Te Awa O Te Atua / Matatā Lagoon Water Quality, Ecology and Options for Improvement

Prepared for:

Whakatāne District Council

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Cover Photo: Western Matatā Lagoon and floodway bays, facing east, May 2024.

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Executive Summary

Te Awa o te Atua / Matatā Lagoon is located at Matatā, at the western edge of the Rangitāiki Plains. Historically a riverine estuary of the Tarawera River, the lagoon is now broadly divided into the eastern lagoon and western lagoon by a causeway.

Whakatāne District Council (**WDC**) holds resource consent for the use and maintenance of structures and restoration planting associated with rehabilitation of Western Matatā Lagoon following the 2005 debris flow event. In order to inform the management of the western lagoon, WDC commissioned science investigations to: a) provide robust information on water quality and ecology values, and b) identify key management options for improving water quality and ecological values in the Lagoon.

History

Prior to about 1917, the Tarawera River and part of the Rangitāiki River joined at Te Awa o te Atua, and flowed out to sea west of Matatā at Mihimarino. In 1914 the Rangitāiki River was diverted to the sea at Thornton, and in 1917 the Tarawera River was cut directly to the sea. These cuts substantially lowered the water levels in Rangitāiki Plains, and without flow from the rivers the original entrance to Te Awa o te Atua closed and the lagoon began to silt up. Later, instillation of flap gates and a weir further isolated the lagoon from the Tarawera River and led to it developing from an estuary to a wetland system.

By 2005 the Matatā Wildlife Refuge Reserve, within Te Awa o te Atua, had been recognised as an outstanding example of a complex dune land-wetland-open-water system on a freshwater-saltwater interface. It had exceptional and high botanical values, and was ranked as a Site of Special Wildlife Interest with high wildlife habitat values.

Morphology post flood rehabilitation works

In 2005 a large flood and debris flow event deposited considerable material into the western lagoon, which almost completely filled it. Rehabilitation and restoration works were completed by *c*. 2011. This provided for a smaller open-water western lagoon (*c*. 7 ha), and four floodway bays on the seaward side separated by embankments (two of these bays are dominated by raupō). There was large scale restoration planting of the embankments, with aquatic emergent plants intended to naturally colonise areas of shallow water so as to provide habitat for wetland birds.

The water depth in the “open-water zone” of western lagoon east of Waimea Stream is about 0.8 to 1.5m. West of Waimea Stream the water is shallower (*c*. 0.5m); this part of the lagoon (1.63ha) was intended to naturally regenerate into “shallow wetland zone”, but emergent aquatic vegetation remains sparse except where raupō has colonised sediment deposited near the mouth of the Waimea Stream.

Hydrology

Two streams flow to western Matatā Lagoon, the Awatarariki Stream (449 ha catchment, mean flow *c*. 119 L/s) and the Waimea Stream (47 ha catchment, mean flow *c*. 10.8 L/s). Several drains also discharge to the western lagoon, carrying surface water from the Matatā township. Water flows out of

the western lagoon to the eastern lagoon via two culverts. The eastern lagoon connects to the Tarawera River via a 1500mm culvert, with a weir structure to maintain the water level in the lagoon.

The median hydraulic residence time of the western lagoon is about 12 days, which is sufficiently short to exert some control on the maximum phytoplankton biomass within the lagoon.

Sediment contamination

The sediments in Te Awa o te Atua contain legacy contamination from toxic chlorinated organic compounds (e.g. dioxins) derived from historic mill's discharges. This is particularly apparent in the eastern lagoon, near the Tarawera River. Sediments in the western lagoon generally have low levels of contamination, but deep, historic sediments still have dioxin concentrations elevated above background concentrations.

Water quality

Water quality in Matatā lagoon west is borderline between eutrophic and supertrophic, with a mean TLI score of 4.96. The shallow water depth allows wind suspension of bottom sediments leading to low water clarity and high turbidity. The Awatarariki Stream contributes the bulk of the catchment nutrient load to the western lagoon. Matatā township is also likely to be a significant source of nutrients via shallow groundwater seepage.

Plants

Te Awa o te Atua is known as an outstanding example of a complex dune land-wetland-open-water system on a freshwater-saltwater interface. Past surveys have recorded 185 plant species in Te Awa o te Atua, including two threatened ferns.

The eastern lagoon consists of raupō reedland in addition to large areas of oioi-juncus rushland, Flaxland. Marsh ribbonwood shrubland is common near the Tarawera River. The dunes on the seaward side are dominated by grassland and *Muehlenbeckia* shrubland with patches of Willow/ *Machaerina juncea* rushland communities.

The western lagoon was remediated and planted in about 2010. It consists of a series of floodway bays on the coastal side, and an open lagoon with associated riparian wetlands on the townside. The more eastern floodway bays are dominated by raupō. Raupō and the jointed rush (*Machaerina* sp*)* is regenerating in shallow areas along the edge of the western lagoon and is extending into the lagoon where sedimentation has occurred at the mouth of the Waimea Stream. However, the width of aquatic emergent wetland vegetation on the margin of the western lagoon remains small and considerably less than what was intended to regenerate into shallow wetland habitat following the post-flood remediation.

Plant pests (including gorse, pampas grass and willow) are a problem in the western lagoon, particularly on drier areas of the wetlands, and where there has been recent disturbance near the sedimentation floodway bays, and on the embankment of the walkway.

The western lagoon itself has low cover of submerged macrophytes, probably due to the often-turbid water and grazing pressure from waterfowl.

Fish

Fish identified in Matatā Lagoon and tributary streams include: shortfin eel, longfin eel, inanga, banded kōkopu, common bully, giant bully, goldfish, rudd, and *gamusia*. Longfin eel and inanga are classified as threatened. It is likely that redfin bully and koaro may also pass through the lagoon to access stream habitat.

Birds

Te Awa o te Atua provides high value breeding and feeding habitat for a large number of water birds. Forty-three species of wetland birds have been recorded, and all are either fully or partially dependent on the Reserve for their annual and/or seasonal habitat requirements. A total of 22 of these birds are threatened bird species. These are: NZ dabchick, black shag, pied shag, little black shag, little shag, white heron, reef heron, Australasian bittern, royal spoonbill, grey duck, banded rail, spotless crake, marsh crake, pied stilt, northern NZ dotterel, banded dotterel, red-billed gull, black-billed gull, black-fronted tern, Caspian tern, white-fronted tern and North Island fernbird.

Optimising the habitat values of the western lagoon for water birds will require allowing the expansion of aquatic emergent vegetation to provide shelter, cover and breeding sites. In practice this means allowing emergent wetland plants (e.g. raupō reedland, carex sedgeland, flaxland) to regenerate within, and adjacent to, what is currently open-water.

Interventions to improve water quality

The management actions with most potential to improve ecological values in Matatā Lagoon include:

- Reduce the risk of catchment nutrient loads to Matatā Lagoon by progressing te project to reticulate the town wastewater system.

- Pest plant control and supplementary restoration planting of native vegetation – particularly along the walkway on the northern shore. Control of willow and pampas should be implemented with urgency before infestations become more dense or extensive.

- Allowing the development of aquatic emergent wetlands within the lagoon, and encouraging the expansion of aquatic emergent wetlands in the western end of the lagoon. These provide multiple benefits in removing nutrients and sediment, providing habitat for aquatic life and increasing biodiversity values for birds.

- Introducing floating wetlands near the mouth of Waimea Stream and Awatarariki Stream to remove nutrients, improve biodiversity and manage deposition of sediment in the lagoon.

Contents

1 Introduction

1.1 Background

Whakatāne District Council (**WDC**) holds resource consent for the use and maintenance of structures and restoration planting associated with rehabilitation of the western Matatā Lagoon (Te Awa O Te Atua) following the 2005 debris flow event. In order to inform the management of the western lagoon, WDC commissioned science investigations to: a) provide robust information on water quality and ecology values of the western Matatā Lagoon, and b) identify key management actions for improving ecological values in the western lagoon.

This work is being undertaken by River Lake Ltd in partnership with The Place Group. In this report we:

a. Describe the geographical context of Te Awa o te Atua / Matatā Lagoon, including hydrology, morphology, and changes over time in the extent of open-water and wetlands in Te Awa O Te Atua.

b. Describe the current state for water quality and ecology, with a particular focus on vegetation cover.

c. Identify the key issues for Te Awa o te Atua / Matatā Lagoon with respect to water quality and ecology.

d. Identify potential management options to address the key issues, including vegetation management and planting. A draft Vegetation Planting Plan has been prepared for the area surrounding western Matatā Lagoon.

1.2 Location and Context

Te Awa o te Atua is located at Matatā, at the western edge of the Rangitāiki Plains. It is situated between Awaateatua Beach and State Highway 2, and extends from the Tarawera River mouth to Matatā township. Te Awa o te Atua is part of the Matatā Wildlife Refuge Reserve. Historically a riverine estuary of the Tarawera River, the lagoon is now broadly divided into the eastern lagoon and western lagoon by a causeway to the Matatā Recreation Reserve and camp ground (**Figure 1.1**).

The western lagoon currently consists of open-water near the township (*c*. 7.2 ha), and four floodway bays on the seaward side of the lagoon separated by embankments. The two western bays (*c.* 0.8 and 0.9ha) are shallow areas used to manage sediment deposition from the Awatarariki Stream; the two eastern bays (*c.*3.6 ha and 3.0ha) are dominated by dense raupō reed land. The eastern bays have very little water flow, but are connected to the open-water area via a culvert near the outlet.

Two streams enter western Matatā Lagoon: Awatarariki Stream (449 ha) enters the lagoon via the settling bays, and the Waimea Stream (47 ha) enters near Richmond Street. Several drains also discharge to the lagoon. The Waitepuru Stream (142 ha) enters the eastern lagoon parallel to the causeway to the holiday camp. Water flows out of the western lagoon to the eastern lagoon via a culvert to the eastern end of floodway bay 4, and a second culvert under the causeway to the holiday camp (**Figure 1.2**). The eastern lagoon connects to the Tarawera River via a 1500mm culvert.

The total catchment area of Matatā Lagoon (east and west) is about 8.3 km^2 excluding inflows from the Tarawera River.

Figure 1.1: Location of Te Awa o te Atua / Matatā Lagoon and stream networks.

Figure 1.2: Western end of Matatā Lagoon / Te Awa O Te Atua, showing the open-water adjacent to Matatā township, and four floodway bays – two that settle sediment from the Awatarariki Stream and two dominated by raupō reedland (LINZ aerial image from 2022).

1.2.1 Historical context

Prior to about 1917, the Tarawera River and part of the Rangitāiki River joined at Te Awa O te Atua, and flowed out to sea west of Matatā at Mihimarino. At this time, Te Awa o te Atua had abundant wildlife and fish and was a significant trading port with schooners entering to trade flax fibre (TMNRT 2009). In 1914, the Rangitāiki River was diverted to the sea at Thornton, and in 1917 the Tarawera River was cut directly to the sea (**Figure 1.3**). These cuts substantially lowered the water levels in Rangitāiki Plains and allowed further drainage of its wetlands. Without flow from the Tarawera River, the original entrance to Te Awa o te Atua closed and the lagoon began to silt up (see historical aerial images in **Appendix 1**).

In 1955 the Tasman Pulp and Paper mill was built in Kawerau, 16km upstream of Matatā. Waste from the pulp and paper mill discharged to the Tarawera River, and entered the Matatā Lagoon. During the 1960's, wood fibre was deposited in the eastern lagoon from mill discharges to the Tarawera River (Owen et al. 2010). Flap gates were installed to minimise polluted Tarawera River water entering the lagoon. Sediments buried in Matatā Lagoon remain contaminated with toxic chlorinated organic compounds (e.g. dioxins) derived from the mill's discharges. The western lagoon is much less contaminated than the eastern end (Wilkins et al 1992). Deep historic sediments in the western lagoon still have dioxin concentrations elevated above background concentrations but still within residential soil guidelines (Tonkin and Taylor 2009).

Siltation of Matatā lagoon since its disconnection from the Tarawera River has been accelerated by past storm events, including:

- In 1939 a debris flow down the Awatarariki Stream entered the western end of Matatā Lagoon near Clem Elliott Drive.
- The Wahine Storm in April 1968 caused dune blow-out that deposited large quantities of sand into the western lagoon. The sea also washed over the foredunes in July 1978 and again with Cyclone Bola in March 1988. Dune blow-outs have been less common since sand mining ceased in the area (Owen et al. 2010).
- In May 2005, an intense storm caused flooding and a large debris flow through Matatā. This deposited considerable material into the western lagoon and some into the eastern lagoon.

Rehabilitation works and a restoration programme following the 2005 event was largely completed by mid-2010. This provided for a smaller open-water western lagoon (*c*. 7 ha), and four floodway bays on the seaward side separated by embankments, two of these bays are dominated by raupō reed. The embankments and spoil areas were planted with about 44,000 native coastal and wetland plants, but aquatic emergent plants were intended to establish naturally to provide shelter and breeding sites for aquatic and wetland birds (Owen et al 2010) (**Figure 1.2, Figure 1.4**).

The objective of the ecological rehabilitation of the western lagoon was to revegetate indigenous coastal wetland and shrubland, and to re-establish some of the former open-water habitat (Boffa Miskell 2009). Earthwork cross-sections show the planned depth of open-water was about 0.8 to 1.5m with slightly deeper water on the southern side near Arawa Street. The western end of the western lagoon (extending east of the Waimea Stream confluence) was intended to regenerate into a shallow raupō wetland – the boundary between the shallow wetland and open-water corresponded to an area that was dominated by raupō wetland prior to the 2005 flood (**Appendix 2, Figure 1.4**).

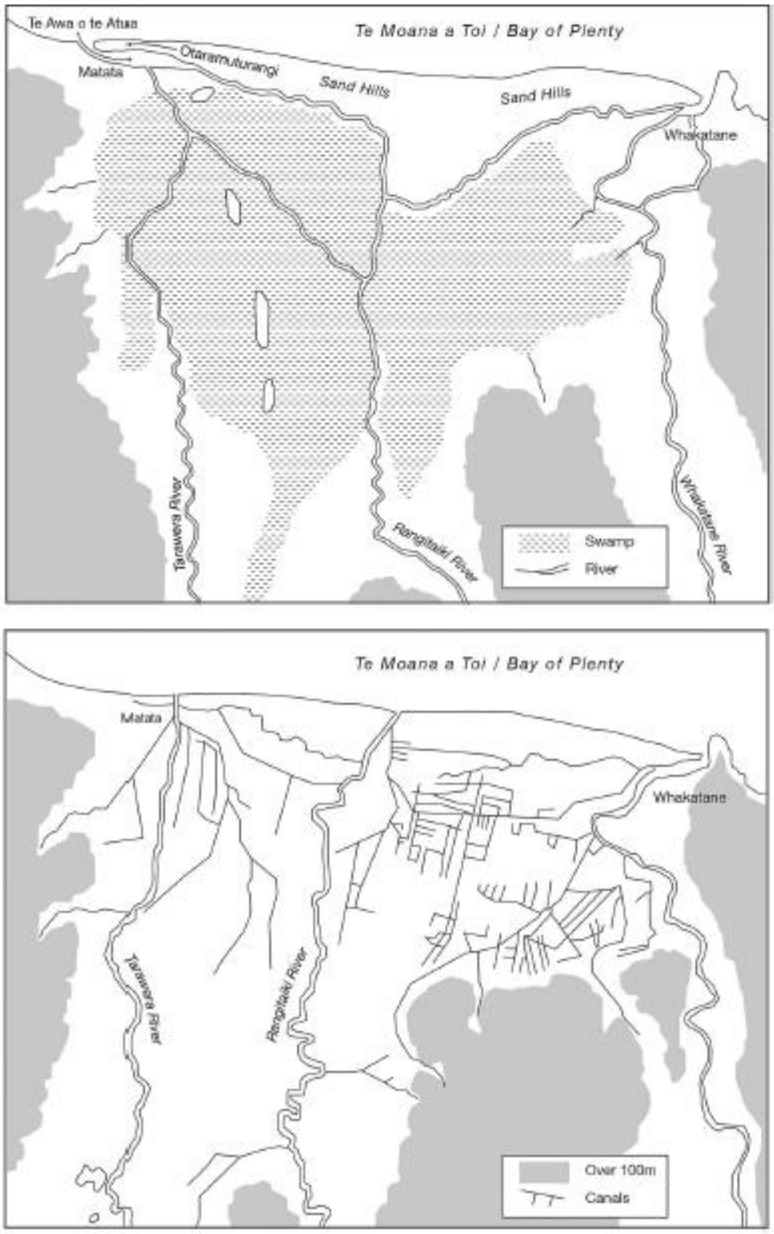

Figure: 1.3: Rangitāiki Plains before and Te Awa o te Atua before (upper) and after (lower) drainage (Waitangi Tribunal 1999).

Figure: 1.4: Extent of open-water (blue) in the western Matatā Lagoon / Te Awa o te Atua in April 2004 (upper), and April 2020 (lower) compared to an aerial image from 2022. Note the expansion of raupō in the eastern lagoon and in the floodway bays wetlands, but the loss of raupō margins in 2021 from the western lagoon.

1.2.2 Management

Matatā Lagoon is within the Matatā Wildlife Refuge Reserve which is administered by the Department of Conservation (**DoC**) pursuant to the Wildlife Act 1953, Reserve Act 1977 and the Conservation Act 1987. The Reserve and the nearby Matatā Scenic Reserve are managed by the Department in close collaboration with a Joint Advisory Committee (established in June 2006 as an outcome of Treaty of Waitangi settlements for Ngāti Awa and Ngāti Tuwharetoa BOP).

Whakatāne District Council manage the recreation reserve between Matatā township and the western Matatā Lagoon, but have also taken wider responsibility for the western lagoon including maintaining the sediment deposition bays where the Awatarariki Stream enters Matatā Lagoon.

A draft Reserve Conservation Management Plan was prepared by DoC in 1989, but was never approved. However, it did result in silt traps being built at the entrance of Awatarariki Stream and Waitepuru Stream (Owen et al. 2010). Also, a non-statutory plan for the "Ecological restoration of wetlands on the Rangitaiki Plains-Matatā Wildlife Refuge" provides management guidance for the Reserve (Wildlands Consultants 2002).

Following the May 2005 flood and debris flow the Department of Conservation (**DoC**) prepared a report assessing options for restoration of biological values in Matatā lagoon, in consultation with Matatā community, tangata whenua and interest groups. DoC's post-flooding vision for the Matatā Wildlife Reserve was:

"*A coastal wetland of high conservation and biodiversity significance that the local community value and is actively involved in it's management. It is managed to protect and enhance native flora and fauna, the natural landscape and as a habitat for freshwater fish, while respecting natural processes*" (Owen et al. 2010).

The Tarawera Awa Restoration Strategy Group (**TARSG**) was formed in 2023 in response to the Ngāti Rangitihi Treaty settlement. This is a co-governance joint committee of the Bay of Plenty Regional Council, whose role it is to, among other things, develop a restoration strategy for the catchment. The group has drafted three high level aspirations and are in the process of consulting on these aspirations before developing a Tarawera Awa Restoration Strategy document, and subsequent Action Plans (TARSG 2024). The draft aspirations are:

1. Rechannel and reconnect the course of the Tarawera, Rangitāiki and Orini Awa back through Te Awa of Te Atua and out to sea at Mihimarino.

2. Work together to protect the Tarawera Awa by dealing with all contamination and discharges into its waters.

3. Regenerate the life sustaining properties of the Tarawera and Te Awa o te Atua so that it can return to the food basket it once was.

