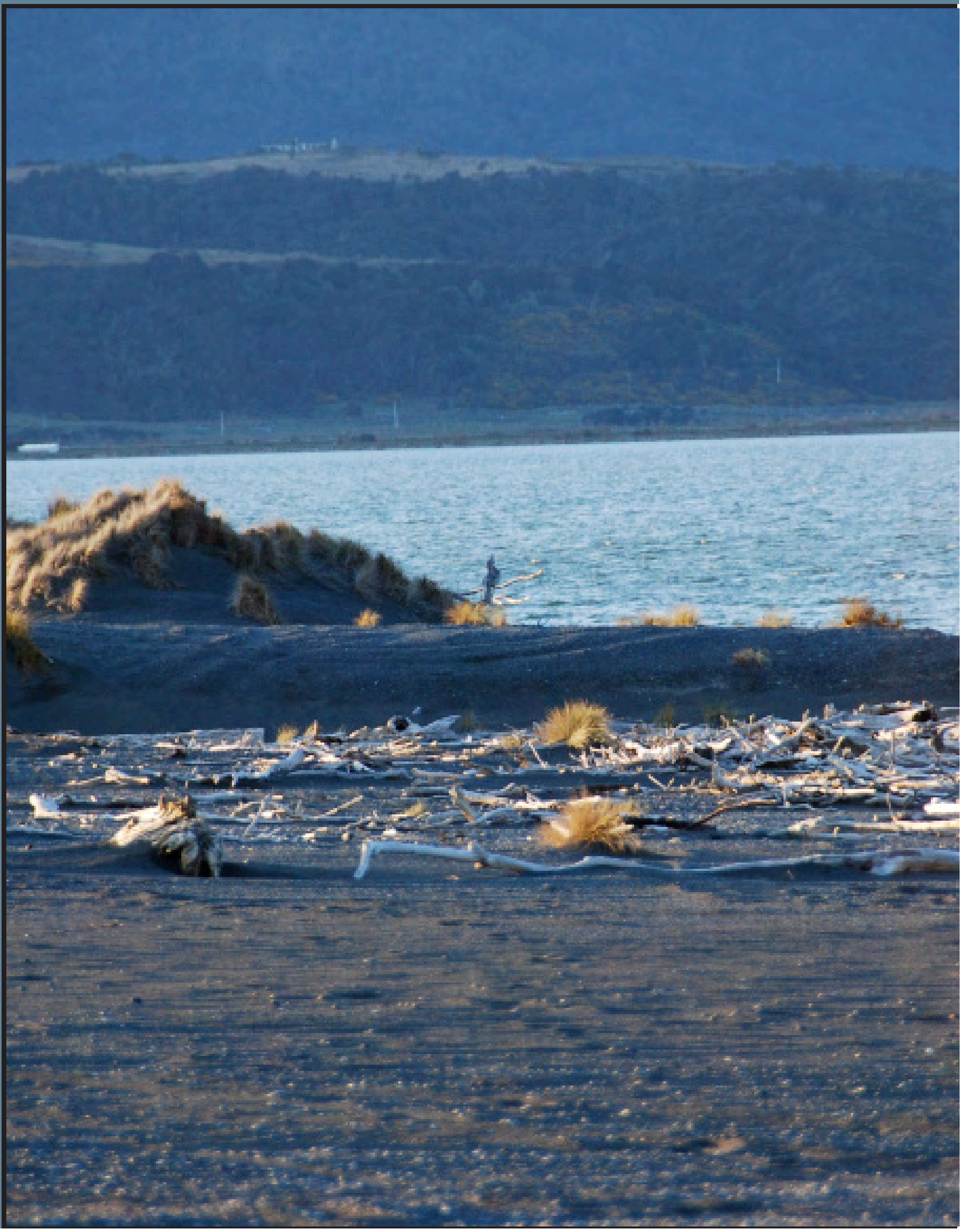
coastalmanagement

Lake Onoke 2007

Vulnerability Assessment & Monitoring Recommendations



Prepared for Greater Wellington Regional Council
October 2007

Cover Photo: Lake Onoke from Onoke Spit

Lake Onoke 2007

Vulnerability Assessment & Monitoring Recommendations

Prepared for
Greater Wellington Regional Council

By

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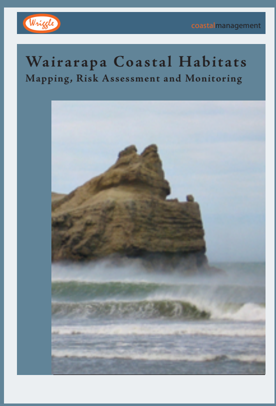
All photos by Wriggle except where noted otherwise. Photos are all of the Lake Onoke, Pounui Lagoon and Onoke spit area.

EXECUTIVE SUMMARY



Developing an understanding of the distribution and risks to coastal and estuarine habitats is critical to the management of biological resources. At present, Greater Wellington Regional Council (GWRC) is developing a long-term monitoring programme to assess the condition of key coastal habitats and estuaries in its region, and recently mapped all the coastline habitat (at a broad scale) and undertook preliminary vulnerability assessments to identify monitoring priorities for the Wellington region (Robertson & Stevens 2007a,b).

Lake Onoke (630ha) is fed by the Lower Ruamahanga River and drains to the sea at Palliser Bay through an opening at the eastern end of the lake. The lake regularly blocks and is opened artificially. It was identified as having a high risk of nutrient, sedimentation, pathogen, and habitat loss problems, and a synoptic field survey and Ecological Vulnerability Assessment was recommended in order to determine monitoring priorities (Robertson & Stevens 2007a). GWRC subsequently contracted Wriggle Coastal Management to undertake this work which is presented in the current report. This report presents an overview of coastal lake characteristics, the methods and results of the Lake Onoke synoptic survey, a completed Ecological Vulnerability Assessment, and monitoring recommendations.

The Ecological Vulnerability Assessment is an adaptation of a UNESCO methodology (UNESCO 2000), and has five key components that need to be completed:

1. **Human Uses and Values** (see Section 5.2).
2. **Ecological Values or Richness** (see Section 5.3).
3. **Presence of Stressors or Likely Causes of Estuary Issues** (see Section 5.4).
4. **Existing Condition and Susceptibility to Stressors** (see Section 5.5).
5. **An Estuary Vulnerability Matrix** (see Section 5.6).

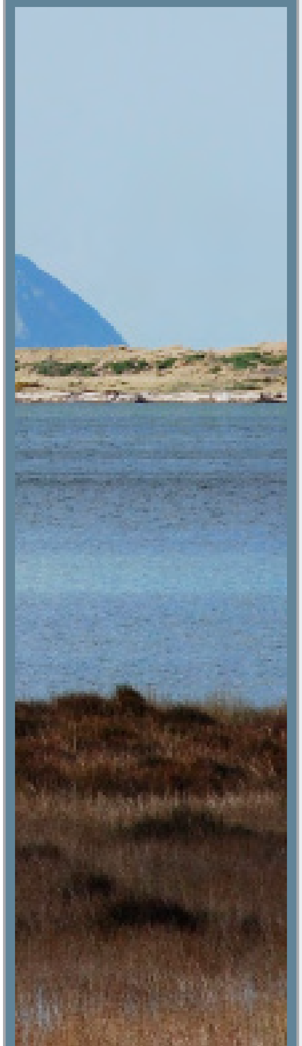
The aim of the assessment is to represent how an estuary ecosystem is likely to react to the effects of stressors - the causes of estuary issues (often human activities) so that an overall "vulnerability" rating can be determined, and priority monitoring indicators can be identified. Components 1-4 are tables that provide background information used to assign "high", "medium", "low" or "very low" ratings. These components are then brought together in Component 5, a pre-developed Estuary Vulnerability Matrix (Stevens & Robertson 2007), which summarises the ratings and is used to identify monitoring and management priorities.

A monitoring programme is then designed for the priority monitoring indicators using the tools provided in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), plus recent extensions developed by Wriggle Coastal Management (e.g. Robertson & Stevens 2007c).

Because coastal lakes are shallow and their mouth is often blocked, they are naturally susceptible to water quality problems. In terms of their ecology, they tend (in their natural state) to have high habitat diversity and ecological richness, which is driven to a large extent by the following features:

- **Extensive Saltmarsh Habitat:** Because coastal lakes have a large area of shallow, wet marginal land with relatively low water level fluctuations, they tend to have a large proportion of their total area in saltmarsh vegetation.
- **Extensive Submerged Aquatic Macrophyte Beds:** Because catchment-specific sediment yields are relatively small (providing good water clarity) and the lakes are shallow (<3m deep), they grow extensive beds of submerged aquatic macrophytes. Such beds are important for regulating water quality and as habitat for invertebrates, fish and waterfowl.

EXECUTIVE SUMMARY (CONTINUED)



However, most New Zealand coastal lakes have been heavily modified through catchment landuse intensification, drainage of wetlands, flood control and frequent mouth openings involving human action. The key issues resulting from such actions are excessive sedimentation, excessive nutrients, disease risk, toxic contaminants, and habitat loss; with responses including increased muddiness, algal blooms, presence of disease-causing organisms, and loss of saltmarsh and macrophyte beds.

The Estuary Vulnerability Assessment identified Lake Onoke as a highly modified, shallow coastal lake estuary. The modifications to the lake include the loss of a large proportion of saltmarsh habitat, likely loss of submerged aquatic macrophyte beds, and reduced water and sediment quality. The existing condition was rated as poor for sedimentation, nutrients, saltmarsh and aquatic macrophytes.

Most of these modifications can be attributed to the extensive drainage, river training and realignment, reclamation and artificial lake outlet actions which were undertaken to develop pastureland and minimise flooding; and to past and present catchment landuse intensification.

Despite these modifications, the lake still has considerable human uses and values, particularly fishing, boating and natural character. Ecologically it is valued for its remaining saltmarsh habitat (particularly Pounui Lagoon), adjoining duneland on Onoke Spit, and its bird and fish-life.

The major threats or stressors to these existing values were identified as follows;

- High nutrient, sediment and pathogen inputs from terrestrial catchment intensification and altered weather patterns from climate change.
- Inappropriate timing and level control of artificial lake mouth opening.
- Further drainage and reclamation of saltmarsh habitat.
- Grazing in saltmarsh habitat.
- Vehicle damage to Onoke Spit dune vegetation and birdlife.
- Ongoing loss of connectivity between Lake Onoke and Pounui Lagoon.
- Further loss of margin buffer land through development.

