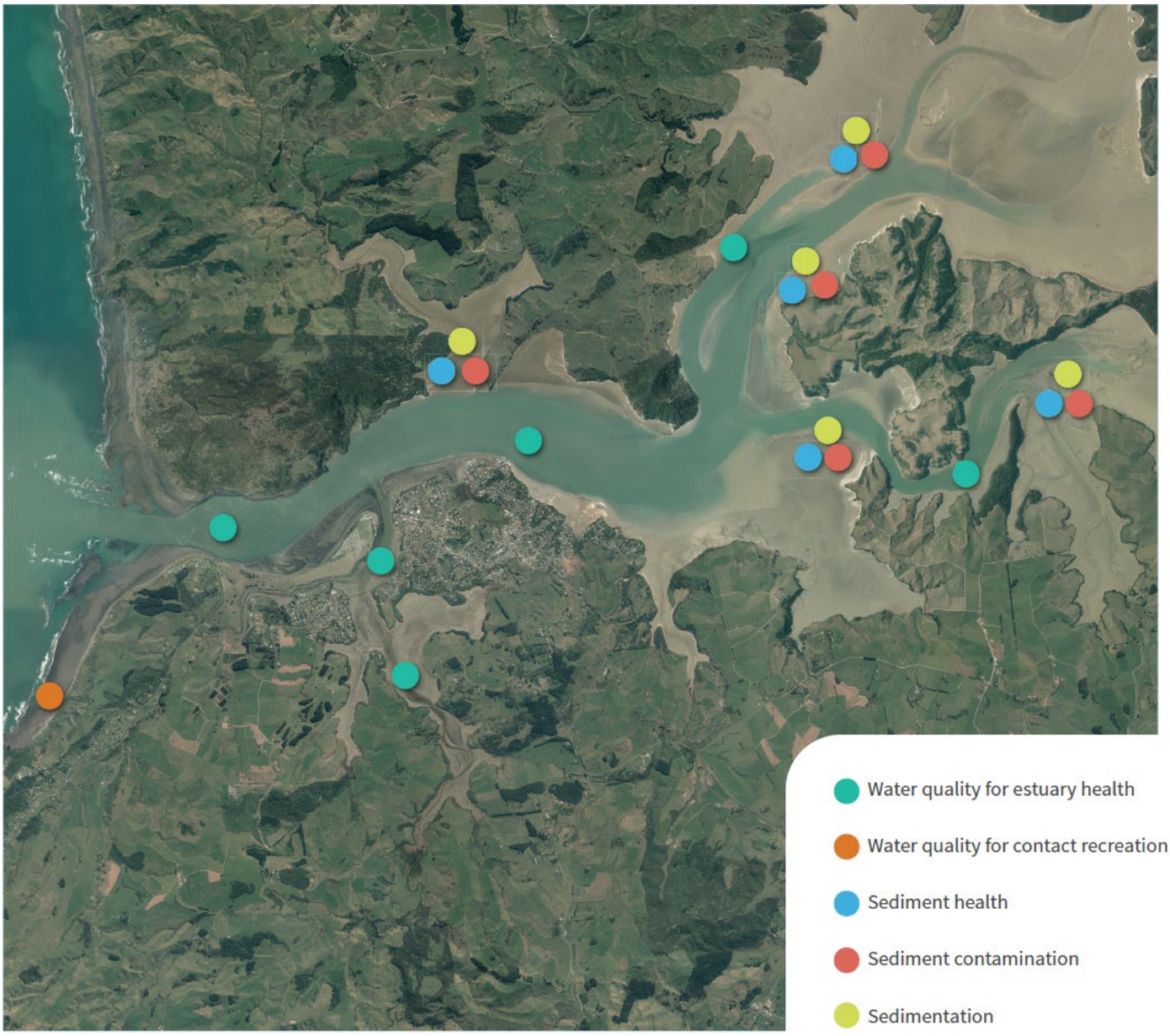
Estuarine sediment contamination

Contaminants delivered to estuaries can end up being stored in sediments which become a potential source of harm to animals and plants. These contaminants are known to accumulate slowly and so are monitored less frequently than other things. We collected sediment samples in 2003 and 2018 and tested for antimony, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, arsenic, organochlorines, and total polycyclic aromatic hydrocarbons. These results are compared to ANZECC guidelines to assess the likelihood of toxic effects.

Estuarine sedimentation

Sedimentation is the deposition of sands and muds that can smother estuarine plants and animals, causing the estuary to become less suitable for organisms. We have been measuring sedimentation in Whāingaroa since 2003 at five sites around the harbour. The depth of sediment is measured repeatedly with the rate of sedimentation calculated from the changes over time. These results are then compared to ANZECC guidelines to assess the likelihood of negative effects.

Monitoring sites



Find out more

Further details regarding the findings of this report card can be found at waikatoregion.govt.nz/environment/natural-resources/coast.

Waikato Regional Coastal Plan review

The findings of the sampling programme are important to inform the review of the Waikato Regional Coastal Plan. More information is available from waikatoregion.govt.nz/planreview

Harbour catchment management plans

WRC is developing management plans for the West Coast harbour catchments. More information is available from waikatoregion.govt.nz/hcmp

Further advice and support

WRC staff can also offer support and advice for projects within the harbour catchments that improve water quality, reduce sedimentation and erosion, stabilise river systems and enhance biodiversity. Phone 0800 800 401