DoC's vision for the Matatā Wildlife Reserve and the first aspiration of the TARSG (above) reflect potentially diverging views on the restoration goals for Te Awa O te Atua. The restoration activities for the lagoon following the 2005 floods were primarily about restoring a wetland ecosystem and open-water within the current flow systems. For Ngāti Rangitihi, the baseline for restoring the lagoon is pre-drainage, when Te Awa o Te Atua was an estuarine system (Hikuroa et al. 2018).

1.2.3 Consents for lagoon restoration following the 2005 flood event

Following the May 2005 debris flow event at Matatā, WDC sought resource consent from Bay of Plenty Regional Council (**BOPRC**) to undertake works to restore the western lagoon, dispose of debris material and stabilise the Awatarariki Stream. In July 2009, following Environment Court appeals, multiple resource consents were issued including:

- Consent 64474 which authorised (among other things) the "*excavation and deposition earthworks within the Western Matatā Lagoon (Te Awa-o-te-Atua) involving reshaping of the lagoon to provide for sediment retention basins, open-water, terrestrial habitat and wetland habitat*".
  - Condition 12.1 of this consent required that the revegetation of the western lagoon was carried out in accordance with the Landscape and Revegetation Plan (Boffa Miskell 2009), and previous ecological landscape concept plan (Wildlands 2007) (**Appendix 2**).
- Consent 64965 (expiring in 2042) granted consent for the continued use of infrastructure established by WDC in accordance with consent 64474. Consent 64965 authorised "…*the ongoing use of in-stream structures and erosion protection works associated with the stabilisation of the Awataraiki Stream and restoration of the Awa-o-te-Atua Lagoon*". The conditions of this consent place binding requirement on WDC (the consent holder) for the ongoing management of the established infrastructure, including:
  - Condition 10 that requires the consent holder to implement a long-term programme to ensure the establishment and survival of indigenous plantings, and the long-term control of pest plants.
  - Condition 11 that requires the consent holder to maintain all structures, water controls, sediment retention basis and other capital works covered by the consent in an effective capacity.

The capital works associated with the restoration of the lagoon were completed by about 2011. While the western lagoon forms part of the Matatā Wildlife Reserve administered by DoC, the cost of maintaining the infrastructure (i.e. desilting the sedimentation ponds) remains the responsibility of WDC as the consent holder. A draft Memorandum of Understanding (**MoU**) (2015) between WDC and DoC regarding maintaining the lagoon and infrastructure has not been adopted. An alternative maintenance arrangement and regime is being considered, and these discussions continue (RCB 2018).

2 Methods of investigation

The descriptions of Matatā Lagoon water quality and ecology used in this report is a synthesis of information from existing reports, analysis of historic datasets and specific investigations and monitoring collected as part of this project.

This project undertook some specific investigations in Matatā Lagoon to inform our understanding of the waterbody and key mitigation options, which included:

- Analyses of historical aerial photographs to delineate changes in lagoon/wetland extent;
- A vegetation survey of the lagoon;
- Fish and waterfowl presence using eDNA in Matatā Lagoon;
- Summary of water quality samples of Matatā Lagoon and inflowing streams collected by WDC

2.1 Water quality sampling

WDC has collected water quality samples from Matatā Lagoon and inflow streams as part of Te Niaotanga ō Mataatua ō Te Arawa Matatā Wastewater project. Surface water samples were collected monthly since November 2021 and bimonthly since 2023.The sample results presented in this report are for the period November 2021 to January 2024 (n=27). The sample sites included western Matatā Lagoon outlet, and tributaries Awatarariki Stream, Waimea Creek, unnamed drain, and Waitepuru Stream. Additional water quality sites along Matatā lagoon west were added in December 2023. The sample site locations are shown in **Figure 2.1** and **Table 2.1**.

Samples were analysed for: temperature (**Temp**.), pH, dissolved oxygen (**DO**), electrical conductivity (**EC**), total nitrogen (**TN**), nitrate-nitrite-nitrogen (**NNN**), total ammoniacal nitrogen (**NH4-N**), total phosphorus (**TP**), dissolved reactive phosphorus (**DRP**), total suspended solids (**TSS**), *E.coli* bacteria (***E.coli***) and carbonaceous Biological Oxygen Demand (**cBOD5**).

Water quality data was expressed using box plots show the median, interquartile range, 5th-percentile, 95th-percentile, minimum, and maximum, as illustrated here.

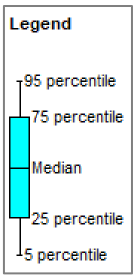

Table 2.1: Surface water quality sample sites in Matatā Lagoon (WDC)

Site id	Site name	Longitude	Latitude
SW1	Awatarariki U/S	176.7462	-37.8854
SW3	Waimea U/S	176.7552	-37.8924
SW5	Waimea D/S ("Clarks drain")	176.7533	-37.8873
SW13	Drain at 53 Arawa St	176.7557	-37.8877
SW6	Waitepuru U/S	176.7579	-37.8942
SW7	Waitepuru D/S	176.7602	-37.8888
SW8	Tarawera River downstream	176.7873	-37.8975
SW9	Tarawera River midstream	176.7768	-37.9189
SW10	Tarawera @ Awakaponga	176.7752	-37.9338
SW11	Matata Lagoon West outlet	176.7611	-37.8874
SW12	Matata Lagoon East at Control Structure	176.7846	-37.8933
SW23 *	Matata Lagoon West	176.7518	-37.8859
SW24 *	Matata Lagoon Mid	176.7555	-37.8874
SW26 *	Matata Lagoon East	176.7588	-37.8882

Sites SW23. SW24 and SW25 were only samples since December 2023

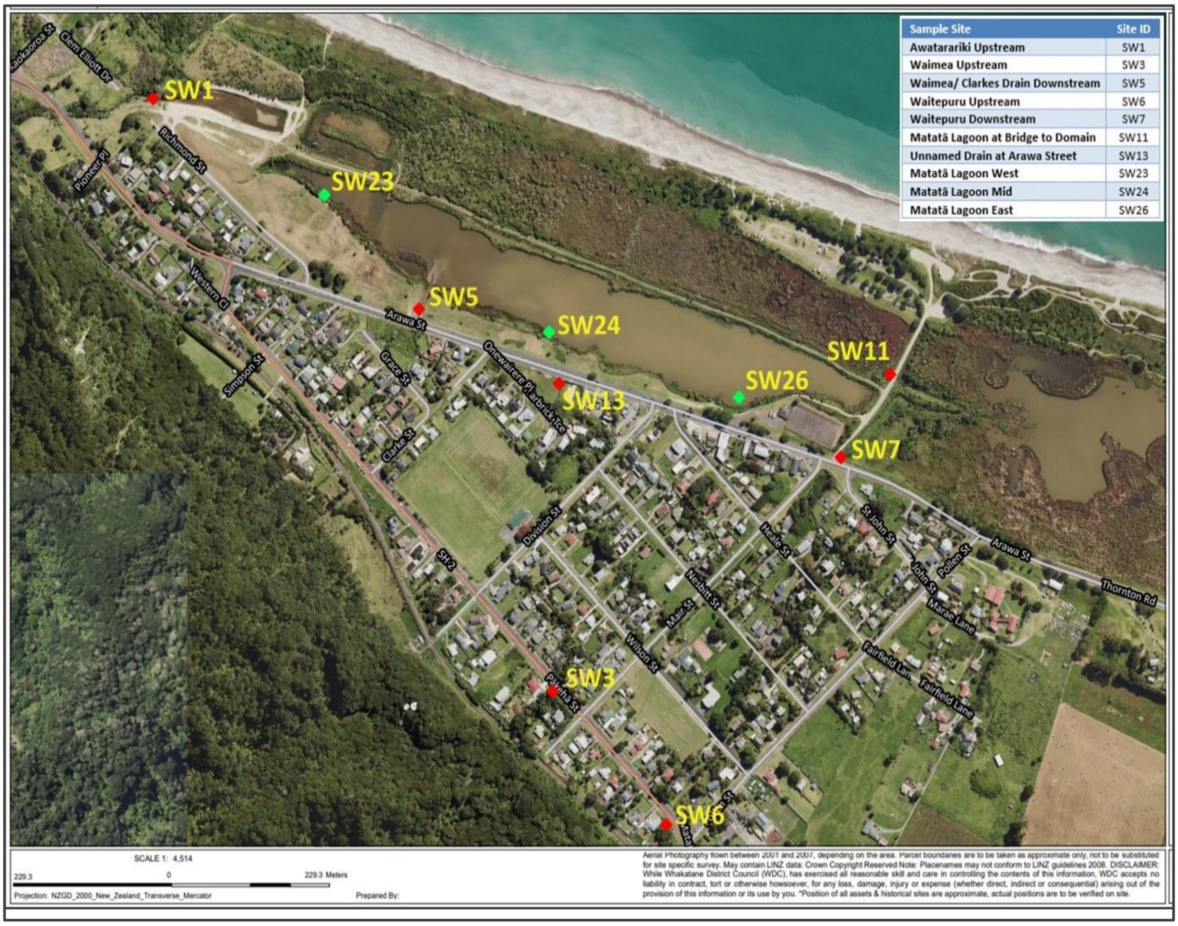

Figure 2.1: Location of water quality monitoring sites in western Matatā Lagoon (green triangles), tributaries and outflow (red triangles) (WDC).

2.2 eDNA

Waterways contain environmental DNA (eDNA) of organisms present. Analysis of eDNA shed from organisms in the water give a qualitative assessment of what fish, aquatic insects, birds and plants may be present (David et al. 2021). Although used as a qualitative tool, the results indicate the strength of the eDNA signal.

Samples of eDNA were collected to supplement existing information on the presence of fish and birds in western Matatā Lagoon. Following collection, the samples were preserved and sent to Wilderlab for processing. The eDNA samples were collected from three locations along the northern shore of western Matatā lagoon (western, mid., and at the outlet under the causeway to the campground). Samples were collected on 22 September 2022 and 17 November 2022.

2.3 Assessing potential nutrient limitation

In order to accurately assess the extent to which nutrients may limit algal growth in a lake, detailed investigations and bioassays are required. However, some indication of potential nutrient limitation can be gained by looking at the absolute concentration of nutrients in the lake and the stoichiometric ratio of N to P, and assuming the absence of other factors limiting phytoplankton or macro-algal growth. Nutrient concentrations are balanced when they equate to the Redfield ratio (i.e., 7.2 by mass). In these situations, either N or P (or both) may limit growth. A TN:TP value less than 7 indicates potential nitrogen limitation, and a TN:TP value greater than 14 indicates potential phosphorus limitation.

Similarly, the ratio of DIN:TP can also be used to indicate potential nutrient limitation. Assuming the absence of other growth limiting factors a DIN:TP of < 1 (by mass) indicates potential N limitation and a DIN:TP > 1 indicates potential P limitation (Schallenberg et al. 2010).

2.4 Lake water quality guidelines

2.4.1 Trophic Level Index (TLI)

Lake water quality is often expressed in terms of trophic state, which refers to the production of algae, epiphytes and macrophytes in a lake. The trophic state of each lake was assessed using the Trophic Level Index (**TLI**) (Burns et al. 2000).

The TLI integrates four key measures of lake trophic state - total nitrogen, total phosphorus, chlorophyll *a* and Secchi depth. The overall TLI score for a lake is the average of individual TLI scores for each variable. The overall score is categorised into seven trophic states indicative of accelerated eutrophication, observed as more nutrients, more algal productivity and reduced water clarity (**Table 2.2**). Regular monitoring over multiple years is usually required to reliably characterise a lake's water quality or TLI.

TLI variables have not been consistently sampled. TLI estimates prior to March 2019 are calculated using only TN and TP (TLI 2). Secchi disc depth has not been directly sampled in Matatā; instead water clarity was measured using clarity tube. Results were adjusted to be expressed as black disc, and black disc measurements were multiplied by 1.25 to provide an estimate of Secchi depth.

Table 2.2: Definition of Trophic Levels based on water quality measures (Burns et al. 2000).

Trophic State	TLI Score	Chl *a* (mg/m³)	Secchi depth (m)	TP (mg/m³)	TN (mg/m³)
Ultra-microtrophic	<1	< 0.33	> 25	< 1.8	< 34
Microtrophic	1 - 2	0.33 – 0.82	15 - 25	1.8 – 4.1	34 - 73
Oligotrophic	2 - 3	0.82 - 2.0	15 - 7.0	4.1 – 9.0	73 - 157
Mesotrophic	3 - 4	2.0 - 5.0	7.0 - 2.8	9.0 - 20	157 - 337
Eutrophic	4 - 5	5.0 - 12	2.8 - 1.1	20 – 43	337 - 725
Supertrophic	5 - 6	12-31	1.1 - 0.4	43-96	725 - 1558
Hypertrophic	>6	>31	<0.4	>96	>1558

2.4.2 National Policy Statement for Freshwater Management (NPS-FM)

The National Policy Statement for Freshwater Management (**NPS-FM 2020**) (MfE 2020) sets out objectives and policies that direct local government to manage water in an integrated and sustainable way. The NPS-FM includes a National Objectives Framework (NOF) which sets compulsory national values for freshwater including: 'human health for recreation' and 'ecosystem health'. Appendix 2 of the NPS-FM sets water quality attributes that contribute to these values, and ranks attributes into bands to help communities make decision on water quality. This includes setting minimum acceptable states called 'national bottom-lines'.

Appendix 2A of the NPS-FM (2020) describes attributes that require limits on resource use, while Appendix 2B of the NPS-FM (2020) describes attributes that require action plans to be developed (**Table 2.3**).

In this report, we discuss water quality state in the context of the NPS-FM bands where possible. For most attributes, insufficient samples have been collected in recent years to accurately define the band for the purpose of the NPS-FM (e.g. *E.coli* bacteria require 60 samples over 5-years), and in these cases the bands only provide a guideline of water quality state.

Table 2.3: NPS-FM attributes and values defining different quality bands pertaining to lakes. *E.coli* bacteria and cyanobacteria relate to suitability for contact recreation while the other bands relate to ecosystem health. Bolded values are the national "bottom-lines".

Table 2A - Attributes requiring limits on resource consents

Attribute	Statistic	Units	Band A	Band B	Band C	Band D	Band E
NH4-N	Median	mg/L	≤0.03	**≤0.24**	≤1.3	>1.3	
NH4-N	Maximum	mg/L	≤0.05	**≤0.4**	≤2.2	>2.2	
E.coli bacteria	% samples >260 cfu/100ml	%	≤20%	≤30%	≤34%	≤50%	>50%
E.coli bacteria	% samples >540 cfu/100 ml	%	≤5%	≤10%	≤20%	≤30%	>30%
E.coli bacteria	Median	*E.coli* / 100mL	≤130	≤130	≤130	≤260	>260
E.coli bacteria	95%ile	*E.coli* / 100mL	≤540	≤1000	≤1200	≤1200	>1200
Phytoplankton	Median	mg *chl-a* /m^3	≤2	≤5	**≤12**	>12	
Phytoplankton	Maximum	mg *chl-a* /m^3	≤10	≤25	**≤60**	>60	
TN (polymictic)	Median	mg/m^3	≤300	≤500	**≤800**	>800	
TP	Median	mg/m^3	≤10	≤20	**≤50**	>50	
Cyanobacteria biovolume	80%ile of potentially toxic cyanobacteria	mm^3/L	≤0.5	≤1.0	**≤1.8**	>1.8	

3 Current State of Te Awa o te Atua / Matatā Lagoon

3.1 Morphology

Prior to the flood event of May 2005, the western Matatā lagoon was an open, shallow basin about 600m long and 200m wide, with fairly uniform water depth of 20-40 cm. At its western end the lagoon shallowed into an area of raupō reed lands through which the Awatarariki Stream and Waimea Stream entered (**Figure 1.4**, **Appendix A**). Much of the past sedimentation of the lagoon was thought to have occurred due to coastal sand blown of the foredunes, in addition to deposition of sediment from the streams. After the May 2005 flood, the western lagoon was almost completely filled with silt and material brought down the Awatarariki Stream (Owen et al 2010).

Following rehabilitation works, the western lagoon now consists of open-water near the township (*c.* 7.2 ha), and four floodway bays on the seaward side of the lagoon separated by embankments. The two western bays (*c.* 0.8 and 0.9ha) are shallow areas used to manage sediment deposition from the Awatarariki Stream; the two eastern bays (*c.*3.6 ha and 3.0ha) are dominated by dense raupō reed land. The eastern bays have very little water flow, but are connected to the open-water area via a culvert near the outlet.

The planned depth of the "open-water zone" (east of Waimea Stream) was about 0.8 to 1.5m with slightly deeper water on the southern side near Arawa Street, while the depth in the "shallow wetland zone" was about 0.5m (Tonkin and Taylor Earthworks Plans, **Appendix 1**). There has not been a recent bathymetry survey to confirm water depths, but most of the intended "shallow wetland zone" (1.63 ha) remains as open-water about 0.5m deep except where sedimentation has occurred near the mouth of the Waimea Stream.

The standing water volume of western Matatā Lagoon is likely in the order of 60,000 m^3 to 72,000 m^3.

3.2 Hydrology

3.2.1 Inflows

Te Awa o te Atua currently has a catchment area of about 8.3 km^2 – excluding tidal inflows from the Tarawera River mouth. Two streams enter western Matatā Lagoon: Awatarariki Stream (449 ha catchment, mean flow 119 L/s) and the Waimea Stream (47 ha catchment, mean flow 10.8 L/s)[1]. The landuse of Awatarariki Stream catchment is 85% regenerating kanuka/pohutukawa-dominated forest and 15% farmland. The 100-year flood event for the Awatarariki Stream is 44 m^3/s, and the design flood flow for the floodway bays is 66 m^3/s (T&T 2009). Several drains also discharge to the western lagoon, carrying surface water from the Matatā township.

[1] Catchment area and mean stream flow are estimates from the River Environment Classification (**REC**). Flow estimates are modelled based on rainfall. Long term flow measurements are not available. NIWA River Maps tool estimates the median flow for Awatarariki Stream and Waimea Stream is 67 L/s and 3.7 L/s respectively. https://shiny.niwa.co.nz/nzrivermaps/

Water flows out of the western lagoon to the eastern lagoon via a 1200mm culvert to floodway bay 4, and a second culvert under the causeway to the holiday camp. The Waitepuru Stream (142 ha) enters the eastern lagoon parallel to the causeway to the holiday camp.

The eastern lagoon connects to the Tarawera River via a 1500mm culvert and unnamed stream (**Figure 3.1**)[2]. This allows brackish water from the Tarawera River and sea to enter the eastern lagoon. Water level in the lagoon is maintained with a weir structure at the upstream end of this culvert. The weir was originally set to maintain a minimum water level of 0.67m RL Moturiki Datum, about 0.6m above the low tide level. However, in 1963 the lagoon level was raised by adding another stoplog to the outlet weir (Owen et al 2010).

The Tarawera River has a mean annual flow of about 30 m^3/s, but the weir and culvert size restrict the amount of tidal water that can enter the lagoon via the Tarawera River.

Figure 3.1: Outlet of eastern Matatā Lagoon to the Tarawera River (ATS 2019).

3.2.2 Hydraulic residence time

Hydraulic residence time is an important factor in determining the water quality of lakes. In large oligotrophic lakes which act as a sink for nutrients, increasing residence time can be detrimental to water quality. However, in shallow eutrophic lakes with high internal nutrient loads, a shorter residence time can improve water quality by better flushing nutrients and phytoplankton biomass (Jørgensen 2002). To be effective, residence time should be reduced to less than about 20 days (Hamilton & Dada, 2016; Abell et al 2020).