Because the lake outlet has a tendency to block, Lake Onoke has a high natural susceptibility to issues such as eutrophication, sedimentation, disease risk and habitat loss. However, the ability to manually open the mouth and maintain tidal flushing means the susceptibility to further change is rated as moderate.

Therefore, based on the combination of poor existing condition (primarily because of the high level of past modification), the low susceptibility (highly susceptible features like macrophytes are no longer present), and the moderate risk of the stressors causing issues (and affecting indicators), Lake Onoke was given a “moderate” overall ecological vulnerability rating.

Monitoring recommendations have been made based on this overall rating to establish a baseline of current habitat and conditions, to measure future changes that may result in impacts on existing values, and to provide additional information to aid management and monitoring decisions. The proposed monitoring targets four of the key issues identified for coastal lakes that are significant issues in Lake Onoke (sedimentation, eutrophication (excessive nutrients), disease risk, and habitat loss).

EXECUTIVE SUMMARY (CONTINUED)

RECOMMENDED MONITORING	Because Lake Onoke has been already been significantly modified, and is now rated as only having "moderate" ecological vulnerability, the recommended monitoring is to establish a "once per year for three years baseline" of existing conditions, with subsequent monitoring being generally repeated on a five yearly cycle or as determined otherwise by the monitoring results. The following is proposed:
SEDIMENTATION	• Broad scale mapping of lake-bed sediment type (when the lagoon is open). • Fine scale monitoring at 1-2 representative lake-bed sediment sites (mid lake towards NW and mid lake towards Onoke Spit) for grain size, total nitrogen, total phosphorus and organic carbon. • Assessment of lake-bed sedimentation rate (using buried plates) at two high deposition areas (including rushland). Ideally measured at annual intervals. • Water clarity (secchi disc - SD) measurements (monthly from Sept. to April) at two representative sites (mid lake towards NW & mid lake towards Onoke Spit).
EUTROPHICATION AND DISEASE RISK	• Broad scale mapping of lagoon macroalgal percent cover. • Measurement of lagoon light penetration or SD, and chlorophyll-*a* (monthly from September to April). • Re-establish existing GWRC monitoring of disease risk at a representative site used for bathing.
MACROPHYTES	• Broad scale mapping of percent cover of submerged macrophytes in Pounui Lagoon (if present).
WETLAND AND TERRESTRIAL MARGIN	• Broad scale mapping of wetland and terrestrial margin vegetation of Lake Onoke and Pounui Lagoon.

In order to help assess monitoring results, make good use of existing data, and look at options for improving the ecological quality of the lake, consideration of the following work is also suggested:

Develop Condition Ratings for Lake Onoke for Reporting Monitoring Results

- Condition ratings are used to set criteria for monitoring indicators that guide the frequency of monitoring and type of management responses. Examples of condition ratings developed for Lake Waituna (Southland) are included in Appendix 1.

Monitor Key Catchment Stressors

- Use existing catchment data to identify "hotspots" where a combination of different factors (e.g. land cover, landuse, slope, area, soil type, geology, rainfall, etc) highlight a high potential for immediate or potential inputs of sediment and/or nutrients. Use the results to determine whether any management response is required.
- Continue existing GWRC monitoring of total phosphorus, total nitrogen and E. coli concentrations in the lower Ruamahanga River, and add suspended solids to the list of analytes. Use the results to determine if a management response is required.

Investigate Improved Connectivity of Lake Onoke and Pounui Lagoon

- Assess the pros and cons of improving the connectivity between Lake Onoke and Pounui Lagoon.

Investigate Optimal Lake Levels for Ecology

- Continue GWRC lake level recording.
- Investigate whether changes to lake level management and mouth opening could improve lake ecology.

1.0 INTRODUCTION

1.1 SCOPE

Developing an understanding of the distribution and risks to coastal and estuarine habitats is critical to the management of biological resources. At present, Greater Wellington Regional Council (GWRC) is developing a long-term monitoring programme to assess the condition of key coastal habitats and estuaries in its region. The first step was to map all the coastline habitat (at a broad scale), and undertake preliminary vulnerability assessments to identify monitoring priorities. The outputs from this initial assessment step have been reported in:

- Wairarapa Coastal Habitats - Mapping, Risk Assessment and Monitoring (Robertson & Stevens 2007a)
- Wellington Harbour, Kapiti, Southwest and South Coasts - Risks and Monitoring (Robertson & Stevens 2007b)

The Wairarapa report identified Lake Onoke as a "coastal lake" with a high risk of nutrient, sedimentation, pathogen and habitat loss problems, and a paucity of ecological information. It recommended a synoptic survey and Ecological Vulnerability Assessment be undertaken to determine monitoring needs and priorities. GWRC contracted Wriggle Coastal Management to undertake this work in September 2007.

1.2 OVERVIEW OF VULNERABILITY ASSESSMENT

The Ecological Vulnerability Assessment is a tool adapted from a UNESCO methodology (UNESCO 2000) that is designed to be used by experts to represent how an estuary ecosystem is likely to react to the effects of potential "stressors" (the causes of estuary issues - often human activities) and to identify monitoring priorities. The approach uses various assessment techniques to produce an overall "vulnerability" rating of the extent to which potential stressors may affect the uses and values of an area. This is then combined with how susceptible the uses and values are to the identified stressors to identify the priority issues that need addressing.

The first step is to summarise background information in four key areas (Section 3);

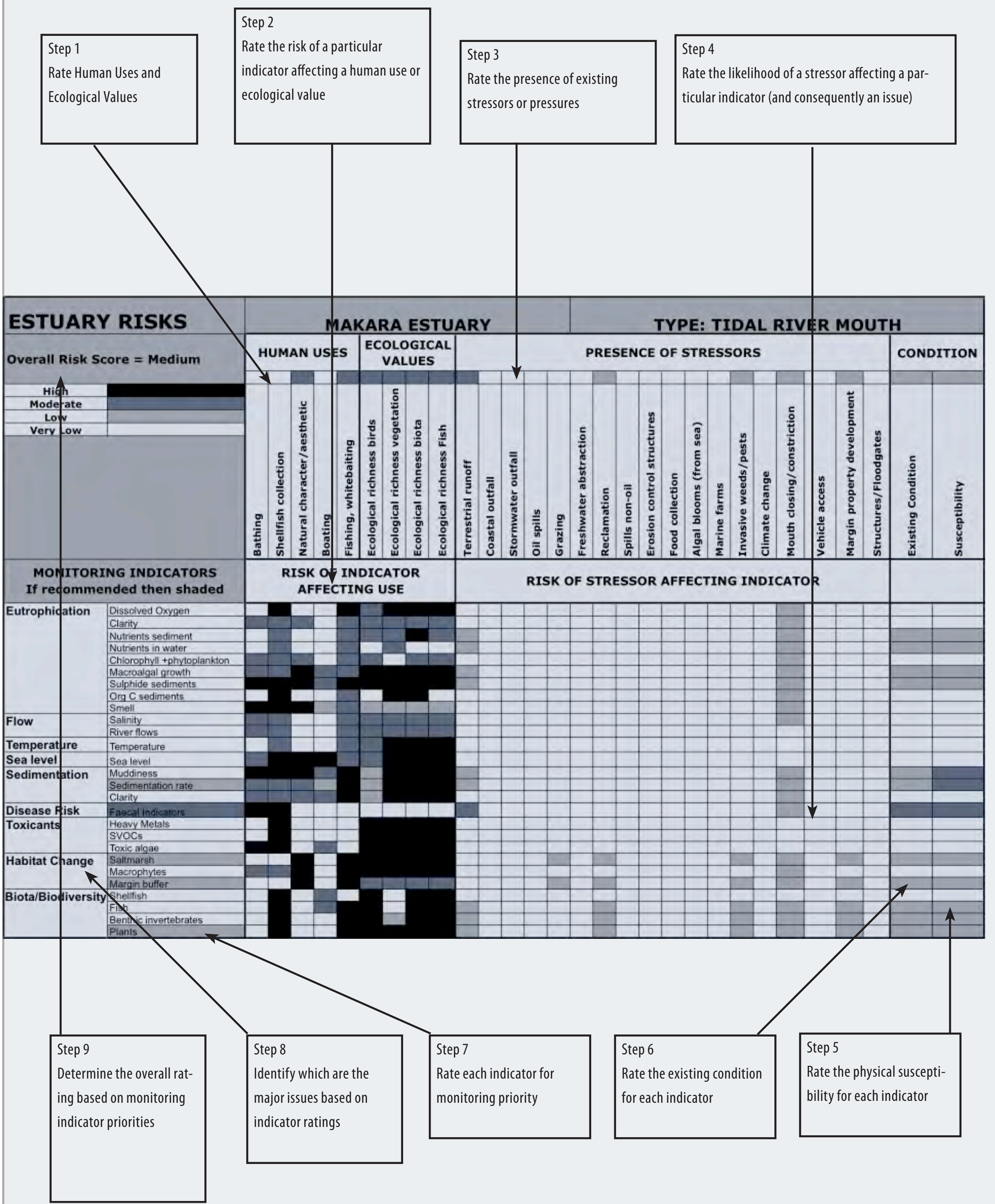
1. **Human Uses and Values**
2. **Ecological Values or Richness**
3. **Presence of Stressors (Likely Causes of Issues)**
4. **Existing Condition and Susceptibility to Stressors**

This information is then summarised within a pre-developed Estuary Vulnerability Matrix (see example on following page, including details on how to fill it in) that ascribes a "vulnerability" ratings (e.g. "very high" "high", "medium", or "low") based on an expert appraisal of the combined inputs. The "vulnerability" ratings are then used to design a monitoring programme for the priority monitoring indicators using currently available tools including those outlined below.

National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002)	• Broad scale habitat mapping using GIS. Broad scale habitat mapping records the location and type of vegetation (e.g. saltmarsh, seagrass, macroalgae) and substrate (e.g. mud, sand, gravel, etc); and is used to provide information primarily on the issues of habitat and margin loss, sedimentation (through the mapping of substrate type), and eutrophication (by mapping macroalgae percent cover). • Fine scale (i.e. detailed) monitoring of dominant habitat. Fine scale monitoring focuses primarily on the physical, chemical, and biological characteristics of coastal and estuary habitat.
Recent Extensions (Robertson & Stevens 2006, Robertson & Stevens 2007a,b)	• Establishment of sedimentation rate measures (using plates buried in sediment). • Estimation of historical sedimentation rates (using radio-isotope ageing of cores). • Assessment of the % cover of macroalgae and macrophytes (separate GIS layers). • Broad scale mapping of the 200m terrestrial margin surrounding the shoreline habitats. • Development of regional condition ratings for key indicators. • Provision of georeferenced digital photos (as a GIS layer).