The median hydraulic residence time for the western lagoon is about 12 days assuming a water volume of 70,000 m^3 and a median combined in-flow from the Awatarariki Stream and Waimea Stream of 0.067 m^3/s. This is likely to be a sufficiently fast turnover to exert some control on the maximum

[2] A second 1500mm culvert near the same location was decommissioned by filing with concrete and no longer operates.

phytoplankton biomass within the lagoon. The residence time will be longer during periods of summer low flows.

3.3 Historic sediment contamination

Wilkins et al (1992) found sediment samples collected from the Tarawera River mouth and the lower (eastern) part of the Matatā Lagoon had dehydroabietic acid (**DHAA**) and other resin acid concentrations 10-15 times greater than the background level (20-30 mg/kg). Sediment samples from the open-water bodies in the western part of Matatā Lagoon (either side of the causeway) did not appear to have a legacy of the pulp and paper waste, with DHAA levels similar to background levels.

Tonkin and Taylor (2009) tested sediments of the western lagoon for dioxins (OCDD, PCDD/F) to confirm the level of risk from excavating sediment as part of remediating the lagoon after the 2005 flood. They found that the dioxin concentrations in recent (shallow) sediments were within background levels, but elevated concentrations were found in deeper (0.8 – 1.4m deep) historic sediments (median 9.2 pg WHO-TEQ/g, range 0.89 pg to 101 pg WHO-TEQ/g). Based on this information, the excavation of sediments to provide open-water after the 2005 debris flows was restricted to a depth of 300mm above the historic lagoon sediments.

3.4 Water Quality

3.4.1 Western lagoon

Water quality in Matatā lagoon west is borderline between eutrophic and supertrophic, with a mean TLI score of 4.96 in 2023. The constituent TLI scores for TL-n, TL-p and TL-c were 4.3, 5.8 and 4.8 respectively – which suggests TN was scarcer than TP in terms of phytoplankton requirements. Secchi depth data was not available, but mean TSS was 51 mg/L (median 24 mg/L), which would correspond to a low water clarity (**Figure 3.2, Table 3.1**).

During 2022 and 2023, the median concentration of TN, TP and Chl-a were 380 mg/m^3, 69 mg/m^3 and 9.5 mg/m^3 respectively, with a maximum Chl-a of 23 mg/m^3. This would correspond to NPS-FM attribute bands of "B", "D" and "C" for TN, TP and Chl-a respectively. Although a longer data record is required to confirm a NPS-FM grading, it appears that the national bottom-line values set for lake attributes in the NPS-FM will not be met for TP.

Assessment of potential limiting nutrients using the stoichiometric ratio of N to P is inconclusive; the median TN:TP is 5.4 - suggesting potential nitrogen limitation, while the mean DIN:TP is 1.4 - suggesting potential phosphorus limitation. During small algal blooms in May, July and August 2023 DRP concentrations were low (e.g. 0.005 mg/L) while nitrate was still abundant (e.g. 0.177 mg/L), but neither dissolved N or dissolved P have been recorded at trace concentrations.

Periphyton and benthic mats of cyanobacteria are common in the western lagoon, and may be competing with the phytoplankton for nutrients. eDNA samples identified the diatom: *Skeletonema potamos*, and the Golden brown algae *Paraphysomonas* and *Oomycota* as abundant in the western lagoon. *Skeletonema* sp. is known as tolerant of a wide range of pH and salinity.

The microbial water quality of Matatā Lagoon outlet does not meet bathing water guidelines because of occasional very high *E.coli* concentrations. The median *E.coli* bacteria concentration is 140 cfu/100mL (equivalent to NPS-FM “C” band), but the 95 percentile *E.coli* concentration is 4550 cfu/100mL (equivalent to NPS-FM “E” band) (**Table 3.1**).

3.4.2 Tributaries

Western Matatā lagoon outlet has similar concentrations of TN as the Awatarariki Stream (its main tributary), but higher concentrations of TP. Concentrations of dissolved nutrients (DRP and NNN) are higher in the tributaries than in the lagoon itself. Median *E.coli* concentrations are similar in both Awatarariki Stream and the western lagoon but the lagoon has a wider range of concentrations. TSS concentrations are also higher at the lagoon outlet than in the Awatarariki Stream, which probably reflects the shallow lagoon being prone to wind induced turbidity (**Figure 3.3** to **Figure 3.5**).

The drain at 53 Arawa Road has very high concentrations of nitrogen and phosphorus but the load to the lagoon will be small due to its small flow. The water quality of the Waimea Stream markedly deteriorates as it flows through Matatā township due to an increase in TN, NNN, NH4-N, TP and DRP concentrations. The pH also declines, which may indicate the influence of shallow groundwater seepage.

The Tarawera River has about twice the concentration of TN and NNN as found in Matatā Lagoon west, similar concentrations of TP and *E.coli* bacteria, but much higher (5 times) concentrations of DRP (**Figure 3.3** to **Figure 3.5**). Much of the phosphorus in the Tarawera River is derived from natural processes of mineralisation and enters the river via old groundwater.

3.4.3 Source of bacteria

Faecal source tracking (**FST**) of samples collected in 2022 and 2023 identified human source faecal bacteria present in:

- Drain at 53 Arawa Street (SW13) on 9 out of 9 occasions;
- Waimea Stream downstream (SW5) on 6 out of 9 occasions;
- Waimea Stream upstream (SW3) on 1 out of 9 occasions;
- Waitepuru Stream downstream (SW7) on 2 out of 9 occasions, and
- Awatarariki Stream (SW1) on 1 out of 9 occasions.

This probably reflects the impact of septic tanks in Matatā township on shallow groundwater seeping to waterways and perhaps directly to the lagoon. FST samples collected from the western Lagoon outlet (SW11) were either avian in origin or not attributable to a specific source.

3.4.4 Influence of birds on water quality

High numbers of waterfowl on the western lagoon may are likely to be contributing to the load of nutrients and faecal bacteria. A number of studies have found that water fowl can be a significant source of faecal coliform bacteria to some lagoons and beaches. This is partially because birds tend to defecate directly in the water, and partially because they have relatively high load of nutrients and faecal bacteria relative to their body size (e.g. Flemming and Fraser 2001, Don and Donovan 2001).

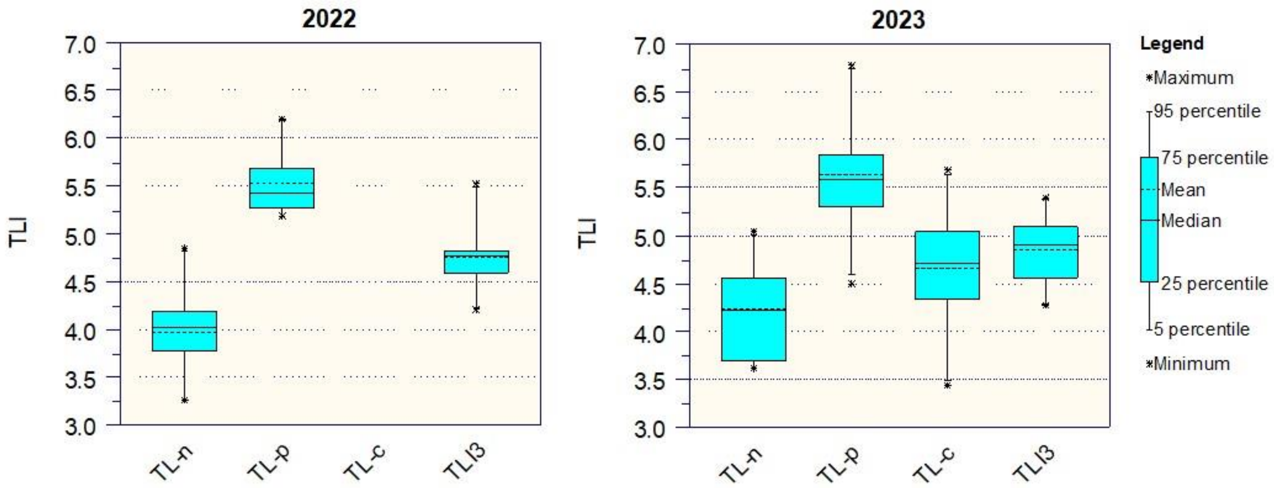

Figure 3.2: Trophic Level Index (TLI) and its constituents for nitrogen (TL-n), phosphorus (TL-p), and chlorophyll-*a* (TL-c) in Matatā Lagoon west outlet site. Data in graphs calculated as 'mean of logs'.

Table 3.1: Water quality statistics for Matatā Lagoon, tributaries and Tarawera River (2021 to 2024).

Site	Variable	n	Median	Min	Max	95 %ile	75 %ile	25 %ile	5 %ile
Awatarariki U/S	pH	25	7.5	6.8	9.1	8.4	7.6	7.4	7.2
Awatarariki U/S	EC (uS/cm)	27	196	113	358	268	215	182	116
Awatarariki U/S	E. coli (cfu/100 mL)	27	160	23	1,000	660	345	80	26
Awatarariki U/S	TSS (mg/L)	25	3.8	<8.0	62	49	5	2.3	0.8
Awatarariki U/S	TN (mg/L)	27	0.36	0.11	0.81	0.63	0.48	0.27	0.12
Awatarariki U/S	NH4-N (mg/L)	27	<0.010	<0.01	0.04	0.022	0.012	0.003	0.001
Awatarariki U/S	NNN (mg/L)	27	0.25	0.067	0.41	0.39	0.30	0.18	0.08
Awatarariki U/S	DRP (mg/L)	27	0.022	0.007	0.04	0.037	0.028	0.019	0.016
Awatarariki U/S	TP (mg/L)	27	0.036	0.025	0.050	0.050	0.043	0.030	0.026
Waimea D/S	pH	25	6.7	6.3	7.7	7.4	6.8	6.6	6.4
Waimea D/S	EC (uS/cm)	27	355	200	409	406	382	298	201
Waimea D/S	E. coli (cfu/100 mL)	27	320	50	7,900	4,245	1,100	220	50
Waimea D/S	TSS (mg/L)	25	5.2	1.6	30	23	8	3.2	1.8
Waimea D/S	TN (mg/L)	27	1.01	0.33	4.10	2.14	1.27	0.86	0.59
Waimea D/S	NH4-N (mg/L)	27	0.068	<0.01	2.1	0.876	0.118	0.051	0.018
Waimea D/S	NNN (mg/L)	27	0.69	0.09	1.60	1.42	1.04	0.50	0.24
Waimea D/S	DRP (mg/L)	27	0.027	0.006	0.062	0.054	0.043	0.019	0.009
Waimea D/S	TP (mg/L)	27	0.069	0.040	0.187	0.155	0.092	0.061	0.042
Waitepuru D/S	pH	25	7.0	6.6	8.3	7.5	7.0	6.9	6.7
Waitepuru D/S	EC (uS/cm)	27	184	106	239	219	197	175	106
Waitepuru D/S	E. coli (cfu/100 mL)	27	380	110	2,600	2,005	800	225	110
Waitepuru D/S	TSS (mg/L)	25	5.4	1.7	230	102	21	4.9	1.9
Waitepuru D/S	TN (mg/L)	27	0.35	0.24	0.85	0.59	0.39	0.29	0.25
Waitepuru D/S	NH4-N (mg/L)	27	0.019	<0.01	0.22	0.092	0.028	0.009	0
Waitepuru D/S	NNN (mg/L)	27	0.16	0.004	0.28	0.26	0.22	0.14	0.06
Waitepuru D/S	DRP (mg/L)	27	0.019	0.005	0.038	0.035	0.024	0.015	0.008
Waitepuru D/S	TP (mg/L)	27	0.042	0.024	0.250	0.104	0.050	0.031	0.026
Tarawera D/S	pH	25	7.4	6.9	9.1	8.0	7.5	7.2	7.0
Tarawera D/S	EC (uS/cm)	27	324	118	549	416	337	273	119
Tarawera D/S	E. coli (cfu/100 mL)	26	120	39	11,000	2,704	190	56	40
Tarawera D/S	TSS (mg/L)	25	13.0	<8.0	33	31	21	7.2	3.7
Tarawera D/S	TN (mg/L)	27	0.61	0.43	1.35	0.99	0.68	0.58	0.45
Tarawera D/S	NH4-N (mg/L)	27	0.022	<0.01	0.26	0.102	0.032	0.018	0.007
Tarawera D/S	NNN (mg/L)	27	0.47	0.36	0.58	0.56	0.52	0.43	0.36
Tarawera D/S	DRP (mg/L)	27	0.048	0.025	0.086	0.078	0.064	0.043	0.035
Tarawera D/S	TP (mg/L)	27	0.071	0.054	0.108	0.107	0.091	0.066	0.057
Lagoon west at outlet	pH	24	7.1	6.6	11.2	9.0	7.2	6.9	6.7
Lagoon west at outlet	EC (uS/cm)	26	203	124	253	236	214	171	130
Lagoon west at outlet	E. coli (cfu/100 mL)	25	140	19	6,300	4,650	323	48	24
Lagoon west at outlet	TSS (mg/L)	24	19.5	5.2	200	151	30	13.0	6.3
Lagoon west at outlet	TN (mg/L)	26	0.38	0.19	0.75	0.66	0.51	0.28	0.20
Lagoon west at outlet	NH4-N (mg/L)	26	0.017	<0.01	0.076	0.055	0.03	0.009	0.005
Lagoon west at outlet	NNN (mg/L)	26	0.07	<0.002	0.38	0.28	0.14	0.01	0.00
Lagoon west at outlet	DRP (mg/L)	26	0.009	0.005	0.073	0.032	0.014	0.007	0.006
Lagoon west at outlet	TP (mg/L)	26	0.069	0.029	0.470	0.235	0.080	0.055	0.046
Lagoon east at outlet	pH	25	6.9	6.5	9.1	7.9	7.3	6.8	6.6
Lagoon east at outlet	EC (uS/cm)	27	231	96	1314	835	333	178	110
Lagoon east at outlet	E. coli (cfu/100 mL)	26	65	12	1,400	576	130	50	14
Lagoon east at outlet	TSS (mg/L)	25	4.5	<8.0	27	24	9	3.0	1.5
Lagoon east at outlet	TN (mg/L)	27	0.36	0.20	0.62	0.61	0.51	0.25	0.21
Lagoon east at outlet	NH4-N (mg/L)	27	0.015	<0.01	0.038	0.035	0.019	0.009	0.005
Lagoon east at outlet	NNN (mg/L)	27	0.01	<0.002	0.48	0.46	0.26	0.01	0.00
Lagoon east at outlet	DRP (mg/L)	27	0.015	0.006	0.076	0.075	0.044	0.008	0.007
Lagoon east at outlet	TP (mg/L)	27	0.063	0.016	0.143	0.116	0.097	0.029	0.019

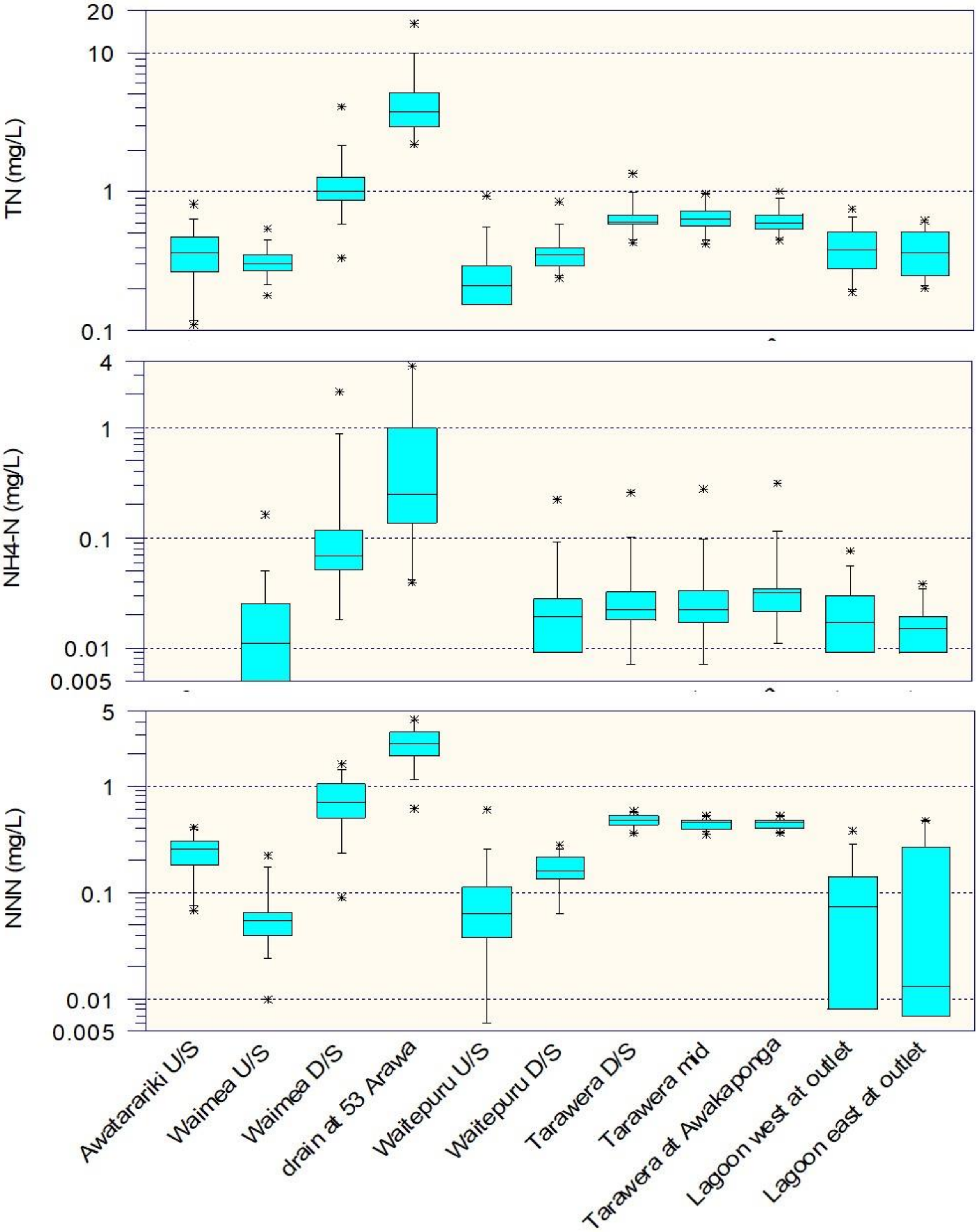

Figure 3.3: Water quality (TN, NH4-N and NNN) in Matatā Lagoon, its tributaries and the Tarawera River (Nov. 2021 to Jan. 2024).

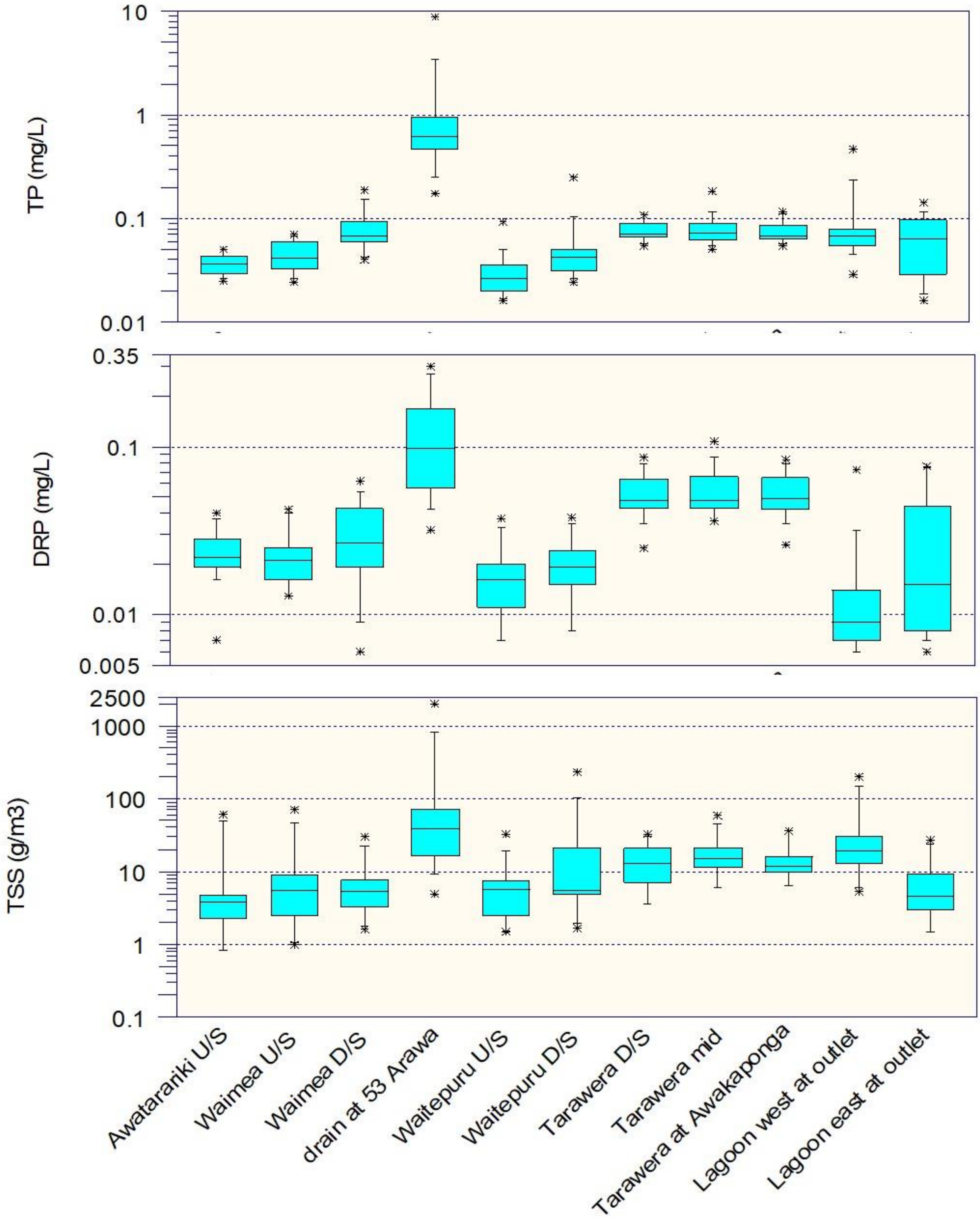

Figure 3.4: Water quality (TP, DRP and TSS) in Matatā Lagoon, its tributaries and the Tarawera River (Nov. 2021 to Jan. 2024).

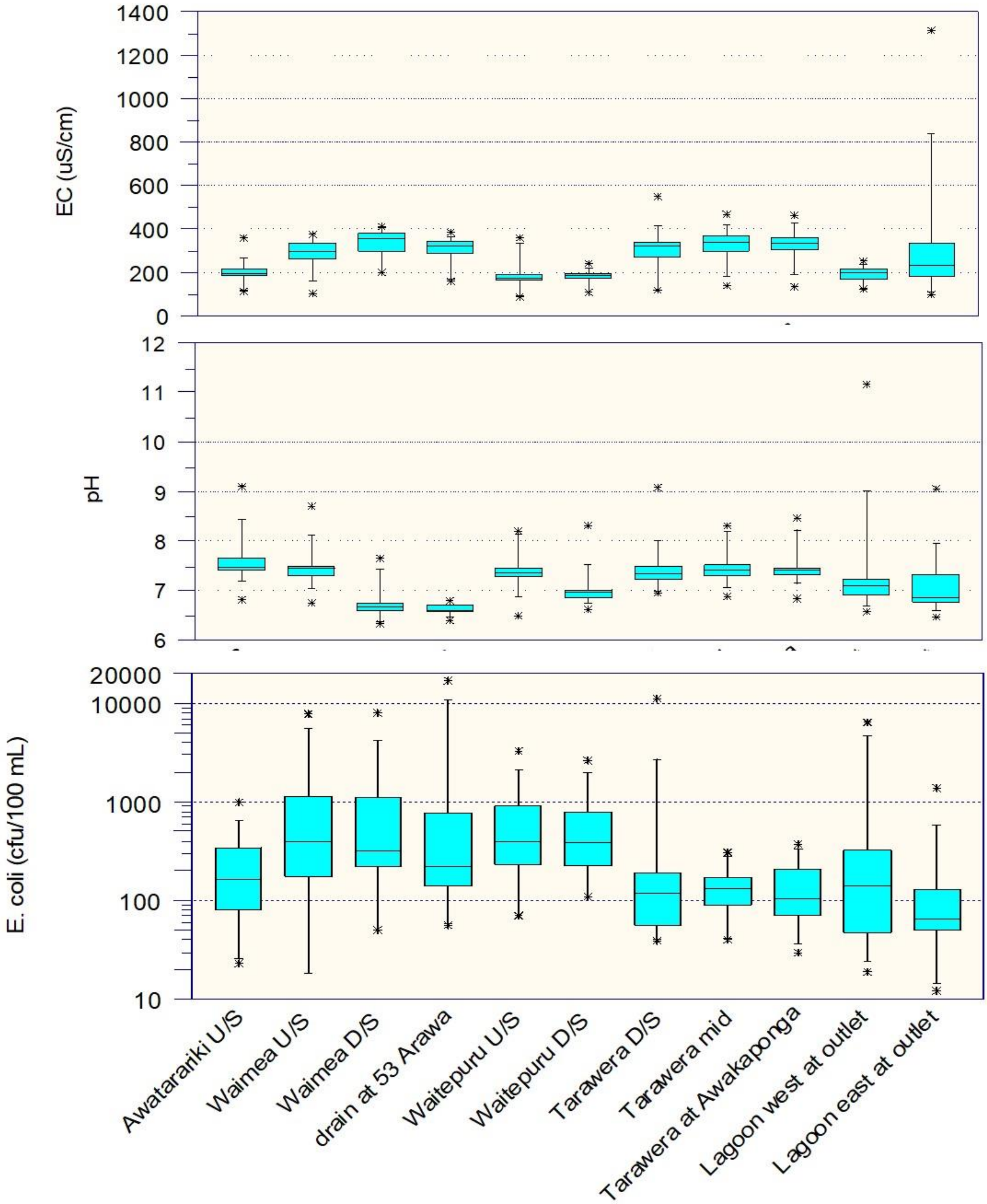

Figure 3.5: Water quality (EC, pH and *E.coli* bacteria) in Matatā Lagoon, its tributaries and the Tarawera River (Nov. 2021 to Jan. 2024).

3.5 Ecological Significance

The Matatā Wildlife Refuge Reserve is within the Te Teko Ecological District. Prior to the 2005 flood event it was described as an outstanding example of a complex dune land-wetland-open-water system on a freshwater-saltwater interface. This is unique in the Whakatāne Ecological Region. The lagoon and wetland areas have been identified as having exceptional and high botanical values (Beadel 1995). Although Te Awa o te Atua was originally an estuary, they are now wetlands. The Rangitāiki Plains once had extensive wetland systems but only only about 1.7% remain today. Te Awa o te Atua is an important component of the remaining remnant wetlands (Irving and Beadel 1992 in Owen et al 2010).

The Matatā Lagoon is recognised as a Site of Special Wildlife Interest of high wildlife habitat value (Rasch 1989).

3.6 Vegetation

3.6.1 Vegetation before 2005

There are two key botanical community types - wetland and dryland. Plant surveys prior to 2005 recorded 185 plant species, including two threatened fern species; the fern *Cylcosorus interruptus* and the sand-binding pingao *Ficinia spiralis* (Owen et al 2010, Appendix 2 and 3).

The western lagoon consisted of shallow open-water with raupō reedland dominating the western third of the site and southern margin, with patches of rautahi (*Carex geminata*). Reed sweet grass (*Glyceria maxima*) was common on the landward side of the raupō and near stream inflows. There was little open mown grass between the Wildlife Refuge and the road.

The eastern lagoon had raupō reedland in addition to large areas of *Apodasmia similus-Juncus sp.* rushland, Flaxland (flax/ *Juncus sp.- Apodasmia similis*, *Machaerina* [3] association), and areas of gorse-pampas-blackberry. Marsh ribbonwood shrubland (*Plagianthus divaricatus*) was common near the Tarawera River, and Reed sweet grass (*Glyceria maxima*) dominant near stream inflows. Invasive willow was present (Beadal 1995 in Owenb et al. 2010).

The dunes on the seaward side of the Matatā wildlife refuge were dominated by grassland and *Muehlenbeckia* shrubland with patches of Willow/ *Machaerina juncea* communities (Beadel 1995 in Owen et al. 2010).

3.6.2 Post 2005 flood event

The debris flow event in May 2005 covered large areas of raupō reedland, *Carex* sedgeland and fescue-pampas grassland at the western end of the western lagoon in silt and debris. The open-water of the western lagoon was also filled with silt and debris, replacing it with a silt pan and a very limited area of shallow water. Flood debris coming from the Waitepuru Stream catchment created a silt fan at the western end of the east lagoon which smothered the raupō reedland and honeysuckletall fescue-pampas grass and vinelands vegetation that was in this area (Owen et al. 2010).

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[3] *Machaerina* was previously called *Baumea. Apodasmia similis* was previously *Leptocarpus similis.*

Within a year of the flooding (June 2006) the whole of the in-filled western lagoon had naturally regenerated and was largely covered by a *Juncus* sp. dominated rush lands with pockets of raupō reed lands and very limited open shallow water areas present (Owen et al. 2010). Raupō later expanded through this area.

By late 2010 extensive restoration earthworks had been undertaken. These earthwork established floodway bays for sediment retention on the coastal side of the reserve area, and a smaller open-water lagoon close to the township with open mown grass areas in between the lagoon and the main road. The planting plan developed by Boffa Miskell in 2009 provided mapping and planting prescriptions for a range of vegetation types around the western lagoon area. Extensive planting was undertaken using a range of wetland, coastal and duneland plants[4]. The two eastern floodway bays were fully vegetated with raupō reed beds and marginal vegetation was in place through natural regeneration and plantings. As part of the restoration in 2010, about 44,000 native coastal and wetland plants were planted on the embankments and spoil dump areas (Owen et al. 2010).

Emergent wetland plants (mostly raupō) were naturally regenerating along the edge of the western lagoon after the 2010 earthworks. However, in May 2021 previously planted vegetation on the embankments to the north side of the lagoon (and western floodway bays) was removed to widen an access track / walkway. Raupō and other emergent wetland vegetation was removed around the same time, with about 0.75 ha of raupō lost from over 1.25km of shoreline (**Figure 3.6**). The disturbed soil has subsequently been colonised by gorse and pampas amongst regenerating and some planted native vegetation.

Currently, the amount and width of aquatic emergent wetland vegetation on the margin of the western lagoon is small. Most of the western lagoon section that was intended to naturally regenerate into shallow wetland habitat remains as open-water except for a section of raupō (0.2 ha) west of the Waimea Stream confluence and a c. 10m wide margin along the southern edge.

[4] In some areas regeneration was slower due to the planting of some species poorly suited to specific sites.

Figure 3.6: Western Matatā Lagoon in May 2021 (upper) and February 2022 (lower) showing the loss of riparian vegetation along the northern causeway and sedimentation bays, and the loss of raupō wetland margins from the open-water (images from Google Earth).

3.6.3 Current Vegetation

Vegetation was reassessed and mapped in December 2022 to establish the current state of the site. The vegetation is discussed below, with reference to the vegetation types described in **Table 3.2** and mapped on **Figure 3.7**. Detailed recommendations regarding planting are provided in **Section 4**. See **Appendix 4** for the plant species list.

The western tip of the lagoon is currently in mixed planting of harakeke, mānuka, cabbage tree (mapped as v2) or is largely unplanted (mapped as v3). This area would benefit from pest plant control and supplementary planting. The use of sedges like rautahi (*Carex germinata*), purei (*Carex secta*), pukio (*Carex virgata*) and giant umbrella sedge (*Cyperus ustulatus*) in v3 would reduce pest plant invasion and still enable access with a machine for cleaning when needed.

The southern margin of the lagoon (D) (township side) alternates between mown grass and native marginal and emergent vegetation like raupō (*Typha orientalis*), jointed baumea (*Machaerina articulata*)[5] and marsh clubrush/ kukuraho (*Bolboschoenus fluviatilis*). In places, patches of swamp willow weed (*Persicaria decipiens*), water pepper (*Persicaria hydropiper*) and *Myriophyllum propinquum* extend out over the water. The pest plant reedsweet grass (*Glyceria maxima*) is present at the eastern end. Grass is mown very close to the water edge in places and maintains a view-shaft over the open-water from housing areas. Further planting of small sections of the lagoon's southern edge (v5 and v6) in some coastal shrubs, and/or patches of sedges (pukio, purei, rautahi, giant umbrella sedge) would provide benefits in providing vegetation cover and reducing weed invasion while also maintaining view shafts to the water.

The northern edge of the lagoon adjacent to the walking track (mapped as v7) retains little native vegetation. Since being cleared in 2021 this area has been dominated by exotic grasses, gorse and pampas, alongside regenerating and some planted native plants (**Figure 3.8**). Natives include: pohuehue (*Muehlenbeckia complexa)*, mānuka (*Leptospermum scoparium)*, harakeke/flax (*Phormium tenax)* and patches of rautahi, kukuraho, jointed baumea, kuawa (*Schoenoplectus tabernaemontani*) and marsh clubrush/ kukuraho. Raupō and jointed baumea are regenerating as emergent plants in some sections of shallow water.

Pest plant control is required along the lagoon's northern edge along with supplementary planting of natives. Suitable species would be rautahi, and giant umbrella sedge, sections of purei and/or pukio, and patches of coastal trees and shrubs like karo (*Pittosporum crassifolium*) and taupata (*Coprosma repens*). Patches of harakehe (*Phormium tenax*) would be suitable low on the embankments, close to the water. Mountain flax/ wharariki (*Phormium cookianum*) can provide a low growing, robust edge on drier ground close to walkways. Purei prefers a wetter environment than pukio, and would be best suited to wetter sites and/or closest to the water, with pukio positioned a little further back. Rautahi and giant umbrella sedge can cope with a range of conditions and would be able to be planted slightly up the embankment as well as planting with the other two species.

The two eastern Floodway Bays (vegetation type 15a and 15b in Floodway Bay 4 and 3 respectively) remain almost fully vegetated with extensive raupō reedbeds, tending towards a drier environment towards the coastal side and the western end (vegetation type 11). In these drier areas pest plants such as willow and pampas are more evident. Pampas dominates the bund separating the two floodway bays (**Figure 3.9**). Plant pest control is required in these areas and the bund should be planted in mānuka and toetoe (*Austroderia toetoe*).

[5] *Machaerina articulata* previously called *Baumia articulata*.

Floodway Bays 1 and 2 are used as sediment detention ponds (B and C) that have been stripped of most of the vegetation within and around the margins during cleaning. At pond C, vegetation has re-established to some extent (v14), however the remaining vegetation around this pond (v13, 15 and 16) consists mostly of exotic species and pest plants, and cover is broken with areas of bare soil.

Plantings into the areas of duneland ecosystems (v12 and v17) are dominated by well-established mānuka. Pampas is common throughout v12. The area at v17 is very sparsely planted and struggling to establish full vegetative cover. Pest plants like gorse and pampas need to be controlled, and supplementary planting of some lower dune species like wiwi (*Ficinia nodosa*), tauhinu (*Ozothamnus leptophyllus*)[6] and pohuehue (*Muehlenbeckia sp.*) would be beneficial.

North and west of Floodway Bay 1 (mapped as v18, 19 and 20) are dryland areas. Pest plant control and supplementary planting of natives would support regeneration of indigenous vegetation. Coastal trees and shrubs would be most appropriate for v20, while a mix of dune species would be more suited in v18 and a range of both into v19. A single licorice plant (exotic) is thriving within v19 and should be controlled to prevent it from extending further or spreading.

3.6.4 Submerged macrophytes

The western lagoon itself has low abundance of submerged macrophytes but benthic algae are common. The general lack of submerged macrophytes is likely due to a combination of high grazing pressure from water fowl and the often very turbid water. The exotic plants of curled pondweed (*Potamogeton crispus*), oxygen weed (*Egeria densa*), and hornwort (*Ceratophyllum demersum*) have all been recorded in the lagoon.

Aquatic plants are a key to maintaining good water quality in natural lakes, by regulating water quality, stabilising sediments, and providing habitat for invertebrates and fish (Hilt et al. 2006; Kelly and Jellyman 2007; Schallenberg et al. 2010, Wetzel 1995). Encouraging the expansion of emergent wetland plants (e.g. raupō, *Machaerina articulata*) will support this role in the aquatic ecosystem, and is an important aspect of improving aquatic ecology in Matatā Lagoon.

Table 3.2: Vegetation types mapped in western Matatā Lagoon in December 2022. Refer to **Figure 3.7** for location of vegetation types.

Vege Type	Description	Pest plants
	Western corner of Open-water / Wetland Zone	
1	No indigenous vegetation. This is a drainage swale.	
2	Mixed planting of harakeke/flax, mānuka, cabbage tree/tī kouka.	Willow saplings, occasional pampas.

[6] Formally *Cassinia leptophylla*

3	Unplanted - mostly kikuyu with some pampas. Lower margins closer to the water include jointed baumea and one or two pukio/swamp sedge/giant umbrella sedge.	Pampas (*Cortaderia selloana*)
4	Aquatic emergent - 75% water pepper, scattered kukuraho in shallow water.	
	Southern edge of Open-water / Wetland Zone	
5	This area included patches of budding clubrush, jointed baumea closest to the water, and harakeke/flax, mānuka and tī kouka/cabbage tree plantings outside those margins. Kikuyu is creeping into the plantings from the mown areas, and pink bindweed is also present.	Pink bindweed, willow seedlings and saplings.
6	Towards the eastern end there are plantings of harakeke/flax, tī kouka/cabbage tree and mānuka with riparian margins of jointed baumea and patches of raupō. Moving west the margins are sparser and narrower, mown grass comes right to the water's edge in places. Near the Waimea Stream mouth raupō and jointed baumea extends out into the lagoon near and enclosed shallow open-water.	Willow, pink bindweed.
	Northern edge of Open-water / Wetland Zone	
7	Track-side margins are partly mown or sprayed and plantings that remain are very sparse. The drier embankment includes patches of pohuehue (*Muehlenbeckia complexa*), exotic grasses, gorse and pampas. The inside margin along the water's edge includes patches/sections of kukuraho, jointed baumea, kuawa, with some rautahi/cutty grass in drier places closer to the tracks, occasional emergent raupō and planted harakeke/flax and mānuka. Raupō and jointed baumea are regenerating as emergent plants in sections of shallow water.	Gorse, pampas, willow, Japanese honeysuckle, blackberry, arum green goddess, lupin. *Sagittaria platyphylla* (arrowhead) is present at the eastern end of the western lagoon.
	Embankment south of Floodway Bays	
8	A small patch that is dry and appears to be a pile of spoil possibly dumped from drain or culvert clearing. Vegetation includes one or two tutu, but is otherwise exotic and weedy, with brush wattle, pampas, Japanese honeysuckle and everlasting pea.	Wattle, pampas, blackberry, Japanese honeysuckle, wild pea flower.
9	Narrow margin between the track and the two western vegetated sediment embayments - lower sections include kukuraho, higher up the embankment there are sections of planted tī kouka/cabbage tree, harakeke/flax and mānuka.	Pampas.