1. INTRODUCTION (CONTINUED)

STEPS IN FILLING OUT VULNERABILITY MATRIX



1.0 INTRODUCTION (CONTINUED)

The project scope was limited to the use of expert judgement to quickly and cost effectively review existing knowledge and identify what issues are most likely to affect the Lake Onoke habitats, and from this make recommendations on monitoring and managing identified issues.

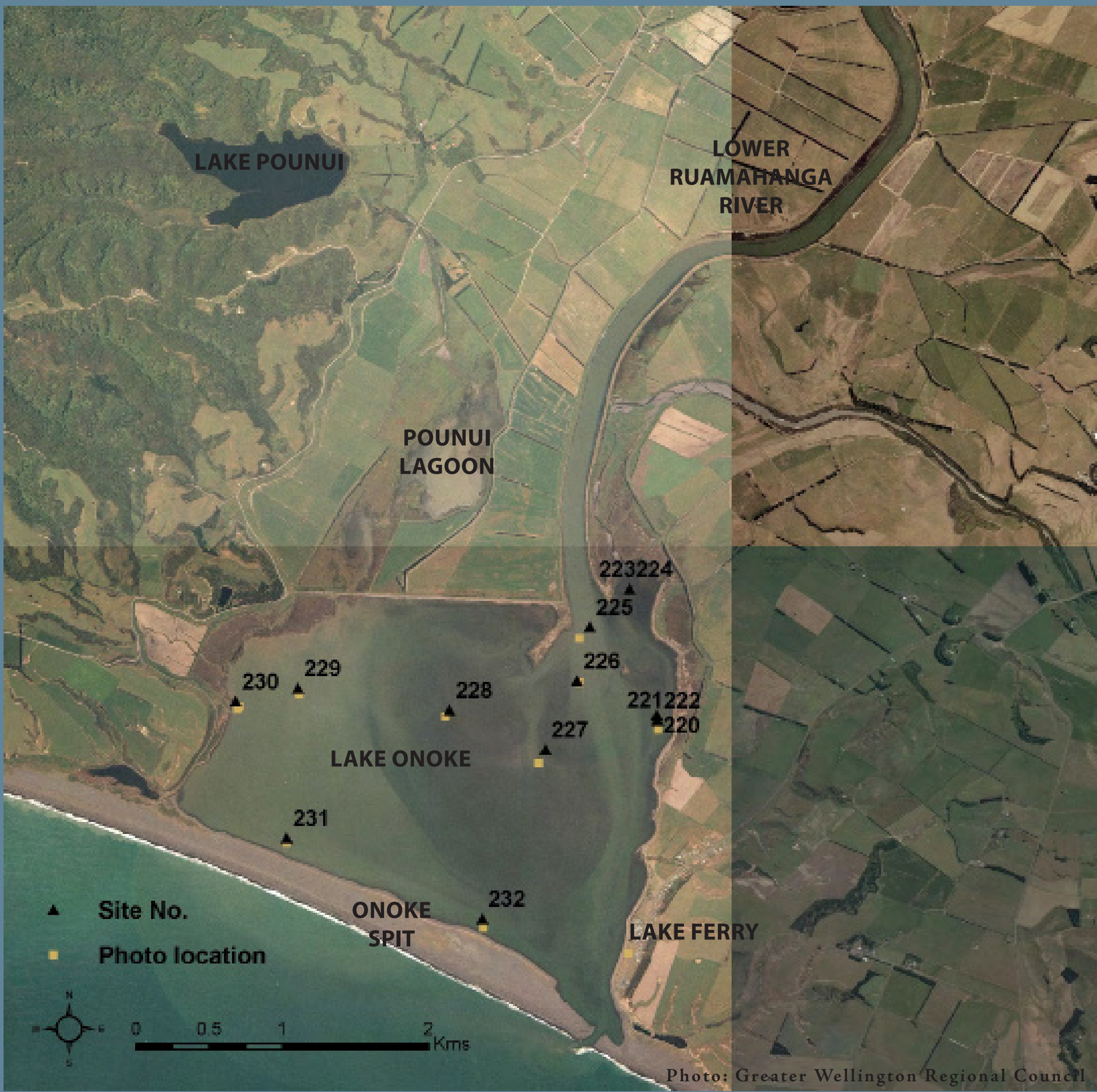
A key feature of the methodology is that it can be used with varying levels of detail. Because many potential stressors may be either absent or unlikely to have a significant impact, expert judgement is commonly used to quickly review existing knowledge and identify what issues are most likely to affect a particular estuary. This then provides a basis for deciding what level of effort should be put into addressing different issues. For example, existing knowledge or a synoptic survey may be sufficient to identify an issue as being both significant and present in a susceptible estuary. If more detailed studies are likely to reach the same conclusion, it may be most appropriate to focus resources on management rather than further study. Conversely, more detailed study may be needed to determine whether management is possible or likely to be effective before it is initiated.

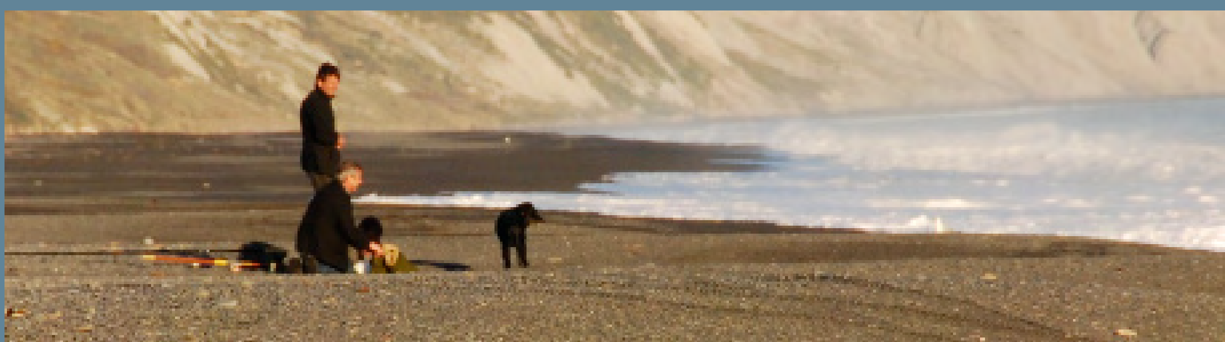
1.3 STRUCTURE

The following report describes the synoptic survey and Ecological Vulnerability Assessment undertaken for Lake Onoke to determine monitoring needs and priorities for GWRC. It provides an overview of coastal lake characteristics, the Lake Onoke field survey results, the completed ecological vulnerability assessment, and monitoring recommendations. The report structure is as follows:

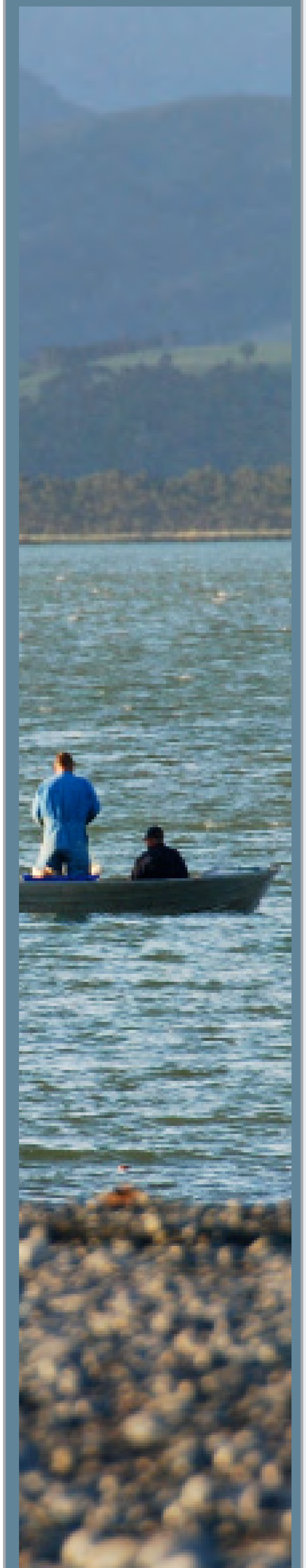
- Section 1. Introduction.
- Section 2. Overview of "coastal lake" characteristics.
- Section 3. Details of the vulnerability assessment methods.
- Section 4. Results of the synoptic field survey.
- Section 5. Completed ecological vulnerability assessment .
- Section 6. Conclusions.
- Section 7. Recommended monitoring.
- An Executive Summary is provided at the beginning of the report.

MAP OF LAKE ONOKE SAMPLING LOCATIONS





2.0 COASTAL LAKE CHARACTERISTICS



Estuaries are coastal waterbodies that are formed when freshwater from rivers flows into and mixes with saltwater from the ocean. Because New Zealand is a narrow, mountainous country with good rainfall it has a both a large number of estuaries relative to its size, and a huge variety of estuary types (McLay 1976, Kirk & Lauder 2000, Hume et al. in press). Coastal lagoons are a type of estuary defined by Kjerfve (1994) as:

> *"an inland body of water, usually oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by one or more restricted inlets, and having depths which seldom exceed a couple of meters. A lagoon may or may not be subject to tidal mixing, and salinity can vary from that of a coastal fresh water lake to a hypersaline lagoon, depending on the hydrologic balance. These lagoons have been formed as a result of rising sea level during the Holocene or Pleistocene and the building of coastal barriers by marine processes".*

Lake Onoke (630ha) is an example of one particular type of coastal lagoon called a "coastal lake". It is fed by the Lower Ruamahanga River and drains to the sea at Palliser Bay through an opening at the eastern end which regularly blocks and is opened artificially. Also draining into Lake Onoke (through two culverts in a stopbank) is Pounui Lagoon (150ha). Pounui Lagoon is fed from Lake Pounui, a lowland lake with an essentially unmodified catchment by Pounui Stream. Lake Pounui is outside the area covered in this report.