16	There is no indigenous vegetation here. The embankment includes pampas, gorse, montbretia, willow, and Japanese honeysuckle.	Pampas, gorse, montbretia, willow, Japanese honeysuckle.
	Floodway Bays	
15a	**Floodway Bay 4 (the most eastern embayment)**: Large areas dominated by raupō with some patches of open-water remaining. Marginal and open-water areas, particularly towards the eastern end, have some patches of purei. Floodway Bay 4 becomes increasingly vegetated moving east to west. Willows are invading.	Willow, pampas.
21	Pampas on the separation bund between floodway bays 3 and 4.	Dense pampas
15b	**Floodway Bay 3 eastern end**: Vegetation dominated by dense raupō with very little visible open-water areas. There is more willow invasion compared to the Floodway Bay 4, as well as pampas from the drier margins on the seaward side.	Willow, pampas, arum green goddess.
11	**Floodway Bay 3 western end**: Vegetation dominated by raupō, with patches of harakeke/flax. Willow and pampas are invading from the seaward side. This area is drier towards the western end, with more mānuka appearing particularly to the seaward side.	Pampas, willow.
13	Scattered natives - tutu, koromiko, harakeke/flax, karamu, mānuka with pampas and willow.	Pampas, willow.
	Floodway Bay 2: Sedimentation basin for Awatarariki Stream	
12	**North of Floodway Bay 2**: Appears to have been planted - dominated by mānuka, some harakeke/flax and taupata. Pampas are common throughout and there are significant weed issues in the dunes immediately adjacent on the seaward side, although outside the mapped/planted area.	Pampas throughout.
13	Scattered natives - tutu, koromiko, harakeke/flax, karamu, mānuka with pampas and willow.	Pampas, willow.
14	Low-lying area close to water level - cleaver, grass-leaved rush, budding club rush, Japanese honeysuckle and willows, with some jointed baumea.	Willow, Japanese honeysuckle.
15	A single island in the middle of a sediment embayment; this area is drier and weedier with mostly fleabane, pampas, brush wattle and gorse.	Pampas, wattle, gorse.
	Floodway Bay 1: Sedimentation basin for Awatarariki Stream	

17	**North of Floodway Bay 1**: Planted area with open areas of grass, mostly kikuyu. Species include karo, harakeke/flax, mānuka, oioi, tī kouka/cabbage tree. Planting is sparse and widely spaced. Gorse is being treated in some areas, and brush wattle was also seen in this area.	Wattle, gorse.
18	**North of Floodway Bay 1:** Unmanaged dune vegetation with what is possibly some planting towards the eastern end.	Pampas.
19	Unmanaged area comprising mostly of kikuyu and pohuehue (*Muehlenbeckia* sp). There is a single patch of licorice plant.	Licorice plant.
20	Mixed exotic with tutu.	
	Open-water	
A	Small section of open-water in the drain section adjacent to vegetation type 4.	
B	Open-water - the westernmost embayment has no vegetation either emergent from the water or on the margins.	
C	Open-water with patches of emergent kukuraho (*Bolboschoenus fluviatilis*).	
D	Open-water - this is the main lagoon.	

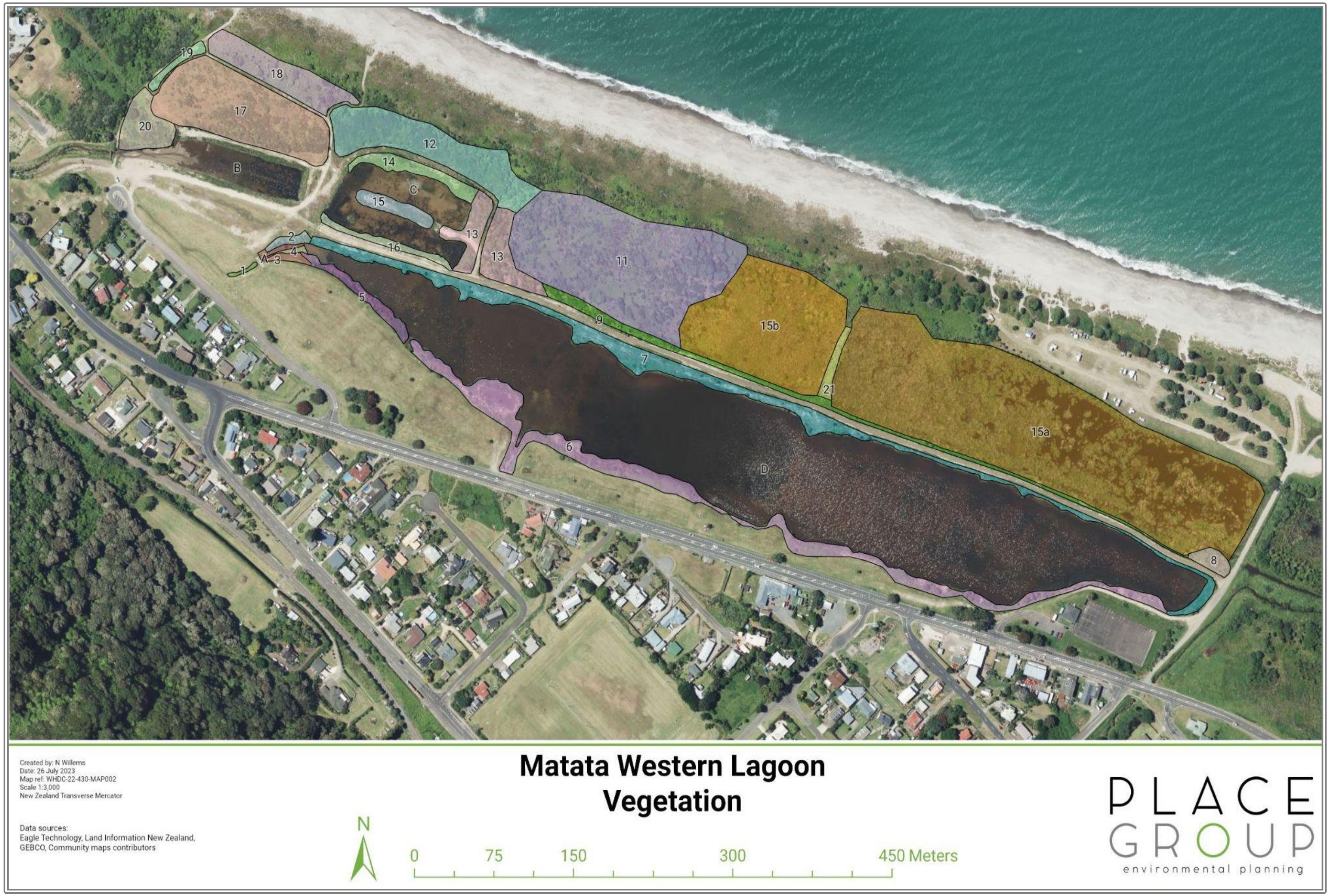

Figure 3.7: Vegetation types of western Matatā Lagoon. Refer to **Table 3.2** for vegetation descriptions.

Figure 3.8: Western Matatā Lagoon walkway (facing east) showing gorse and pampas grass on the embankment (top, 2022_01, middle, 2023_07, lower, 2024_05 after gorse has been sprayed).

Figure 3.9: Western Matatā Lagoon (facing east) showing extensive cover of pampas grass with white flower heads in the sedimentation bay, western end of floodway bay 3, embankment separating the floodway bay 3 and 4, and along the edge of the walk way (May 2024).

3.7 Fish

Fish surveys have found the following species in western Matatā lagoon or tributaries: Shortfin eel (*Anguilla australis*), longfin eel (*Anguilla dieffenbachia*), inanga (*Galaxias maculatus*), banded kōkopu (*Galaxias fasciatus*), common bully (*Gobiomorphus cotidianus*), redfin bully (*Gobiomorphus huttoni*), giant bully (*Gobiomorphus gobioides*), goldfish (*Carassius auratus*), Rudd (*Scardinius erythrophthalmus*), and gamusia (*Gambusia affinis*); shrimp were also common (ATS 2020, NZFWF database). Most of these fish were detected in in recent eDNA samples (**Table 3.3)**. It is noteworthy that the banded kōkopu were only detected at the western end of the lagoon and are likely inhabiting the Awatarariki Stream rather than the lagoon itself. Detection of kahawai eDNA in the western lagoon is likely to be via bird faeces, although juvenile kahawai are known to utilise estuarine areas (**Table 3.3**).

Two fish species present in western Matatā Lagoon have a threat classification, these are longfin eel and inanga, both classified as “At-Risk – Declining”. Gambusia is a national pest “unwanted organism” (Dunn et al. 2018).

Hick et al. (2015) fished the lower Tarawera River in 2014 and found shortfin eel, longfin eel, inanga, common smelt, common bully, redfin bully, parore, stargazer, and yellow eyed mullet.

It is expected that migratory native fish of long-fin eel, banded kokopu, koaro, redfin bully, will pass through Matatā lagoon in order to reach upstream habitats in the Awatarariki Stream, Waimea Stream and Waitepuru Stream.

Table 3.3: Fish eDNA present in samples from western Matatā Lagoon. Numbers are the eDNA sequences detected.

		Nov-22			Sep-22		
Scientific Name	Common Name	Matata west	Matata mid	Matata outlet	Matata west	Matata mid	Matata outlet
Carassius auratus	Goldfish	✓ 6699	✓ 1254	✓ 4504	✓ 9560	✓ 12381	✓ 22776
Scardinius erythrophthalmus	Rudd	✓ 756	✓ 7965	✓ 8575	✓ 0	✓ 32	✓ 1349
Gambusia affinis	Mosquitofish	✓ 264	✓ 356	✓ 563	✓ 234	✓ 0	✓ 78
Anguilla australis	Shortfin eel	✓ 637	✓ 734	✓ 1194	✓ 726	✓ 209	✓ 184
Anguilla dieffenbachii	Longfin eel	✓ 21	✓ 5	✓ 19			
Galaxias maculatus	Inanga	✓ 19		✓ 143			
Galaxias fasciatus	Banded kokopu	✓ 295					
Gobiomorphus cotidianus	Common/Cran bully	✓ 647	✓ 422	✓ 221			
Gobiomorphus	Bullies	✓ 7317	✓ 3489	✓ 2246	✓ 995	✓ 383	✓ 888
Anguilla	Eels	✓ 236		✓ 5			
Arripis trutta	Kahawai			✓ 14			

3.8 Birds

3.8.1 Birds before 2005

The Matatā Lagoon is recognised as a Site of Special Wildlife Interest of high wildlife habitat value. It shows a progression of estuarine rush wetland to freshwater raupō-flax wetland, bordered by scrub and dunes. Many bird species inhabit the Reserve including banded rail, NZ dabchick, spotless crake, marsh crake, Australasian bittern, white heron, reef heron, and Caspian tern and North Island fernbird (Rasch 1989).

Forty-three species of wetland birds have been recorded at the Reserve. All of these species are either fully or partially dependent on the Reserve for their annual and/or seasonal habitat requirements. A total of 22 of these birds are threatened bird species (Owen et al. 2010, **Appendix 3**).

Owen et al (2010) described the bird community of Matatā Wildlife Reserve as follows:

"The wetland has many features of good wetland wildlife habitat. There are open-water areas in both lagoons for loafing water birds especially waterfowl, shallow margins for wading birds, sheltered areas of vegetation for secretive species such as fernbird, rail and bittern, banks for shags and herons to roost and islands for potential breeding sites.

In addition to these species, grey teal, NZ scaup, grey duck, mallard, paradise shelduck, black swan and Canada geese reside in good numbers at the lagoons especially during the waterfowl hunting season when the Reserve becomes extremely popular as no hunting is permitted. Wading birds such as spur-winged plover, black-fronted dotterel and royal spoonbill also frequent the wetland most often at the western end of the east lagoon.

Daily inhabitants include good numbers of the following waterfowl NZ scaup, Australasian shoveler, paradise shelduck, grey teal, grey duck, NZ dabchick, Australasian coot, mallard, black swan, Canada geese and feral geese. The following wading birds use the shallow or dry margins of the two lagoons, *pied stilt, white-faced heron, spur-winged plover, white heron, royal spoonbill, variable oystercatcher and northern NZ dotterel. Other rare migratory visitors recorded there include little egret, black-fronted dotterel, sharp-tailed sandpiper, turnstone, banded dotterel, black-fronted tern, white-winged black tern and Eastern cattle egret.*

The open-water areas are used regularly by little shag, little black shag, black shag, pied shag, Caspian tern, white-fronted tern, red-billed gull, black-billed gull, and southern black-backed gull. Pukeko, banded rail, North Island fernbird and Australasian bittern inhabit the dense vegetated raupō reed lands and salt marsh margins of both lagoons.

A total of twenty-two threatened bird species ([Robertson et al. 2021]) have been recorded at the Reserve. They are NZ dabchick, black shag, pied shag, little black shag, little shag, white heron, reef heron, Australasian bittern, royal spoonbill, grey duck, banded rail, spotless crake, marsh crake, pied stilt, northern NZ dotterel, banded dotterel, red-billed gull, black-billed gull, black-fronted tern, Caspian tern, white-fronted tern and North Island fernbird"

3.8.2 Bird habitat since 2005

The loss of open-water in the western lagoon after the 2005 flood reduced habitat for waterfowl, shag, heron, wader, tern and gull species which utilised this area. The loss of raupō reedlands and carex sedgeland areas from the western end of the western lagoon after the 2005 flood reduced habitat for spotless crake, banded rail, marsh crake, North Island fernbird and Australasian bittern that inhabit these areas. These secretive species rely on dense wetland vegetation and their margins for their habitat, feeding and breeding requirements. Waterfowl also use these areas extensively for loafing, resting, and breeding (Owen et al. 2010).

Large areas of raupō reedland have developed in the floodway bays which is valuable in recreating previous habitat. However, there is little open-water directly connected to the raupō reedland in these areas which limits its use for waterfowl. An important component of the original regeneration planting plans for the western lagoon of Te Awa of Te Atua was to have raupō reedland, and flaxland as a riparian margin surrounding much of the open-water.

Emergent wetland plants (mostly raupō) were naturally regenerating along the edge of the western lagoon after the 2010 earthworks. However, in mid-2021 most of this raupō vegetation (about 0.75 ha over 1.25km of shoreline) was removed – reducing habitat for aquatic life and wetland birds.

Currently, the amount and width of aquatic emergent wetland vegetation on the margin of the western lagoon is small. Most of the western lagoon section that was intended to naturally regenerate into shallow wetland habitat remains as open-water except for a section of raupō (0.2 ha) west of the Waimea Stream confluence and a *c*. 10m wide margin along the southern edge.

Owen et al (2010) observed in late 2010, after the earthworks to restore the lagoon but before any natural regeneration of riparian or wetland plants, that:

"*The western lagoon will over time provide adequate habitats for native and introduced water bird species, some of which are already well established but in low numbers. To improve this attractiveness, the margins will need some aquatic emergent vegetation to make them more suitable to water birds by providing shelter, cover and breeding sites. In its current raw state this is unlikely to be fully achieved*."

The amount of aquatic emergent wetland vegetation on the margin of the western lagoon is currently small. Realising and optimising the habitat values of the western lagoon for birds will require allowing emergent wetland plants (e.g. raupō reedland, *Carex* sedgeland, flaxland) to regenerate within, and adjacent to, what is currently open-water.

Few bird surveys have been undertaken in Matatā in recent years. However, eDNA samples have identified dominant waterfowl that use the open-water for the lagoon, including: mallard duck, Eurasian coot, NZ scaup, pāpango, grey teal, pukeko, black swan, Australasian shoveler, paradise shelduck, and pied stilt (**Figure 3.4**). In addition to this, bird sighting for Matatā recorded with www.ebird.org during 2023-24 included: silver gull, kelp gull, little pied cormorant, little black cormorant, pied cormorant, swamp harrier, sacred kingifisher, Caspian tern, bar-tailed godwit, graylag goose, Canada goose, pacific black duck, NZ grebe, white-faced heron, royal spoonbill, NZ fernbird, welcome swallow, and Muscovy duck.

Table 3.4: Bird eDNA present in water samples from western Matatā Lagoon. Numbers are the eDNA sequences detected.

		Nov-22			Sep-22		
Scientific Name	**Common Name**	**Matata west**	**Matata mid**	**Matata outlet**	**Matata west**	**Matata mid**	**Matata outlet**
Anas platyrhynchos	Mallard duck	✓ 142		✓ 260	✓ 190	✓ 87	✓ 0
Fulica atra	Eurasian coot	✓ 109	✓ 5	✓ 14	✓ 64	✓ 0	✓ 9
Aythya novaeseelandiae	NZ scaup, pāpango	✓ 350		✓ 36			
Aythya sp.	Diving ducks				✓ 0	✓ 43	✓ 0
Anas chlorotis or gracilis	Brown or grey teal	✓ 37					
Porphyrio melanotus	Pukeko	✓ 104		✓ 126	✓ 0	✓ 0	✓ 35
Cygnus atratus	Black swan	✓ 36	✓ 6		✓ 0	✓ 0	✓ 5
Anas rhynchotis	Australasian shoveler	✓ 9					
Tadorna variegata	Paradise Shelduck			✓ 26	✓ 89	✓ 0	✓ 0
Himantopus	Pied stilt				✓ 0	✓ 0	✓ 11
Larus	Seagull	✓ 20					
Zosterops lateralis	Silvereye	✓ 20					
Sturnus vulgaris	Common starling	✓ 17					
Passer domesticus	House sparrow	✓ 19		✓ 22	✓ 34	✓ 0	✓ 0
Melopsittacus undulatus	Budgerigar	✓ 63					
Turdus	Thrush	✓ 19			✓ 55	✓ 0	✓ 0
Turdus merula	Blackbird				✓ 10	✓ 0	✓ 0

3.9 Ecological issues affecting Te Awa o te Atua / Matatā Lagoon

Key ecological and water quality issues identified in western Te Awa o te Atua / Matatā Lagoon include:

- Historic contamination of buried sediments that restricts the ability to deepen the lagoon.
- Turbid water with low clarity and high nutrient concentrations. Possible seepage of septic tank disposal to the lagoon via shallow groundwater.

- Pest plants (including gorse, pampas grass and willow) are a problem in the western lagoon, particularly on drier areas of the wetlands, in areas where there has been recent disturbance near the sedimentation floodways, and on the embankment of the walkway.

- Limited aquatic emergent vegetation along margins of open-water in the western lagoon to support better water quality and provide habitat for birds and aquatic life.

- Past removal of aquatic emergent macrophytes and riparian vegetation from the embankments beside the walkway has resulted in loss of habitat and pest plant invasion. These actions may reflect a lack of awareness of the ecological concept plan for western Matatā Lagoon (**Appendix 2**) which allows for wetland margins and natural regeneration of shallow wetland habitat within what is currently open-water.

- There is a need to balance the retention of open water in the western lagoon with allowing the development of aquatic emergent vegetation to support better water quality and provide habitat for birds and aquatic life. Currently, raupō and the jointed rush (*Machaerina* sp*)* is regenerating in shallow areas along the edge of the western lagoon and is extending into the lagoon where sedimentation has occurred at the mouth of the Waimea Stream. However, the width of aquatic emergent wetland vegetation on the margin of the western lagoon remains small and considerably less than what was intended to regenerate into shallow wetland habitat following the post-flood remediation.

- Siltation near Waimea Stream mouth reducing water depth can be turned into an opportunity to develop aquatic emergent vegetation at the western end of the lagoon.

4 Management Actions to improve Te Awa o te Atua / Matatā Lagoon

4.1 Introduction

A summary of ecological issues facing western Matatā Lagoon and potential management actions to address these are described in **Table 4.1**. This section describes the key management actions to address ecological issues for western Matatā Lagoon; these are:

- Reduce the risk of catchment nutrient loads to Matatā Lagoon by progressing reticulation of the town wastewater system.
- Pest plant control and supplementary restoration planting of native vegetation.
- Encouraging aquatic emergent wetlands to develop along the lagoon margins and at the western end. These provide multiple benefits in removing nutrients and sediment, providing habitat for aquatic life and increasing biodiversity values for birds.
- Install floating wetlands near the mouth of Waimea Stream and Awatarariki Stream to remove nutrients, improve biodiversity and manage deposition of sediment in the lagoon.

Figure 4.1 maps the proposed location of recommended actions in western Matatā lagoon relating to pest plant control, native planting, areas for aquatic emergent wetlands and possible areas for floating wetlands.

Table 4.1: Potential interventions to address ecological and water quality issues in western Matatā Lagoon

Issues	Causes	Potential management options
Poor water quality, low clarity	External (catchment) nutrient load	o Reticulate sewage to reduced risk of leaching from septic tanks. o Create treatment wetlands in the western end of Lagoon West to treat incoming water flows (and improve habitat).
	Internal nutrient load via sediment resuspension. An option for deepening the lagoon is restricted by a buried layer of historic contaminated sediment.	o Emergent wetlands will help stabilise sediments and provide habitat for zooplankton. o Install floating wetlands near stream inflows to remove nutrients and provide habitat.
Siltation near Waimea Creek	Sediment from stream inflows reducing water depth at confluence	o Direct Waimea Creek to wetlands in the western lagoon by using a peninsular or floating wetlands.
Loss of native riparian plants and colonisation by weeds on northern shoreline	Recent removal of riparian planting on northern shore has allowed weed colonisation.	o Enhance native riparian cover with pest plant control and planting of natives.
Limited cover of aquatic emergent wetlands resticting benefits for water quality, aquatic life and birds	Partially due to the direct removal of raupo.	o Agree on management plan to identify areas intended for open water and areas where wetland development is encouraged.
High values for birds but native bird habitat reduced with loss of emergent wetlands	Direct removal of riparian plants and raupo has reduced native bird cover.	o Enhance native riparian plant cover with pest plant control and planting of natives. o Enhance bird habitat with floating wetlands.

4.2 Reduce catchment nutrient loads - Matatā town wastewater reticulation

4.2.1 General

Reducing external nutrient loads is an important strategy for lake restoration. In rural catchments diffuse pollution from agriculture contributes the majority of nutrients (Gluckman 2017), but in urban catchments, point sources (e.g. wastewater) can be a major source of external nutrient loads; controlling these can provide substantial nutrient load reductions.

General approaches to improving lake water quality have been described in several recent reviews for New Zealand lakes (e.g., Abell *et al*. 2020, Hamilton 2019, Abell 2018, Hill 2018, Gibbs and Hickey 2012). Abell et al. (2020) grouped restoration techniques as: a) controlling external loads, b) controlling internal loads, c) biomanipulation and d) hydraulic manipulation; a summary of these restoration techniques is in **Appendix 5**.

McDowell and Nash (2012) found that land management strategies (e.g. fertiliser management) were the most cost-effective way of mitigating phosphorus exports. Edge-of-field strategies, which remove P from runoff (i.e., wetlands) or prevent runoff were less cost-effective, but had other benefits including removing other contaminants like nitrogen. Similarly in urban areas, addressing external nutrient loads at source is often the most cost-effective management strategy.

4.2.2 Western Matatā Lagoon

Matatā lagoon has poor water quality and low water clarity. There are multiple factors driving the poor water quality including: external inputs from rivers and groundwater, internal nutrient loads from waterfowl, and shallow water depth allowing sediment resuspension and mobilising nutrients within the sediment layer.

The greatest load of nutrients to Western Matatā lagoon likely come from the Awatarariki Stream due to its large contributing catchment. Most of the catchment is in native forest, but there may be some opportunity to address nutrient inputs from the upper catchment that is in farmland (e.g. through use of detainment bunds in paddocks).

The contribution of Matatā township to the lagoon's nutrient load has not been quantified, but the water quality of the Waimea Stream considerably deteriorates as it flows through Matatā township and has indications of human sourced faecal bacteria. This probably reflects the impact of septic tanks in Matatā township on shallow groundwater seeping to waterways and perhaps directly to the lagoon. Reticulation of Matatā town wastewater is an important aspect of improving water quality. WDC is progressing reticulation through the Te Niaotanga ō Mataatua ō Te Arawa Matatā Wastewater project.

4.3 Pest Plant Control and Native Planting around Western Matatā lagoon

Te Awa o te Atua is known as an outstanding example of a complex dune land-wetland-open-water system, and for having high habitat values for birds. Controlling pest plants and supplementary planting is fundamental to maintaining these values. It is also an important aspect of consent conditions requiring the establishment and survival of indigenous plantings, and the long-term control of pest plants.

Recommendations for pest plant control and planting are provided in **Table 4.2**, with reference for each vegetation type mapped in **Figure 3.7**. The western lagoon area is re-establishing indigenous wetland ecosystems but in many areas pest plant control is important for ensuring survival of native plant communities. Control of willow, pampas and other weeds should be implemented with urgency before infestations become more dense or extensive. The location of mature pampas is visible in recent aerial images (**Figure 4.1**). *Sagittaria platyphylla* (arrowhead) is present at the eastern end of the western lagoon. This pest plant is classed as an exclusion or eradication species, and should be eradicated from the area.

Several areas around the western lagoon have well-established native vegetation that only requires some maintenance with pest plant control. In other areas, supplementary planting (and occasionally full planting) is required to establish appropriate native vegetation and reduce pest plant invasion. The native vegetation provides important habitat, provides a transition to aquatic habitat and improves aesthetics.

The use of low-growing sedges or low growing flax species can provide an aesthetically pleasing margin while also retaining viewing. They have the added advantage of enabling the use of grass-specific herbicides to control kikuyu and other exotic grass species (e.g. reed sweet grass and mercer grass) to prevent them dominating some of the margin areas.

Planting the right species in the right zone will promote higher survival rates, e.g. planting wetland plants near the water, coastal trees and shrubs (e.g. taupata and karo) in drier areas, with dune plants (e.g. pohuehue, wiwi, tauhinu) restricted to back dune habitats on the seaward side.

Movement of machinery can be a significant contributor to the spread of pest plants such as *glyceria maxima*. This risk of spreading pest plants can be minimised by ensuring machinery is checked and cleaned before and after moving between sites.

Table 4.2: Recommended planting for western Matatā Lagoon. Refer to **Figure 3.7** for location of vegetation types.

Vege Type	Planting recommendations	Pest plant control and additional management
	Western corner of Open-water / Wetland Zone	
1	No planting required.	
2	Any planting can comprise the same species already used, with the addition of some coastal shrub species like karo, taupata (*Coprosma repens)*.	Making this area larger, wider, into a compact shape may help maintain the plantings with less maintenance needed. Supplementary planting may be useful.
3	Low-growing sedges - giant umbrella sedge, rautahi, pukio/swamp sedge, purei (closest to water).	Alternatively, control pest plants - grasses can be controlled using haloxyfop (brand name eg Gallant) to control grass species and promote sedges and rushes.
4	No planting required.	
	Southern edge of Open-water / Wetland Zone	
5	No planting required.	Reducing kikuyu and control of pink bindweed would promote growth of indigenous species. Where there are already native plantings, broadening the band of planting may help maintain it.
6	Supplementary planting could include some patches of purei and pukio/swamp sedge. The edges of this type of planting could be maintained with haloxyfop spray to maintain	Maintain low-growing sedges and rushes around the margins.

	a tidy edge rather than mowing into the sedges.	
	Northern edge of Open-water / Wetland Zone	
7	Near top of embankment: Mountain flax to as an edge with the pathway. Occasional patches of coastal shrubs like karo, and taupata. Close to the water: purei in patches by the water, rautahi higher up slope. Where the area below the walkway is wider: rautahi, occasional harakeke, mānuka, tī kouka/cabbage tree.	Pest plant control of pampas and gorse. Pest plant control of *Sagittaria platyphylla* (arrowhead) is present at the eastern end of the western lagoon. This pest is classed as an exclusion or eradication species.
	Embankment south of Floodway Bays	
8	Plant coastal shrubs and mānuka.	Site preparation will need to be thorough, undertaken several times over a couple of seasons, and well-maintained following planting to avoid being inundated with Japanese honeysuckle and other weeds.
9	No planting required.	Pest plant control of pampas
16	Purei (a few) closest to the water, pukio/swamp sedge and mostly rautahi to the top of the embankment.	Not much space for planting here and access required for cleaning.
	Floodway Bays	
15a	**Floodway Bay 4 - the most eastern embayment**: No planting required.	Willow poisoning.
21	Mānuka with cabbage trees and occasional harakeke/flax. Mānuka and coastal shrubs towards the dunes.	Pest plant control of pampas.
15b	**Floodway Bay 3 eastern end**: No planting required.	Pest plant control of pampas and willow.

11	**Floodway Bay 3 western end**: No planting required in the wetter areas. Reassess planting needs following pest plant control.	Pest plant control (e.g. pampas and willow).
13	Add karo, taupata, mānuka and occasional tī kouka. Closer to the water (ie the embankment down into the sediment detention area) rautahi and maybe into purei/pukio/swamp sedge if suitable sites are available.	Pest plant control.
	Floodway Bay 2: Sedimentation basin for Awatararik Stream	
12	**North of Floodway Bay 2**: Coastal shrubs - karo, taupata, occasional pohutukawa (noting view shafts from township should be considered). Supplementary planting only, maintain existing mānuka.	Pest plant control is the main need here
13	Add karo, taupata, mānuka and occasional tī kouka. Closer to the water (ie the embankment down into the sediment detention area) rautahi and maybe into purei/pukio/swamp sedge if suitable sites are available.	Pest plant control.
14	Purei closest to water, grading to pukio/swamp sedge and rautahi or Māori sedge. Occasional harakeke/flax and a clump of tī kouka/cabbage tree.	
15	Add karo, taupata, mānuka and occasional tī kouka. Closer to the water (ie the embankment down into the sediment detention area) rautahi and maybe into purei/pukio/swamp sedge if suitable sites are available. If the intent is for this to be accessed with a machine periodically for cleaning, then plant the top with rautahi or Maori sedge, that can cope with the dry and recover after being driven on.	Spray weeds before planting the island.

	Floodway Bay 1: Sedimentation basin for Awatarariki Stream	
17	**North of Floodway Bay 1**: This is the closest to dune other than vegetation types 12 and 18. Planting needs to be infilled using coastal shrubs - karo, taupata, possibly a few pohutukawa. Pohuehue could be planted in patches along the northwestern corner and western end, with some wiwi.	
18	**North of Floodway Bay 1:** Low priority, planting not required.	
19	Areas of pohuehue and occasional coastal shrubs, wiwi closer to the coastal end (match area to the west).	Pest plant control and spray licorice plant.
20	Coastal shrubs could be planted in a supplementary way, also a few harakeke/flax, mānuka.	
	Open-water	
A	No planting required.	
B	No planting required, although the margins could be enhanced with some patches of purei/pukio/swamp sedge, even just a few. Maybe some jointed baumea/kutakuta/kuawa.	Emergent plantings should not be added if the pond is required to maintain maximum capacity for sediment retention or is likely to be cleared frequently. Some emergent pests can be carefully removed during cleaning and then small sections re-established by replanting the clumps into the margins.
C	No planting required.	Likely to occasionally need to be cleared unless the intent is for this to become a shallow vegetated wetland area. Existing emergent species will likely spread so can be left if desired or removed if not.
D	**Main western lagoon**: No planting required, however planted floating wetlands would benefit bird habitat and water quality.	Allow aquatic emergent plants to expand

4.4 Aquatic emergent wetlands

4.4.1 General

Wetlands provide multiple benefits to support ecological functions, nutrient removal and biodiversity. They are an interface between terrestrial and aquatic environments that provide shelter, cover and breeding sites for birds, fish and other aquatic life.

Wetlands are the ‘kidneys of the landscape’. They are a natural interface between land and water that cleans the water. Contaminants are attenuated and removed through processes of denitrification, plant uptake, deposition, adsorption and mineralization. Emergent wetland plants stabilise sediment, filter the water, enhance denitrification and help remove and immobilise heavy metals from the water (e.g. Kadlec and Wallace 2009, Guigue J et al. 2013). Aquatic emergent plants also provide habitat for zooplankton that predate on phytoplankton and provide a natural control on their biomass.

Constructed wetlands can be both an effective and cost-effective way of removing sediment and nitrogen. The effectiveness of wetlands for nutrient removal depends on a range of factors including: design, hydraulic loading, incoming nutrient concentrations and seasonal temperatures (Mitch et al. 2000, Hamill et al. 2010).

There is considerable potential to encourage in-lake wetlands in Matatā Lagoon that would provide multiple benefits of stabilising sediment, improving water quality, improving biodiversity and enhancing habitat for invertebrates, fish and birds.

4.4.2 Western Matatā Lagoon

An important component of the original regeneration planting plans for the western lagoon of Te Awa of Te Atua was to have raupō reedland, and flaxland as a riparian margin surrounding much of the open-water. Substantial sections around the lagoon margins, and particularly to the west of Waimea Stream mouth, were intended to naturally regenerate into shallow wetlands, however the amount of aquatic emergent vegetation remain relatively small. This is illustrated by **Figure 4.1** which shows the extent of what was originally intended as open-water in the concept plans for the remediation works (Wildlands 2007). There is room for considerable wetland expansion before this area is impinged.

Water depth will limit where emergent aquatic plants can grow. For example, water depth needs to be shallow for raupō to establish, but once established the plants can extend to about 1.2m depth. Areas of the lagoon deeper the 1.2m will remain free of emergent plants like raupō.

Optimising the habitat values of the western lagoon for water birds will require allowing the expansion of aquatic emergent vegetation to provide shelter, cover and breeding sites. In practice this means allowing emergent wetland plants (e.g. raupō reedland, carex sedgeland, flaxland) to regenerate within, and adjacent to, what is currently open-water.

There is an opportunity to actively develop aquatic emergent wetlands along the lagoon margins and particularly west of Waimea Stream. This may involve allowing sediment accumulation at the western end of the lagoon by directing the flow the Waimea Stream towards the west. This could be done by creating a peninsular to direct the flow or placing a series of floating wetlands to achieve a similar effect (see possible location in **Figure 4.1**).

4.5 Floating wetlands

4.5.1 General

Floating wetlands consist of buoyant mats or platforms that are mass-planted with emergent wetland plants, and are anchored on the surface of treatment ponds or nutrient rich lakes. The plant roots grow through the mats and down into the water column forming large, dense mats. Large root systems develop to allow the plants to obtain their nutrient requirements from the water column. Localised anaerobic zones are created beneath/within the floating mats where the process of denitrification is favoured. Biofilms develop over the extensive root surface area and serve to increase organic matter breakdown, nutrient adsorption and trapping of fine particulates (Sukias 2010).

Floating wetlands are widely used around New Zealand for water treatment and ecological enhancement. They can provide protected islands for bird habitat and breeding; their root systems provide habitat and shelter for fish and zooplankton, and the shade provided by the plant mats reduces algal growth and results in increased settling of suspended solids onto the bottom of the lake.

Floating wetlands can be very effective at nutrient removal, and particularly nitrogen removal. To be most effective for mass nutrient removal, floating wetlands need to be installed in a location where a flow of water passes through them. They are about twice as effective at removing nitrogen and phosphorus as conventional constructed wetlands, but their expense to install makes them less cost-effective (Tanner et al. 2011, Hamill 2010).

4.5.2 Western Matatā Lagoon

Floating wetlands may be a good option for Matata lagoon. If used strategically in locations near the mouth of the Waimea Stream and the Awatarariki Stream, they could provide multiple benefits including removing nutrients, shading the water, and providing habitat for birds and fish.

In the shallow water of Matata Lagoon, their root system will also influence water flow, so a string of floating wetlands near the Waimea Stream mouth could help direct where sedimentation occurs. This gives the opportunity to use floating wetlands to direct sedimentation towards the west to support expansion of shallow emergent wetlands in this area of the lagoon. An example of how floating wetlands could be placed in western Matata Lagoon is shown in **Figure 4.1**.

Figure 4.1: Western Matatā Lagoon showing approximate extent of open-water in concept plans for remediation works, and possible locations for floating wetlands. White flowers of pampas are visible along the walkway and in the western end of Floodway Bay 2, indicating areas requiring plant best control. (Aerial image, May 2024).

4.6 Summary: Actions to improve water quality and ecology

Intervention options to improve water quality in Te Awa o te Atua / Matatā Lagoon are summarised in **Table 4.2**. The high priority actions were chosen that would address multiple issues, in a cost-effective way, and with low risk of adverse effects.

The management actions with most potential to improve ecological values in Matatā Lagoon include:

- Reduce the risk of catchment nutrient loads to Matatā Lagoon by reticulating the town wastewater system.
- Pest plant control and supplementary restoration planting of native vegetation – particularly along the walkway on the northern shore. Control or eradication of *Sagittaria platyphylla* (arrowhead) from the eastern end of the western lagoon.
- Allowing development aquatic emergent wetlands within the lagoon, and encouraging expansion of aquatic emergent wetlands in the western end of the lagoon. These provide multiple benefits in removing nutrients and sediment, providing habitat for aquatic life and increasing biodiversity values for birds
- Floating wetlands near the mouth of Waimea Stream and Awatarariki Stream to remove nutrients, improve biodiversity and manage deposition of sediment in the lagoon.

Table 4.2: Summary of intervention options to address ecological and water quality issues in Te Awa o te Atua /Matatā Lagoon

Management Option	Description	Effectiveness	Limitations
Reduce catchment sediment and nutrient loads.	Reticulation of sewage to reduce the risk of septic tank leaching contributing nutrients or microbial contamination.	WQ - Moderate/ High	Sewage reticulation will only partially address nutrient inputs.
Plant pest control and native planting	Enhance habitat with plant pest control and native riparian planting on the northern shore of western Matata Lagoon open water zone.	Habitat - High for native birds	Planting species should be sympathetic to view shafts.
Wetland creation to improve biodiversity and improve water quality from Waimea Creek.	Creation of aquatic emergent wetlands west of Waimea Creek mouth. This will require a bund to direct the flow to Waimea Creek to the west. Additional benefit of improving biodiversity values for native birds and fish.	WQ- High Habitat - High	Moderate to high capital cost. Design needs to allow for flood flows and the possibility of a future rediversion of the Tarawera River back into the lagoon.
Floating wetlands	Install additional floating wetlands to remove nutrients and provide habitat.	WQ - High Habitat - High	Costly compared to wetlands, but a good option to direct water flow. Best suited to near inflows with high nutrient concentrations.

5 Conclusions and Recommendations

5.1 Conclusion

Te Awa o te Atua /Matatā lagoon is an outstanding example of a complex dune land-wetland-open-water system on a freshwater-saltwater interface. It has high botanical values and provides high value breeding and feeding habitat for a large number of water birds. The western lagoon was remediated in about 2010, however the width of aquatic emergent wetland vegetation on the margin of the western lagoon remains considerably less than what was intended to regenerate into shallow wetland habitat following the post-flood remediation.

The lagoon is shallow and typically has low water clarity and high nutrient concentrations indicative of eutrophic to supertrophic conditions.