Coastal lakes are present predominantly on the east and south coasts of the South Island (e.g. Waituna Lagoon, Wainono Lagoon, Lake Ellesmere, Lake Grassmere and Wairau Lagoon) and in terms of the classification proposed by Kjerfve (1994) this type of lagoon is exceedingly restricted, or blocked, with respect to exchanges of water with the ocean via a lagoon mouth. The water body is typically fresh or brackish, and the lagoon is more usually closed from the sea than open to it. Kirk & Lauder (2000) list their distinctive characteristics as:

- Vulnerable to human use of the surrounding lands and contributing catchments through changes to their hydrological regimes, and their sediment and chemical input loads.
- Vulnerable to global climate change through alterations to input river hydrology and through the possibility of accelerated sea level rise that may increase rates of coastal erosion.
- Associated with mixed sand and gravel coasts, with high wave energy, strong longshore sediment transport, small tides and undergoing long-term erosion.
- Openings to the sea are rare and short-lived unless created by human action.
- Natural water levels are generally higher and have a smaller range than those now occurring through ongoing human intervention. Lower average water levels relate to agricultural uses of low-lying land marginal to lagoons.
- Ocean salt content of the water body is low. It is derived from salt spray, from overwash of the enclosing barrier beach, or from inlet throughflow by the tide in the later stages of artificial openings.
- Wind waves and currents are an important, if not dominant, agent of mixing within the lagoon.
- They typically possess important ecological values (e.g. saltmarsh, birdlife and fishery) and contain a mosaic of different habitats.

2.0 COASTAL LAKE CHARACTERISTICS (CONT.)

In terms of their ecology, coastal lakes (in their natural state) tend to have high habitat diversity and ecological richness, which is driven to a large extent by the following features:

- **Extensive Saltmarsh Habitat:** Because coastal lakes have a large area of shallow, wet marginal land with relatively low water level fluctuations, they tend to have a large proportion of their total area in saltmarsh vegetation. For example, Waituna Lagoon (1350ha) was once surrounded by a huge peat bog wetland of 10,000-20,000ha (Stevens & Robertson 2007).
- **Extensive Aquatic Macrophyte Beds:** Because catchment-specific sediment yields are relatively small (providing good water clarity) and the lakes are shallow (less than 3m deep), they grow extensive beds of aquatic macrophytes (e.g. horse-mane's weed, *Ruppia* sp). *Ruppia* has been suggested as a keystone species in Waituna Lagoon (Schallenberg & Tyrrell 2007) because of its importance as a habitat for invertebrates and fish, as a food source for invertebrates and waterfowl, and its role in regulating water quality.

However, most New Zealand coastal lakes have been heavily modified through catchment landuse intensification, drainage, flood control and frequent mouth openings involving human action. The key issues or responses to such actions are:

KEY COASTAL LAKE ISSUES	
Excessive Sedimentation	Because coastal lakes are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived. Because coastal lakes are shallow, the muds are easily resuspended. This causes low turbidity which limits (or in some cases curtails) macrophyte growth, which in turn encourages phytoplankton growth and further lowers water clarity. Symptoms of eutrophication can result if nutrient levels are excessive and flushing is restricted (i.e. the mouth is not opened regularly).
Excessive Nutrients	Increased nutrient richness of coastal lake ecosystems stimulates the production and abundance of aquatic macrophytes (e.g. *Ruppia* sp) and saltmarsh vegetation. If excessive, it stimulates fast-growing algae such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce and *Enteromorpha*). Under phytoplankton bloom conditions, water column clarity can be reduced to low levels, limiting light available for macrophyte growth and drastically reducing habitat diversity and ecological richness (e.g. Lake Ellesmere). Also of concern are the mass blooms of macroalgae which can become widespread on intertidal flats and shallow subtidal areas of coastal lakes and cause major ecological impacts on water and sediment quality and the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the coastal lake environment, can survive for some time. Human contact with estuary water that has been contaminated with human and animal faeces, exposes them to these organisms and they risk getting sick.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), toxic heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Coastal lakes have many different types of habitats including shellfish beds, aquatic macrophyte beds, salt marshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and hard shores. The major stressors causing habitat degradation or loss in coastal lakes are: artificial mouth openings (increasing salinity and lowering lake levels), drainage and reclamation of salt marsh, sea level rise, population pressures on margins, pest and weed invasion, altered river input flows (damming, diversion and irrigation), over-fishing, polluted runoff and wastewater discharges.

3.0 METHODS

3.1 VULNERABILITY ASSESSMENT

This section provides a brief overview of the key components of the vulnerability assessment, and the sources of information used to assess each component. The completed assessment is presented in Section 5.

1. HUMAN USES

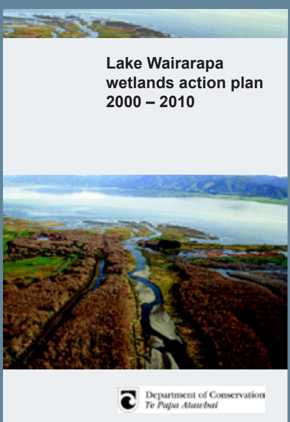
Information on the human uses and values of the lake and its margins were based on local knowledge and available information. However, given formal consultation with key users, including iwi and DoC, was not undertaken, the overall accuracy of this component is imprecise. The human use rating is based primarily on the estimated number of persons involved:

- Low: < 10 per year.
- Medium: 10 to 50 per year (< 30 per day in summer).
- High: > 30 per day (maybe just in summer) but < 200 per day.
- Very High: > 200 per day.

2. ECOSYSTEM RICHNESS (VALUES)

Ecosystem richness defines an ecosystem's natural riches (generally interpreted as habitat diversity and biodiversity). It can be supposed that the more rich and diversified an ecosystem is, the greater the losses will be in the event of a disruption. The ecological richness component is divided into four subcategories; birds, vegetation, fish and other biota. The ecosystem richness of the Lake Onoke coastal habitat was assessed based on expert opinion, observations during the field visit, and available literature (see table below). In addition, several Gee Minnow fish traps were set overnight on 12 September in the rushes near the eastern stopbank of Pounui Lagoon by Alton Perry (GWRC). On 13 September the traps were checked for fish abundance and diversity and the saltmarsh vegetation was broadly categorized.

Catchment and monitoring information:	Watts, L. and Perrie, A. 2007. Lower Ruamahanga River instream flow assessment. GWRC report. ENV/05/08/03, GW/EMI-G-07/135.
Lake and wetland management:	Airey, S., Puentener, R., and Rebergen, A. 2000. Lake Wairarapa wetlands action plan 2000-2010. DOC Report.
Habitat Types:	Robertson, B.M. and Stevens, L. 2007. Wairarapa Coastal Habitats: Mapping, Risk Assessment and Monitoring. Prepared for Greater Wellington Regional Council. 120p. Ogle, C.C.,; Moss, T.; Druce, A. P. 1990: Vascular flora of Lake Wairarapa and its adjacent wetlands, Wellington. Head Office, Dept. of Conservation, (Science and Research series)
Fish	Hicks, B. J. 1993 (1): Investigation of the fish and fisheries of the Lake Wairarapa wetlands, Rotorua. Freshwater Fisheries Centre, MAF. (New Zealand freshwater fisheries miscellaneous report, no. 126.)



3. PRESENCE OF STRESSORS

Stressors are activities (often in the catchment) that affect the ecological condition of coastal habitat (e.g. terrestrial runoff, grazing, stormwater discharges, reclamation). Because their harmful effects cause a variety of environmental deteriorations they are identified, and their risk characterised according to their estimated effect on relevant condition indicators (e.g. loss of saltmarsh, macroalgal growth, etc.). The assignment of risk is based on a combination of existing data (e.g. landuse, sediment and nutrient areal loadings, rock type, erosion susceptibility, river input quality), observation and expert opinion.

3.0 METHODS (CONTINUED)

3.1 VULNERABILITY ASSESSMENT (CONTINUED)

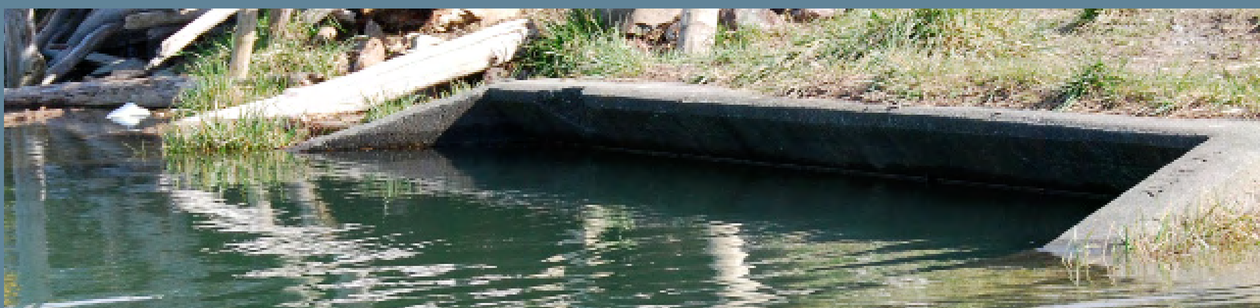
4. ECOSYSTEM EXISTING CONDITION AND SUSCEPTIBILITY

The **"existing condition"** is a measure or estimate of the existing condition of the estuary as assessed by relevant condition indicators (e.g. signs of eutrophication, sedimentation, habitat loss). The existing condition of the Onoke area was primarily assessed based on expert opinion, supported by available information and monitoring data. In addition, salinity, temperature, pH, dissolved oxygen, and water clarity were measured from a number of sites in the lake (see map on page 3 for site details) using a YSI meter and a Secchi Disc (SD) during the field visit on 12 and 13 September 2007. At the same sites, sediment samples were also collected from the lake bed using a small Eijelkamp sediment grab, and qualitative assessments were made of sediment type and the presence of sulphides.

"Susceptibility" is assessed to provide an estimate of the susceptibility of the ecosystem to degradation. For example, an estuary where the mouth closes regularly and is poorly flushed, is physically susceptible to water and sediment quality degradation. Various tools were used to help determine the susceptibility of Lake Onoke, in particular flushing potential estimates and eutrophication susceptibility protocols (e.g. Bricker et al. 2001). Where uncertainty existed over the presence or potential impact of stressors, a conservative (protective) estimate was used.

5. VULNERABILITY AND MONITORING RECOMMENDATIONS

The combined information collected and assessed in components 1, 2, 3, and 4 is used to determine an overall "vulnerability" rating and identify the priority monitoring indicators. This information is then used to design a monitoring programme using the tools provided in the National Estuary Monitoring Protocol (Robertson et al. 2002) plus recent extensions developed by Wriggle Coastal Management (Robertson & Stevens 2007).