Water quality and habitat values for aquatic life and birds could be improved by the following actions:

- Continue with process to reticulate septic tanks.
- Controlling pest plants. Control of willow, pampas should be implemented with urgency before infestations become more dense or extensive. Control or eradication of *Sagittaria platyphylla* (arrowhead) from the eastern end of the western lagoon.
- Supplementary restoration planting of native vegetation in selected areas along the lagoon margins.
- Allowing development of aquatic emergent wetlands within the lagoon, and encouraging expansion of aquatic emergent wetlands in the western end of the lagoon.
- Installing floating wetlands near the mouth of Waimea Stream and Awatarariki Stream to remove nutrients, improve biodiversity and manage deposition.
- Ensure that any machinery used in the lagoon area is check and clean before moving between sites to minimise the risk of spreading pest plants.

5.2 Future monitoring and investigations

Monitoring and investigations that would assist in managing Matatā Lagoon includes:

- Map the bathymetry of the lagoon to understand sedimentation issues.
- Investigate groundwater inflows into the western lagoon.
- Continue water quality monitoring of the western lagoon Waimea Stream and the Awatarariki Stream.

- Biannual mapping of vegetation cover using drone aerial imagery to assist with managing macrophyte extent relative to the vegetation plan.

- Monitor the dissolved oxygen regime using dataloggers during summer to understand water quality dynamics, potential stress on aquatic organisms and better characterise the productivity in the lagoon.

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Appendix 1: Historical images of Te Awa o Te Atua, Matatā Lagoon

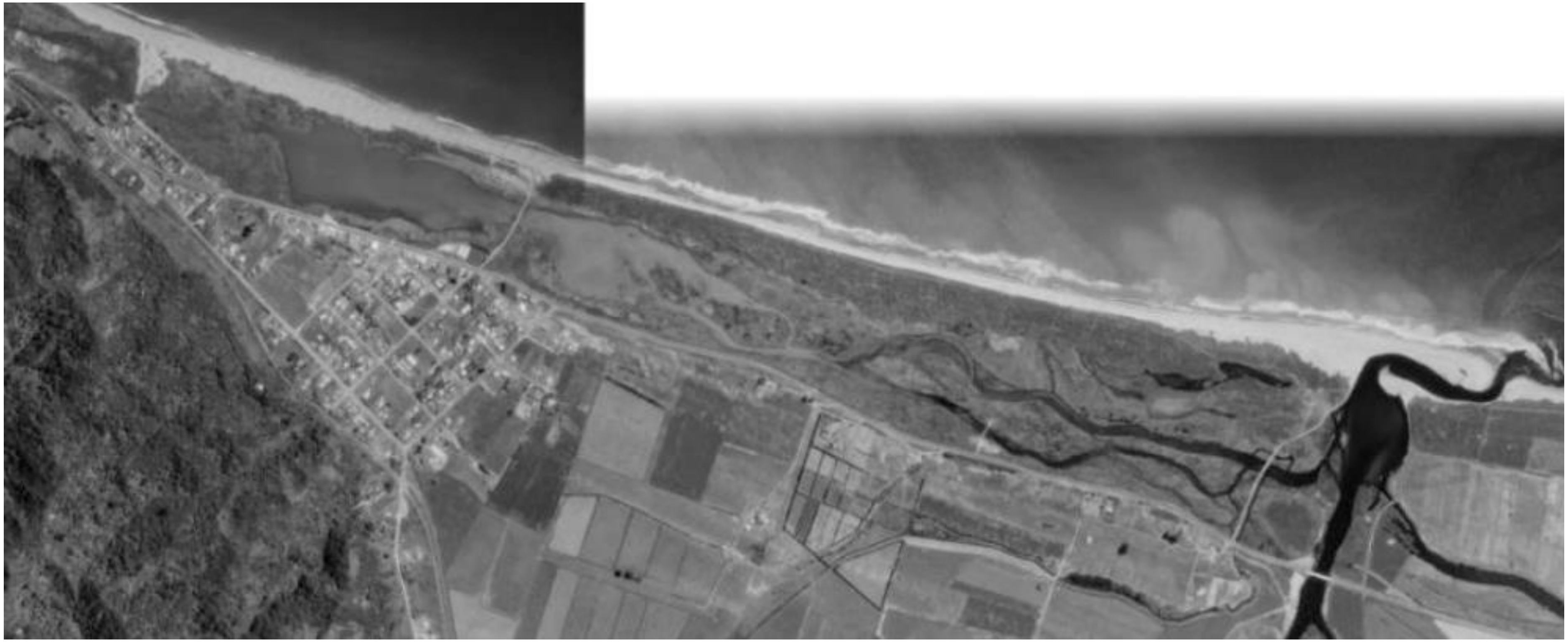
Images made available by a joint project between Local Government Geospatial Alliance (LGGA) and Land Information New Zealand (LINZ) - Retrolens Historical Imagry Resource.

1943-1950

1961-1963

1974

1981

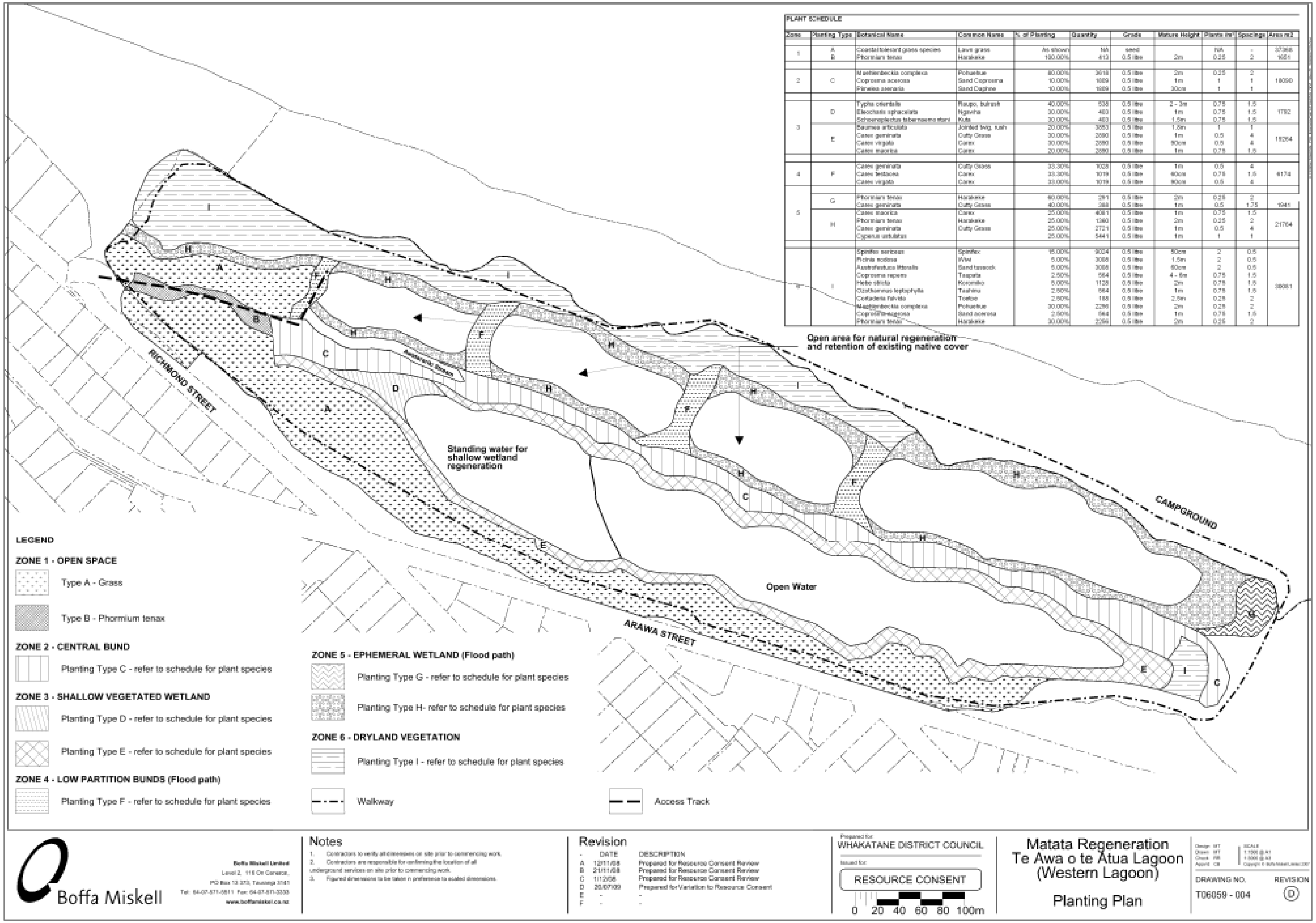


2003

2011 (soon after completion of the earthworks for rehabilitation of the western lagoon)

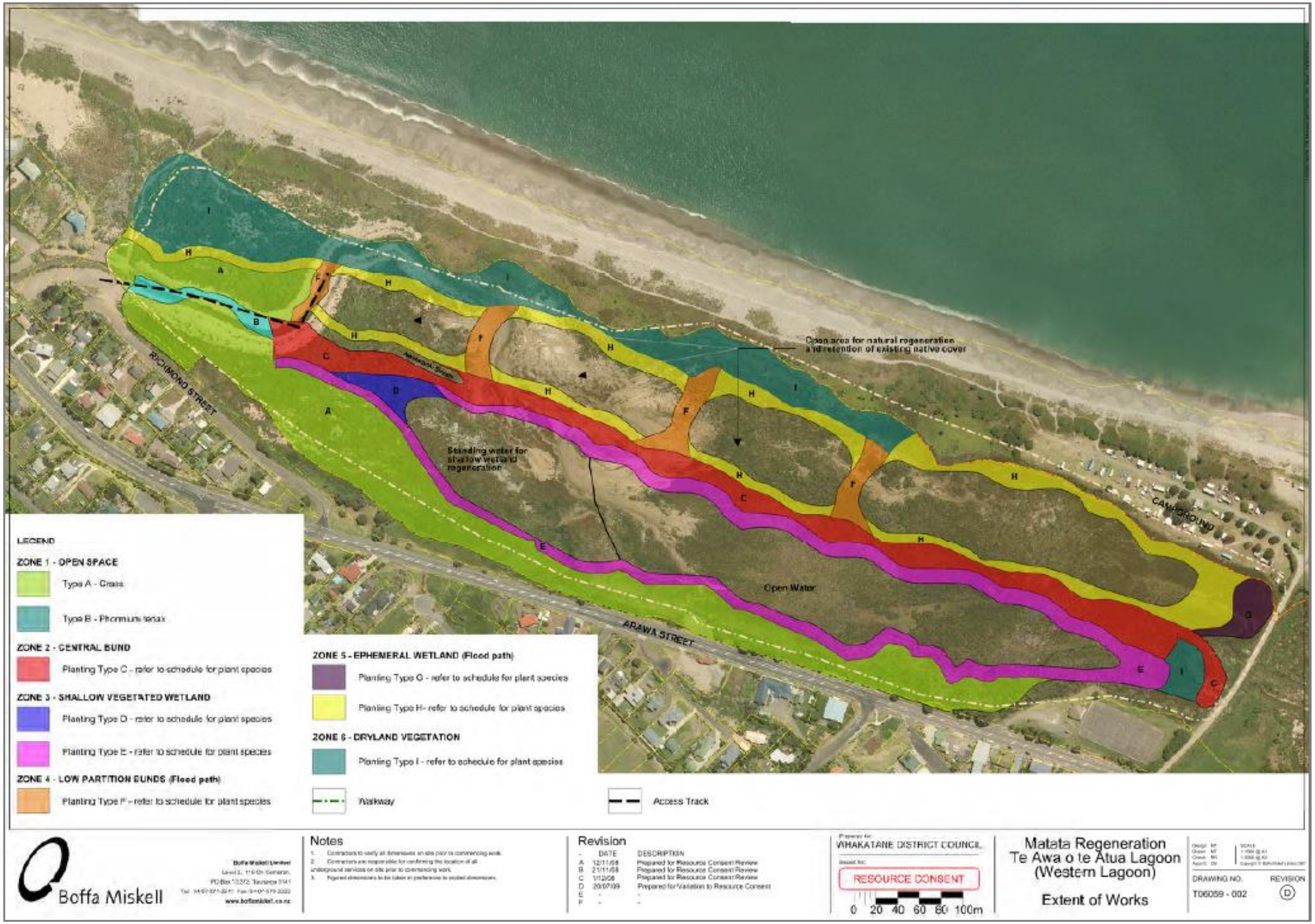
Appendix 2: Matatā Western Lagoon Regeneration Planting Plan

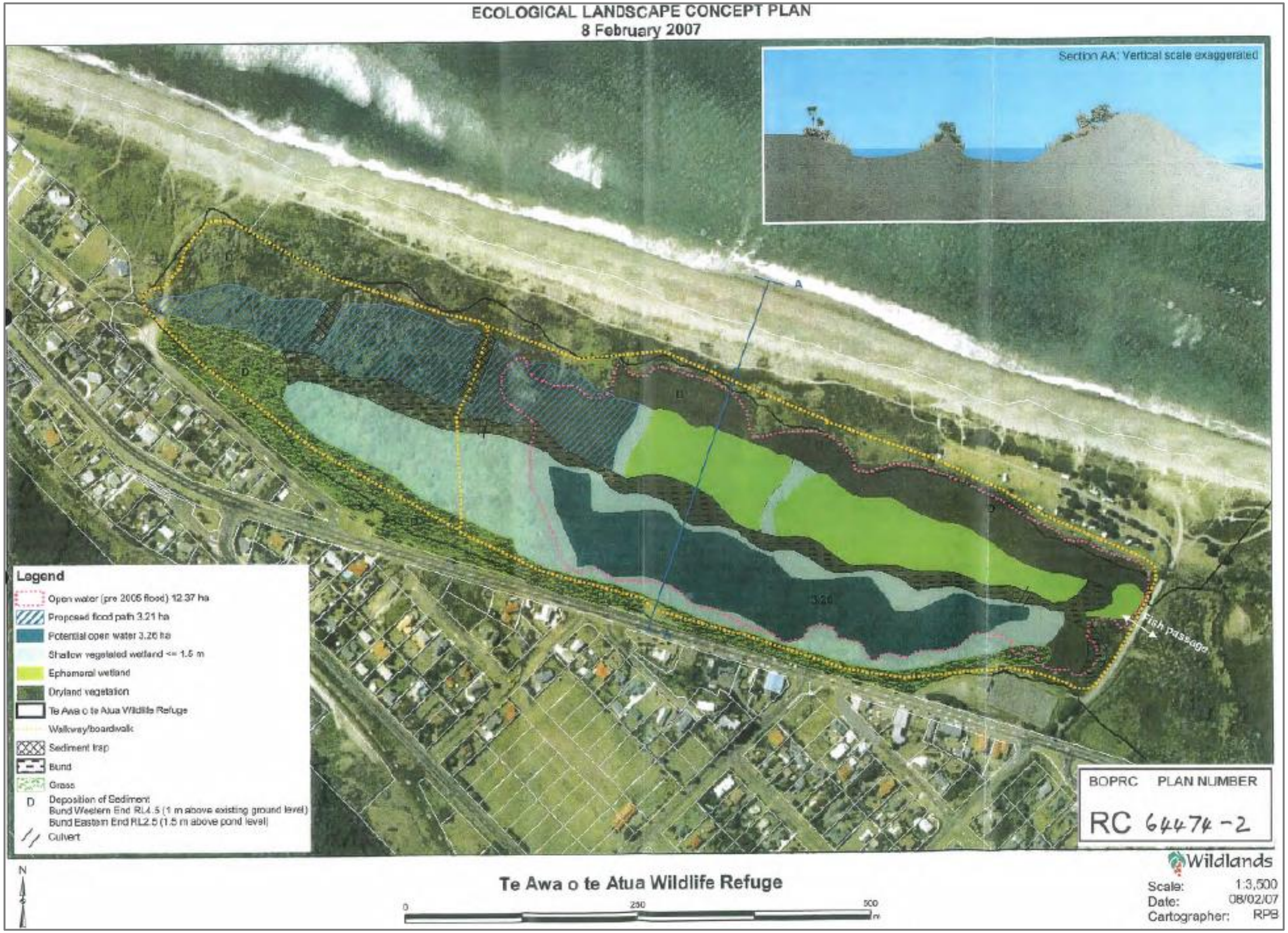
Matatā Regeneration Planting Plan and extent of works prepared for the resource consent hearing. From Boffa Miskell (2009) and Wildland (2007).

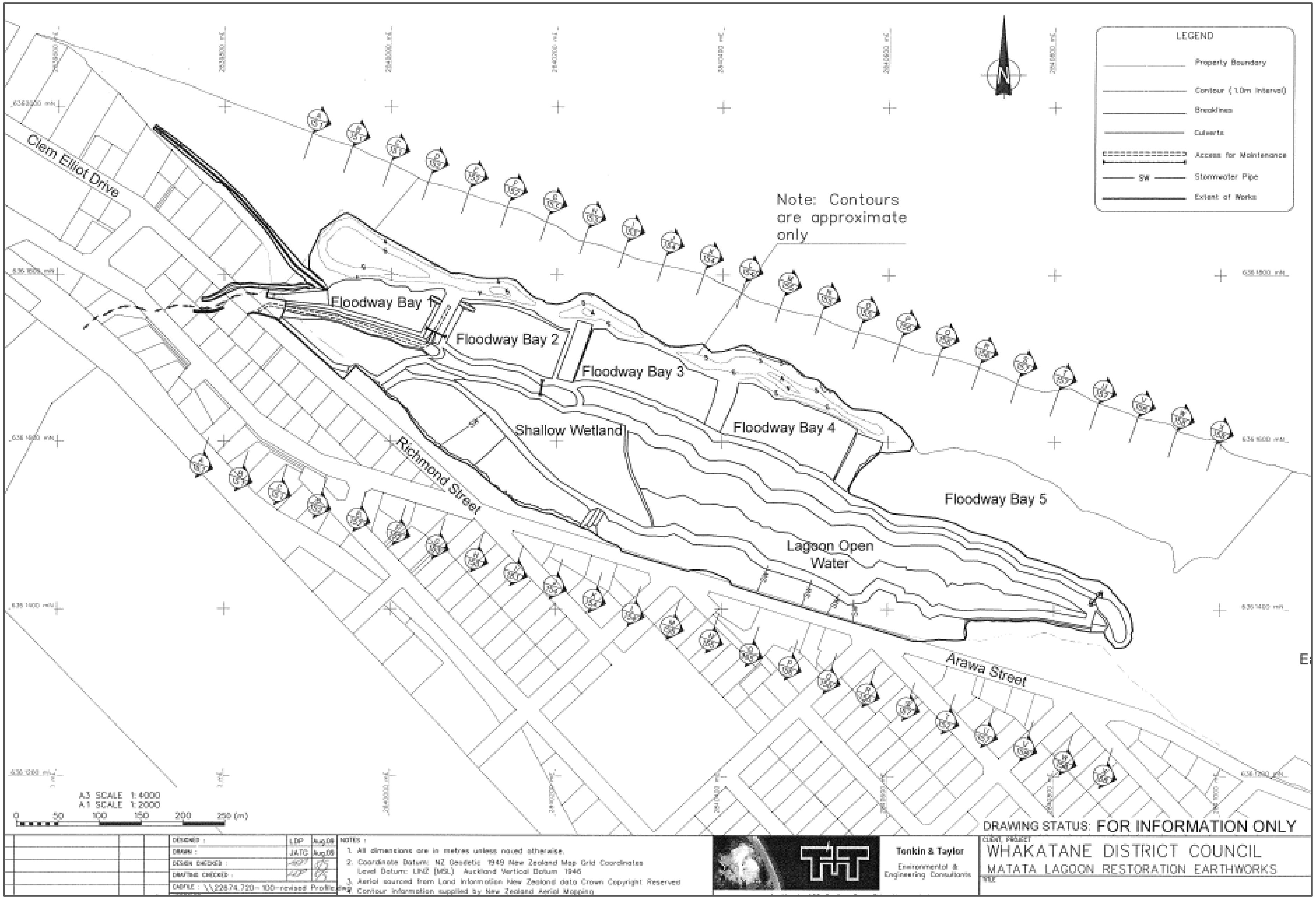


PLANT SCHEDULE

Zone	Planting Type	Botanical Name	Common Name	% of Planting	Quantity	Grade	Mature Height	Plants /m²	Spacings	Area m2
1	A	Coastal tolerant grass species	Lawn grass	As shown	NA	seed		NA	-	37368
	B	Phormium tenax	Harakeke	100.00%	413	0.5 litre	2m	0.25	2	1651
2	C	Muehlenbeckia complexa	Pohuehue	80.00%	3618	0.5 litre	2m	0.25	2	18090
		Coprosma acerosa	Sand Coprosma	10.00%	1809	0.5 litre	1m	1	1	
		Pimelea arenaria	Sand Daphne	10.00%	1809	0.5 litre	30cm	1	1	
3	D	Typha orientalis	Raupo, bulrush	40.00%	538	0.5 litre	2 - 3m	0.75	1.5	1792
		Eleocharis sphacelata	Ngawha	30.00%	403	0.5 litre	1m	0.75	1.5	
		Schoenoplectus tabernaemontani	Kuta	30.00%	403	0.5 litre	1.5m	0.75	1.5	
	E	Baumea articulata	Jointed twig, rush	20.00%	3053	0.5 litre	1.8m	1	1	15264
		Carex geminata	Cutty Grass	30.00%	2090	0.5 litre	1m	0.5	4	
		Carex virgata	Carex	30.00%	2090	0.5 litre	90cm	0.5	4	
		Carex maorica	Carex	20.00%	2090	0.5 litre	1m	0.75	1.5	
4	F	Carex geminata	Cutty Grass	33.30%	1028	0.5 litre	1m	0.5	4	6174
		Carex testacea	Carex	33.30%	1019	0.5 litre	60cm	0.75	1.5	
		Carex virgata	Carex	33.00%	1019	0.5 litre	90cm	0.5	4	
5	G	Phormium tenax	Harakeke	60.00%	291	0.5 litre	2m	0.25	2	1941
		Carex geminata	Cutty Grass	40.00%	388	0.5 litre	1m	0.5	1.75	
	H	Carex maorica	Carex	25.00%	4081	0.5 litre	1m	0.75	1.5	21764
		Phormium tenax	Harakeke	25.00%	1360	0.5 litre	2m	0.25	2	
		Carex geminata	Cutty Grass	25.00%	2721	0.5 litre	1m	0.5	4	
		Cyperus ustulatus		25.00%	5441	0.5 litre	1m	1	1	
6	I	Spinifex sericeus	Spinifex	15.00%	9024	0.5 litre	50cm	2	0.5	38061
		Ficinia nodosa	Wiwi	5.00%	3088	0.5 litre	1.5m	2	0.5	
		Austrofestuca littoralis	Sand tussock	5.00%	3088	0.5 litre	60cm	2	0.5	
		Coprosma repens	Taupata	2.50%	564	0.5 litre	4 - 6m	0.75	1.5	
		Hebe stricta	Koromiko	5.00%	1128	0.5 litre	2m	0.75	1.5	
		Ozothamnus leptophylla	Tauhinu	2.50%	564	0.5 litre	1m	0.75	1.5	
		Cortaderia fulvida	Toetoe	2.50%	188	0.5 litre	2.5m	0.25	2	
		Muehlenbeckia complexa	Pohuehue	30.00%	2256	0.5 litre	2m	0.25	2	
		Coprosma acerosa	Sand acerosa	2.50%	564	0.5 litre	1m	0.75	1.5	
		Phormium tenax	Harakeke	30.00%	2256	0.5 litre	2m	0.25	2	


RICHMOND STREET
ARAWA STREET
CAMPGROUND
Open area for natural regeneration and retention of existing native cover
Standing water for shallow wetland regeneration
Open Water
LEGEND
ZONE 1 - OPEN SPACE
Type A - Grass
Type B - Phormium tenax
ZONE 2 - CENTRAL BUND
Planting Type C - refer to schedule for plant species
ZONE 3 - SHALLOW VEGETATED WETLAND
Planting Type D - refer to schedule for plant species
Planting Type E - refer to schedule for plant species
ZONE 4 - LOW PARTITION BUNDS (Flood path)
Planting Type F - refer to schedule for plant species
ZONE 5 - EPHEMERAL WETLAND (Flood path)
Planting Type G - refer to schedule for plant species
Planting Type H - refer to schedule for plant species
ZONE 6 - DRYLAND VEGETATION
Planting Type I - refer to schedule for plant species
Walkway
Access Track
Boffa Miskell
Notes
Revision
DATE
DESCRIPTION
A 12/11/08 Prepared for Resource Consent Review
B 21/11/08 Prepared for Resource Consent Review
C 1/12/08 Prepared for Resource Consent Review
D 20/07/09 Prepared for Variation to Resource Consent
WHAKATANE DISTRICT COUNCIL
RESOURCE CONSENT
0 20 40 60 80 100m
Matata Regeneration
Te Awa o te Atua Lagoon
(Western Lagoon)
Extent of Works
DRAWING NO.
T06059 - 002
REVISION
D


ECOLOGICAL LANDSCAPE CONCEPT PLAN
8 February 2007
Section AA: Vertical scale exaggerated
A
Fish Passage
Legend
Open water (pre 2005 flood) 12.37 ha
Proposed flood path 3.21 ha
Potential open water 3.26 ha
Shallow vegetated wetland <= 1.5 m
Ephemeral wetland
Dryland vegetation
Te Awa o te Atua Wildlife Refuge
Walkway/boardwalk
Sediment trap
Bund
Grass
D Deposition of Sediment
Bund Western End RL4.5 (1 m above existing ground level)
Bund Eastern End RL2.5 (1.5 m above pond level)
Culvert
N
BOPRC PLAN NUMBER
RC 64474-2
Wildlands
Te Awa o te Atua Wildlife Refuge
0
250
500
Scale: 1:3,500
Date: 08/02/07
Cartographer: RPB


LEGEND
Property Boundary
Contour (1.0m Interval)
Breaklines
Culverts
Access for Maintenance
SW
Stormwater Pipe
Extent of Works
Note: Contours are approximate only
N
Clem Elliot Drive
Floodway Bay 1
Floodway Bay 2
Floodway Bay 3
Floodway Bay 4
Floodway Bay 5
Shallow Wetland
Lagoon Open Water
Richmond Street
Arawa Street
A3 SCALE 1:4000
A1 SCALE 1:2000
0 50 100 150 200 250 (m)
DRAWING STATUS: FOR INFORMATION ONLY
DESIGNED : LDP Aug.08
DRAWN : JATC Aug.08
DESIGN CHECKED :
DRAFTING CHECKED :
CADFILE : \\22874.720-100-revised Profile.dwg
NOTES :
1. All dimensions are in metres unless noted otherwise.
2. Coordinate Datum: NZ Geodetic 1949 New Zealand Map Grid Coordinates
Level Datum: LINZ (MSL) Auckland Vertical Datum 1946
3. Aerial sourced from Land Information New Zealand data Crown Copyright Reserved
4. Contour information supplied by New Zealand Aerial Mapping
Tonkin & Taylor
Environmental & Engineering Consultants
WHAKATANE DISTRICT COUNCIL
MATATA LAGOON RESTORATION EARTHWORKS

Appendix 3: Birds Recorded in Matatā Wildlife Refuge

From Owen et al. (2010), Appendix 4. Complied by Keith Owen, Department of Conservation.

Status: E – Endemic, I – Introduced, M – Migrant, N – Native
* Indicates that these species are listed as threatened species (Miskelly *et al*. 2008).

Scientific name	**Common name**	**Status**
Poliocephalus rufopectus	New Zealand dabchick *	E
Phalacrocorax carbo novaehollandiae	Black shag *	N
Phalacrocorax varius varius	Pied shag *	N
Phalacrocorax sulcirostris	Little black shag *	N
Phalacrocorax melanoleucos brevirostris	Little shag*	N
Egretta novahollandiae novahollandiae	White-faced heron	N
Ardea modesta	White heron *	N
Egretta garzetta immaculata	Little egret	N
Egretta sacra sacra	Reef heron *	N
Ardea ibis coromanda	Eastern cattle egret	M
Botaurus poiciloptilus	Australasian bittern *	N
Platalea regia	Royal spoonbill*	N
Cygnus atratus	Black swan	I
Branta canadensis maxima	Canada goose	I
Anser anser	Greylag goose	I
Tardona variegata	Paradise shelduck	E
Anas platyrhynchos platyrhynchos	Mallard	I
Anas superciliosa	Grey duck *	N
Anas gracilis	Grey teal	N
Anas rhynchotis	Australasian shoveler	N
Aythya novaeseelandiae	New Zealand scaup	E
Circus approximans	Swamp harrier	N
Gallirallus philippensis assimilis	Banded rail *	N

Porzana tabuensis tabuensis	Spotless crake *	N
Porzana pusilla affinis	Marsh crake *	N
Porphyrio melanotus melanotus	Pukeko	N
Fulica atra australis	Australian coot	N
Haemotopus unicolor	Variable oystercatcher	E
Himantopus himantopus leucocephalus	Pied stilt *	N
Charadrius obscurus aquilonius	Northern New Zealand dotterel *	E
Charadrius bicinctus bicinctus	Banded dotterel *	E
Elseyornis melanops	Black-fronted dotterel	N
Vanellus miles novaehollandiae	Spur-winged plover	N
Arenaria interpres	Ruddy turnstone	M
Calidris acuminata	Sharp-tailed sandpiper	M
Larus dominicanus dominicanus	Southern black-backed gull	N
Larus novaehollandiae scopulinus	Red-billed gull*	N
Larus bulleri	Black-billed gull *	E
Chlidonias leucopterus	White-winged black tern	M
Chlidonias albostriata	Black-fronted tern *	E
Hydroprogne caspia	Caspian tern *	N
Sterna striata	White-fronted tern *	E
Bowdleria punctata vealeae	North Island fernbird *	E

Appendix 4: Plant list discussed in text

* exotic/introduced
^ pest plant - requires control/treatment

Common name	Scientific name
brush wattle*^	*Paraserianthes lophantha*
budding clubrush	*Isolepis prolifera*
crack willow*^	*Salix fragilis*
everlasting pea*^	*Lathyrus latifolius*
fleabane*	*Conyza sumatrensis*
giant umbrella sedge	*Cyperus ustulatus*
grass-leaved rush	*Juncus planifolius*
gray willow*^	*Salix cinerea*
harakeke/flax	*Phormium tenax*
Japanese honeysuckle*^	*Lonicera japonica*
jointed baumea	*Machaerina articulata*
karamu	*Coprosma robusta*
karo	*Pittosporum crassifolium*
kikuyu*	*Cenchrus clandestinus*
koromiko	*Veronica stricta var. stricta*
kuawa	*Schoenoplectus tabernaemontanii*
kukuraho/marsh clubrush	*Bolboschoenus fluviatilis*
kutakuta/bamboo spike sedge	*Eleocharis sphacelata*
licorice plant*^	*Helichrysum petiolare*
mānuka	*Leptospermum scoparium*
Māori sedge	*Carex maorica*
montbretia*^	*Crocosmia x crocosmiiflora*
oioi	*Apodasmia similis*
pampas *^	*Cortaderia jubata (purple), Cortaderia selloana*

pingao	*Ficinia spiralis*
pohuehue	*Muehlenbeckia complexa var. complexa*
pukio/swamp sedge	*Carex virgata*
purei	*Carex secta*
raupō	*Typha orientalis*
rautahi/cutty grass	*Carex geminata*
spinifex	*Spinifex sericeus*
taupata	*Coprosma repens*
tī kouka/cabbage tree	*Cordyline australis*
tutu	*Coriaria arborea var. arborea*
water pepper*	*Persicaria hydropiper*
wiwi	*Ficinia nodosa*

Appendix 5: Restoration techniques to address eutrophication in shallow lakes.

Restoration techniques to address eutrophication in shallow lakes. Reproduced from Table 1 in Abell et al. (2020).

Group	Restoration method	Purpose	Application	Examples	Advantages	Disadvantages	References
Reduce external nutrient loads	Diffuse and point source control	Minimize nutrient loading	Essential component of a sustainable lake restoration strategy to control eutrophication	∘ Lake Müggelsee, Germany ∘ Lake Peipsi, Estonia/Russia ∘ Loch Leven, Scotland ∘ City Park Lake, Louisiana, USA	∘ Addresses the root cause	∘ Sufficient reductions typically require major economic costs, for example, to fund land-use change or improved wastewater treatment	Ruley and Rusch (2002); Jeppesen et al. (2005)
Reduce internal nutrient loads (physical)	Dredging	Reduce internal loading by removing nutrient-enriched sediments	Best suited to small lakes and/or iconic lakes due to the high costs	∘ City Park Lake, Louisiana, USA ∘ Lake Kraenepoel, Belgium	∘ Directly removes nutrients ∘ Increases depth	∘ Expensive ∘ Disposal of dredgeate can be difficult	Peterson (1979, 1981); Van Wichelen et al. (2007)
	Sediment capping (passive)	Reduce internal load by creating a physical barrier between benthic sediments and the water column	Generally suited to smaller lakes with high internal loads	∘ Taihu Lake, CN (one embayment)	∘ Maybe opportunities to use inexpensive local soil/sand	∘ Adverse effects to benthic biota such as mussels	Xu et al. (2012)
Reduce internal nutrient loads (chemical)	Phosphorus inactivation/ flocculation	Reduce concentrations of dissolved nutrients (primarily P) by adsorption. May be combined with flocculant use to remove organic material	Generally suited to smaller lakes with high internal loads	∘ Minneapolis Chain of Lakes, USA ∘ Lake Rotorua, New Zealand	∘ Potentially rapid improvements ∘ Cost-effective (internal) load reductions ∘ Well-established	∘ Reduced efficacy in shallow lakes due to sediment resuspension ∘ Adding chemicals to waterbodies can be culturally/ socially sensitive ∘ Metal toxicity needs to be considered ∘ Not a sustainable solution alone	Welch et al. (1988); Huser et al. (2016); Smith et al. (2016); Wang and Jiang (2016); Vargas and Qi (2019)
Bio-manipulation	Fish removal (zooplanktivorous)	Increase cladoceran zooplankton biomass → reduce phytoplankton biomass	Applicable to lakes with abundant zooplanktivores, for example, juvenile *Perca fluviatilis*	∘ Lake Vaeng, Denmark	∘ Established method in western European lakes with abundant zooplanktivores	∘ High, ongoing effort required to maintain low biomass ∘ Results are inconsistent ∘ Only suitable for lakes with abundant zooplanktivorous fish	Meijer et al. (1999); Søndergaard et al. (2008)
	Fish removal (benthivorous)	Reduce bioturbation and nutrient excretion	Applicable to lakes with high biomass of benthivorous fish such as *Cyprinus carpio*	∘ Wolderwijd, The Netherlands ∘ Lake Susan, Minnesota, USA ∘ Lake Ohinewai, New Zealand	∘ Can support biodiversity objectives if fish are invasive	∘ High, ongoing effort required to maintain low biomass ∘ Results are inconsistent	Meijer et al. (1999); Søndergaard et al. (2008); Bajer and Sorensen (2015); Tempero et al. (2019)

Promote bivalves	Increase filtration rates and phytoplankton grazing	Untrialled as a deliberate method, although potentially suitable for lakes that are very shallow (relatively low volume) and oligo-mesotrophic (more suitable physicochemical habitat conditions)	◦ Lake Faarup, Denmark (following an undesired invasion by zebra mussels)	◦ Could promote biodiversity if native species are used	◦ Requires suitable host fish for larval development ◦Habitat conditions may be unsuitable in lakes that are the greatest priorities for restoration	Jeppesen et al. (2012); Burns et al. (2014)
Macrophyte harvesting	Remove nutrients present in plant tissues	Very shallow (low volume) lakes with high abundance of invasive macrophytes	◦ Lake Wingra, Wisconsin, USA ◦ Lake Rotoehu, New Zealand	◦ Removing invasive plants can promote native plant biodiversity ◦ Plants could provide a resource (e.g., feedstock), pending research and development	◦ High, ongoing effort required to maintain low biomass ◦ Nutrient removal expected to be minor compared with external loads	Carpenter and Adams (1978); Quilliam et al. (2015)
Floating wetlands	Uptake dissolved nutrients. Potentially also increase denitrification and settling.	Small lakes, embayments, and drains where high coverage is feasible	◦ Lake Rodó, Uruguay	◦ May provide additional habitat values ◦ Can provide a visual focus for lake restoration efforts	◦ Field trials that demonstrate successful application to manage eutrophication are lacking ◦ Not applicable to restore medium-large lakes ◦ Plant harvesting necessary for optimum performance	Rodríguez-Gallego et al. (2004); Pavlineri et al. (2017); Bi et al. (2019)
Algicides	Directly reduce phytoplankton biomass	May be suitable as an emergency measure	◦ Cazenovia Lake, New York, USA	◦ Effective at causing rapid short-term declines in phytoplankton biomass with sufficiently high doses	◦ Toxic effects on other biota ◦ Sediment contamination ◦ Culturally/socially controversial ◦ Not generally recommended as a lake restoration method	Effler et al. (1980); Fan et al. (2013)

(continued)

Table 1. Continued.

Group	Restoration method	Purpose	Application	Examples	Advantages	Disadvantages	References
	Macrophyte reestablishment	Promote reestablishment of macrophytes by planting founder colonies and/or protecting plants with exclosures and wave buffers	Suitable for lakes that have experienced improved clarity but macrophyte reestablishment is hindered by lack of viable seeds/propagules or grazing	◦ Delta Marsh, Manitoba, Canada	◦ Can yield improved macrophyte growth in some areas	◦ Only suitable for lakes that have already been partially restored and have suitable light conditions and substrate	Evelsizer and Turner (2006); Hilt et al. (2018)
Hydrologic alterations	Inflow diversion	Reduce external loads	Applicable to lakes for which external loads are dominated by a single surface inflow, and there is a suitable receiving waterbody nearby	◦ Lake Rotoiti, New Zealand	◦ Step-change reductions in external loads	◦ Potential ecological impacts to receiving waterbody ◦ High capital costs ◦ Feasibility depends on local hydrology and not possible for most lakes	Hamilton and Dada (2016)
	Increase dilution and/or flushing	Dilute poor-quality lake water with higher quality water	Applicable to lakes for which there is a suitable donor waterbody nearby	◦ Moses and Green lakes (USA) ◦ Lake Veluwe (The Netherlands) ◦ West Lake, CN	◦ Major improvement in water quality possible	◦ Potential ecological impacts to donor waterbody ◦ High capital costs ◦ Feasibility depends on local hydrology and not possible for most lakes	Welch (1981); Ibelings et al. (2007); Jin et al. (2015)
	Water-level management	◦ Increasing depth can reduce sediment resuspension ◦ May restore riparian vegetation, depending on the hydrologic regime	Very shallow lakes or lakes where the riparian vegetation communities are impaired due to the existing hydrologic regime	◦ Volkerak–Zoommeer lake system, The Netherlands	◦ Can improve habitat for plants and wildfowl	◦ Can only improve water quality indirectly ◦ Land tenure and surrounding topography can be a constraint to increasing lake level ◦ Not a primary method to reduce trophic status	Gulati and van Donk (2002)