4.0 RESULTS

4.1 LAKE ONOKE SYNOPTIC SURVEY RESULTS

The synoptic survey of Lake Onoke water and sediment quality was undertaken on 12-13 September 2007 by Wriggle Coastal Management Scientist Dr Barry Robertson and Alton Perrie, GWRC Environmental Scientist. Table 1 details the sampling results, with station locations shown on page 3. At the time of sampling, the lake level was high (1m above normal) and the mouth was due to be opened the following day (sea condition permitting).

In overview, the results showed that Lake Onoke was shallow (<3m deep), well oxygenated, well mixed and very low water clarity. In terms of sediment, the lake bed was very muddy towards the west and much sandier to the east (i.e. in the main high current areas). Very little sign of aquatic life was found in the sediments.

TABLE 1 SYNOPTIC SURVEY RESULTS, LAKE ONOKE 12 SEPTEMBER 2007

Station	Measure	Results	
W220	Depth	1.9 m (eastern side towards shore, river mouth end)	
	Sediment Type	Clean muddy sand, no black sulphides, little sign of macroinvertebrates	
	Water (0.5m)	Salinity 2.05 ppt, temp. 11.48 degC, pH 7.44, DO 11.4 mg/l, secchi disc 115cm	
W223	Depth	1 m (near river mouth)	
	Sediment Type	Hard sand/mud, no sample	
	Water (0.5m)	Salinity 2.0 ppt, temp. 11.5 degC, pH 7.4, DO 11.4 mg/l, secchi disc 120cm	
W225	Depth	4.5 m (mid channel near river)	
	Sediment Type	Mud sands, no black sulphides, little sign of macroinvertebrates but a few amphipods, *Potamopyrgus*.	
	Water (0.5m)	Salinity 1.7 ppt, temp. 11.2 degC, pH 7.5, DO 11.25 mg/l, secchi disc 116cm	
W226	Depth	2 m (edge of channel near river)	
	Sediment Type	Sandy mud, no black sulphides, little sign of macroinvertebrates.	
	Water (0.5m)	Salinity 1.8 ppt, temp. 11.3 degC, pH 7.4, DO 11.3 mg/l, secchi disc 120cm	
W227	Depth	1.7 m (mid lake)	
	Sediment Type	Muddy sand, no black sulphides, little sign of macroinvertebrates.	
	Water (0.5m)	Salinity 2.4 ppt surface and 3.5 ppt near bottom, temp. 11.6 degC, pH 7.5, DO 11.2 mg/l, secchi disc 120cm	
W228	Depth	1.9 m (mid lake)	
	Sediment Type	Muddy sand, no black sulphides, little sign of macroinvertebrates, 1 amphipod.	
	Water (0.5m)	Salinity 3.42 ppt surface and 3.5 ppt near bottom, temp. 11.5 degC, pH 7.6, DO 11.3 mg/l, secchi disc 120cm	

4.0 RESULTS (CONTINUED)

4.1 LAKE ONOKE SYNOPTIC SURVEY RESULTS (CONTINUED)

TABLE 1 (CONTINUED) SYNOPTIC SURVEY RESULTS, LAKE ONOKE

STATION	MEASURE	RESULTS	
W229	Depth	2 m (mid lake towards western shore)	
	Sediment Type	Sandy mud (very sticky), no black sulphides, little sign of macroinvertebrates, 2 amphipods.	
	Water (0.5m)	Salinity 3.2 ppt surface and 3.2 ppt near bottom, temp. 11.3 degC, pH 7.7, DO 11.3 mg/l, secchi disc 120cm	
W230	Depth	1.8 m (mid lake towards western shore)	
	Sediment Type	Mud (very sticky), no black sulphides, little sign of macroinvertebrates, 3 amphipods.	
	Water (0.5m)	Salinity 3.1 ppt surface and 3.2 ppt near bottom, temp. 11.4 degC, pH 7.7, DO 11.45 mg/l, secchi disc 110cm	
W231	Depth	2.1 m (adjacent to western shore)	
	Sediment Type	Mud (very sticky), some organic detritus, no black sulphides, little sign of macroinverte-brates.	
	Water (0.5m)	Water looks green, salinity 2.58ppt surface and 2.6 ppt near bottom, temp. 11.4 degC, pH 7.7, DO 11.18 mg/l, secchi disc 123cm	
W232	Depth	3.5 m (50m off shore at ocean end and towards lagoon mouth)	
	Sediment Type	Sandy mud, shells and polychaete tubes com-mon, no black sulphides, signs of moderate mac-roinvertebrate life (amphipods, polychaetes, shells).	
	Water (0.5m)	Water looks green, salinity 2.5ppt surface and 2.6 ppt near bottom, temp. 11.4 degC, pH 7.7, DO 11.25 mg/l, secchi disc 125cm	

4.2 POUNUI LAGOON FISH TRAPPING

Low intensity fish trapping undertaken overnight on 12-13 September 2007 in margin rushes around the eastern shores of Pounui Lagoon with Gee minnow traps found shortfinned eels, goldfish, rudd, inanga, brown mudfish and common bully. See following page for photographs of fish captured and released.

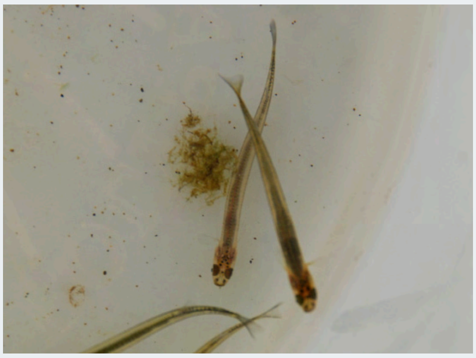
4.0 RESULTS (CONTINUED)

FISH CAUGHT IN POUNUI LAGOON 12-13 SEPTEMBER 2007

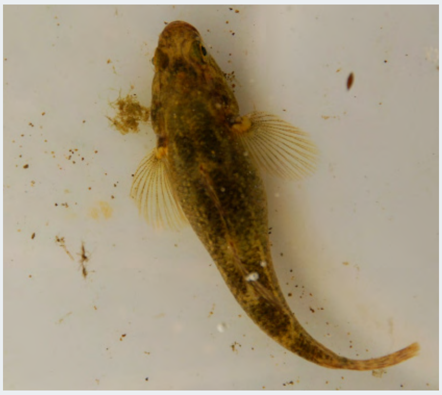
Shortfinned eel

Mudfish

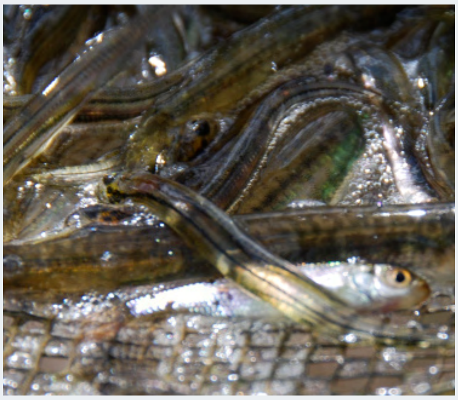
Goldfish



Inanga (Whitebait)



Common Bully



Rudd (the silver one) and Inanga

5.0 VULNERABILITY ASSESSMENT

5.1 OVERVIEW

This section documents the information gathered on Lake Onoke and Pounui Lagoon, and the vulnerability ratings given to each of the following key components:

1. Human uses and values (see Section 5.2),
2. Ecological richness (see Section 5.3),
3. Presence of stressors (likely causes of estuary issues) (see Section 5.4), and
4. Existing condition and susceptibility to stressors (see Section 5.5).

The rating scales used are essentially three broad categories (Low, Moderate, High) designed to enable each issue to be evaluated and, based on the outcome, decisions made regarding what type and level of monitoring and management is appropriate. This is dome by combining the information into a pre-developed Estuary Vulnerability Matrix (see Robertson & Stevens 2007) which summarises the ratings and includes the major issues and their monitoring indicators to identify monitoring and management priorities (Section 5.6).

5.2 HUMAN USES AND VALUES

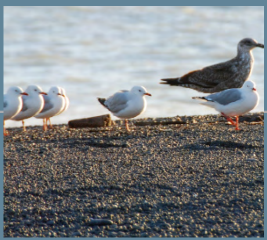
Low	Moderate	High

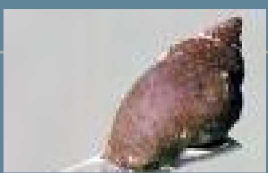
	Bathing	**Lake Onoke**	Low-moderate - some areas favoured (north of mouth for bathing). Surfing popular at mouth.
		Pounui Lagoon	Not used for bathing.
	**Shellfish collection**	**Lake Onoke**	Low. No known edible shellfish beds.
		Pounui Lagoon	No edible shellfish present.
	**Duckshooting/Fishing**	**Lake Onoke**	Fishing (especially with nets) is undertaken in the lake especially near the mouth for a variety of fish including whitebait, kawhai, and flounder. Traditionally Lake Onoke was an important site for eel fishing, in particular in autumn when the seaward migration of adult breeding eel congregated at the lake (Hicks 1993). Duck shooting probably occurs at the northern end of the lake.
		Pounui Lagoon	Popular for duckshooting. Fishing use uncertain.
	**Natural character and aesthetics**	**Lake Onoke**	Moderate. Focal point for area.
		Pounui Lagoon	Moderate.
	**Boating**	**Lake Onoke**	Lake is used for yachting, windsurfing, kayaking, motorboating.
		Pounui Lagoon	Low use, duckshooting access possibly.

5.0 VULNERABILITY ASSESSMENT (CONT.)

5.3 ECOLOGICAL RICHNESS

Low	Moderate	High





Birdlife	**Lake Onoke**	Lake Onoke and the 5km Onoke Spit, Lake Wairarapa, and surrounding wetlands (including Pounui Lagoon), are internationally recognised sites for rare birdlife and are home to 96 bird species (Forest and Bird website). Onoke Spit: a valued breeding site for Caspian terns, banded dotterels, white fronted terns and black-backed gulls (Airey et al. 2000).
	Pounui Lagoon	See above.
Vegetation	**Lake Onoke**	**Saltmarsh**: Limited areas of saltmarsh vegetation around lake margins - the western edge is the most unmodified and is dominated by rushland and saltmarsh ribbonwood (*Plagianthus divaricatus*) (Robertson & Stevens 2007). **Aquatic Macrophytes**: Absent. **Phytoplankton**: Likely to be elevated given green colour of water. **Macroalgae**: none present on 12 Sept. and locals can't remember seeing any green macroalgal blooms around margins. **Duneland**: Onoke Spit dune has high botanical value as it is home to pingao, spinifex and mat plant communities of *Raoulia australis* and *Pimelea arenaria*.
	Pounui Lagoon	**Saltmarsh:** DOC have identified the saltmarsh vegetation of Pounui Lagoons to have high botanical value (Airey et al. 2000). Pounui Lagoons (total area approximately 150ha), were originally part of Lake Onoke, and were found to include 2 main estuarine habitats; open water and lagoon bed (approximately 50ha) and salt marsh vegetation (approximately 100ha). The vegetation was dominated by jointed wire rush (*Apodasmia similis*), flax (*Phormium tenax*) and saltmarsh ribbonwood (*Plagianthus divaricatus*). A small amount of raupo (*Typha orientalis*) was present in the lower lagoon (nearest the lake) and a much large amount in the upper lagoon. **Aquatic Macrophytes**: Not investigated - likely to be present because clarity good (Ogle 1990). DOC recently carried out investigation (results pending). **Phytoplankton**: Likely to be low. **Macroalgae**: Not present.
Biota (macro-invertebrates)	**Lake Onoke**	Initial qualitative investigations on 12 Sept 2007 indicate low abundance and diversity.
	Pounui Lagoon	Unknown.
Fish	**Lake Onoke**	Lake Onoke and surrounding wetlands (including Lake Wairarapa) have been identified as wetlands of national importance to fisheries (Hicks 1993). Species present includes 10 native species which migrate between the sea and freshwater. The nationally threatened brown mudfish and giant kokopu have been recorded in the wetlands (Airey et al. 2000). Lake Ōnoke remains an important Māori eel fishery, although eel numbers have decreased considerably.
	Pounui Lagoon	See above. Low intensity trapping undertaken on 12-13 Sept 2007 in margin rushes found shortfinned eels, goldfish, rudd, inanga, brown mudfish and common bully.

5.0 VULNERABILITY ASSESSMENT (CONT.)

5.4 PRESENCE OF STRESSORS

No problem | Moderate problem | Big problem

ISSUE	INDICATORS	LAKE ONOKE
Terrestrial Runoff	**Nutrients, Sediment and Pathogens**	Catchment runoff of nutrients, sediment and pathogens is expected to be elevated based on the following: Watts & Perrie (2007) classified the lower Ruamahanga River as "poor quality", with the main causes being changes in land cover and land use practices, and the influence of point source municipal wastewater discharges. Guideline values for clarity and dissolved nutrients were generally exceeded on more than half of the sampling occasions since monitoring began in 2003. Summary water quality data for Lower Ruamahanga River (median, min, max) are provided below (Watts & Perrie 2007): Turbidity (7.6, 0.4, 358 NTU); Total Nitrogen (0.64, 0.05, 2.1 mg/l); NO_3-N (0.505, <0.01, 1.5 mg/l); NH_4-N (0.011, <0.01, 0.07 mg/l); Total Phosphorous (0.04, 0.005, 0.382mg/l); DRP (0.019, <0.005, 0.061 mg/l); E. coliforms (110, 12, 3800 per 100ml). NIWA (see maps on website) predict a high annual nitrogen yield from the catchment (>20 kg/ha/yr) and a moderate sediment yield (10-200 t/km^2/yr).
	Heavy Metals	No obvious sources in catchment.
	SVOCs	No obvious sources in catchment.
Point Source Discharges (including Stormwater)	**Nutrients, Sediment, Pathogens, Toxicants.**	Watts & Perrie (2007) report one direct discharge of treated municipal sewage to the Lower Ruamahanga River, from the Martinborough oxidation ponds, and indirect discharges from the Greytown oxidation ponds (via Papawai Stream) and Featherston (via Lake Wairarapa). Other discharges of treated sewage occur upstream (e.g. Masterton), and therefore may also affect water quality in the Lower Ruamahanga River. Loadings of nutrients, pathogens and sediment from these sources are expected to be much less than from terrestrial catchment runoff. Point source inputs will, however, cause minor loadings of heavy metals and SVOCs.
Margin Encroachment		Low - some areas of wetland threatened.
Reclamation, Drainage, Floodbanks, Floodgates 		Extensive reclamation of saltmarsh areas have been undertaken in the past (see figures on page 14). It is estimated that since early European settlement 40-47% of wetlands in the lower Wairarapa remain (or 7% of wetlands if open waters such as Lake Wairarapa are excluded) (Moore et al. 1984). Most of the large changes occurred following severe flooding in 1947, covering 200km^2 additional to the lake areas (Airey et. al 2000). This prompted the Tauherenikau River control works, the Ruamahanga cut off, Oporua spillway and the barrage floodgates. Between 1964 and 1984 works included; the installation of the barrage control gates at the outlet to Lake Wairarapa in 1974, the diversion of the lower Ruamahanga River to bypass Lake Wairarapa and flow directly to Lake Onoke, the construction of the Oporua Floodway, the separation of Pounui Lagoon from Lake Onoke and drainage and reclamation of 1237ha of wetlands. As a result of these works, floods now only cover an area of ~7 km^2 additional to the lake areas. Lake level management has also reduced flood duration, which now generally last less than 10 days per year (Hicks 1993). Airey et al. (2000) reported that "in the mid 1960s Pounui Lagoon was separated from Lake Onoke by a stopbank, with the lagoon only connected with Lake Onoke through two culverts. Flapgates on the culverts stop tidal flows moving back into the lagoon, and thereby prevent flooding of farmland. Hicks (1993) looked at the effect the flapgates had on fish habitat and fish passage. He concluded that the flapgates restricted the entry of saline water as well as fish. He recommended the complete removal of the flapgates as automation was likely to be too costly. As a compromise a 10x30cm slot was cut into one floodgate in 1995. The effect of the slot has not yet been monitored". The major effects of these stressors are expected to be direct and indirect habitat loss.
Grazing in margins		Grazing amongst saltmarsh margins does occur and has the potential to damage saltmarsh vegetation.
Man-made structures		Presence of seawalls, wharves and marinas is very low. See above for floodbanks, floodgates etc.
Spills		Low risk of spills.
Seafood Collection		No edible shellfish.
Algal Blooms (sea)		Low.
Aquaculture		Low.
Invasive weeds/pests		Low - but large uncertainty - some weeds growing in wetland areas, particularly gorse, also exotic fish.
Sea Level Rise		Lagoon is likely to be eroded on seaward side as sea level rises with climate change - causing loss of lagoon area. Also gradual margin erosion of saltmarsh vegetation reducing its overall area.
Fire		Low.
Water Abstraction		Low.
Vehicle access		Low, but present on dune margin (Onoke Spit).

5.0 VULNERABILITY ASSESSMENT (CONT.)

AERIAL PHOTOGRAPHS SHOWING EXTENT OF HABITAT LOSS

CURRENT SITUATION
Lake Onoke and Pounui Lagoons (red dot) showing the causeway between the lake and the lagoon, and the floodbanks encircling the lagoons, the northern edge of the lake, and the banks of the lower Ruamahanga River (Photo, GWRC).

1940'S SITUATION
Lake Onoke and Pounui Lagoons showing how the lake and lagoons were connected, and the much larger extent of saltmarsh vegetation (Photo GWRC).

5.0 VULNERABILITY ASSESSMENT (CONT.)

5.5 SUSCEPTIBILITY AND EXISTING CONDITION

No problem | Moderate problem | Big problem

<table>
<tr><th>ISSUE</th><th>INDICATORS</th><th colspan="2">LAKE ONOKE</th></tr>
<tr><td rowspan="5">Eutrophication</td><td>Physical Susceptibility
Flushing Potential (FW/V)</td><td colspan="2">Lake Onoke, when open to the sea, is expected to be well flushed. At a mean depth of approximately 1.5m it is expected to have little vertical stratification. Its flushing potential (FP) is given by the ratio of freshwater inflow(m^3/day)/estuary volume (m^3). With an area of 630ha, the lake volume is approximately 9 million m^3. Mean monthly freshwater inflows are almost always above 40 m^3/s. This gives an FP of 0.4 which according to Bricker et al. (1999) fits the "LARGE" category (i.e. a high potential to flush nutrients and phytoplankton from the estuary).
When the lagoon mouth is closed, there is no flushing so flushing potential is "LOW" at such times.</td></tr>
<tr><td>Nutrient Influence
MOUTH OPEN
based on ASSETs approach (Bricker et al. 1999)</td><td>(I) With Mouth Open
Nutrient Influencing Factor Rating (Bricker et al. 1999) (N limited):
Assume 15 ‰ = Salinity of estuary (Se); 32 ‰ = Salinity of ocean (So).
Nitrogen concentration in inflow to the estuary (river input data) (Nin) = 0.64 mg/L
Nitrogen concentration of the ocean (Nsea) = 0.02 mg/L
Background nitrogen concentration (Nb) = Nsea(Se/So) = 0.02x0.5 = 0.04
Human derived nitrogen concentration (Nh) = Nin (So-Se)/So = 0.64 (32-15)/32 = 10.9/32 = 0.34
Expected total N concentration (Nc) = Nh + Nb = 0.34 + 0.04 = 0.3
INFLUENCING FACTORS (IF) Formula = Nh/(Nb + Nh) = 0.34/(0.3) = 1.13 which corresponds to "HIGH" score (Bricker et al. 1999).
Combining the "large" flushing potential with the "high" nutrient influence equates to a "moderate to low" overall susceptibility of the estuary (when open) to eutrophication problems.</td><td rowspan="2">Background Nutrient Information
River Input Concentrations (Lower Ruamahunga R.) units mg/l; median (min, max) (GWRC data Watts & Perrie 2007): TN 0.64 (0.05-2.1); NO_3-N 0.505 (<0.01-1.5); NH_4-N 0.011 (<0.01-0.07); DRP 0.019 (<0.005-0.061); TP 0.04 (0.005-0.382).
Sea Input Concentrations: Not measured but expect low concentrations (NO_3-N <0.02; DRP<0.005).
Limiting Nutrient: The ratio of TN:TP can be used as a guide to which nutrient is in shortest supply and therefore most likely to be limiting to algal growth. Balanced growth is estimated to occur at a ratio of 7.2:1 by weight. If the ratio falls below this then nitrogen is likely to be the limiting nutrient. River inflow TN:TP = 16 by weight which indicates P is likely to be the limiting nutrient when the lake mouth is closed. When open, the lake will be diluted with seawater and is likely to be N limited.</td></tr>
<tr><td>Nutrient Influence
MOUTH CLOSED</td><td>(II) With Mouth Closed
Nutrient Influencing Factor Rating (P limited):
When the lagoon mouth is closed, the diluting influence of the sea is lost but freshwater input nutrient concentrations remain the same. This means the nutrient influencing factor will remain at a "HIGH" score. Combining the "low" flushing potential with the "high" nutrient influence equates to a "HIGH" overall susceptibility of the estuary (when closed) to eutrophication problems.</td></tr>
<tr><td>Clarity Influence</td><td colspan="2">Excessive declines in water clarity may create an environment beyond the acceptable level of tolerance for the living components of an estuary. Low clarity is most often caused by runoff from silt or clay soil catchments and/or high phytoplankton concentrations, and is exacerbated by sediment resuspension in shallow, wind-exposed lakes. Water clarity in Lake Onoke is very low (generally <1.2m Secchi Depth (SD)) and is probably attributable to a mix of all of these reasons. The lake is shallow and very exposed, catchment runoff of silt and clay is high (dominant rock type is soft), the filtering effect of the once extensive wetland between the lake and the river has been mostly lost with the diversion of the Lower Ruamahanga River from Lake Wairarapa to Lake Onoke, and preliminary observations indicate that phytoplankton concentrations may at times be elevated (but no quantitative monitoring data is available to confirm this). The major detrimental impact on the ecology of shallow coastal lakes of low water clarity is a reduction in, or loss of, submerged aquatic macrophyte habitat (Hilton & Phillips 1982). Recent grab samples, visual observations and local knowledge confirm that submersed macrophyte presence in the lake is highly unlikely. However, water clarity is not expected to be the only cause for the absence of macrophytes. A general rule of thumb is that aquatic macrophytes can grow to a depth of about 1.5 times the SD measurement. In relation to Lake Onoke, and assuming SD is <1m for long periods, then macrophyte growth should be present in the upper 1m of water (if nothing else was limiting its growth). The reason it isn't is almost certainly the result of regular level fluctuations during the growing season over a range of 0.5 to 1m (GWRC data). Under such conditions, submersed macrophytes will not survive. With macrophyte absence, a major ecological shift occurs towards a more turbid, phytoplankton-dominated and less biodiverse system. The explanation is that submersed macrophytes use available nutrients in the water, depriving the phytoplankton of these same nutrients and, in addition, they anchor nutrient-rich bottom sediments in place, buffering the action of waves, and depriving the phytoplankton of nutrients contained in bottom sediments that would otherwise be stirred up.
Nuisance macrophyte growth (e.g. sea lettuce (Ulva)and Enteromorpha) is also affected by water clarity, wind exposure, and long periods out of the water which likely explains its reported absence from the lake.
Overall: Existing clarity condition is "POOR", susceptibility to further change is "MODERATE".</td></tr>
<tr><td>Existing Symptoms</td><td colspan="2">Dissolved oxygen (DO), sediment anoxia, sulphides, nuisance macroalgae and phytoplankton blooms: 12 Sept 2007; DO at high concentrations; no anoxia in lake sediments or obvious presence of sulphides (see Section 3); no macroalgal blooms; water colour visibly green suggesting elevated phytoplankton concentrations. Overall: Existing symptoms are "MODERATE".</td></tr>
</table>

5.0 VULNERABILITY ASSESSMENT (CONT.)

5.5 SUSCEPTIBILITY AND EXISTING CONDITION

No problem | Moderate problem | Big problem

ISSUE	INDICATORS	LAKE ONOKE
Sedimentation	Area of Muddiness	Extensive areas of muddy sediments occur in the central to western end of the lake, where exposure to the major current flows is less. Localised muddy areas around streams, rushland beds and sheltered embayments. Existing condition is therefore POOR and susceptibility to further change is MODERATE (given the ability to manually open the estuary).
	Sedimentation rate	Not yet measured but given the likely elevated inputs, it is expected to be moderate to high in the central to western portion of the lake. High levels are also likely in the fringing saltmarsh areas. Existing condition is therefore MODERATE-HIGH and susceptibility to further change is MODERATE.
	Clarity	Very low; Secchi disc <1.3m. Existing condition is therefore POOR and susceptibility to further change is MODERATE.
Disease Risk	Faecal Indicators	Disease risk is MODERATE particularly during heavy rain. Very few measurements in lagoon. Loading from runoff in catchment likely to be high from intensive beef, sheep and dairying.
Toxicants	Heavy Metals	No measurements but also no obvious significant sources in catchment. Existing condition is therefore GOOD and susceptibility to further change is LOW.
	SVOCs	No measurements but also no obvious significant sources in catchment. Existing condition is therefore GOOD and susceptibility to further change is LOW.
	Toxic algae	Low risk of ocean sources of toxic algae. Existing condition is therefore GOOD and susceptibility to further change is LOW.
Habitat Loss & Biodiversity	Saltmarsh/Wetland	Very extensive past reclamations of saltmarsh habitat. Risk of further reclamations unknown. Major susceptibility will be to increased sedimentation (some areas may grow) and loss through sea level rise. Existing condition is therefore MODERATE (some salt marsh present in Pounui Lagoon and around Lake Onoke) and susceptibility to further change is also MODERATE.
	Aquatic Macrophytes	Submerged aquatic macrophytes are now absent from Lake Onoke, but were likely to be present in the past when the lake was clearer and level fluctuations much less. Where drawdowns persist for several years or are frequent during a single growing season, as in Lake Onoke, submersed vascular plants will not survive. Existing condition is therefore POOR but susceptibility to further change is LOW. Their presence in Pounui Lagoon is unknown, but possible. Existing condition is therefore GOOD and susceptibility to further change is LOW.
	Margin buffer	Most of 200m margin with the lake and saltmarsh and dune areas is already highly modified (grassland and stopbanks). Existing condition is therefore POOR but susceptibility to further change is LOW.
	Shellfish (edible)	Not likely to be present.
	Fish	A decline on past levels of fish, particularly eels, has occurred but extensive populations still exist in lake and particularly in Pounui Lagoon. The impact of low water clarity, loss of wetlands and aquatic macrophyte habitat and lake level fluctuations have been the major stressors. Existing condition is therefore MODERATE and susceptibility to further change is LOW.
	Benthic Invertebrates	Benthic macro-invertebrate populations were likely to be much more diverse and abundant in the past. Currently, preliminary findings indicate that they are present at low levels in the lake. Existing condition is therefore POOR and susceptibility to further change is LOW. Pounui Lagoon is likely to have much higher levels - existing condition is GOOD and susceptibility to further change is LOW.
	Invasive Species	No major invasive species identified. Existing condition is GOOD and susceptibility to further change is LOW.

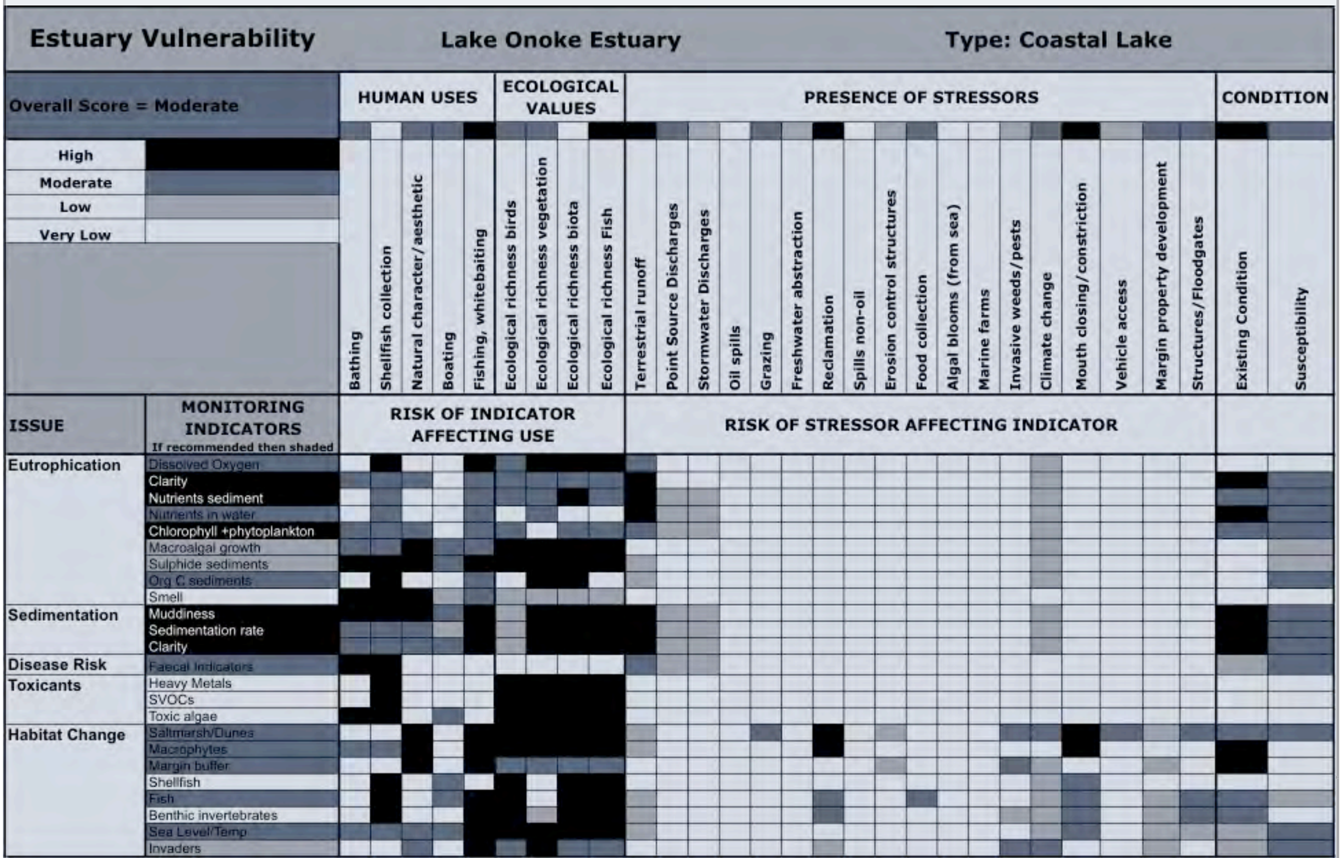

A very turbid Lower Ruamahanga River

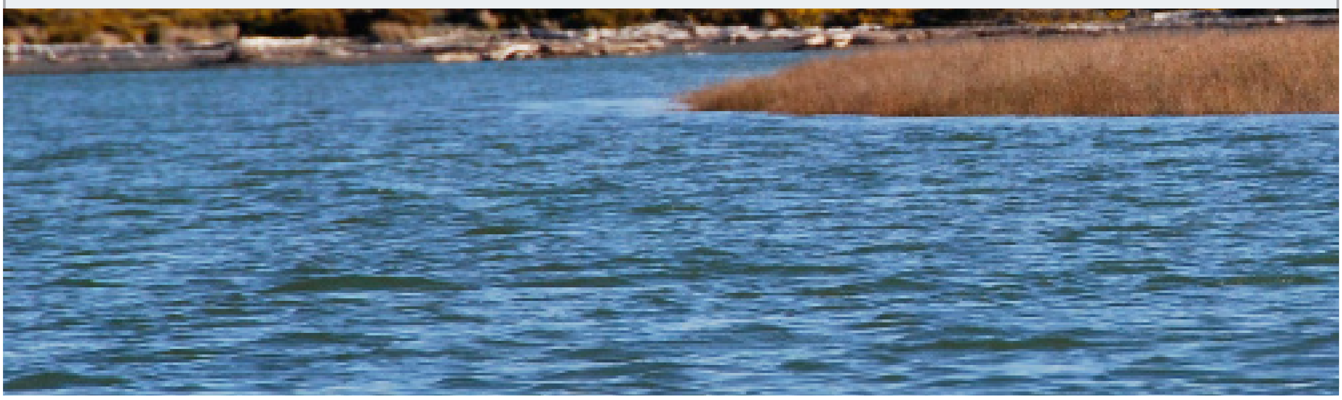

Floodgate and floodbank between Lake Onoke and Pounui Lagoon

5.0 VULNERABILITY ASSESSMENT (CONT.)

5.6 LAKE ONOKE ESTUARY VULNERABILITY MATRIX

The completed Lake Onoke Estuary Vulnerability Matrix is presented below. It shows that the combination of the existing condition, and the susceptibility and the risk of the stressors causing issues (and affecting indicators), was in the moderate category overall. This overall rating was placed in the moderate rather than high category because although the existing condition was poor for sedimentation, nutrients, saltmarsh and aquatic macrophytes, the susceptibility to further change was moderate (given the ability to manually open the mouth and maintain tidal flushing).





6.0 CONCLUSIONS

The Estuary Vulnerability Assessment identified Lake Onoke as a highly modified, shallow coastal lake estuary. The modifications to the lake include the loss of a large proportion of saltmarsh habitat, likely loss of submerged aquatic macrophyte beds, and reduced water and sediment quality. The existing condition was rated as poor for sedimentation, nutrients, saltmarsh and aquatic macrophytes.

Most of these modifications can be attributed to the extensive drainage, river training and realignment, reclamation and artificial lake outlet actions which were undertaken to develop pastureland and minimise flooding; and to past and present catchment landuse intensification.

Despite these modifications, the lake still has considerable human uses and values, particularly fishing, boating and natural character. Ecologically it is valued for its remaining saltmarsh habitat (particularly Pounui Lagoon), adjoining duneland on Onoke Spit, and its bird and fish-life.

The major threats or stressors to these existing values were identified as follows;

- High nutrient, sediment and pathogen inputs from terrestrial catchment intensification and altered weather patterns from climate change.
- Inappropriate timing and level control of artificial lake mouth opening.
- Further drainage and reclamation of saltmarsh habitat.
- Grazing in saltmarsh habitat.
- Vehicle damage to Onoke Spit dune vegetation and birdlife.
- Ongoing loss of connectivity between Lake Onoke and Pounui Lagoon.
- Further loss of margin buffer land through development.

Because the lake outlet has a tendency to block, Lake Onoke has a high natural susceptibility to issues such as eutrophication, sedimentation, disease risk and habitat loss. However, the ability to manually open the mouth and maintain tidal flushing means the susceptibility to further change is rated as moderate.

Therefore, based on the combination of poor existing condition (primarily because of the high level of past modification), the low susceptibility (highly susceptible features like macrophytes are no longer present), and the moderate risk of the stressors causing issues (and affecting indicators), Lake Onoke was given a "moderate" overall ecological vulnerability rating.

Monitoring recommendations have been made based on this overall rating to establish a baseline of current habitat and conditions, to measure future changes that may result in impacts on existing values, and to provide additional information to aid management and monitoring decisions.

The proposed monitoring targets four of the key issues identified for coastal lakes that are significant issues in Lake Onoke (sedimentation, eutrophication (excessive nutrients), disease risk, and habitat loss). Monitoring uses priority indicators based on the tools provided in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), plus recent extensions developed by Wriggle Coastal Management (Robertson & Stevens 2007). The recommended monitoring is outlined on the following page:

7.0 RECOMMENDED MONITORING

	Because Lake Onoke has been already been significantly modified, and is now rated as only having "moderate" ecological vulnerability, the recommended monitoring is to establish a "once per year for three years baseline" of existing conditions, with subsequent monitoring being generally repeated on a five yearly cycle or as determined otherwise by the monitoring results. The following is proposed:
SEDIMENTATION	• Broad scale mapping of lake-bed sediment type (when the lagoon is open). • Fine scale monitoring at 1-2 representative lake-bed sediment sites (mid lake towards NW and mid lake towards Onoke Spit) for grain size, total nitrogen, total phosphorus and organic carbon. • Assessment of lake-bed sedimentation rate (using buried plates) at two high deposition areas (including rushland). Ideally measured at annual intervals. • Water clarity (secchi disc - SD) measurements (monthly from September to April) at two representative sites (mid lake towards NW and mid lake towards Onoke Spit).
EUTROPHICATION AND DISEASE RISK	• Broad scale mapping of lagoon macroalgal percent cover. • Measurement of lagoon light penetration or SD, and chlorophyll-*a* (monthly from September to April). • Re-establish existing GWRC monitoring of disease risk at a representative site used for bathing.
MACROPHYTES	• Broad scale mapping of percent cover of submerged macrophytes in Pounui Lagoon (if present).
WETLAND AND TERRESTRIAL MARGIN	• Broad scale mapping of wetland and terrestrial margin vegetation of Lake Onoke and Pounui Lagoon.

In order to help assess monitoring results, make good use of existing data, and look at options for improving the ecological quality of the lake, consideration of the following work is suggested:

Develop Condition Ratings for Lake Onoke for Reporting Monitoring Results

- Condition ratings are used to set criteria for monitoring indicators that guide the frequency of monitoring and type of management responses. Examples of condition ratings developed for Lake Waituna are included in Appendix 1.

Monitor Key Catchment Stressors

- Use existing catchment data to identify "hotspots" where a combination of different factors (e.g. land cover, landuse, slope, area, soil type, geology, rainfall, etc) highlight a high potential for immediate or potential inputs of sediment and/or nutrients. Use the results to determine whether any management response is required.
- Continue existing GWRC monitoring of total phosphorus, total nitrogen and E. coli concentrations in the lower Ruamahanga River, and add suspended solids to the list of analytes. Use the results to determine if a management response is required.

Investigate Improved Connectivity of Lake Onoke and Pounui Lagoon

- Assess the pros and cons of improving the connectivity between Lake Onoke and Pounui Lagoon.

Investigate Optimal Lake Levels for Ecology

- Continue GWRC lake level recording.
- Investigate whether changes to lake level management and mouth opening could improve lake ecology.

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APPENDIX 1 EXAMPLE OF ESTUARY CONDITION RATINGS

OVERVIEW

RATING
Very Good
Good
Fair
Poor
Early Warning Trigger

At present, there are no formal criteria for rating the overall condition of estuaries in NZ, and development of scientifically robust and nationally applicable condition ratings requires a significant investment in research and is unlikely to produce immediate answers.

Therefore, to help interpret their monitoring data, a series of interim broad and fine scale estuary condition ratings have been proposed for Southland's estuaries (Robertson & Stevens 2006, 2007, this report). The interim condition ratings (presented below) are based on a review of monitoring data, use of existing guideline criteria (e.g. ANZECC (2000) sediment guidelines), and expert opinion. They indicate whether monitoring results reflect poor, fair, good, or very good conditions, and also include an "early warning trigger" to indicate where rapid or unexpected change occurs. For each of the condition ratings, a recommended monitoring frequency is proposed and a recommended management response is suggested. In most cases the management recommendation is simply to develop a plan to further evaluate an issue and consider what response actions may be appropriate.

At this stage, the interim condition ratings reflect the best guidance able to be provided based on the available information and budget. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available, and new ratings developed for other indicators e.g. macroinvertebrate (infauna and epifauna). The interim condition ratings for Waituna Lagoon, based on Robertson & Stevens (2006, 2007) are presented below along with a brief rationale for their use. It is recommended that a similar set of condition ratings be developed for Lake Onoke.

Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

METALS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Nitrogen

In shallow estuaries like those in Southland, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

APPENDIX 1 EXAMPLES OF ESTUARY CONDITION RATINGS

Total Phosphorus

In shallow estuaries like those in Southland, the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Good	200-500mg/kg	Monitor at 5 year intervals after baseline established
Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source
Poor	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Macroalgae Percent Cover

Certain types of macroalgae can grow to nuisance levels in nutrient-enriched estuaries causing sediment deterioration, oxygen depletion, bad odours and adverse impacts to biota.

MACROALGAE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	%cover <1%. No nuisance conditions	Monitor at 5 year intervals after baseline established
Good	%cover 1-10%. No nuisance conditions	Monitor at 5 year intervals after baseline established
Fair	%cover 10-50%. Isolated nuisance conditions	Monitor yearly. Initiate Evaluation & Response Plan
Poor	%cover >50%. Widespread nuisance conditions	Monitor yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend of % cover increasing	Initiate Evaluation and Response Plan

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<0.5mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	0.5-1mm/yr	Monitor at 5 year intervals after baseline established
Moderate	1-2mm/yr	Monitor at 5 year intervals after baseline established
High	2-3mm/yr	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>3mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan