WETLANDS ON PRIVATE LAND IN THE WAITUNA CATCHMENT, SOUTHLAND

ECOLOGY, HYDROLOGY & WATER QUALITY

Prepared for Department of Conservation

September 2015 (finalised July 2017)

QUALITY STATEMENT

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REVISION SCHEDULE

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1	20/05/15	Section 4 and 5 for LW Review	Kristy Harrison	Sue Bennett	Sue Bennett	Sue Bennett
2	10/06/15	Section 1 to 5 for LW Review	James Dommisse, Simon Beale, Isobel Oldfield, Kristy Harrison	Kristy Harrison, Tom Kerr	Sue Bennett	Sue Bennett
3	25/09/15	Full Draft Report	James Dommisse, Simon Beale, Isobel Oldfield, Kristy Harrison, Sue Bennett	Kristy Harrison, Tom Kerr	Sue Bennett	Sue Bennett
4	27/10/16	Revised Draft Report	Kristy Harrison	Sue Bennett	Sue Bennett	Rima Krause
5	18/7/17	Final Report	Kristy Harrison	Sue Bennett	Sue Bennett	Rima Krause

Executive Summary

Report Objective

The objective of this study is to provide a report on the hydrology, ecology and water quality of the Waituna Catchment to establish the baseline information against which gains can be measured through the 10 year Living Water Programme. This study specifically focusses on wetlands on private land as required by the project brief and subsequent discussions with the Living Water team.

The purpose of this project is to:

- Review the current state, and identify significant gaps in knowledge
- Recommend future requirements to fill gaps
- Identify opportunities for restoration and/or enhancement with priority sites suggested
- Provide recommendations for monitoring in order to fill gaps in knowledge and measure short- and long-term improvements in biodiversity and habitat quality, and
- Provide a geographic information system (GIS) map showing data collected and layered to provide a visual picture of data collected.

Methodology

There are several parties working in the Waituna Catchment and there is a significant amount of information available. To avoid duplication of effort, we have identified any relevant information sources, compiled the available data and identified the locations in GIS, but we have not undertaken detailed analysis of previous projects.

Gaps in knowledge, and the ability of the current monitoring regime to assess achievement of the objectives of the programme, have been identified. Methods for obtaining further information or additional monitoring programmes that are required to fulfil the Living Water Programme objectives have been developed.

Hydrology and Hydrogeology

The Waituna Catchment is drained by three main creeks:

- Waituna Creek ~104 km^2 in area and discharge of 1,800 L/s
- Carran Creek ~29 km^2 in area and discharge of 790 L/s
- Moffatt Creek ~17 km^2 in area and discharge of 190 L/s.

Some sections of the creeks have been straightened and deepened and are mechanically cleared to maintain drainage of farmland. Channels are typically 2 m to 7 m wide, and are a few centimetres to 1 m deep. Due to the extensive drainage network in the catchment, rainfall events tend to cause significant change in stream flows and flooding. Prior to drainage, these flows would have been intercepted by wetlands and slowly released to the catchment.

The Waituna Catchment occurs within the Waihopai Groundwater Zone. The groundwater consists of an unconfined gravel aquifer ranging from 1m to 25m in thickness, below this is a confined aquifer more than 200m thick, consisting of mudstone and lignite. Groundwater in the unconfined aquifer comes from rain falling on the catchment. The wetlands in the catchment will be primarily influenced by the unconfined upper aquifer.

The aquifer consists of three zones: the Northern Zone, Mokotua Infiltration Zone and Southern Zone. The Southern Zone comprises of peat, which has the ability to remove nitrogen but release phosphorus into the groundwater. The mid-catchment the Mokotua Infiltration Zone contains areas of high permeability where nitrogen will leach readily to groundwater. The Northern Zone in the upper catchment has minimal nutrient leaching potential. Groundwater contributes about half of the flow in the creeks, through natural seepage and artificial drainage. The remaining flow in the creeks comes from surface runoff. Groundwater also discharges directly into the Waituna Lagoon through seepage.

Groundwater abstraction from bores across the catchment amounts to 1% of the total rainfall and hence is not considered significant on a catchment scale. However, localised drawdown from bores may cause significant drainage of nearby wetlands. There are no consented water takes from the creeks in the catchment, although permitted takes (<2 L/sec) are likely to occur.

There has been no overall decline in groundwater levels in the catchment since 2012, which would indicate no evidence of over-abstraction. As expected, groundwater levels are typically highest at end of winter and lowest at end of summer. Groundwater fluctuations are generally greatest in the upper/mid catchment and lowest in the lower catchment.

Water Quality

Waituna Lagoon is a relatively shallow coastal lagoon of 1,350 ha, with fluctuating water levels dependent upon whether the lagoon is open or closed to the sea. The lagoon periodically opened naturally prior to agricultural development in the catchment. However, the lagoon has been opened mechanically since 1908, generally at lower lagoon levels than would occur naturally. The lagoon then closes naturally under the correct conditions.

The Waituna lagoon receives nutrients (nitrogen and phosphorus) and sediment from its farming catchment. Nutrients can be delivered to the lagoon either via the creeks from surface run-off and groundwater through seepage or tile drain discharges and direct from the groundwater which discharges to the lagoon. The sediment in the lagoon is from bank erosion along the creeks and potentially from erosion in the catchment caused during flood events.

There are concerns around the water quality of the Waituna Lagoon, particularly the amount of nutrients which the lagoon receives. There is concern that the levels of nutrients in the lagoon may result in phytoplankton blooms which in turn could cause a change from clear water with native *Ruppia* reed beds to turbid, murky water. If this occurs, this would dramatically change the lagoon and the plants and animals that are associated with it. During lagoon openings, nutrients are flushed out of the lagoon, dependent upon the duration of the opening event. Regular flushing of the lagoon was an important element of the management regime proposed by the Lagoon Technical Group. However, this needs to be balanced against the sensitivity of *Ruppia* reed beds to saline conditions and lowered water levels during their growth season in spring and summer.

Water quality monitoring of the creeks and the lagoon indicate that nutrient concentrations exceed the national guidelines, meaning that they contain excessive nutrients. There was no trend in concentrations that could be determined, indicating that the conditions have neither improved nor declined over the last 10 years. The nutrient concentrations in the lagoon exceed the limits set by the Lagoon Technical Group when the lagoon is closed, but reduces below them when it is opened and flushed to the sea. Given the variability caused by the opening regime, it is difficult to determine long-term trends in lagoon nutrient concentrations.

Monitoring of groundwater indicates that elevated nutrients are present across much but not all the catchment. Waituna Creek has the highest concentrations and commonly exceeds national nutrient guidelines. Much of the flow in the creeks is sourced from the groundwater, and hence this represents a source of nutrients in the creeks, estimated to be 11% of nitrogen and 15% of the phosphorus loads to Waituna Creek. The elevated nutrients in the groundwater are sourced from a combination of farming inputs and naturally occurring inputs from the aquifer.

There a number of mitigation measures that can be used to reduce nutrient and sediment loads to the creeks and the lagoon which are being trialled in the catchment at the moment. These include fencing, riparian planting, installation of constructed wetlands, and nitrogen and phosphorus filters on discharges from tile drains. DairyNZ have reported on the potential social and economic impacts of a number of other on-farm measures that can be used to reduce nutrient loads. Environment Southland has undertaken bank reconstruction along Waituna Creek to reduce the sediment load to the lagoon from collapsing banks.

Ecology

Waituna Lagoon represents an exceptional example of a coastal lake-type lagoon within a largely intact coastal wetland system. The importance of the lagoon and wetland is recognised by its designation as a national Scientific Reserve and Ramsar site of international importance.

The lagoon contains important habitat for resident and migratory birds including nationally critical and endangered species. The lagoon is home to a *Ruppia*-dominated community not well represented elsewhere in the country. It also supports several native fish species, and a valued recreational trout fishery. Shoreline vegetation is largely unmodified, being mainly in conservation estate as the Awarua-Waituna Wetlands, and includes notable cushion-bog and sand-ridge plant associations.

The *Ruppia* community is sensitive to the saline conditions and reduced water levels that result from the opening of the lagoon. When the lagoon was open for a prolonged period in 2012 and 2013, the extent of the *Ruppia* beds reduced significantly. During the 2014-2015 growth season and most of the 2015-2016 season, due to concerns over the state of native *Ruppia* reed beds, the lagoon was kept closed even though the lagoon levels rose above levels that would have resulted in opening in previous years (NIWA, 2015). This resulted in substantial recovery for macrophyte beds including *Ruppia*.

The Waituna Catchment consists of flat flood plains and gently modulated hills. Most of the catchment (70%) is modified and consists of high yielding pasture grasses for farming. Unmodified vegetation is associated with wetlands in the flood plains, particularly being bogs.

Some native threatened plants have been identified in the catchment, including the shrub swamp mingimingi (*Coprosma pedicellata*) near the Waituna Scenic Reserve and the swamp nettle (*Urtica linearifolia*) and tufted hair grass (*Deschampsia cespitosa*) in the western and eastern margins of the lagoon. Bog pine (*Halocarpus bidwillii*) and cushion plant (*Donatia novae-zealandiae*) have been found on private land during High Value Area assessments performed in the catchment. A number of weeds are present, including invasive species which are of concern for wetland ecosystems.

The Waituna Catchment supports a number of fish species in the creeks including longfin eels (*Anguilla dieffenbachii*), shortfin eels (*A. australia*), common bully (*Gobiomorphus cotidianus*) and giant kokopu (*Galaxias argenteus*), for which the Waituna Catchment is a stronghold.

An assessment of the stream bank (riparian) and in-stream habitat in the creeks in the catchment was performed in 2015. The survey found that in general, riparian habitat in the creeks were in average to good condition, however in certain segments where there is little or no stock exclusion fencing, there was extensive bank slumping and poor riparian condition. The in-stream habitat was considered to be relatively consistent across the catchment and of poor to average quality for tuna (eels), as a result of excessive fine sediment, uniform shallow habitat and little plant cover. However, there were pockets of excellent quality habitat in the lower end of Carran Creek.

In areas of Waituna Creek, one side of the creek is kept unfenced to allow access for mechanical clearance by Environment Southland to maintain the drainage network. It was noted that improved riparian management, including fencing both sides, may reduce sediment accumulation and therefore the need for drain clearance.

The quality of in-stream habitat could be improved by complete fencing to provide stock exclusion, which will allow rank grass and other vegetation to provide cover for fish, planting of overhanging, draping vegetation along the stream edge, particularly where bank reconstruction has occurred, and provide permanent cover in reconstructed areas, such as wood structures or large rock rip-rap.

Wetlands on Private Land

There are currently 6,901 hectares of wetland in the catchment and 215 hectares on private land. The information available on wetlands on private land identifies the areas in terms of hydrosystems and wetland classes in the catchment.

The dominant wetland class on private land is bog, followed by unclassified wetlands, terrestrial wetlands, shallow water wetlands and then small areas of swamp, marsh and fen.

In terms of artificial influences, land drainage through the construction of tile drains and open drains probably has the greatest overall influence on wetland fragments because they directly affect water levels. Groundwater abstraction and surface water takes may cause localised lowering of groundwater levels and potential reductions in stream flows, but the effects are considered small in relation to water inflows and outflows at a catchment level and much smaller than the impacts of land drainage.

Wetland fragments close to Waituna Lagoon (within c.60 metres) receive of water directly from the Lagoon due to large changes in lagoon water levels. Groundwater levels and stream flows are affected by changes in lagoon water levels and affect wetlands with a groundwater or surface water source.

There is no information available on the water quality in the private wetlands or their impact on nutrient loads into the catchment.

The most comprehensive information on the condition of wetlands on private land in the Waituna Catchment has been provided by the voluntary High Value Area (HVA) programme run by Environment Southland. This involves the survey of remnant areas of native biodiversity in the Southland region. To date HVA surveys have been conducted on 24 private properties in the catchment. These have included ten properties that contain wetland communities, including some which are covenanted with the QEII Trust. The nationally threatened were recorded in several of the surveyed wetlands.

The predominant wetland class found in the HVA surveys was bogs with some areas featuring small areas of swamp, fen and shallow water. The predominance of bogs in these areas is consistent with the results of the mapping exercise undertaken by DOC across the catchment. The bogs have a substrate of peat and support a cover of manuka scrub and shrubland and wire rush rushland while the swamps tend to support flaxland. Threatened species found were bittern (*Botaurus poicilotilus*), fernbird (*Bowdieria punctata*) and swamp mingimingi, along with locally uncommon bog pine and cushion plant.

Overall, the wetlands surveyed have been assessed to be in good condition with a favourable connectivity in terms of proximity of other wetlands and formally protected areas. Some are contiguous with conservation land and reserves and form an important buffering function.

Monitoring and Management Recommendations

The focus of the monitoring and management recommendations are wetlands that are located on private land, as there are already extensive programmes of work associated with the wetlands on public land and the Waituna Lagoon.

Wetland Restoration Actions

On the ground physical works should be the focus of the Living Water Programme and should be prioritised based the benefits achieved to wetland condition, water quality and biodiversity. We recommend that that the key priorities for physical works in the wetlands are:

1. **Fencing** – to exclude stock and prevent loss in wetland extent;
2. **Preventing and Reverting Land Drainage** – to reduce water loss and maximise water input to wetland.
3. **Controlling Nutrient Run-Off** – to reduce nutrient runoff to wetlands to improve water quality and reduce weed growth.

These actions are considered a priority for protecting and improving wetland extent and condition. We consider other actions, such as weed and pest control and planting, to be useful but we suggest that these should have less priority. These other measures can improve biodiversity and can supplement the primary actions.

Monitoring

The recommended monitoring programme focuses on collecting information that can be used to determine the benefits of physical works on the ground over the project time frame. The monitoring programme includes:

- **Hydrology and Hydrogeology Monitoring.** This monitoring is focused on developing an understanding of the water system across the catchment around the wetlands and how this may change as a result of interventions undertaken. It will inform any works to improve the water system of the wetland.

- **Water Quality Monitoring.** This will include:
  - Surface water and groundwater quality monitoring across the catchment to monitor the effect of the overall project on water quality;
  - Site-specific monitoring of surface water and/or groundwater coming into and discharged from the wetlands (dependent upon the nature of the wetland) at selected sites.
- **Ecology Monitoring.** This monitoring will focus on gathering quantitative and qualitative information wetland condition and rare species within the wider catchment.
- **Site-Specific Wetland Monitoring.** More intensive monitoring that can be implemented at a sample of wetland fragments throughout the catchment and/or in high priority wetlands as identified in our separate report on the prioritisation of wetlands in the catchment.

Reporting

Reporting of the restoration actions and monitoring performed is important to ensure to demonstrate the result of the programme and to ensure that knowledge is transferred. Reporting recommended for the project includes:

- **Annual Summary Report.** This will identify the restoration works undertaken and the monitoring carried out. Detailed analysis will not be carried out at this frequency. It should also identify the outcomes of any external projects that had been undertaken and reported during the past year. This will provide a useful ongoing identification and review of relevant information.
- **Five-Yearly Outcomes Report.** This will be undertaken approximately every five years in the middle of the project and again towards the end. It will present the findings of restoration work and monitoring undertaken, including analysis of data and recommendations for the next five years.

The implementation of the recommended restoration actions, monitoring and reporting procedures will enable the protection of the existing wetlands on private land and assessment of improvements in wetland condition, water quality and biodiversity within the catchment. This will help to achieve the objectives of the Living Water Programme and ensure its success.

Department of Conservation

Wetlands on Private Land in the Waituna Catchment, Southland: Ecology, Hydrology & Water Quality

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1 Introduction

1.1 Background

The Living Water Programme is a joint initiative between the Department of Conservation (DOC) and Fonterra working with local communities, dairy farmers and other stakeholders to improve water quality in sensitive water catchments. The Awarua-Waituna Catchment is one of five Living Water Programme sites across New Zealand. The other sites are the Kaipara Harbour, Firth of Thames / Tīkapa Moana, Waikato Peat Lakes and Te Waihora / Lakes Ellesmere.

Living Water is a 10 year commitment to work in the Awarua-Waituna Catchment, commencing in 2013. The focus of the programme is land in private ownership as the DOC Arawai Kākāriki programme addresses land in Crown ownership. The vision for the Waituna Catchment is "*to work with the local community to continue to enhance the health of the Waituna Catchment and the lagoon, to create healthy, functioning farms and wetlands living side by side now and in the future*" (Fonterra & DOC, 2014).

The Waituna Catchment site goals for 2014 to 2015 (Fonterra & DOC, 2014) are as follows:

- Protect and enhance remaining wetland fragments on private land within the catchment
- Work with Ngāi Tahu on protection of key mahinga kai species such as tuna (eels)
- Enhance local pride in enhancement projects through ongoing community engagement
- Work closely with the Waituna Partners Group to complement and enhance other work going on in the catchment through the Community Investment in Water (CIW) programme
- Work alongside the DOC Arawai Kākāriki wetland restoration programme on public conservation land within the catchment, and
- Be widely known in the community for the work that CIW is carrying out.

The Living Water Programme has identified several objectives which need to be met. One of these is to develop baseline reports to establish the current state of water quality, ecology and hydrology. The baseline reports will enable the partnership to make informed decisions on priorities for operational work and enable DOC and Fonterra to measure the effectiveness of projects against the objectives, outcome, output monitoring framework. This study contributes to this objective by providing baseline information on the water quality, ecology and hydrology of in the Waituna Catchment and wetlands on private land.

1.2 Report Purpose and Scope

The objective of this study is to provide a report on the hydrology, ecology and water quality of the Waituna Catchment to establish the baseline information against which gains can be measured through the 10 year Living Water Programme. This study presents a high level review of information for the catchment but with a specific focus on wetlands on private land as requested by the Living Water team.

More specifically, the purpose of this report is to:

- Review the current state, and identify significant gaps in knowledge
- Recommend future requirements to fill gaps
- Identify opportunities for restoration and/or enhancement with priority sites suggested
- Provide recommendations for monitoring in order to fill gaps in knowledge and measure short- and long-term improvements in biodiversity and habitat quality; and
- Provide a GIS map showing data collected and layered to provide a visual picture of data collected.

This report responds to a Request for Proposal issued by the Department of Conservation in November 2014 (DOCDM-1499821). This report is based on a review of existing information and GIS data and focuses on wetland sites on private land. It can be read in conjunction with the wetland site prioritisation report prepared by MWH in September 2015 and finalised in June 2017 (MWH, 2017).

1.3 Structure

The report includes the following sections:

- Section 1 introduces the Living Water Programme and the objectives of this report
- Section 2 describes the methodology used
- Sections 3 to 6 contains a summary of the hydrology, hydrogeology, ecology and water quality information at a catchment scale and the available information on private wetlands in the catchment
- Section 7 summarises the information gaps identified through the study
- Section 8 details the recommendations with respect to monitoring, management and reporting.

2 Methodology

2.1 Approach

Existing information and on-going monitoring programmes have been reviewed to determine the current state of the hydrological, ecological and water status of the Waituna Catchment, particularly for wetlands on private land. Any gaps in existing information and the ability of the current monitoring regime to assess achievement of the objectives of the programme have been identified. Methods for obtaining further information or additional monitoring programmes that are required have been developed and are provided as recommendations.

2.2 Sources of Information

There are a large number of stakeholders working in the Waituna Catchment and there is a significant amount of information available. However, there is relatively little research that has been undertaken on wetlands on private land.

Reports, monitoring results and GIS data for the Waituna Catchment was sourced directly from DOC, Environment Southland, Fonterra and from publicly available databases (GNS, LINZ and NIWA).

A scientific "stocktake" had been completed in February 2013 which contained a summary of all scientific studies and technical reports that have been prepared for the Waituna Catchment (Ryder, 2013). Specifically, it covered past and present work being undertaken within the catchment by DOC, Environment Southland, Ngai Tahu and Southland District Council. The report covered the catchment as a whole, and was used to identify relevant information and data which could be used for the present study which has a greater focus on wetlands on private land.

As of 2015, there were several projects in the catchment that were yet to be reported. This included the DairyNZ Action Plan, the cultural opportunities mapping being led by Te Ao Marama Incorporated, and the Environment Southland Surface Water Quality Study. There were also several Living Water studies and partnerships in progress such as a riparian and in-stream habitat assessment, eel/tuna habitat quality index, denitrification and phosphorus sorption filters, and conversion of a duck pond to a water treatment wetland. To avoid duplication of effort, this report has identified any relevant information sources, compiled the available data, and identified site locations in GIS, but has not undertaken detailed analysis of these projects.

A full list of data sources used in the preparation of this report is provided in Appendix A and the list of references in Section 9.

2.3 Hydrology

There are several parties undertaking investigations into the hydrology and hydrogeology in the catchment. MWH undertook a review and summary of the available information for the catchment, including elements relevant to private wetlands.

The tasks undertaken included:

- Review of relevant literature related to surface water and groundwater and identification of information sources related to wetland fragments
- Review of current research and studies from Universities, Crown Research Institutes and local government
- Inventory of known sources of surface water and groundwater and monitoring sites collated in GIS, including a description of the key attributes of each site such as length of record, data frequency, whether the data is currently monitored
- Collating existing information on all known springs, surface water drains / streams / creeks, tile drains and groundwater and surface water abstraction locations
- Analysis of gaps in the knowledge and understanding of hydrological influences on wetland fragments
- Preparation of a monitoring plan to complement the existing monitoring being undertaken.

2.4 Water Quality

The primary source of information on the water quality in the Waituna Catchment is Environment Southland's State of the Environment monitoring network, which includes sites on the main stream channels and in Waituna Lagoon. Environment Southland has also completed a more detailed review of water quality in the catchment, including the smaller tributaries, in the Surface Water Quality Study which was completed in 2015.

The review of current state of water quality for wetlands on private land involved:

- Sourcing surface water and groundwater quality monitoring data from Environment Southland State of the Environment monitoring and the Surface Water Quality Study
- Comparison of water quality data against national and regional environmental guidelines, analysis of relative concentrations between sampling locations and any historical trends
- Identifying any areas of the catchment and any parameters for which water quality information is limited, and
- Developing a monitoring programme to address identified data gaps.

2.5 Ecology

MWH undertook a review and summary of the available information relevant to the current ecological state of wetlands on private land.

The review comprised the following:

- Meetings and discussions with staff from DOC and Environment Southland;
- Review of existing literature, including reports and data that have been prepared on the ecology of the catchment and wetlands on private land;
- Gathering of available data into GIS format, namely:
  i. Aerial photography
  ii. Regional and District Plan information
  iii. Cadastral information
  iv. Public and private land ownership
  v. Protected areas
  vi. Existing aquatic and terrestrial ecology monitoring sites
  vii. Riparian habitat mapping data (Holmes, Goodwin, & Allen, 2015)
  viii. Biological Databases (NZ Freshwater Fish Database, NZ Herpetofauna Database)
  ix. Landcare Databases (LCDB v4.0)
  x. DOC Databases (Wetlands of NZ).
- Summarising existing monitoring to identify areas where monitoring could be rationalised and/or where there are gaps in order to address both the needs of the scientific community and the local community, including both qualitative and quantitative measures of ecological health.

2.6 GIS Constraints Analysis

A multi-criteria GIS constraints analysis (MCA) was conducted to determine wetlands on private land which are a priority for protection or restoration. This involved overlaying existing datasets of information available in GIS and using criteria developed in consultation with DOC, Fonterra and other stakeholders. The constraints analysis resulted in a ranking of private properties across the catchment as to their priority for restoration. The results of this work is discussed in a separate report (MWH, 2017).

2.7 Gap Analysis and Monitoring Recommendations

A gap analysis on the available information was undertaken, both on a catchment scale and for wetlands on private land, to provide recommendations for both physical works and monitoring programmes. The monitoring can be used to better understand the relationship between hydrology, water quality and ecology in order to enhance aquatic and wetland values, and to monitor the effects of changes in the catchment over the 10 year Living Water Programme.

3 Hydrology and Hydrogeology

The purpose of this section is to summarise the available information on the hydrology and hydrogeology of the Waituna Catchment. This is to provide the wider context within which wetlands on private land exist. A discussion of information specific to wetlands on private land in provided in Section 6.

3.1 Introduction

An understanding of climatic variations and the movement of groundwater and surface water through the Waituna Catchment is useful for identifying the main hydrological influences on wetland fragments.

The Waituna Catchment is divided into three groundwater zones based on different physical and chemical properties (see Figure 3-2). The three zones are named the Northern Zone, Mokotua Infiltration Zone and Southern Zone (Rissmann, 2011)[1]. The three main streams in the catchment are the Waituna Creek, Carran Creek and Moffatt Creek (Figure 3-3).

Figure 3-1 shows a schematic conceptual model of a hydrological water balance for wetland fragments in the Waituna Catchment. Nearly all groundwater is sourced from rain or snowfall which drains through the soil. Stream flows are a combination of rainfall, surface water runoff, groundwater inflows and anthropogenic discharges (e.g. tile drains, novaflow drainage pipe, open drains).

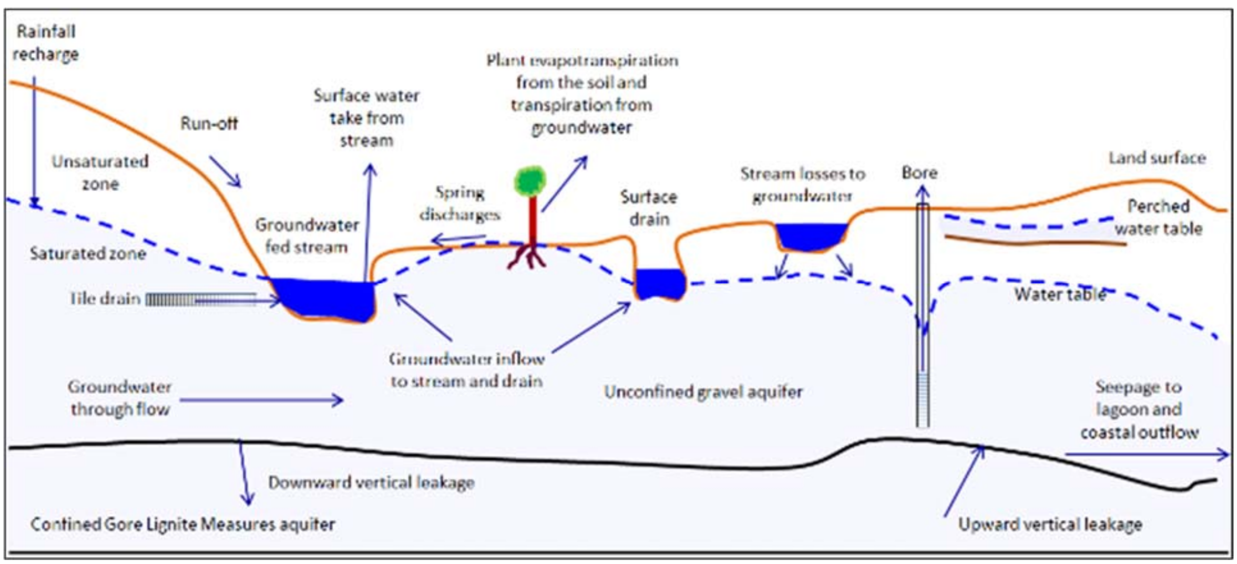

Figure 3-1: Conceptual model showing the hydrological system in the Waituna Catchment

A number of climate, groundwater and surface monitoring has been conducted within and near the Waituna Catchment. Overall, there appears to be no signs of over abstraction from surface water or groundwater sources and rainfall appears consistent. Table 3-1 provides a summary of the climatic, groundwater and surface water processes at a catchment level based on a review of existing information. This information is further discussed in Sections 3.2 to 3.4.

[1] We note that more detailed mapping of the physiographic zones has been prepared subsequent to the drafting of this report. However, the general zones still apply.

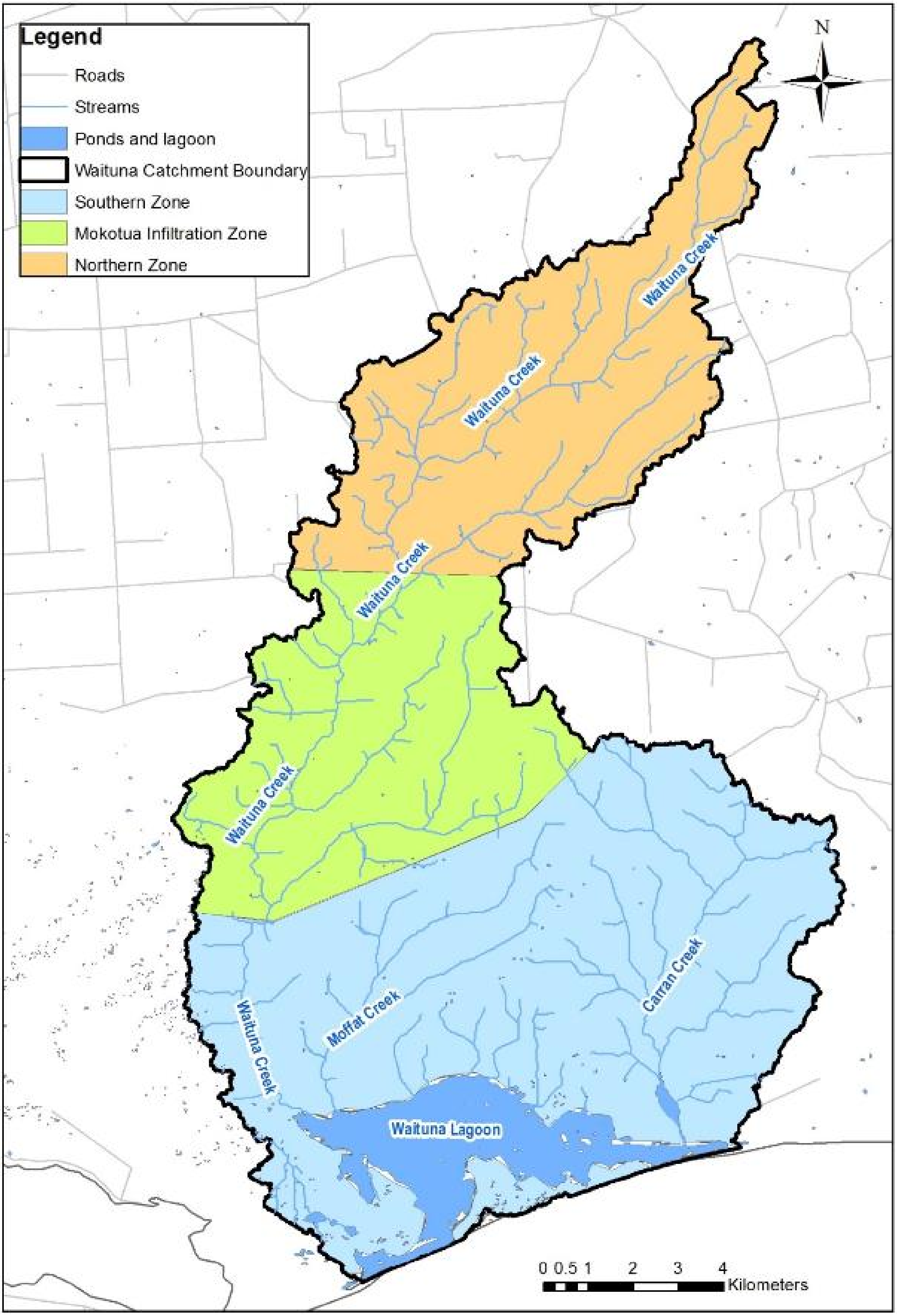

Figure 3-2: Zones of distinctly different physical and chemical properties of groundwater after Rissmann et al (2012)

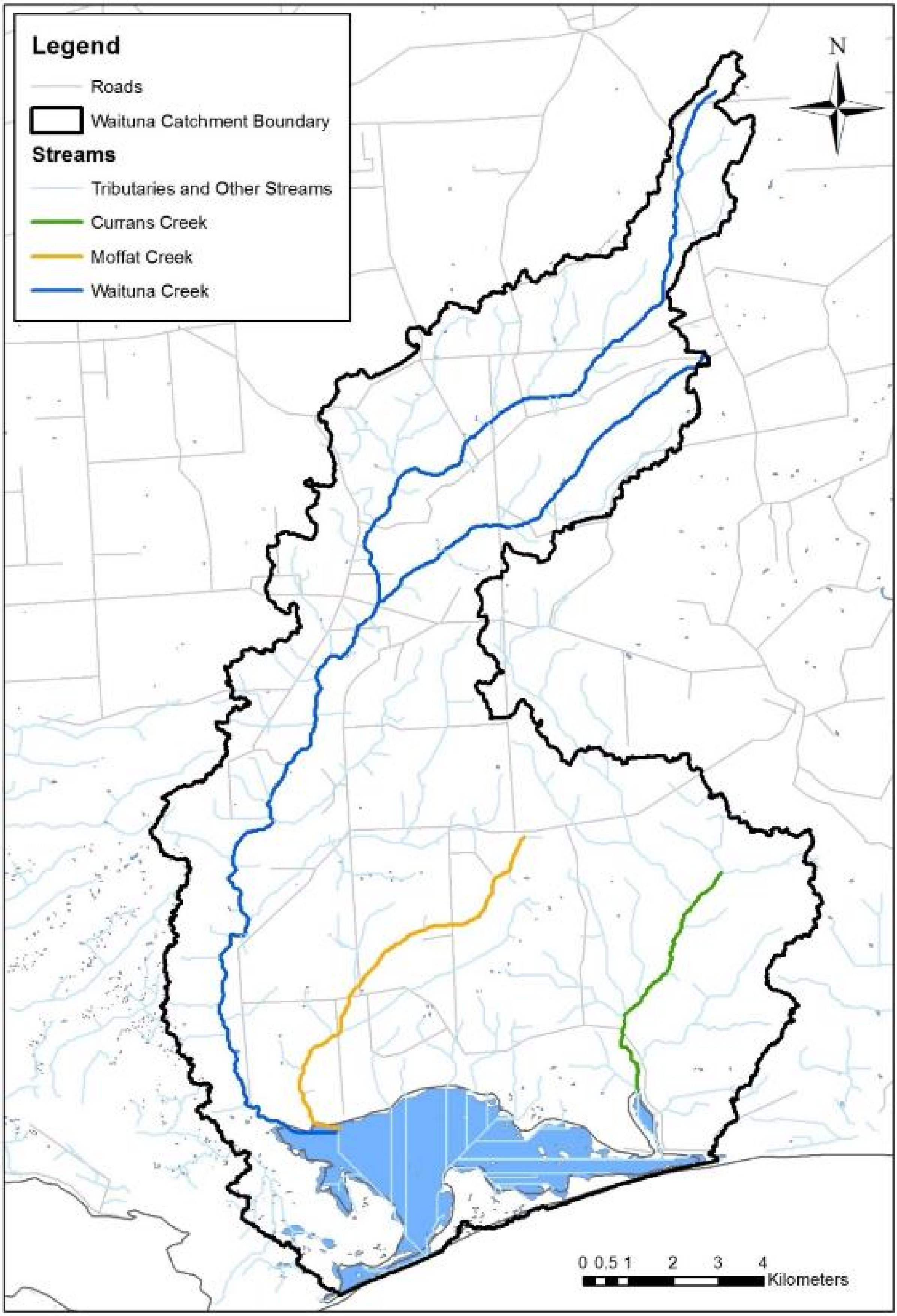

Figure 3-3: Location of the main channels of Waituna, Moffat and Currants Creek as well as other smaller and tributary streams

Table 3-1: Description of climate, groundwater and surface water process at a catchment level

<table>
<tr><th colspan="3">Precipitation and Evapotranspiration</th></tr>
<tr><td>General description</td><td colspan="2">Rainfall and snow melt is the origin of all water to both groundwater and surface water. The highest rainfall occurs from January to June.

After precipitation has fallen, about one third is then removed from the Waituna Catchment as a result of evapotranspiration (Wilson, 2011). Evapotranspiration is the combined removal of water through evaporation and water uptake by plants. On average, rainfall is greater than evapotranspiration between April and September and less than evapotranspiration between October and March (Rissmann et al, 2012).</td></tr>
<tr><th colspan="3">Groundwater</th></tr>
<tr><td>General description</td><td colspan="2">The Waituna Catchment occurs within the Waihopai Groundwater Zone. The zone consists of an unconfined aquifer (where groundwater is present at the water table) of moderate to low permeability poorly sorted silty, sandy clay-bound gravels ranging from less than 1 m to about 25 m in thickness (Rissmann et al, 2012). The unconfined aquifer is underlain by the 200 m plus thick, Gore Lignite Measure aquifers, largely comprised of mudstone and lignite.

There are 170 groundwater bores within the Waituna Catchment, ranging from 1.4 m deep up to 270 m deep. Groundwater level data in Appendix B show that in general, groundwater levels are closer to the land surface in the lower catchment, hence the lower catchment has greater potential to support groundwater fed wetlands.

Rissmann et al (2012) breaks groundwater within the Waituna Catchment into three zones of different physical and chemical properties. Environment Southland is doing further work to characterise these zones (the Surface Water Quality Study). The three zones are named Northern Zone, Mokotua Infiltration Zone and Southern Zone (see Figure 3-2). The zone data show that in the upper Waituna Catchment, rainfall drains slowly to groundwater and in the middle and lower catchment, rainfall drains quickly to groundwater. With regards to groundwater quality, the Southern Zone contains peaty soil and organic material creating reducing conditions which removes Nitrate-Nitrogen from groundwater.</td></tr>
<tr><td>Where does it come from?</td><td colspan="2">Nearly all groundwater in the unconfined aquifer is sourced from rainfall which drains through the soil. Within the Waituna Catchment approximately 48% (521 mm/yr) of the mean annual rainfall (1,080 mm/yr) drains through the soil and into groundwater (Morgan & Evans, 2003).

The remaining groundwater is sourced as seepage from streams (Wilson, 2011). Therefore in general, higher rainfall usually means higher groundwater levels. Since rainfall is generally greater than evapotranspiration during winter, groundwater levels are generally higher during winter and lower during summer.</td></tr>
<tr><td rowspan="2">Where does it discharge to?</td><td>Transpiration</td><td>At some locations within the Waituna Catchment, groundwater levels and stream flows show daily variations as a result of water uptake by plants (Rissmann et al, 2012). Though groundwater removal from transpiration is small relative to the whole catchment water balance (Rissmann et al, 2012), the diurnal water level variations show direct reliance of some wetland vegetation on both groundwater and surface water.</td></tr>
<tr><td>Discharge to Surface Water</td><td>Originally, there was a slow release of groundwater into streams from extensive wetland areas like the Awarua. However, since the introduction of artificial drainage, groundwater flows much more rapidly to streams. This results in increased peak stream flows and reduced summer stream flows compared with the flows that would naturally occur (Rissmann et al, 2012). Rissmann et al (2012) states that groundwater contributes 43% to 63% of the total flow in Waituna Catchment streams.

The groundwater contribution to stream flow is made up of natural groundwater seepage from the side of the stream, from the stream bed, from tile drains, novaflow drainage pipe, open drains and springs.

Tile drains and open drains tend to result in lower groundwater levels and may have potentially adverse effects on wetland fragments that are dominantly sourced by groundwater.

Environment Southland keeps no record of springs. Springs may feed groundwater to a wetland fragment or may act as a conduit discharging groundwater away from a</td></tr>
</table>

		wetland fragment. Given that groundwater is close to the land surface over most of the catchment, it is likely that a number of springs exist. It is estimated that 72 million m^3 of groundwater discharges to surface water each year (Wilson, 2011) which is much greater than the volume of groundwater abstracted from bores within the catchment. Details of groundwater abstraction from bores are provided in the next section of the table.
	Seepage to Waituna Lagoon	In wetland fragments that border Waituna Lagoon, some groundwater beneath the wetland will directly discharge into the lagoon. Rissmann et al (2012) suggest that groundwater seepage from the whole Waituna Catchment into Waituna Lagoon is relatively significant and equates to between 10 and 14 million m^3/yr.
	Groundwater Abstraction from Bores	Groundwater abstraction from bores has the potential to lower groundwater levels, hence impacting on wetland fragments that are primarily fed by groundwater. As of April 2014, there were 62 bores within a 2 km radius of the Waituna Catchment boundary which had consents to abstract groundwater. A summary of this data is provided in Appendix B. The total groundwater abstraction from these bores was 4,553 m^3/d or 53 L/s of which 46% came from the unconfined gravel aquifer, 37% from the deeper confined Gore Lignite Measures aquifers and 17% from bores from which insufficient information was available to determine the source. Since the wetlands will be mostly influenced by the unconfined aquifer, a conservative approach was taken to include bores less than 50 m deep as unconfined in the cases where bore depths were supplied but no bore log was available. Most takes occur within and near the upper Waituna Catchment with relatively few takes near Waituna Lagoon. The maximum consented daily rate of take from any one single bore ranges from 0.5 L/s to 1.7 L/s. The primary use for all but one of the consents is dairying. To put the current groundwater takes in context, the annual consented volume extracted by all 62 bores is 1.3 million m^3 per year, which is just over 1% of the mean annual recharge from rainfall over the entire Waituna Catchment (100 million m^3 per year). Thus at a catchment scale, groundwater abstraction is just a small part of the overall groundwater water balance when compared with discharge to surface water and discharge to Waituna Lagoon. However, despite the relatively small volume of groundwater abstractions within the catchment, Burbery (2012) identified localised drawdown at bore F47/0252 in the upper Waituna Catchment during summer which was interpreted to reflect the effects of groundwater abstraction. Further investigation of the potential effects of groundwater abstraction on groundwater levels was undertaken using a groundwater model developed as part of this investigation. A figure in Appendix B shows the combined groundwater drawdown (in meters) from all bores likely to be screened in the shallow unconfined aquifer. Drawdown was determined after 365 days continuous pumping at a daily rate equal to the annual volume divided by 365 days. Though the maximum predicted drawdown of 2.7 m is probably high given the likely connection between groundwater and surface water, the model highlights the potential for localised effects on groundwater levels, especially in the upper part of the catchment as previously identified by Burbery (2012).
Surface Water		
General description	The Waituna Catchment consists of three major surface water catchments shown in Figure 3-3: • Waituna Creek Catchment (~104 km^2) with average discharge of 1,800 L/s • Carran Creek Catchment (~29 km^2) with average discharge of 790 L/s • Moffatt Creek Catchment (~17 km^2) with average discharge of 190 L/s Some sections of these creeks have been substantially straightened and deepened and are maintained primarily as drainage channels with regular mechanical clearance. The creek channels generally range in width from 2 m to 7 m with water depth ranging from a few centimeters to one	

	meter (MWH, 2008). Despite some modifications, these creeks are still ecologically productive and provide good habitat in some reaches. Rainfall events tend to cause rapid surface flooding in these creeks (MWH, 2008). A number of much smaller streams also flow into the lagoon, particularly along the western and northern shores (Ryder, 2013). An extensive network of farm drains (both open and sub-surface) make up the broader drainage network (NIWA, 2013). In general, streams receive about half of their flow from rainfall in the form of run-off from the land surface and about half their flow from groundwater. Groundwater may enter the streams or surface drains via direct seepage through the stream bed and sides of the stream, through groundwater discharged via tile drains and groundwater discharged via springs. Through concurrent gaugings during a period of baseflow conditions (conditions when the flow is dominantly sourced from groundwater), Rissmann et al (2012) shows how the flow in Waituna Creek increases with distance from the upper catchment through to Waituna Lagoon as result of the cumulative addition of groundwater over the length of the creek.
Consented takes	There are no consented surface water takes within the Waituna Catchment. However, there is an unknown number of permitted surface takes for stock water. These takes are all assumed to be a permitted activity meaning that they are less than 2 L/s.
Waituna Lagoon	Water levels in Waituna Lagoon influence water levels in adjacent streams and groundwater bores. The study by Jackson et al (2001) concluded that 1) changes in lagoon water levels will only have effects within 20 m of streams and drains flowing into the lagoon and 2) overall, water level changes in the lagoon are not well coupled to the drainage of farmland, and that periods of very wet ground conditions are more the result of the balance of rainfall and evaporation. Later work by Rissmann et al (2012) describes how filling the lagoon causes surface water in the drains to rise upstream, resulting in more water logged soils. With specific regards to groundwater, further work by both Rissmann et al (2012) and Burbery (2012) show that an increase in lagoon surface water levels causes the water table to rise at some locations along the margins of the lagoon, but not at others. Thus there appears to be some differences depending on site locations.

3.2 Climate

3.2.1 Climate Monitoring

Climate station site locations are shown in Figure 3-5 and a summary of the information is provided in Appendix B. Whilst other climate sites exist within and near the catchment, these sites were chosen because they contain a long-term record.

3.2.2 Rainfall Trends

Accumulative monthly residual rainfall (AMRR) shows the cumulative deviation from the mean monthly rainfall. The AMRR from Invercargill shows below average monthly rainfall from 1942 to 1981 and above average monthly rainfall from 1982 through to 2015 (see Figure 3-4).

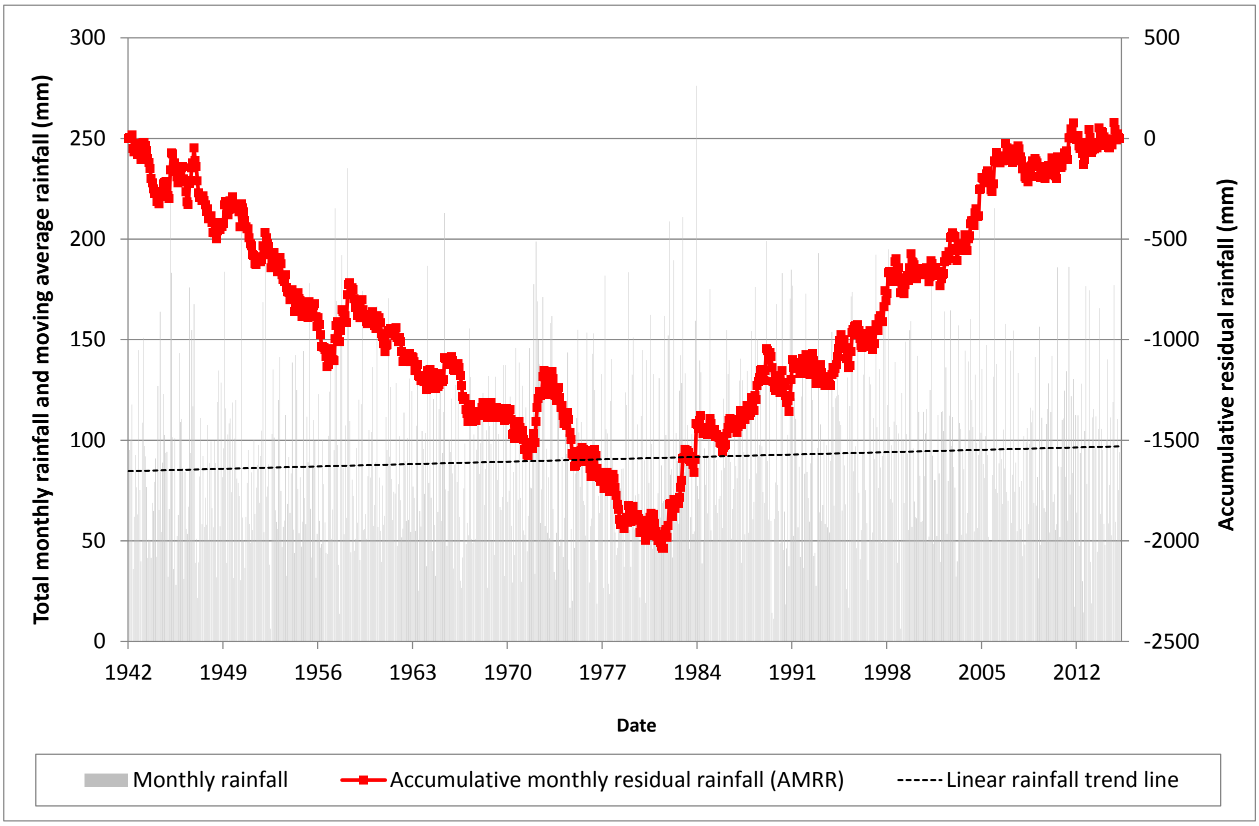

Figure 3-4: Monthly rainfall statistics for Invercargill (NIWA Agent Number 5814)

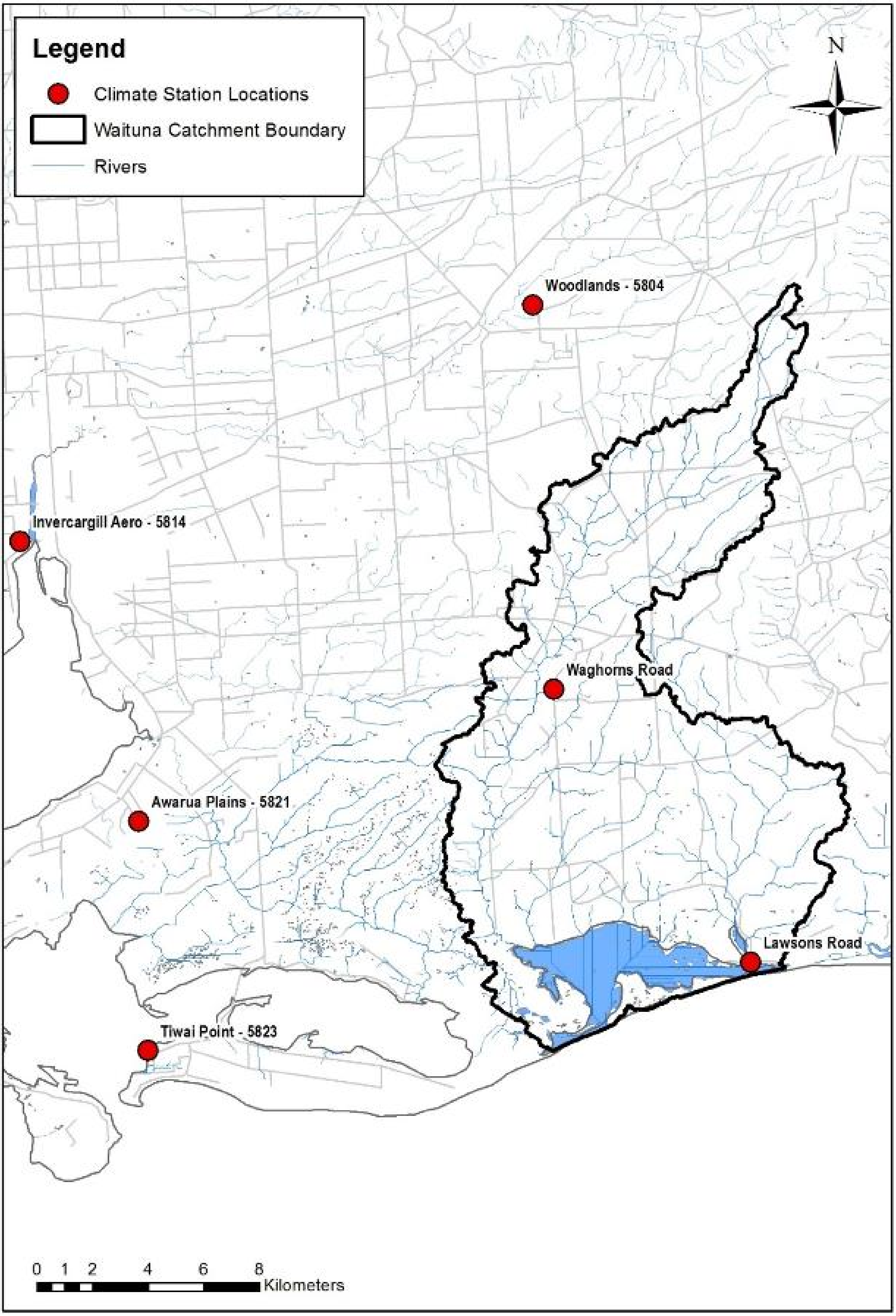

Figure 3-5: Climate station locations

3.3 Groundwater Levels

3.3.1 Groundwater Monitoring

The earliest groundwater level monitoring within the Waituna Catchment commenced during the 1970's and early 1980's by L&M Mining (Rissmann & Wilson, 2012), however, much of this data has been lost.

The first groundwater level monitoring by Environment Southland commenced in 2000. However, these sites have since been removed from the monitoring program and are under review. Currently, Environment Southland has no regular groundwater level monitoring sites within the Waituna Catchment. A summary of the bores previously monitored by Environment Southland is shown in Figure 3-6 with additional information provided in Appendix B.

3.3.2 Groundwater Trends

To evaluate the current state of groundwater levels in the shallow unconfined aquifer, monthly manual groundwater level readings from bores within the Waituna Catchment have been plotted against daily rainfall and the monthly residual rainfall at the Lawsons Road site as shown in Figure 3-7 and Figure 3-8. Further data is provided in Appendix B.

Most of the data show highest groundwater levels in May 2011 when monitoring first commenced and lowest levels in April 2013 after a summer of low rainfall. However, since April 2013, groundwater levels have recovered slightly and have remained at a generally similar level.

Overall, the data shows no decline in groundwater levels since mid-2012. Thus at a catchment scale, groundwater levels in wetland fragments that are primarily groundwater fed are likely to have remained relatively stable over the past 3 years. However, it should be noted that the groundwater record only shows short-term trends and does not show the trend prior to 2012. In addition, more detailed information would be required to assess localised trends.

Based on groundwater modelling, Burbury et al (2012) showed that rainfall drainage from the land surface into the groundwater system is rapid and occurs within a matter of hours to a few days. Figure 3-8 shows that in general, groundwater levels in bore F46/0391 rise soon after large rainfall events. The times when there is a less immediate response is probably the result of time gaps in the measurement record or rainfall that occurred when soil moisture levels were low (hence rainfall fills up the soil profile rather than draining to the water table).

There is insufficient length of groundwater data to determine seasonal trends in the lower Waituna Catchment. However, sufficient information back to 2000 exists for bore F46/0391 screening the unconfined aquifer in the upper Waituna Catchment. Groundwater levels in this bore (Figure 3-9) show a distinct seasonal variation with highest levels at the end of winter and lowest levels at the end of summer.

An important observation with regards to groundwater-fed wetland fragments is that in general, groundwater fluctuations are greatest in the upper/mid catchment and lowest in the lower catchment nearer to Waituna Lagoon. This may have an effect on the type of wetlands present at different locations within the catchment. For example, fen wetlands have a water table at or just below the surface with slight to moderate water level fluctuations (Johnson & Gerbeaux, 2004). This explains why this wetland type is most abundant in the lower Waituna Catchment.

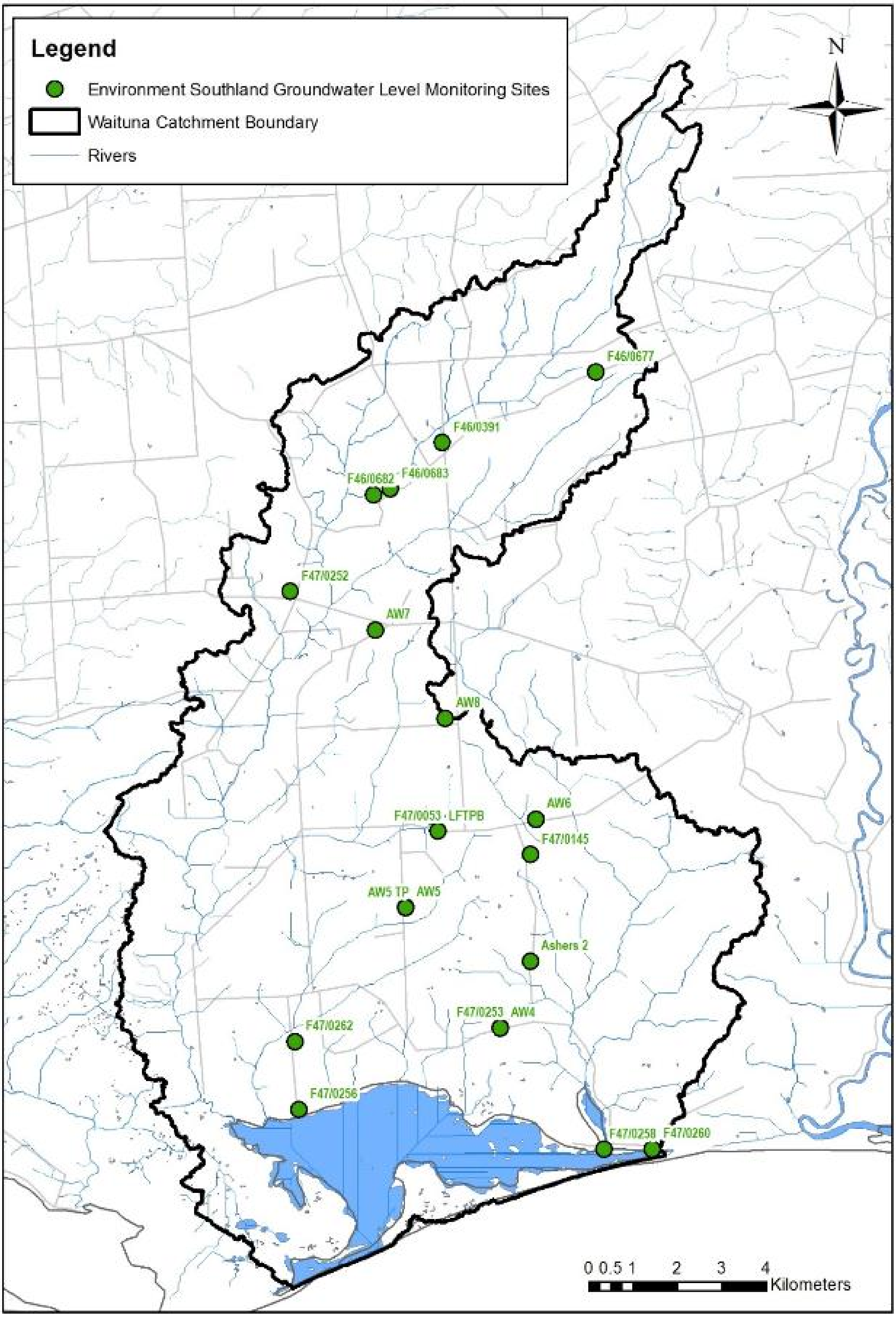

Figure 3-6: Historical groundwater level sites monitored by Environment Southland

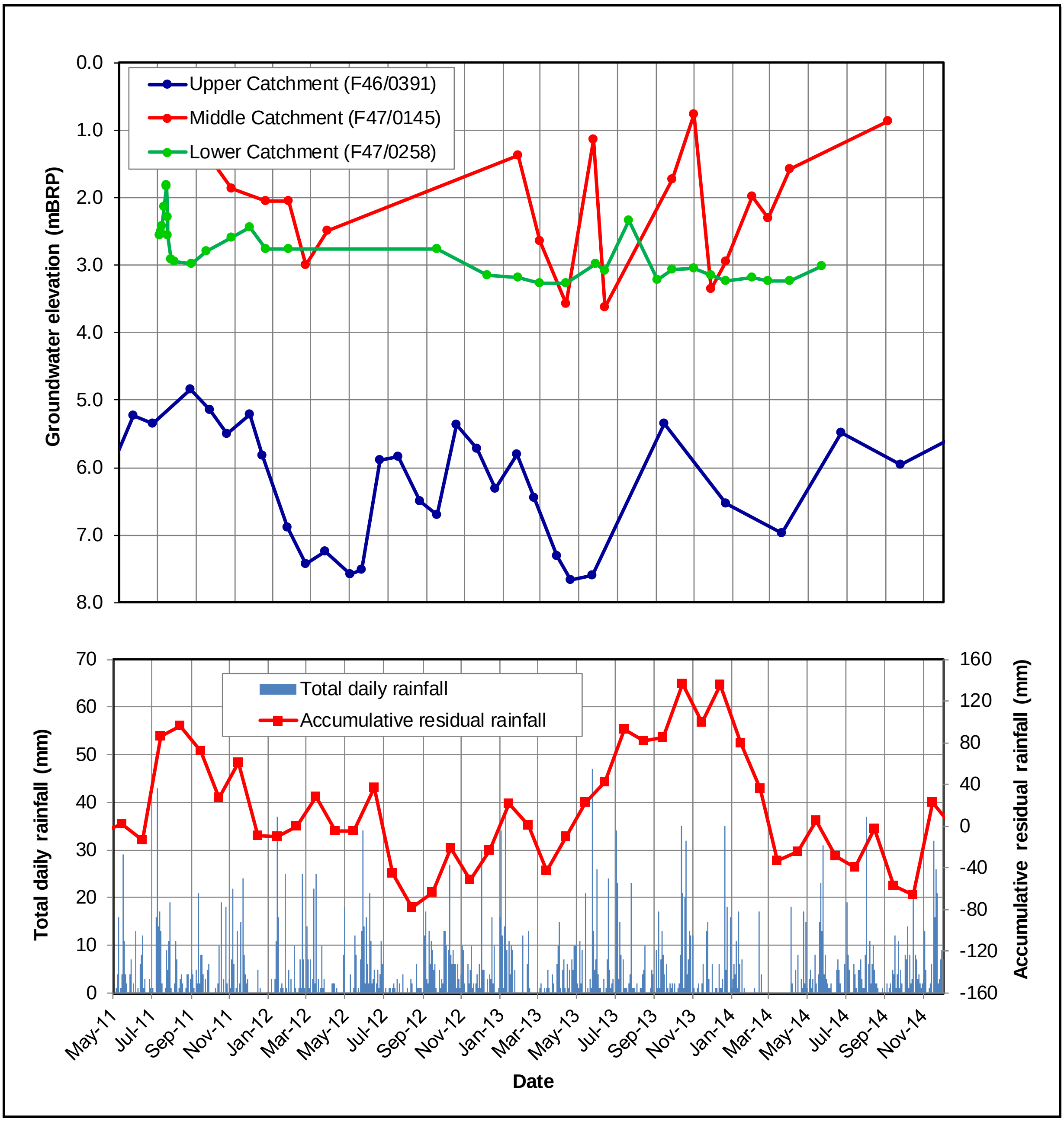

Figure 3-7: Groundwater levels trends (in the unconfined aquifer) at different locations within the Waituna Catchment plotted against versus daily rainfall and the monthly accumulative residual rainfall from Lawsons Road

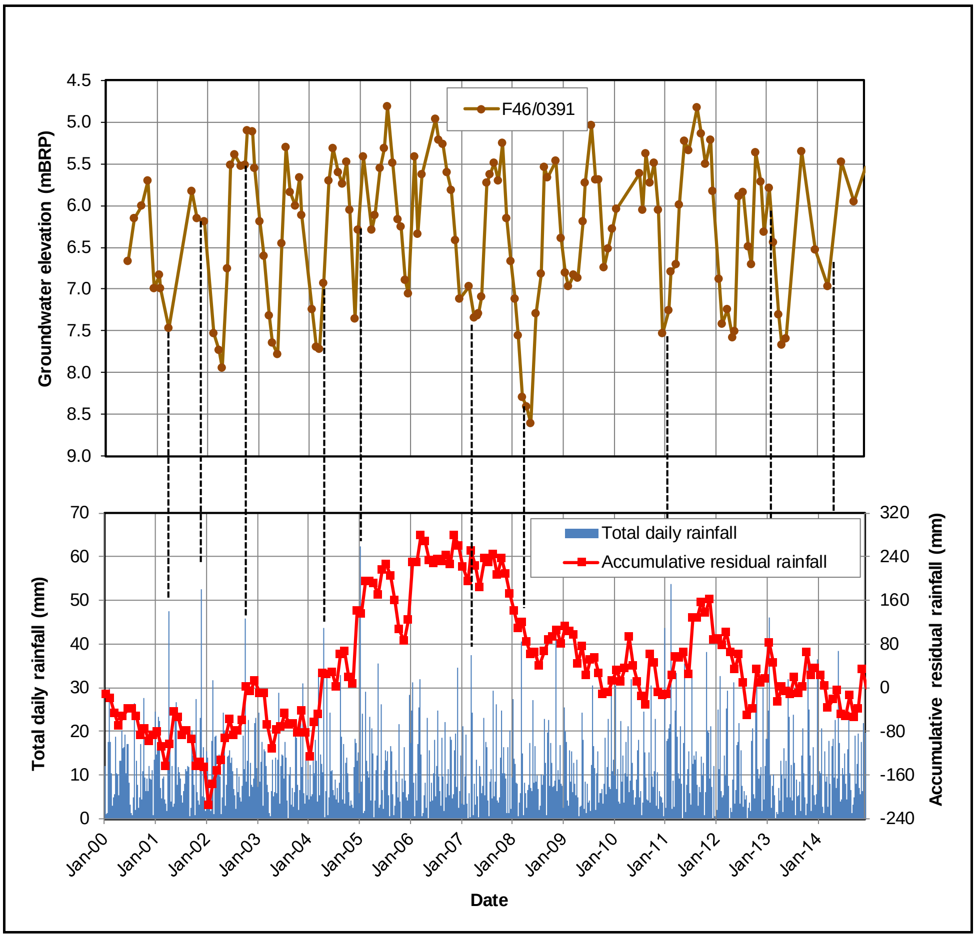

Figure 3-8: Long term groundwater level trends at bore F46/0391 in the upper Waituna Catchment (2000 to 2014). Dashed lines show large rainfall events

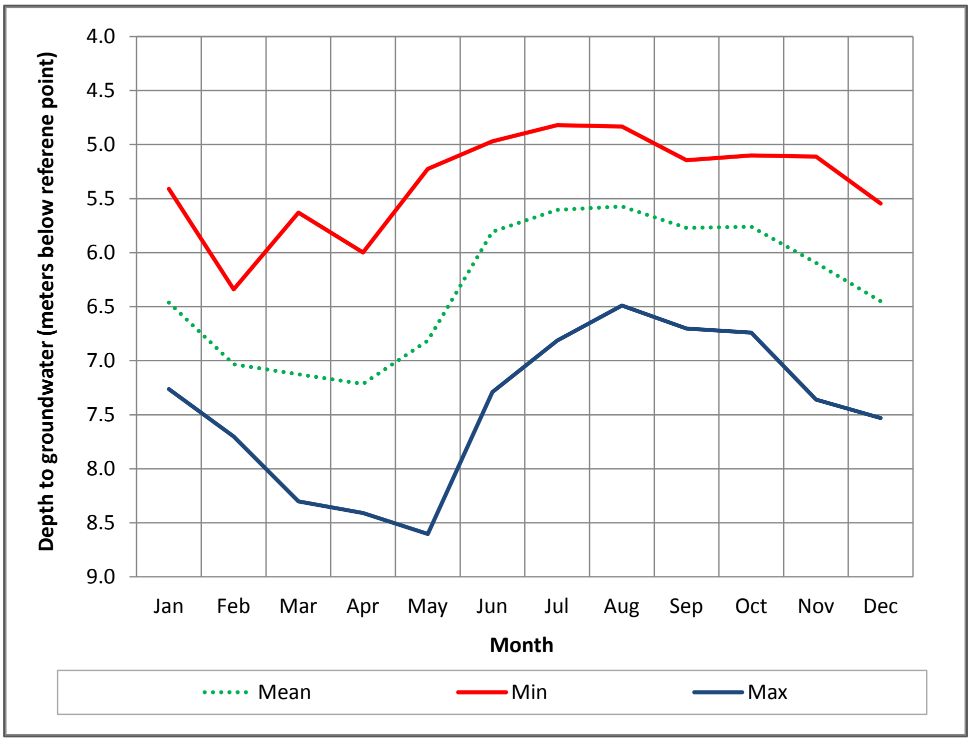

Figure 3-9: Groundwater levels for bore F46/0391 in the upper Waituna Catchment (2000 to 2014)

3.4 Surface Water Flows

3.4.1 Surface Water Flow Monitoring

Reliable long-term surface water flow data from within the Waituna Catchment is focused on the lower catchment. However, a good relationship exists between the flow record from Waihopai River at Kennington and Waituna Creek at Marshall Road, as well as Carran Creek at Waituna Lagoon Rd and Moffat Creek at Moffat Creek Rd. This was used by NIWA to interpolate flow records back to 1995 (Tanner, Hughes, & Sukias, 2013).

Surface water flows are monitored continuously by Environment Southland at the lower end of Waituna Catchment at Waituna Creek, Moffat Creek and Carran Creek. In additional, water levels in Waituna Lagoon are monitored at Waghorn Road. The locations of sites currently monitored by Environment Southland are shown in Figure 3-10.

3.4.2 Surface Water Flow Trends

Environment Southland monitors the flow in Waituna Creek, Moffat Creek and Carran Creek. These creeks drain the three major surface catchments shown in Figure 3-3. Figure 3-11 shows the mean daily flows in each creek since records began along with rainfall recorded at Lawsons Road. The data shows large flow events after large rainfall events followed by a more gradual recession.

One observation is that prior to about April 2014, Moffat Creek at Moffat Road appears to show a greater flow than Carran Creek 1km upstream of Waituna Lagoon Road. However Figure 3-11 shows that after April 2014, Carran Creek appears to have higher flows. The cause is not known but may warrant further investigation. From a visual observation of the data there appears to be no change in flows over time apart for Carran Creek or Waituna Creek but a possible decrease in Moffat Creek.

Environment Southland provided MWH with water level data from Waituna Lagoon dating back to January 2010 (see Figure 3-12). The sudden drops in lagoon water levels occur in response to mechanical opening of the Waituna lagoon to the sea. When the lagoon is open, water levels stabilise at around 0.6 m above mean sea level (AMSL), increasing to approximately 2.75 m AMSL when the lagoon is closed. It appears that rapid lagoon level rises, possibly due to heavy rainfall or flood events, have been the precursor to lagoon opening in the past, as opposed to other management criteria.

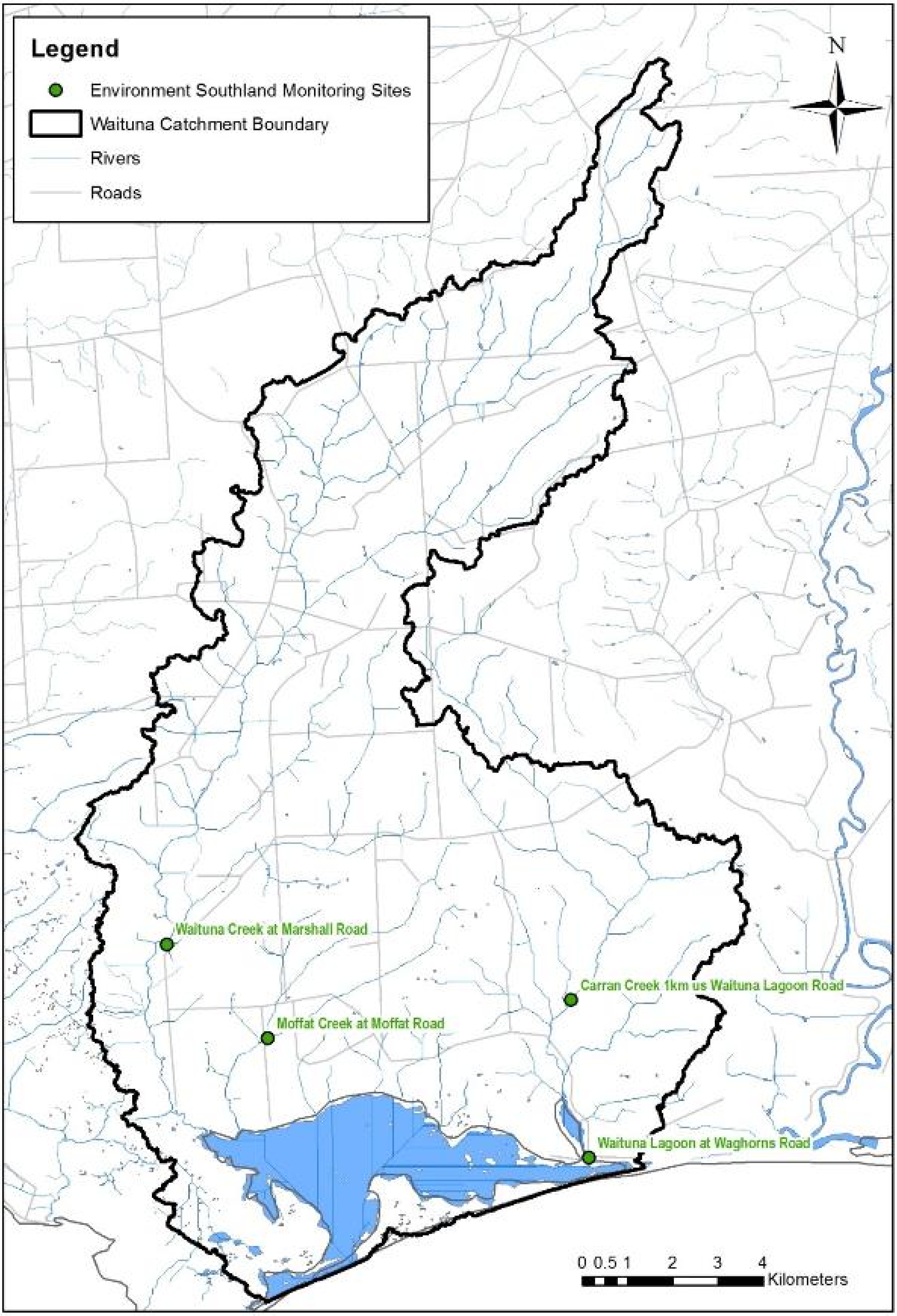

Figure 3-10: Surface water flow and Waituna Lagoon sites monitored by Environment Southland

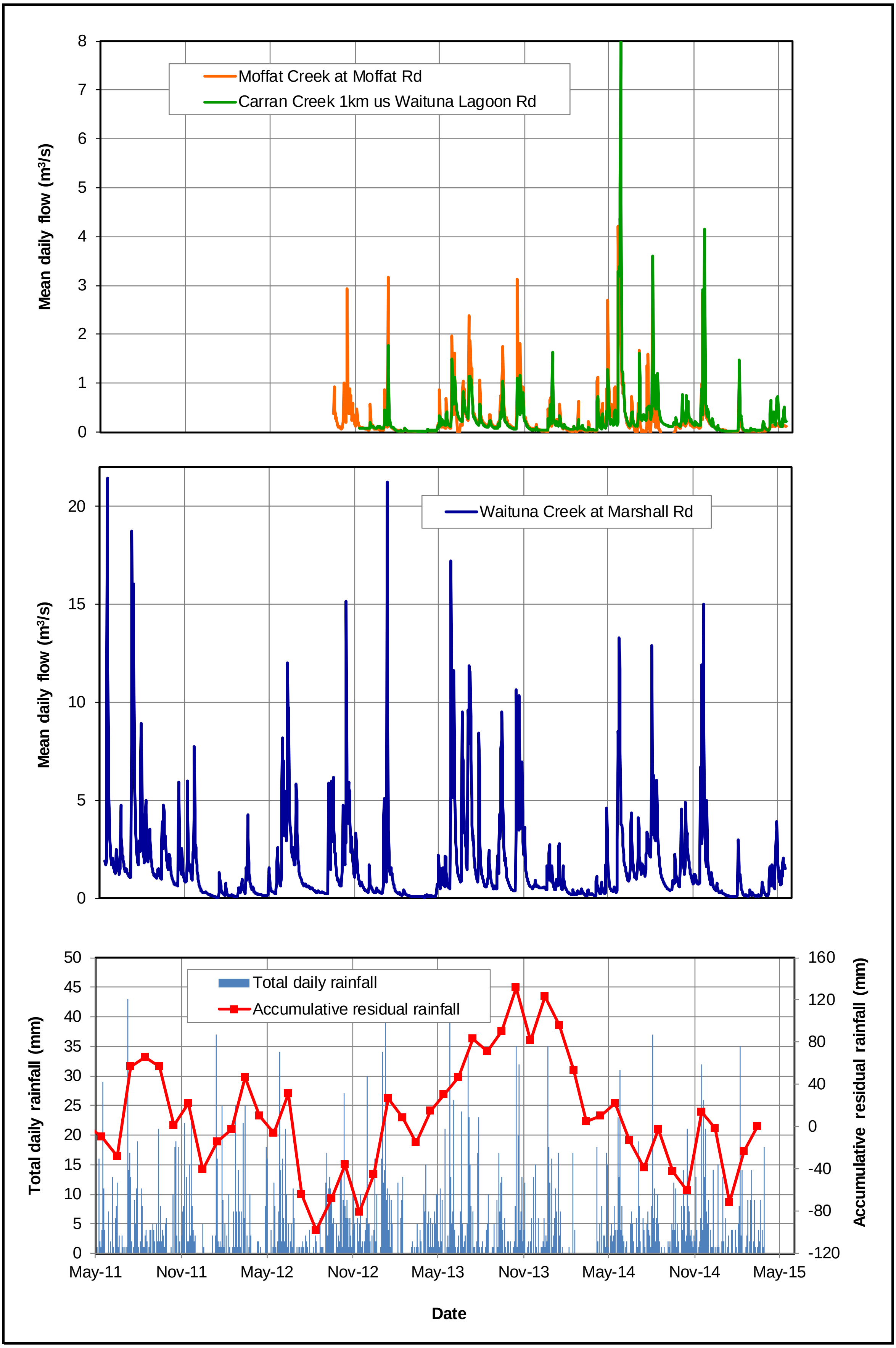

Figure 3-11: Mean daily stream flows versus rainfall since 2011 at Lawsons Road

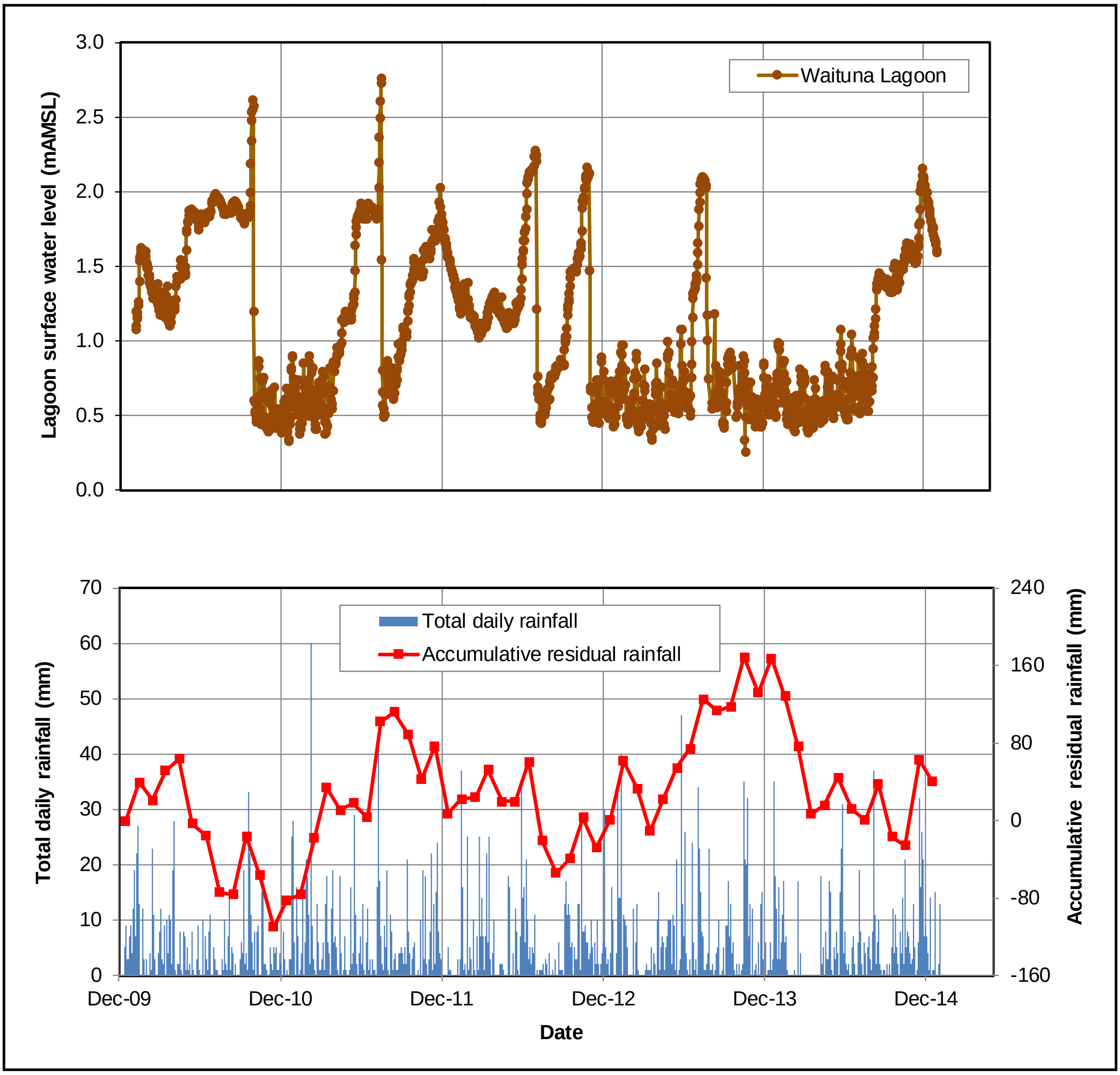

Figure 3-12: Water level elevation in Waituna Lagoon versus rainfall since 2009 at Lawsons Rd

4 Water Quality

The purpose of this section is to summarise the available information on the water quality of the Waituna Catchment as a whole. This is to provide the wider context within which the wetlands on private land exist.

4.1 Introduction

Groundwater and surface water quality data was provided by Environment Southland for all monitoring locations within the Waituna Catchment and Waituna Lagoon. This monitoring information has been collected under various monitoring projects including state of the environment monitoring, the intensive surface water quality study in 2011 and 2012 and drain clearing events. The following sections summarise the results from the analysis of this data. Graphs of all data are attached in Appendix C.

4.2 Surface Water Quality

4.2.1 Surface Water Quality Monitoring

Environment Southland monitors four surface water sites around the Waituna Catchment as part of the long-term State of the Environment monitoring programme. A further 13 sites were added and monitored for one year in 2012 to provide an understanding of water quality within the catchment at a finer scale (Environment Southland, n.d.). The results from this State of the Environment monitoring have been included in the data assessment presented in Section 4.2.2. A detailed assessment of this data is expected as part of the Surface Water Quality Study which was completed in 2015.

The Waituna Catchment comprises three sub catchments which are drained by Waituna, Moffat and Carran Creeks. All three of these creeks have been substantially modified, primarily through straightening and deepening of the channel. Regular mechanical clearance is undertaken to maintain the channels in their human modified state which results in release of sediment and associated bound nutrients downstream and into Waituna Lagoon (Tanner, Hughes, & Sukias, 2013).

NIWA presented a summary of the effects on water quality from drain clearing in 2012. The report stated that total suspended solids and total phosphorous concentrations increased significantly during drain clearance with the highest measurements since records began occurring during drain clearing periods. Drain clearing was also found to affect the drain channel morphology, bank vegetation and in-stream ecological and physical conditions. In contrast, concentrations of nitrate and total nitrogen differed minimally from long term concentrations during drain clearing periods (Ballantine & Hughes, 2012).

Waituna Creek drains the largest sub-catchment and would be expected to contribute the greatest load of nutrients and sediment to the Waituna Lagoon. However, in 2013 NIWA noted that in general Waituna Creek recorded the highest concentrations of suspended sediment and total nitrogen while Moffat Creek recorded the highest concentrations of total phosphorous (Tanner, Hughes, & Sukias, 2013).

Ryder Consulting undertook a stocktake of scientific knowledge relating to the Waituna Catchment in 2013 and noted that monitoring of surface water between 2005 and 2010 found regular exceedances of the relevant guideline values for water clarity, dissolved reactive phosphorous, faecal coliforms, nitrate nitrite nitrogen and unionised ammonia. It was noted that nitrate and total nitrogen showed increased trends within the catchment over the monitoring period (Ryder, 2013). This information was summarised from a technical report written by Environment Southland in 2011 (Meijer, 2011).

Research to date indicates the surface water quality within the Waituna Catchment is being impacted by human activities on land, which results in the discharge of sediment, nutrients and pathogens. Direct discharges from land to surface water bodies contribute a significant proportion of the concentrations of nutrients recorded. Leaching to groundwater also has the potential to contribute a significant mass of nitrogen to surface water, particularly in water bodies such as the Waituna Creek where significant baseflow discharge occurs (Wilson, 2011). Section 3.3 summarises available information on groundwater quality within the catchment.

4.2.2 Surface Water Quality Trends

For the purposes of this analysis, surface water monitoring locations were grouped by sub-catchment, namely the Carran Creek, Moffat Creek or Waituna Creek. Locations within the Carran and Waituna sub-catchments were then further separated based on their location within the catchment. This resulted in six site groupings as shown in Figure 4-1. Sites with long-term data records are represented by larger circles, with sites that had only been monitored occasionally indicated by smaller circles on the map.

Water quality monitoring results were compared against applicable guideline values or standards. For ammoniacal nitrogen (NH4-N) the ANZECC 95% protection level toxicity trigger value (toxicity trigger value) was used. For total nitrogen (TN), dissolved reactive phosphorous (DRP) and total phosphorous (TP), the physical and chemical stressors trigger values for lowland rivers (nutrient effects trigger value) were used. *E.coli* results were compared against water quality standards in the Environment Southland Regional Plan.

Table 4-1 to Table 4-3 summarises the water quality data from each sub-catchment. Graphs summarising the raw data against the guideline values are presented in Appendix C. It is noted that there was significant variability in the water quality monitoring results and no statistically significant trends could be found. However, there was some evidence of decreasing water quality over time, particularly in the lower catchment. The high variability in water quality results is likely to be due to the analysis of a wide range of data with differing frequencies, ranging from short-term one off samples through to long term state of the environment monitoring. It is expected that a more detailed analysis of water quality trends in the catchment will result from the Environment Southland Surface Water Quality Study (previously known as the Longitudinal Study) which was completed in 2015.

Figure 4-2 colour-codes each surface water monitoring location by their status against the selected guideline values. Red indicates that a number of samples exceeded the toxicity trigger value for ammoniacal nitrogen. Orange indicates that results were below the toxicity trigger value for ammoniacal nitrogen but generally exceeded the nutrient trigger values for nitrate, total nitrogen, dissolved reactive phosphorous and total phosphorous. Green indicates that the site predominantly met all the relevant guideline values. Grey indicates that there was insufficient data to make an assessment.

For sites within the Waituna Catchment where there is sufficient data, all monitored locations exceeded the nutrient effects trigger value and two sites exceeded the toxicity trigger value. No sites were found to meet all of the relevant guidelines. This indicates that adverse water quality conditions are found throughout the catchment.

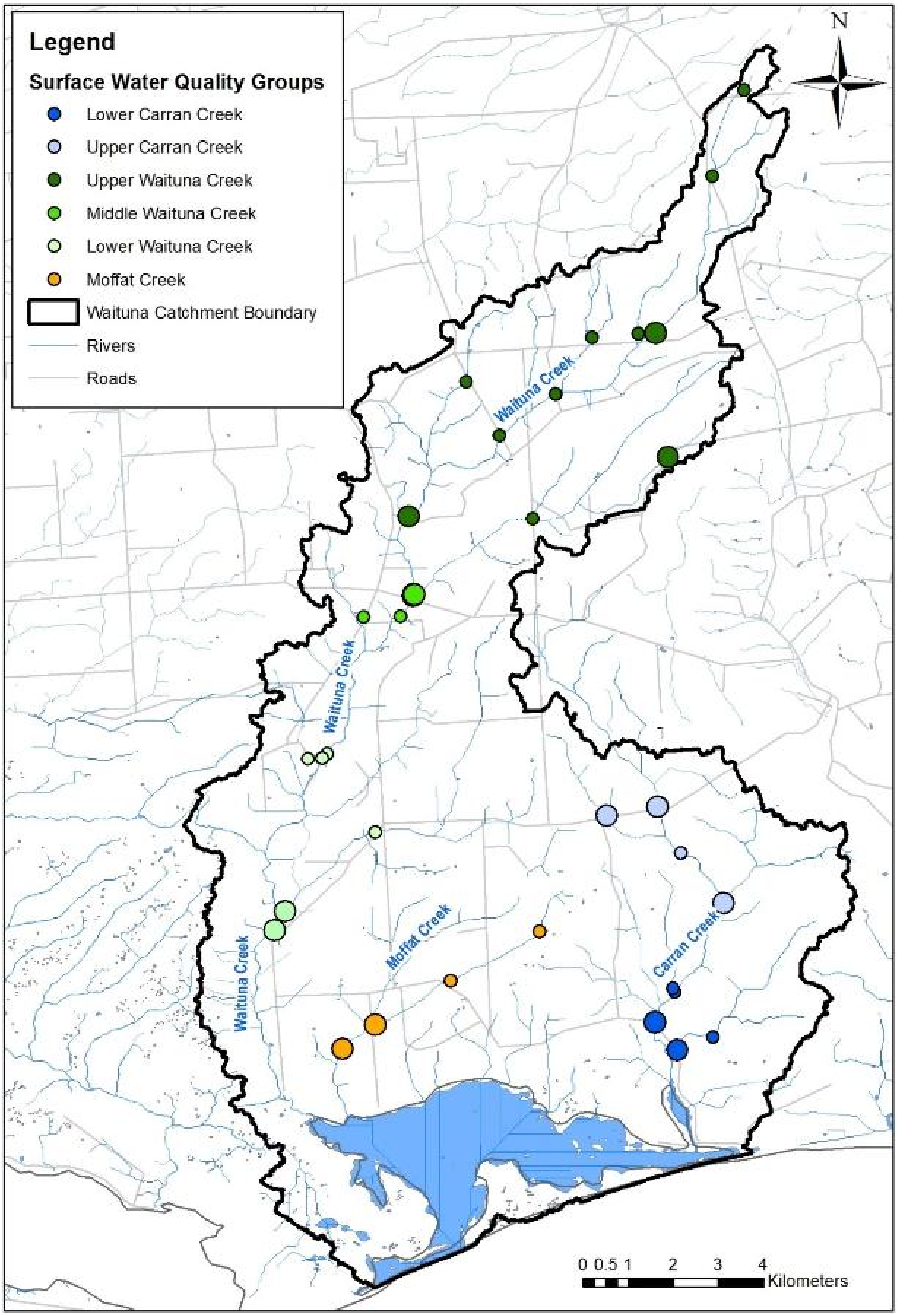

Figure 4-1: Surface water monitoring sites grouped by catchment location

Table 4-1: Surface Water Summary – Waituna Creek 1995 - 2015

Parameter	Description
Temperature	Temperature varied between 5°C and 20°C as would be expected given seasonal variations. There does not appear to be an increasing or decreasing trend over time.
Conductivity	Conductivity results remained relatively consistent over the monitoring period with results ranging between approximately 150µS/cm and 300µS/cm.
Dissolved Oxygen	Dissolved oxygen results were variable through the reporting period for both concentration and percentage saturation. Percentage saturation results ranged for 60 to 140. These are likely to represent diurnal fluctuations. A number of results at the lower catchment recorded very low percentage saturation results in 2011.
Clarity	Within the lower and mid catchment visual clarity appears to improve over the reporting period although considerable variation makes this hard to verify. Within the upper catchment, visual clarity was variable with Waituna Creek Tributary at White Road[1] recording particularly poor results.
Nitrogen	Nitrate + nitrite concentrations appear to have increased over the monitoring period however considerable variation make this trend difficult to verify. Concentrations were recorded over 5mg/L in the upper catchment, with particularly high peaks in concentrations in the lower and upper catchments recorded in the last few years. Ammoniacal nitrogen concentrations were generally low at the Waituna Catchment, with greater spikes in concentration observed in the last few years, particularly in the upper catchment. All results remained well below the 95% toxicity guideline with the exception of a number of samples at Waituna Creek at Marshall Road (lower catchment) between 1999 and 2001. The pattern of total nitrogen results was generally consistent with those observed for nitrate + nitrite and ammoniacal nitrogen In general all results considerably exceeded the nutrient trigger value for lowland rivers.
Phosphorous	Dissolved reactive phosphorous (the bioavailable form) concentrations were generally elevated above the nutrient trigger value at the lower catchment. Concentrations appear to be consistent across the monitoring record however. Within the upper catchment results were generally below the trigger value with two samples recording significantly elevated concentrations in 2013. At the upper catchment concentrations at Waituna Creek 1 metre upstream of Waituna Road (upper catchment) were generally low, however concentrations at Waituna Creek at White Pine Road (upper catchment) and 1 metre upstream of Rimu Seaward Downs Road (upper catchment) were generally elevated, in some cases significantly. Total phosphorous concentrations were generally more variable. Concentrations in the lower and mid catchments mostly exceeded the trigger value, while concentrations in the upper catchment remained low with the exception of Waituna Creek at White Pine Road which typically recorded results above the nutrient trigger value.
E.coli	*E.coli* concentrations at the Waituna Catchment appeared to increase although significant variation makes this increase difficult to verify, a number of results exceeded 10,000 CFU particularly in the last few years within the lower catchment. The majority of results at all sites met the Environment Plan Standard of less than 1,000CFU, however there were a number of exceedances of this standard.

[1] This site is where the Waituna Creek Tributary crosses White Road in the upper catchment but is called "Waituna Creek at White *Pine* Road" in the ES data set and is identified as such in the graphs in Appendix C.

Table 4-2: Surface Water Summary – Carran Creek 1995 - 2015

Parameter	Description
Temperature	Temperature varied between 2°C and 18°C as would be expected given seasonal variations. There does not appear to be an increasing or decreasing trend over time.
Conductivity	There is a clear difference in conductivity results between Carran Creek at Waituna Lagoon Road that recorded conductivity results approximately 100 µS/cm greater than those recorded at Carran Creek tributary consistently throughout the monitoring period which may have been due to a tidal influence at this site. The Carran Creek results are consistent with those recorded within the upper area of the catchment and with the results recorded at the Waituna Creek catchment.
Dissolved Oxygen	Dissolved oxygen concentration and percentage saturation varied throughout the catchment with percentage saturation results generally falling between 40% and 120%.
Clarity	Visual clarity at the Carran catchment is variable although generally lower than at the Waituna Catchment. All monitoring locations recorded results within a similar range within both the upper and lower catchment.
Nitrogen	Nitrate + nitrite concentrations were elevated at Carran Creek at Waituna Lagoon Road but generally much lower at the Carran Creek tributary. Concentrations, particularly at Carran Creek were variable but generally lower than those recorded at the Waituna Creek. The same pattern observed for nitrate + nitrite was also evident for the ammonical nitrogen results. All results recorded were well below the 95% toxicity guideline with the exception on one result from Carran Creek east branch in 2011. The pattern of total nitrogen results was generally consistent with those observed for nitrate + nitrite and ammoniacal nitrogen In general all results considerably exceeded the nutrient trigger value.
Phosphorous	Dissolved reactive phosphorous concentrations at the Carran Creek catchment were consistently elevated above the nutrient trigger value. The lower catchment results indicates that concentrations have increased over the monitoring period with an apparent increases in concentration recorded at both Carran Creek and its tributary around 2009. Total phosphorous concentrations followed a similar pattern to that of dissolved reactive phosphorous with an increase in concentrations observed around 2009.
E.coli	*E.coli* concentrations at the Waituna Catchment appear to increase although significant variation makes this increase difficult to verify, a number of results exceeded 10,000 CFU particularly in the last few years particularly at the lower catchment. Similarly to the other parameters results at Carran Creek tributary were generally lower than those recorded at other locations. The majority of samples met the Environment Southland Plan standard, however exceedances of this value appear to increase in occurrence and size towards the later part of the monitoring period.

Table 4-3: Surface Water Summary – Moffat Creek 1995 - 2015

Parameter	Description
Temperature	Temperature varied between 5ºC and 20ºC as would be expected given seasonal variations. A number of samples recorded particularly low temperatures in 2012 however there does not appear to be an increasing or decreasing trend over time.
Conductivity	Conductivity at Moffat Creek varied considerably during the monitoring period with readings over 300µS/cm recorded in 2008.
Dissolved Oxygen	Dissolved oxygen results were variable through the reporting period for both concentration and percentage saturation. Percentage saturation results ranged for 60% to 140%. These are likely to represent diurnal fluctuations.
Clarity	The range in visual clarity at the Moffat Creek catchment was similar to that of the Carran Creek catchment with significant variability observed at all sampling locations.
Nitrogen	Nitrate + nitrite concentrations were generally lower than those recorded in the Waituna Creek however there appears to be more frequent spikes in concentration in the last few years as noted in the Waituna Creek, this may be due to more frequent monitoring however rather than a change in the actual concentrations within the creeks. Ammoniacal nitrogen concentrations were generally low at the Moffat Creek catchment with all results remaining well below the toxicity guideline. The pattern of total nitrogen results was generally consistent with those observed for nitrate + nitrite and ammoniacal nitrogen In general all results considerably exceeded the nutrient trigger value.
Phosphorous	Dissolved reactive phosphorous and total phosphorous concentrations at Moffat Creek catchment consistently exceeded the nutrient trigger value with results at Moffat Creek 900 metres downstream of Moffat Road particularly elevated.
E.coli	*E.Coli* concentrations at the Waituna Catchment appear to be increase although significant variation makes this increase difficult to verify, a number of results exceeded 10,000 CFU particularly in the last few years particularly at the lower catchment The majority of results fall below the Environment Southland Plan standard, however there are a number of exceedances which are over 10,000CFU or ten times the standard.

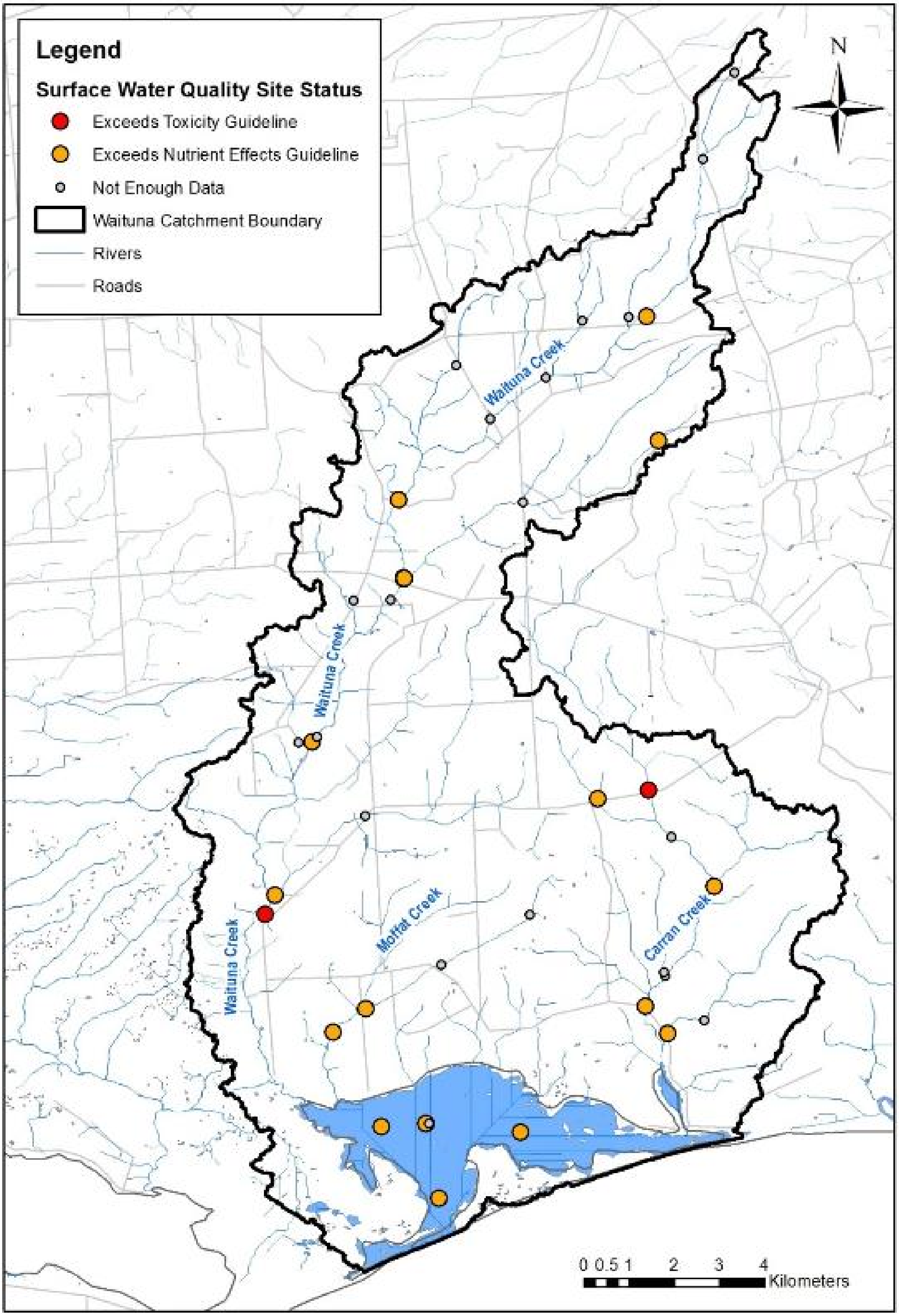

Figure 4-2: Surface Water Monitoring - Water Quality Status

4.3 Groundwater Quality

4.3.1 Groundwater Quality Monitoring

Groundwater from the Waituna Catchment replenishes surface water bodies including Carran, Moffat and Waituna Creeks, the Waituna Lagoon and can discharge directly to sea. It is estimated that approximately 20 to 50 percent of the flow within the Moffat and Waituna creeks is sourced from groundwater recharge (Wilson, 2011).

Groundwater quality can be influenced by a range of factors including geology, aquifer recharge and the overall rate of groundwater circulation within the aquifer system. Shallow groundwater within unconfined aquifers is also often influenced by human land uses.

A technical report completed for Environment Southland in March 2011 stated that overall nitrate-nitrogen concentrations in groundwater in the Waituna Catchment were low, however the report also noted that only one bore sampled was confirmed to be sourced from the unconfined aquifer. Dissolved reactive phosphorous concentrations were found to be elevated however this report stated that this can occur from natural rock-water interactions as well as from anthropogenic sources (Wilson, 2011).

Environment Southland completed a technical report entitled Waituna Catchment Groundwater Resource in May 2012, which undertook further research into the data (Rissmann & Wilson, 2012). This report characterised groundwater within the Waituna Catchment and identified three zones based on distinct physical and chemical properties: the Northern Zone, Mokotua Infiltration Zone and Southern Zone (refer Figure 3-2).

The Northern Zone was identified as having relatively good water quality with shallow aquifers across this zone showing little impact from intensive land use due to cation exchange and chemical sorption processes that buffer groundwater in this area. Generally the groundwaters in this zone are low in nitrates.

The Mokotua Infiltration Zone was associated with poor groundwater quality due to rapid infiltration of water through soils in the area with little to no attenuation or treatment of nutrients. Nitrates are generally high in this area of the catchment.

The Southern Zone which includes the highest proportion of wetlands was dominated by reducing groundwater due to the abundance of organic carbon. The natural reducing conditions reduce concentrations of nitrate within the groundwater in this area, however due to organic soils phosphorous concentrations are up to 50 times higher than in the northern zone (Rissmann & Wilson, 2012).

The technical report also identified natural background concentrations for nitrate (≤1mg/L) and dissolved reactive phosphorous (≤0.03mg/L). These values were considered to represent the thresholds beyond which it becomes increasingly likely that the source of the nutrients is human land uses (Rissmann & Wilson, 2012).

The report concluded that the majority of Waituna groundwaters exhibited median nitrate concentrations well below the relevant guideline values for ecosystem and human health. These low values were attributed to the predominance of reducing conditions within the catchment. In contrast approximately 63 percent of the bores covered in the technical report were found to have total phosphorous concentrations in excess of the relevant guideline values. It was noted however that it was difficult to determine whether these exceedances were due to natural or human processes. It was considered that the elevated concentrations are likely derived from a combination of human inputs (e.g. animal and human effluent and fertiliser) and naturally occurring inputs from lignite aquifers.

Elevated ammoniacal-nitrogen levels were recorded in bores within the Waituna Catchment. These elevated concentrations were attributed to the ammonification of organic matter under reducing conditions within peat and lignite aquifers. The peat and lignite aquifers are predominantly located within the southern section of the catchment.

It is considered that groundwater is likely to contribute approximately 11 percent of the total nitrogen loadings and 15 percent of the total phosphorous loadings to Waituna Creek (Rissmann & Wilson, 2012).

Rissman used geological data to spatially model the natural capacity of regional aquifers to attenuate or remove nitrate through natural chemical reactions. The model found that approximately 85 percent of regional aquifers exhibited a high to very high sensitivity to nitrate accumulation (Rissmann, 2011).

4.3.2 Groundwater Quality Trends

For the purposes of this analysis, groundwater monitoring site locations were grouped based on their proximity to the main surface water catchments: Carran, Moffat or Waituna Creek[2]. The three groups used are presented in Figure 4-3. Sites with long term data records are represented by larger circles on the map.

Groundwater quality monitoring results were compared against applicable guideline values or standards. For ammoniacal nitrogen (NH4-N) the ANZECC 95% protection level toxicity trigger value (toxicity trigger value) was used. For total nitrogen (TN), dissolved reactive phosphorous (DRP) and total phosphorous (TP), the physical and chemical stressors trigger values for lowland rivers (nutrient effects trigger value) were used. *E.coli* results were compared against water quality standards in the Environment Southland Regional Plan.

Table 4-4 to Table 4-6 summarises the groundwater quality data from each sub-catchment. Graphs summarising the raw data against the guideline values are presented in Appendix C. . It is noted that there was significant variability in the groundwater quality monitoring results and no statistically significant trends could be found. The high variability in water quality results is likely to be due to the analysis of a wide range of data with differing frequencies. It is expected that a more detailed analysis of groundwater quality trends in the catchment will result from the Environment Southland Surface Water Quality Study (previously known as the Longitudinal Study) which was completed in 2015.

Figure 4-4 colour-codes the groundwater monitoring locations by their nutrient status against the selected guideline values. Red indicates that a number of samples exceeded the toxicity trigger value for ammoniacal nitrogen. Orange indicates that results were below the toxicity trigger value for ammoniacal nitrogen but generally exceeded the nutrient trigger values for nitrate, total nitrogen, dissolved reactive phosphorous and total phosphorous. Green indicates that the site predominantly met all the relevant guideline values. Grey indicates that there was insufficient data to make an assessment.

For the majority of groundwater monitoring sites within the Waituna Catchment there is insufficient data to provide evidence of compliance or exceedance with guideline values. For the seven sites were there was enough data, five sites exceeded guideline values: two sites within the Waituna Creek sub-catchment found to exceed the toxicity trigger value and three sites in the Moffat Creek sub-catchment exceeded the nutrient effects trigger values. Two sites near the mouth of Carran Creek were found to meet all of the relevant guidelines. This indicates that there is some evidence of elevated nutrients in groundwater in the Waituna Catchment which are likely to be sourced from a combination of farming inputs (leaching) and naturally occurring inputs from the aquifer.

[2] It is noted that groundwater and surface water catchments may not always correlate, but the use of surface water catchments allows for pooled analysis of data and (if required) the application of appropriate land management techniques on a sub-catchment scale.

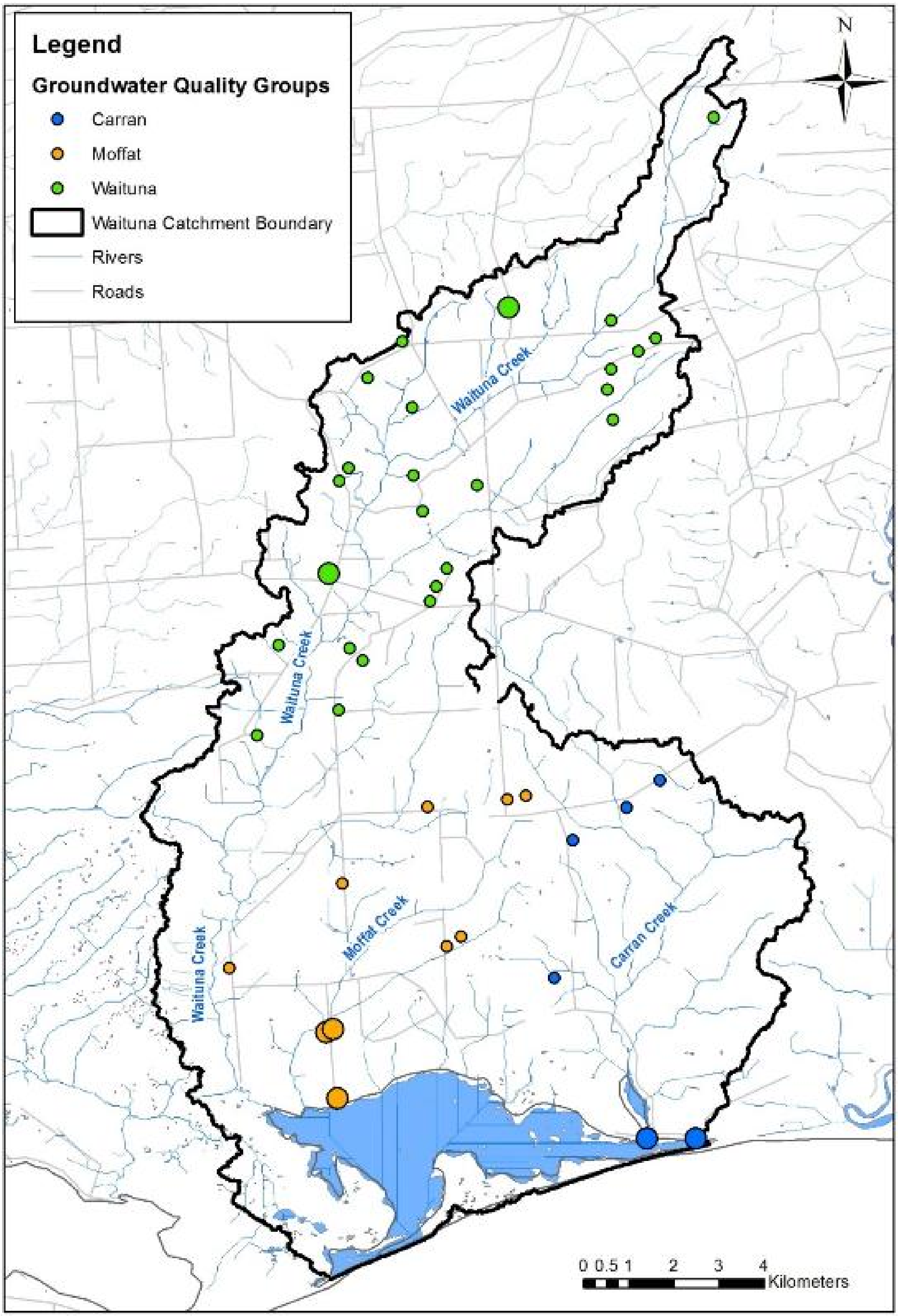

Figure 4-3: Groundwater monitoring sites grouped by catchment location

Table 4-4: Groundwater Summary – Waituna Creek catchment 2009 to 2013

Parameter	Description
Conductivity	Conductivity within the catchment was generally between 200 µS/cm and 400 µS/cm with significant variability.
Nitrogen	In general nitrate + nitrite concentrations were elevated particularly within some of the bores within the lower catchment that were only sampled a few times. Concentrations of ammoniacal nitrogen at the Waituna Catchment area were generally elevated in comparison with the Carran and Moffat catchment areas, in particular bore F47/0252 (mid-catchment) consistently recorded results above the 95% toxicity value. In general, concentrations of total nitrogen were elevated above the nutrient trigger value at the Waituna Catchment area. In particular bores at the lower area of the catchment recorded particularly high concentrations.
Phosphorous	Dissolved reactive phosphorous results appear to be increasing at the lower catchment however a lack of sample results means the increase cannot be verified. Results were variable with approximately half the results across the Waituna Creek catchment exceeding the nutrient trigger value. A similar pattern was observed for total phosphorous concentrations as for dissolved reactive phosphorous although a number of elevated concentrations were also recorded at the upper catchment bores.

Table 4-5: Groundwater Summary - Carran Creek catchment 2011 to 2013

Parameter	Description
Conductivity	Conductivity results were significantly variable with higher conductivities generally recorded in bore F47/0254 (lower catchment).
Nitrogen	Nitrate + nitrite results were generally low at the Carran catchment area, with the exception of F47/0254 which recorded consistently elevated results. Ammoniacal nitrogen concentrations were generally well below the 95% toxicity value with the exception of a one-off sample from a bore which is not monitored regularly. Total nitrogen results appear to have decreased over the monitoring period, in particular concentrations in bore F47/0254 decreased to below the nutrient trigger value in 2012.
Phosphorous	Dissolved reactive phosphorous concentrations were variable between bores and over time at the Carran catchment area, in particular bore F47/0254 recorded concentrations consistently elevated above the nutrient trigger value. In contrast concentrations of total phosphorous were generally below the nutrient trigger value for all bores.

Table 4-6: Groundwater Summary - Moffat Creek catchment 2011 to 2013

Parameter	Description
Conductivity	Conductivity results were inconsistent across all bores with results generally between 850µS/cm and 400µS/cm lower. Conductivity was generally higher within the lower catchment potentially due to saltwater impacts.
Nitrogen	Nitrate + nitrite concentrations were generally consistent across all bores with the exception of E47/0129 (lower catchment) which recorded significantly elevated results up to 8mg/L. Ammoniacal nitrogen results were generally consistent across the Moffat catchment area with the exception of bore F47/0256 (lower catchment) which recording results consistently elevated above the 95% toxicity trigger value. Total nitrogen concentrations in all bores were generally elevated above the nutrient trigger value, in particular F47/0256 (lower catchment) recorded concentrations consistently elevated above other bores in the area.
Phosphorous	Dissolved reactive phosphorous concentrations at all bores were generally elevated above the nutrient trigger value with bore F47/0256 (lower catchment) recorded very elevated results in comparison to other bores and the trigger value. Similarly total phosphorous concentrations generally exceeded the nutrient trigger value with particularly elevated results recorded in bore F47/0256 (lower catchment).

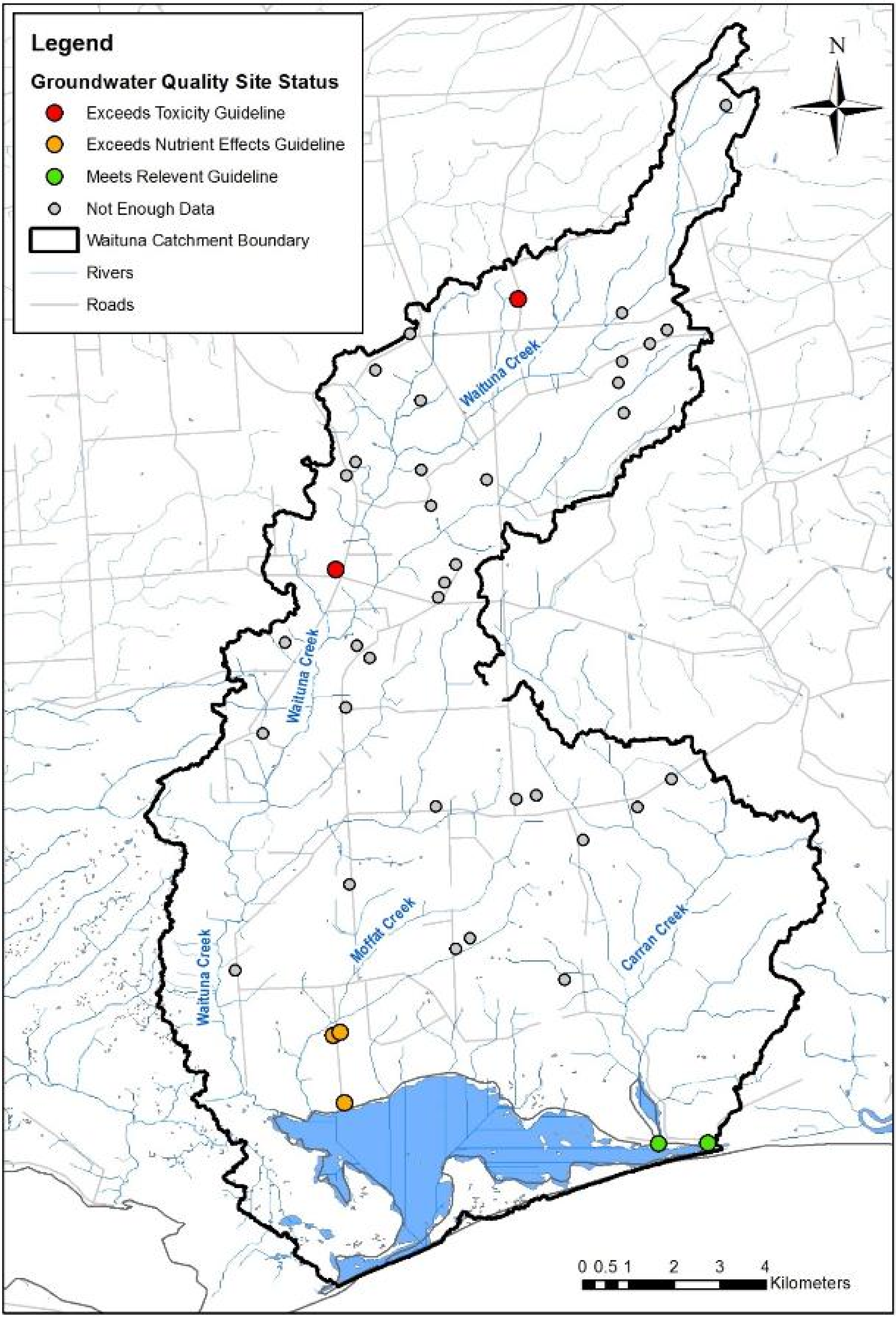

Figure 4-4: Groundwater Monitoring - Water Quality Status

4.4 Waituna Lagoon Water Quality

4.4.1 Lagoon Water Quality Influences

Waituna Lagoon is a relatively shallow coastal lagoon of 1,350 ha. It is classified as an intermittently closed and open lagoon, with lagoon openings occurring naturally prior to development of the catchment. Since 1908, water levels in the lagoon have been artificially managed and temporary openings have been undertaken to facilitate recreational fishing, prevent flooding, enable drainage of the farms in the lower catchment, and more recently to encourage flushing of nutrient-rich water and sediment out of the lagoon (Johnson & Partridge, 1998; DOC, 2015). Closure of the lagoon occurs naturally through the accumulation of gravels at the river mouth, given the correct wave and tidal conditions. Currently, lagoon opening is being balanced between the need for a stable environment for *Ruppia* during its growth season and the drainage needs of the community.

The Waituna Lagoon is a sensitive receiving environment which receives nutrients and sediment from its catchment, which has been significantly modified for farming and large scale conversion to dairying in recent years. Due to artificial drainage and the clearance and straightening of streams, water now flows more rapidly into streams, reducing the opportunity for natural attenuation and treatment of contaminants such as nitrogen and phosphorous (Wilson, 2011). There are concerns around the water quality of the lagoon, particularly as the lagoon is exhibiting signs of eutrophication (McDowell, Gongol, & Woodward, 2012). Eutrophication occurs when a water body receives excess nutrients, primarily nitrogen and phosphorous. Eutrophication can cause algal blooms, fish kills and changes to aquatic species community structure and composition. It can also cause economic effects that can include losses to tourism, fishing and real estate (McDowell, Gongol, & Woodward, 2012).

Aqualinc undertook a high level regional scale study of the state of Southland's water quality. The study noted agricultural land use was the most significant contribution of nutrient contaminants at a regional scale (Aqualinc, 2014).

There have been a number of studies undertaken to investigate options for reducing elevated nutrients in surface and groundwater prior to discharge to the Waituna Lagoon.

As part of the DairyNZ Action Plan for the Waituna Catchment, farm system modelling and catchment modelling has been undertaken and is in the process of being reported. This will enable a detailed understanding of the nature and source of the loads from the catchment to the lagoon. The modelling will update the mean annual nutrient losses from all dairy farms in the catchment as well as assess the magnitude of this load relative to all other catchment sources. Simulations of the impact of nitrogen and phosphorus loss under a suite of targeted farm practice change scenarios have been undertaken, which will be used to understand the catchment-wide load reductions which could be achievable. The catchment modelling will quantify total off-farm nutrient, sediment and bacteria loads to the lagoon as well as estimate river concentrations. The model will also be used to evaluate the collective impacts of individual on-farm mitigation strategies on total annual loads and in-river concentrations.

Once reported, it is understood that the farm system modelling and catchment modelling being undertaken as part of the DairyNZ Action Plan will enable to good understanding of the source of the various contaminants entering the streams and lagoon. This will enable the assessment of the various options that are available to reduce these loads.

AgResearch investigated the potential for controlled drainage to decrease nitrogen and phosphorous losses through tile drains within the catchment. The AgResearch report concluded that while no controlled drainage system is guaranteed to decrease loads of nutrients and sediment the peak runoff control appeared to be a viable option and therefore it was recommended that further investigations be undertaken to determine the feasibility of applying peak runoff control in the Waituna Catchment (McDowell, Gongol, & Woodward, 2012).

GNS Science was commissioned by Environment Southland in 2012 to investigate the suitability of using in-situ denitrifying bioreactors and phosphorous sorbent filters within tile drains. Tile drain discharges have been shown to contain concentrations of nitrate between 0.002 to 67mg/L, with phosphorous concentrations of 0.004 to 2.4mg/L. GNS Science stated the bioreactors and sorbent filters are a cost effective method of removing up to 100% of the nutrients before discharge to surface water. A pilot trial was proposed to trial these methods, which have been successfully used overseas, in Southland (Cameron, Lovett, Tschritter, Ledgard, & Schipper, 2014).

As part of the Living Water Programme, in association with Environment Southland and DairyNZ, a “nitrogen catcher” has been established within the catchment to demonstrate the effectiveness of a woodchip filter for the removal of nitrogen from tile drain discharges. A similar phosphorus based treatment device is being planned within the catchment.

NIWA prepared a report for Environment Southland in June 2013 which investigated priorities for constructed wetlands within the Waituna Catchment (Tanner, Hughes, & Sukias, 2013). The report concluded that the Waituna Creek catchment had the highest concentrations of suspended solids and total nitrogen and therefore was potentially the most appropriate location for constructed wetlands. NIWA predicted that total suspended solid loads could be reduced substantially through constructed wetlands occupying just 0.5% of the contributing catchment. Annual total nitrogen and total phosphorous loads could be reduced by 30% if approximately 2% and 2.5%, respectively of the contributing catchment was occupied by constructed wetlands. To reduce total nitrogen and total phosphorous loads by 50% as recommended by the Lagoon Technical Guidelines (Environment Southland, 2013) it was predicted that approximately 5% of the contributing catchment would need to be occupied by constructed wetlands (Tanner, Hughes, & Sukias, 2013).

This indicates the importance of natural as well as constructed wetlands. Wetlands cover 6,901ha of the Waituna Catchment, including the lagoon itself, which is 1,354 ha, and the network of wetlands along the creeks. Much of these wetlands are on public land and are part of the Ramsar site. This represents 34% of the total area of the catchment (being 20,423 ha); these wetlands are likely to be reducing the load of nutrients that enter Waituna Lagoon. However, receipt of nutrients will place stress on these natural wetlands and may encourage the growth of weeds and reduce biodiversity.

A constructed wetland has been created within the catchment by to demonstrate the effectiveness and feasibility of building further constructed wetlands. The project has been led by Environment Southland, in association with Living Water and DairyNZ, using funding from the Ministry for the Environment Fresh Start for Fresh Water Clean Up Fund.

Environment Southland have also undertaken bank reconstruction in the Waituna Catchment to reduce the amount of sediment and nutrients (mainly phosphorus) that is deposited into the channel and hence reaching the lagoon. About half of the banks which have been identified as potentially needing reconstruction have been completed as shown in Figure 4-5. Approximately 14km of the length of Waituna Creek was rebattered and 17 tonnes of rock armouring was installed (Environment Southland, 2017).

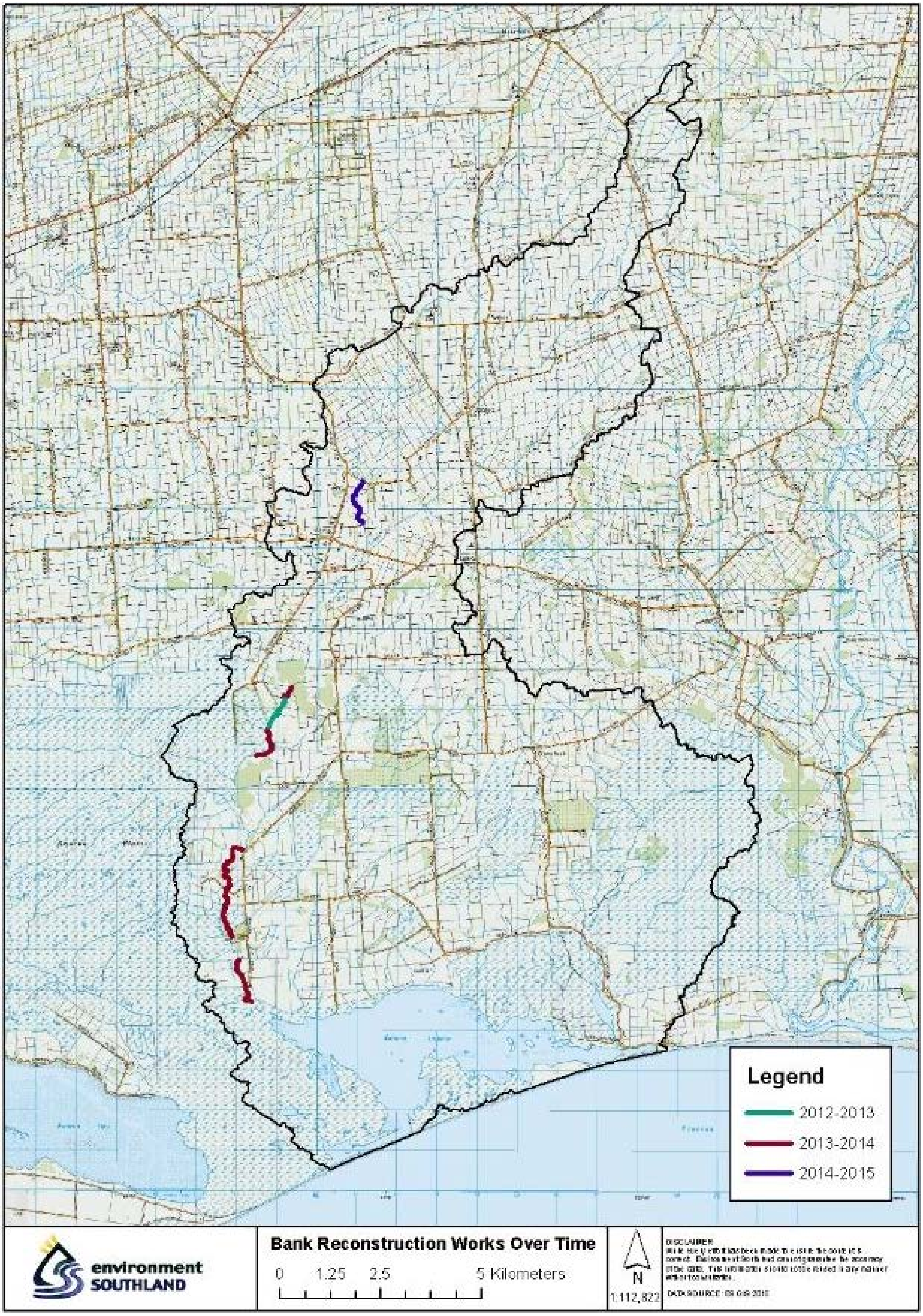

Figure 4-5: Extent of bank reconstruction undertaken in the catchment (Environment Southland)

4.4.2 Lagoon Water Quality Trends

Lagoon water quality is monitored by Environment Southland at five locations (Figure 4-6). Four sites (centre, east, west and south) are monitored using grab samples for a range of parameters. Samples are taken from the top 10cm of the water column, as well the bottom 10cm of the water column. The fifth monitoring site (platform) is a telemetry system which provides continuous data for chlorophyll a, conductivity, dissolved oxygen, turbidity and temperature.

For each monitored parameter, results taken at the surface and results taken at the bottom of the lagoon have been graphed separately to identify trends. Results were compared against the relevant guidelines taken from the Environment Southland Lagoon Technical Guidelines (Environment Southland, 2013). *E.coli* results were compared against the 1,000 MPN limit given in the Environment Southland Regional Plan. All graphs are presented in Appendix C.

The water quality in the lagoon is directly affected by whether the lagoon is open or closed. When the lagoon is open, nutrients are flushed out but the lagoon becomes brackish and saline. When the lagoon is closed, nutrients accumulate and it becomes a largely freshwater environment. The transition from open to closed is indicated in the graphs by the change in conductivity.

Table 4-7 summarises the water quality results taken at the surface of the lagoon. Table 4-8 summarises water quality taken from the bottom of the lagoon. Refer to Figure 4-2 for a graphical representation of monitoring results against guidelines values. For four of the five sites within the Waituna Lagoon where there is sufficient data, all exceeded the nutrient effects trigger value for nitrate, total nitrogen, dissolved reactive phosphorous and total phosphorous. None of the sites exceeded the toxicity trigger value for ammoniacal nitrogen. This indicates that adverse water quality conditions are present in the lagoon, but toxic levels of nutrients are not always reached.

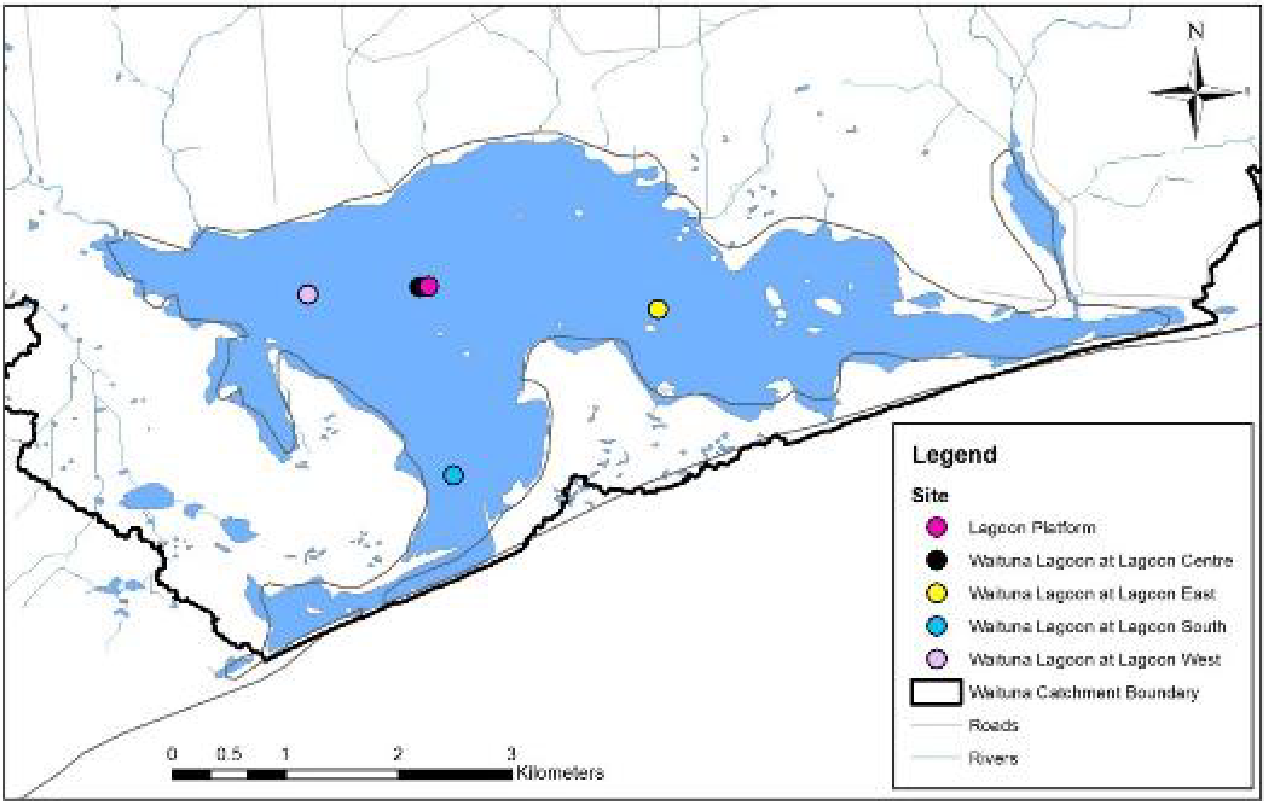

Figure 4-6: Waituna Lagoon Water Quality Monitoring Locations

Table 4-7: Lagoon Water Quality – Surface Samples (1999 to 2014)

Parameter	Description
Temperature	As expected, temperature results show a strong seasonal cyclical trend with consistent results across all four monitoring locations. The grab samples results were consistent with the continuous data provided by telemetry.
Conductivity	Conductivity results show considerable variability although results are recently consistent across all four sites. Results are generally higher when the lagoon is open due to influence of saltwater from the sea and lower when the lagoon is closed due the greater proportion of freshwater at the lagoon. Conductivity results are also consistent between the continuous data and the grab samples.
Dissolved Oxygen	Dissolved oxygen results appear to be relatively consistent across time and across all four monitoring locations. In general dissolved oxygen saturation results are between 80% and 120%. Results were consistent between the grab sampling and the continuous data provided by telemetry.
Nitrogen	Nitrate + nitrite results appear to show an increasing trend in concentration with greater variability and more peaks in concentration observed since approximately 2009. This change in 2009 may be due to increase sampling frequency which has identified the inherent variability rather than an actual increase at the lagoon. Ammoniacal nitrogen results remained relatively consistent over time as well as between the monitoring sites. Total nitrogen results were very variable across all sites. In general, results reflect the opening and closing of the lagoon, with a decrease in nitrogen concentrations due to dilution and flushing when the lagoon opens and an increase while the lagoon is closed due to a build up from freshwater sources. During winter 2014 the lagoon stayed shut and nitrogen therefore increased in concentration with a decrease in summer due to plant uptake and other removal mechanism. In general total nitrogen results exceeded the relevant Lagoon Technical Group guideline.
Phosphorous	Dissolved reactive phosphorous (the most bioavailable form) and total phosphorous results were both variable. Similar to nitrogen, phosphorous concentrations were influenced by the opening and closing of the lagoon. In general total phosphorous results exceeded the relevant Lagoon Technical Group guideline.
E.coli	*E.coli* results were generally consistent across all four monitoring locations and across time with the exception of some significantly elevated results recorded in 2010. Results were generally below the Environment Southland Standard with the exception of a handful of samples in 2011.

Table 4-8: Lagoon Water Quality – Bottom Samples (2011 to 2014)

Parameter	Description
Temperature	As expected temperature results show a strong seasonal cyclical trend with general consistent results across all four monitoring locations. Results were also consistent with the continuous data provided by telemetry.
Conductivity	Conductivity results show considerable variability although results are recently consistent across all four sites. Results were generally consistent with continuous data provided by telemetry and showed the same pattern as the surface samples which reflects the opening and closing of the lagoon.
Dissolved Oxygen	Dissolved oxygen results appear to be relatively consistent across time and across all four monitoring locations. In general dissolved oxygen saturation results are between 80% and 120%. Results were also consistent with the grab sample data.
Nitrogen	Nitrate + nitrite results, in general appear to be reasonably consistent with the surface results. Ammoniacal nitrogen concentrations remained relatively consistent over time as well as between the monitoring sites. Total nitrogen results were very variable across all sites and generally consistent with the surface results. Similar to the surface samples, samples at depth showed a pattern which reflected the opening and closing of the lagoon and generally exceeded the relevant Lagoon Technical Group guideline.

Parameter	Description
Phosphorous	Dissolved reactive phosphorous (the most bioavailable form) and total phosphorous results were variable. Similar to the surface samples, samples at depth showed a pattern which reflected the opening and closing of the lagoon and generally exceeded the relevant Lagoon Technical Group guideline.
E.coli	*E.coli* results were generally consistent across all four monitoring locations and across time. All results were below the relevant Environment Southland standard.

4.5 Summary of Water Quality Monitoring Results

The following summarises the information from the available water quality monitoring data.

Surface Water:

- Waituna Creek: Clarity appeared to improve over the monitoring period, but was highly variable. Nitrogen was elevated and generally exceeded the nutrient guidelines. Phosphorus was more variable and often exceeded nutrient guidelines. The majority of sites met the Environment Southland standard for *E. coli* bacteria.
- Carran Creek: Clarity was generally worse than Waituna Creek. Nitrogen was lower than in Waituna Creek but still exceeded the nutrient guideline. Phosphorus concentrations appear to be increasing and were above the nutrient guideline. Bacteria concentrations generally complied with the Environment Southland standard but instances of elevated results increased in frequency over time.
- Moffatt Creek: Clarity was similar to Carran Creek. Nitrogen was lower than Waituna Creek but exceeded the nutrient guideline. Phosphorus exceeded the guideline with some significantly elevated results. Bacteria concentrations generally complied with the Environment Southland standard.

Groundwater:

- Waituna Creek catchment: Nitrogen was elevated above the nutrient guideline, and in the mid catchment, ammonia was above the toxicity guideline. Half of the results for phosphorus were above the nutrient guideline.
- Carran Creek catchment: Nitrogen results were generally low and appear to have reduced. Phosphorus was generally low and complied with the nutrient guidelines except for one bore.
- Moffatt Creek catchment: Nitrogen results generally exceeded the nutrient guidelines, with some instances of highly elevated results. Phosphorus was generally elevated above the nutrient guideline.

Waituna Lagoon:

- Nitrogen and phosphorus concentrations reflected whether the lagoon was open or closed. When closed, nutrient concentrations increased and generally exceeded the Lagoon Technical Guidelines. When the lagoon was open, both nutrients decreased and were less than the Lagoon Technical Guidelines. Results generally complied with the Environment Southland standard for bacteria.
- There were similar results for samples taken at the surface and at depth in the lagoon, which may indicate mixing of the water column by wave and wind action.

5 Ecology

The purpose of this section is to summarise the available information on the ecology of the Waituna Catchment to provide the wider context within which the wetlands on private land exist.

5.1 Introduction

This section provides a review of existing reports and GIS data that have been prepared on the ecology of the Waituna Catchment as a whole. The ecological information on the catchment has been sourced from Environment Southland (ES) and DOC, as well as publicly available reports online.

Information reviewed includes:

- Environment Southland State of Environment reports including ecosystem sites monitored annually for macroinvertebrates, periphyton and sedimentation, and fish monitoring sites
- Inanga spawning sites
- HVA survey information
- Freshwater Systems of New Zealand (FENZ) databases
- Bioweb herpetofauna database
- Bioweb threatened plant databases
- Landcare Research Land Environments of New Zealand (LENZ) threatened environments classifications
- Landcare Research Land Cover Database (LCDB v4.0)
- Landcare Research Potential Vegetation of New Zealand.

5.2 Ecological Setting

The Waituna Catchment is located within the Makarewa Ecological Region and within the Southland Plains and Waituna Ecological Districts. The mid- and upper-catchment falls within the Southland Plains Ecological District while the catchment downstream of Mokotua and Kapuka lies in the Waituna Ecological District. The Waituna Ecological District is differentiated from the Southland Ecological District by its lower relief and prevalence of poorly drained deep acid peats and strongly leached and podzolised soils.

Land Environments of New Zealand (LENZ)[3] classifies the land within the catchment into two land environments: L3.1a and Q4.1c. The first land type is associated with flat floodplains and encompassing most of the catchment. The land environments are differentiated according to landform and the parent material. These are outlined in Table 2-2.

The Threatened Environment Classification is a combination of three national databases: LENZ, Land Cover Database (LCDB) and the protected areas network and provides an indication of the percentage of indigenous vegetation cover and protected land remaining in land environments. Land environments with less than 10% indigenous vegetation cover remaining are defined as acutely threatened environments. Much of the Waituna Catchment is a land environment category that is not threatened (L3.1a), meaning that there is still a reasonable proportion of the land environment nationally that is protected and remains in native vegetation cover. The land environment category Q4.2c including the undulating hills in the catchment are acutely threatened because very little of this category is protected and only 3% of this land environment nationally remains in native vegetation. This land type is frequently used for farming and is under-represented in the reserves network.

[3] The Land Environments of New Zealand (LENZ) is an environmental classification of New Zealand and includes numerical data layers describing various aspects of New Zealand's climate, landforms and soils.

Table 5-1: Land Environments (Level IV)

LENZ	Description	Threat Category	Percentage Indigenous Vegetation Remaining Nationally[4]
L3.1a	Flat floodplains with recent, imperfectly drained soils of moderate fertility from alluvium.	Not threatened	38
Q4.2c	Gently undulating hills with well drained soils from loess and alluvium.	Acutely threatened	3

5.3 Vegetation Cover

Likely pre-human vegetation cover in the catchment has been modelled as rimu-miro-totara/kamahi forest in the upper catchment with wetlands occupying most of the lower half of the catchment and along riparian margins (Figure 5-1). Small areas of duneland occur on the coast.

Today, much of the vegetation cover in the catchment consists of high yielding pasture grasses associated with dairy farms and other farmland used for stock grazing. Farmland covers approximately 70% of the catchment. Indigenous vegetation cover is generally associated with wetlands which increase in prominence in the lower, poorly drained reaches of the catchment. Most of the wetlands in the catchment are bogs which generally support a cover of manuka scrub and shrubland and wire rush rushland.

5.3.1 Threatened Plants

Information supplied by the Department of Conservation shows that three species of nationally threatened plants occur in the catchment. These are swamp mingimingi (*Coprosma pedicellata*), swamp nettle (*Urtica linearifolia*) and tufted hair grass (*Deschampsia cespitosa*). These plants are all classified under the New Zealand Threat Classification System[5] as "At Risk-Declining". Swamp mingimingi has been recorded in the vicinity of the Waituna Scenic Reserve while a number of survey records show that the swamp nettle and tufted hair grass occur around the western and eastern margins of Waituna lagoon. Swamp nettle is typically found in flaxland and tufted hair grass in *Carex* sedgeland.

The presence of bog pine (*Halocarpus bidwillii*) and the cushion plant (*Donatia novae-zealandiae*) in one swamp near the Waituna Lagoon was highlighted in the High Value Areas assessments undertaken for Environment Southland. Although not threatened nationally, bog pine is uncommon in lowland and coastal Southland while the cushion plant is rare outside of localised areas in the Waituna Scientific Reserve.

5.3.2 Weeds

Weeds that commonly occur across much of the catchment are gorse (*Ulex europaeus*), broom (*Cytisus scoparius*), blackberry (*Rubus fruticosus*), elderberry (*Sambus nigra*) and Himalayan honeysuckle (*Leycesteria formosa*). Weeds that are of conservation concern for wetlands and the areas of native forest and shrubland are grey willow (*Salix cinerea*) and shade tolerant Chilean flame creeper (*Tropaeolum spaciosum*) and Darwin's barberry (*Berberis darwinii*) due to their invasive nature.

[4] Percentage of indigenous vegetation cover remaining on that Land Environment category nationally.
[5] The New Zealand Threat Classification System lists all existing species that exist in New Zealand according to their threat of extinction. The system is made up of manuals and corresponding taxa status lists. The status of each species group (birds, plants, reptiles, etc.) is assessed over a 3-year cycle.

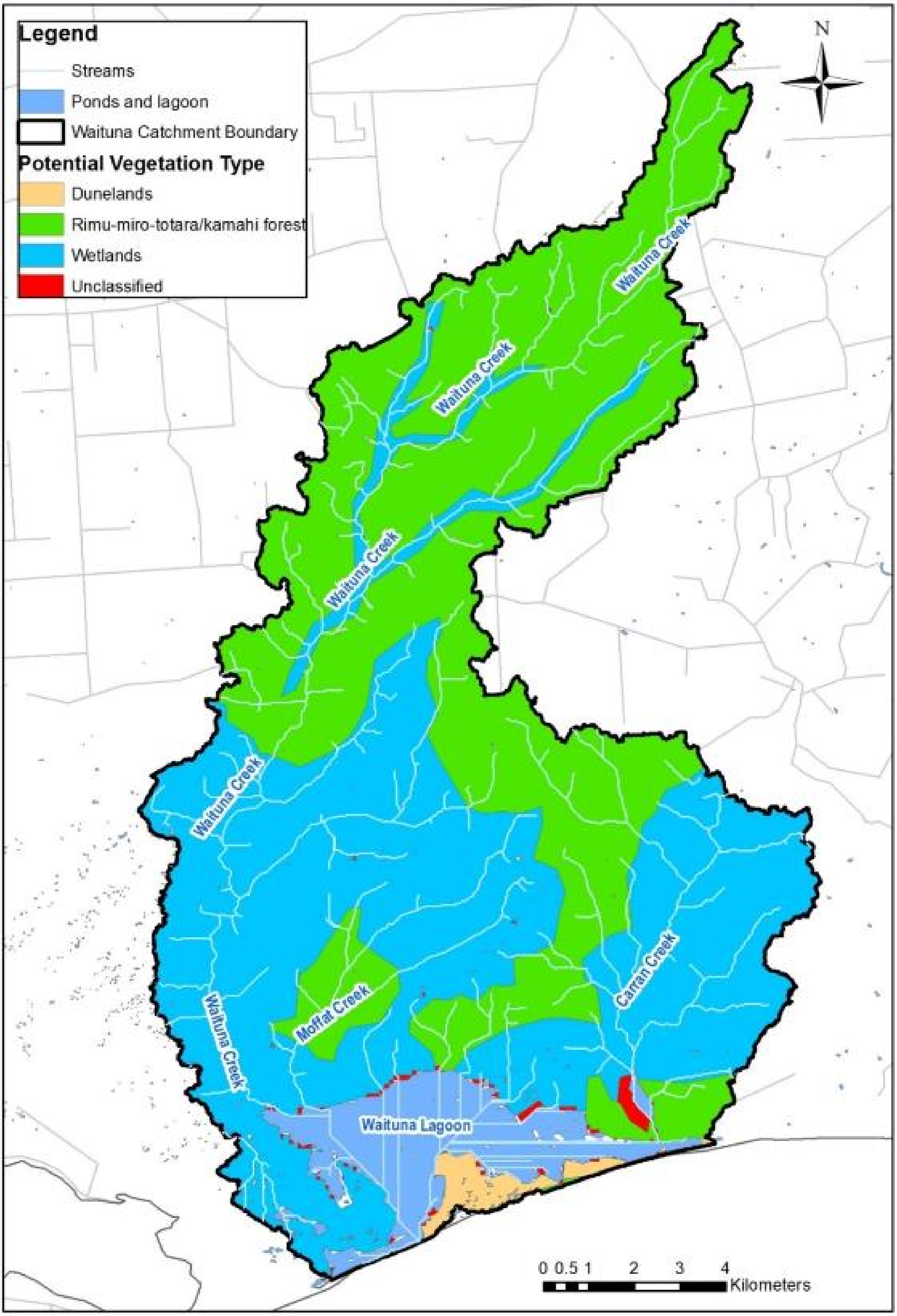

Figure 5-1: Potential Vegetation Cover in Waituna Catchment (Source: Landcare Research)

5.4 Avifauna (Birds)

The Waituna Lagoon is known as an internationally significant site for birdlife. It provides habitat for both resident and migratory species including several threatened and at risk birds. Seventy-three species of birds have been recorded in the lagoon, including both international and internal migratory waders (Thompson & Ryder, 2003).

Changes in the level of the lagoon have the potential to alter available wading bird habitat. When open to the sea the lagoon provides extensive tidal mudflats, which form an important summer wader habitat. At high lagoon levels, inundation of the wetlands around the lagoon shoreline provides preferred habitat for white-faced heron (*Egretta novaehollandiae*), Australasian bittern (*Botaurus poicilotilus*), spotless crakes (*Porzana tabuensis tabuensis*) and marsh crakes (*P. pusilla affinis*) (Thompson & Ryder, 2003).

Avifauna observed during High Value Area (HVA) surveys in the Waituna Catchment indicate that remaining areas of forest, shrubland and wetlands provide habitat for a number of native bird species. The forest dwelling birds commonly observed in and around forest and shrubland remnants were wood pigeon (*Hemiphaga novaeseelandiae*), tui (*Prosthemadera novaeseelandiae novaeseelandiae*), bellbird (*Anthornis melanura melanura*), brown creeper (*Mohoua novaeseelandiae*), grey warbler (*Gerygone igata*), fantail (*Rhipidura fuliginosa fuliginosa*) and silvereye (*Zosterops lateralis lateralis*). The wetlands and their margins were found to provide habitat for three nationally threatened species. These are the “nationally endangered” bittern, the “at risk declining” fernbird (*Bowdieria punctata*) both cryptic wetland species, and the “critically threatened” black billed gull (*Chroicocephalus bulleri*) which is usually seen feeding around areas of open water. Pukeko (*Porphyrio porphyrio*) and grey faced heron (*Egretta novaehollandiae*) were the most common aquatic birds observed due to their preference for feeding in open areas such as around wetland margins and adjacent areas of pasture.

5.5 Herpetofauna (Lizards and Frogs)

Records of lizards and frogs are held in the New Zealand Herptetofauna Database.

The database shows that the Otago Large Gecko (*Woodworthia* sp. Otago Large), which has a threat classification of “at risk declining”, has been recorded at one site in the Waituna Scenic Reserve. In the lowlands, this species of gecko is typically found in native forest and shrubland. Other lizards recorded in the catchment are the Common skink (*Oligosoma nigriplantare*) and the Cryptic skink (*Oligosoma inconspicuum*). There are four records for Common skink and one record for Cryptic skink from observation in wetlands in the vicinity of Waituna Creek. Both species usually live under rocks and logs in open areas with low vegetation. Neither species is nationally threatened.

No records for native or introduced frogs are present in the catchment. No native frog species are known to occur in the Southland region.

5.6 Freshwater Ecology

5.6.1 Aquatic Habitat

An assessment of the riparian and in-stream habitat in the creeks in the Waituna Catchment was performed in 2015 (Holmes, Goodwin, & Allen, 2015). This was performed through a randomised sample approach to gathering information on a number of 1,000m stretches of the creeks, so presents a representative sample of the catchment. The survey used a collaborative approach involving many community groups to facilitate the research.

The survey found that, in general, riparian habitat in the creeks were in average to good condition, however in certain segments where there is little or no stock exclusion fencing, there was extensive bank slumping and poor riparian condition. In areas of Waituna Creek, one side of the creek is kept unfenced to allow access for the mechanical sediment and plant clearance by Environment Southland to maintain the drainage network, in particular, the outfalls for tile drains. The balance between maintenance of the drainage network with the need to access and riparian fencing was recognised. It was noted that improved riparian management may reduce the need for drain clearance.

The in-stream habitat was relatively consistent across the catchment and of poor to average quality for eel/tuna (*Anguilla spp.*). Excessive fine sediment on and within the stream bed, uniform shallow (<0.5m deep) run habitat and little stream edge cover was the cause of the poor habitat ratings. However, there were pockets of excellent quality habitat in the lower end of Carran Creek. The bank reconstruction work had resulted in a reduction in in-stream habitat, but the negative impact can be moderated by the presence of extensive macrophyte beds which provide fish cover.

The report suggested that the quality of eel/tuna habitat could be improved by:

- Completing riparian fencing to provide stock exclusion, which will allow rank grass and other vegetation to provide fish cover
- Planting of overhanging, draping vegetation along the stream edge, particularly where bank reconstruction has occurred, and
- Providing permanent cover in reconstructed areas, such as in-stream wooden structures or large rip rap to provide spaces for fish.

5.6.2 Fish Fauna

A search of the New Zealand Freshwater Fisheries Database (NZFFD) revealed 18 surveys have been undertaken in the Waituna Creek Catchment (Ryder, 2013).

A total of nine native fish species and one exotic species have been identified in the catchment. Four of the native species have a threat classification of “at risk declining”: longfin eel (*Anguilla dieffenbachii*), giant kokopu (*Galaxias argenteus*), inanga (*Galaxias maculatus*) and redfin bully (*Gobiomorphus huttoni*). One species, the lamprey (*Geotria australis*), is classified as “nationally vulnerable” (DOC, 2014). The most common fish species located in surveys were shortfin eel (*A. australis*), longfin eel, common bully (*Gobiomorphus cotidianus*) and giant kokopu. The Waituna Catchment is known as a stronghold for giant kokopu (IUCN, 2017).

One exotic species is present in the catchment: brown trout (*Salmo trutta*). This forms the basis of a popular recreational fishery (Thompson & Ryder, 2003).

5.6.3 Macroinvertebrates

Macroinvertebrate communities in the catchment are of relatively poor quality, and are dominated by taxa typically found in slow flowing lowland streams such as amphipods, sandfly larvae, midge larvae, snails and worms. These species can indicate poor water and habitat quality.

5.7 Waituna Lagoon

Waituna Lagoon is part of the internationally recognised 20,000 ha Awarua Wetland. The lagoon and immediately surrounding wetland (an area of 3,500ha) known as the Waituna Wetland Scientific Reserve, was designated a Ramsar Wetland of International Importance in 1976, with the wider wetland complex being included in 2008. The lagoon is also culturally significant to Ngai Tahu which was recognised under a Statutory Acknowledgement in 1998 (Rissmann & Wilson, 2012).

Waituna Lagoon represents an exceptional example of a coastal lake-type lagoon within a largely intact coastal wetland system (Thompson & Ryder, 2003). The Lagoon contains important habitat for resident and migratory birds including nationally critical and endangered species. Its internationally important status, along with the surrounding wetland, is recognised by its designation as a Ramsar site.

The aquatic ecology of the lagoon includes a *Ruppia*-dominated macrophyte community not well represented elsewhere. Studies have found that the *Ruppia* community is sensitive to saline conditions and reduced water levels that result from the opening of the lagoon. *Ruppia* beds have declined during successive years of opening but gradually recovered when the lagoon was closed during the growth period (NIWA, 2015; NIWA, 2016). When the lagoon was open for a prolonged period in 2012 and 2013, the extent of the *Ruppia* beds reduced significantly. The subsequent complete closure of the lagoon during the 2014-2015 growth period and most of the 2015-2016 season resulted in substantial recovery for macrophyte beds, which increased from 30% cover in 2015 to 58% cover in 2016 (NIWA, 2015; NIWA, 2016). This included *Ruppia* cover of 57%. This meets the >30-60% target set by the Lagoon Technical Group as an ecological health objective for the lagoon (NIWA, 2016).

The lagoon offers a high diversity and abundance of aquatic habitats for fish, including significant habitat provided by the macrophyte beds. Fish surveys undertaken by DOC have found lower than expected fish diversity in the lagoon, with indications that closing the lagoon my result in lower diversity, as this restricts access to the lagoon from marine and estuarine species (DOC, 2008). The impacts of closing and opening of the lagoon on marine, estuarine and diadromous species are likely to be dependent upon the season and length of time the lagoon is closed. The lagoon also supports exotic fish species and is a valued recreational trout fishery (Thompson & Ryder, 2003).

Shoreline vegetation patterns are largely unmodified and include notable cushion-bog and sand-ridge plant associations. In surrounding areas, the presence of several alpine and sub-alpine species at sea level is of botanical interest.

There are a significant number of monitoring programmes being undertaken both in the Lagoon and the surrounding wetlands on public and private land. These have not been reviewed in detail for the purposes of this report but include annual monitoring of macrophyte beds in the lagoon, aquatic and terrestrial habitats and fish monitoring.

6 Wetland Fragments

This section provides an overview of available information on extent and condition of wetland fragments in the catchment, with a focus on wetlands on private land.

6.1 Wetland Extent

As in other parts of New Zealand, many of Southland's wetlands have been converted to farmland (Campbell, Clarkson, & Clarkson, 2003). It is estimated that there is approximately 32,970 hectares of wetlands remaining throughout the Southland Region, compared to 415,785 hectares which is the estimated historic extent (Ausseil, A.; Gerbeaux, P.; Chadderston, W.L.; Stepherns, T.; Brown, D.; Leathwick, J., 2005). This equates to 7.9% of the former extent of wetlands remaining in the region, and 13.2% of remaining wetlands nationally. Southland has the second largest proportion of wetlands remaining for any region in the country, behind only Westland which retains 21% of former wetland extent (ibid.). Nationally only 10.11% of wetlands remain, making wetlands one of the most threatened ecosystems.

There are currently 6,901 hectares of wetland in the Waituna Catchment which includes 215 hectares on private land (Figure 6-1). The modelled historic extent of wetlands is illustrated in Figure 5-1. This is derived from the predicted potential natural vegetation cover of New Zealand. This indicates that there has been extensive wetland drainage in the catchment.

Research has shown that threats to wetlands in Southland include drainage, weed invasion, nutrient enrichment, and impacts from adjacent land uses (Campbell, Clarkson, & Clarkson, 2003). Many remaining wetlands are small which can pose a problem from a preservation and restoration perspective due to weed invasion, water table lowering and fertiliser drift on wetland edges. Swamps were found to be the least well represented wetland type in the region, although all wetland types were poorly represented (ibid.).

DOC provided GIS information on the extent of private wetland fragments as at 2008, in terms of hydrosystems and wetland classes present in the catchment. This information is derived from hydrology and vegetation mapping undertaken for DOC in 2010 (Boffa Miskell, 2010). The project involved mapping of wetlands on both the conservation estate and private land, and ground-truthing of wetlands on the conservation estate to confirm wetland, structural and vegetation classes. The wetland mapping exercise also involved classification of the historic extent of wetlands to hydrosystem level but not wetland class level due to difficulties in aerial photography interpretation.

DOC is currently undertaking a mapping exercise to better understand changes in wetland extent in the catchment between 2008 (when the previous mapping was performed) and 2012 (most recent aerial photography). The final GIS layer has been made available to this project and was used to remove areas of wetland which appear to have been drained and are no longer present. This information was the primary base information for identifying the wetlands suitable for restoration (MWH, 2017). Previous reports have indicated that the delineation of wetlands could be improved by using radar imagery or LIDAR, although field work is still necessary for verification (Ausseil, A.; Gerbeaux, P.; Chadderston, W.L.; Stepherns, T.; Brown, D.; Leathwick, J., 2005). More recently, drones have been used to capture high level imagery which can be used to more accurately delineate wetland edges.

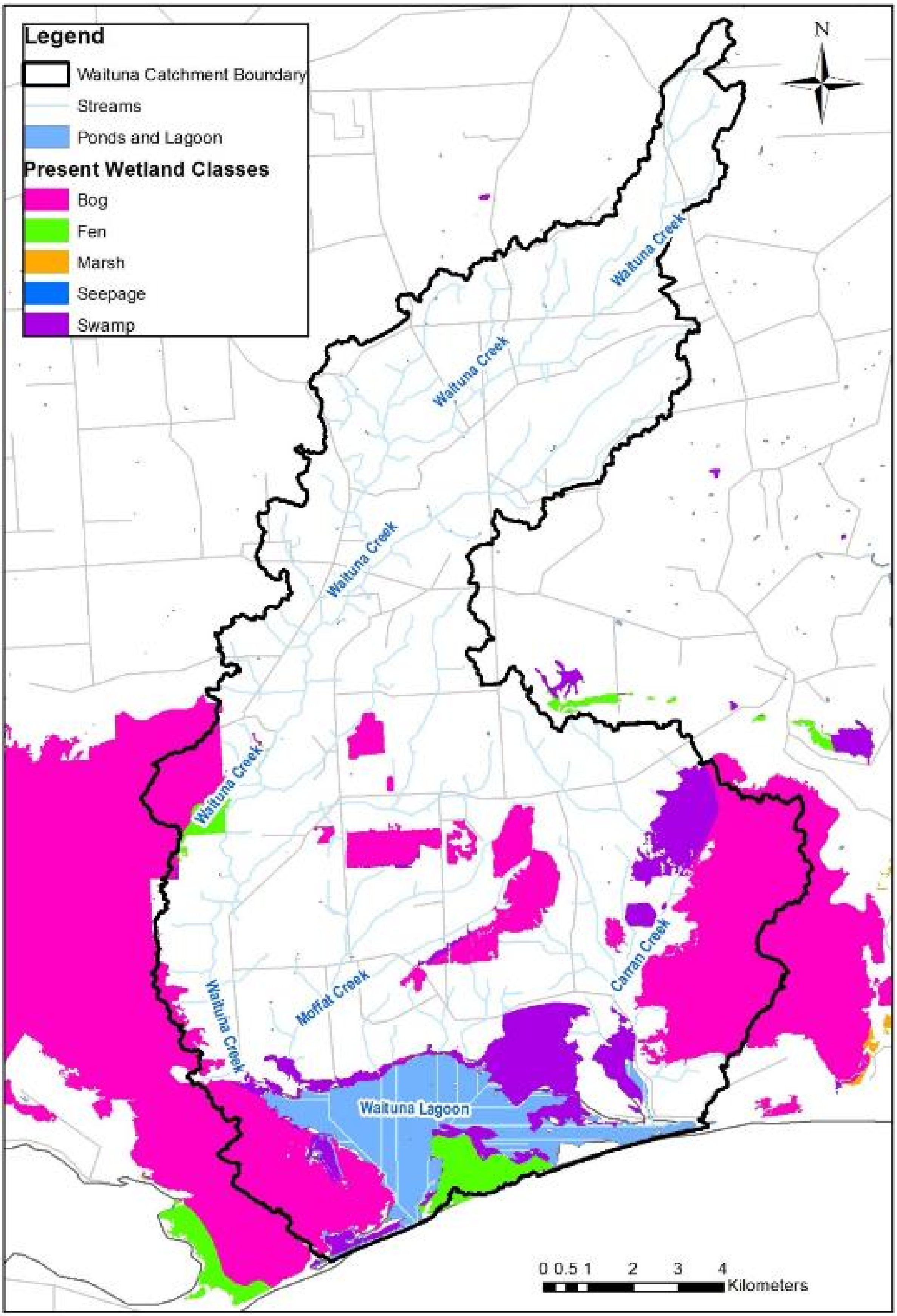

Figure 6-1: Wetland Types in Waituna Catchment (Source: DOC GIS data)

6.2 Wetland Types

The Department of Conservation classifies wetland fragments on private land under different hydrosystems, wetland classes and water sources. The wetland classes identified in the catchment are summarised in Table 6-1. To provide a more detailed understanding of the hydrological regime, the corresponding wetland class description from Johnson and Gerbeaux (2004) is also provided in the table. In reality, there will be considerable overlap of classifications as most wetland classes can occur within more than one hydrosystem.

The dominant wetland type in the Waituna Catchment is bog, followed by wetlands with an unknown class, terrestrial, shallow water then more minor areas of swamp, marsh and fen. The location and extent of the various wetland classes represented within the Waituna Catchment are shown in Figure 6-1 and individually for each class of wetland in Appendix D.

Approximately 12% of the total wetland fragments are classified as “unknown”. The majority of unknown classified wetland fragments occur in the middle catchment near Waituna Creek or in the lower catchment near Carran Creek. These fragments are described as Palustrine meaning that they are fed by freshwater in the form of rain, groundwater and/or surface water. Approximately 11% of the wetlands are classified by DOC as “terrestrial”. This wetland class is not described by Johnson and Gerbeaux (2004), but the DOC shapefile identifies the dominant of water source in these wetlands (where listed) as swamp. Since the dominant water source to the unknown and terrestrial wetland fragment areas are described as swamp, the hydrological regime are expected to be largely similar to swamps.

6.2.1 Bog

A bog is a peatland which is entirely fed by rainfall, receiving neither groundwater nor surface water runoff. Bogs are low in nutrients, poorly drained, and usually acidic with a water table that is generally close to or just above the ground surface. Bogs occur on relatively level or very gently sloping ground, including hill crests, basins and terraces (Johnson & Gerbeaux, 2004).

Bogs total 1,933 hectares and are the most widespread wetland class in the Waituna Catchment. Bogs occur in the mid and lower catchment but are absent from the upper catchment as a result of steeper topography, better drained soils and slightly deeper depths to groundwater. Bogs occur at locations further from major streams, confirming the dominance of rainfall sourced water rather than stream flows.

In theory, peat bog wetlands will be perched above the water table. In many areas this occurs because the peat has accumulated over time or sits on top of a low permeability layer such as clay. The construction of surface drains can result in shrinkage of peat, leading to a loss of soil structure, land subsidence, and loss of soluble phosphorus. It can result in increased stream flows and changes in water chemistry. A surface drain within a peat bog in the Waituna Catchment is shown in Figure 6-2.

Given the reliance on rainfall, long term climatic cycles effecting rainfall such as El Nino / La Nina cycles will be important to bog wetland extent. Based on the long-term rainfall from Invercargill showing above average rainfall for about the last 30 years, bog wetlands in their natural state should be well supplied with water.

Figure 6-2: Drainage of a peat bog wetland near Drummond (Source: Environment Southland)

6.2.2 Shallow Water

Shallow water wetlands are aquatic habitats, generally less than a few metres deep, having standing water for most of the time. This wetland class accommodates the margins of lakes, rivers, and estuary waters which can include an open body of water (Johnson & Gerbeaux, 2004).

Shallow water wetlands total 281 hectares in the Waituna Catchment. These generally occur along streams. The map in Appendix D shows the location of shallow water wetlands within the Waituna Catchment.

Riverine Shallow Water Wetlands (associated with rivers and streams)

Most shallow water wetlands have a riverine hydrosystem, meaning that Waituna, Moffat and Carran Creeks along with various surface drains and smaller natural streams provide the dominant sources of water. Riverine wetlands occur throughout the catchment, but in the upper catchment they are more common than other wetland classes. This is probably because the upper catchment has more freely drained soils and generally deeper groundwater levels which would not support many of the different wetland classes observed in the lower part of the catchment.

The upper reaches of Waituna Creek are weakly connected to groundwater and probably receive more water from rainfall run-off from the land surface. In contrast, the lower reaches of Waituna Creek appear to be more connected groundwater because groundwater levels are generally closer to the land surface (Rissmann & Wilson, 2012) and because the unconfined aquifer thins out in the lower catchment potentially forcing more groundwater to the surface and into the stream (Wilson, 2011). Given that the lower reaches of Waituna Creek may be more influenced by groundwater than the upper reaches, land drainage and groundwater abstraction has the potential to be greatest effects on stream flows in the lower catchments. Currently, most groundwater abstraction occurs in the upper catchment which may limit these effects.

Palustrine Shallow Water Wetlands (rain, groundwater and surface water fed but not associated with streams)

A smaller number of shallow water wetlands are classed as Palustrine and occur throughout the Waituna Catchment. Many of these wetlands occur close to the main channels and tributaries of Waituna Creek, Moffat Creek and Carran Creek as well as small lakes. The DOC GIS information refers to the water sources of these wetlands as lake or swamp.

Lacustrine Shallow Water Wetlands (influenced by lake or lake like water bodies)

There is one very small area of shallow water wetland classed as Lacustrine located at the lower end of Carran Creek close to a lake or pond near Waituna Lagoon. The DOC GIS information describes the main water source as lake, suggesting the wetland could be affected by changes in lake levels.

6.2.3 Swamp

A swamp is fed by surface runoff and groundwater from adjacent land meaning that they receive a relatively rich supply of nutrients and sediment. They usually have a combination of mineral and peat substrates and occur in basins, on valley floors, deltas and plains (Johnson & Gerbeaux, 2004).

Swamps total 92 hectares in the Waituna Catchment. Swamps are located throughout the catchment, with many close to stream channels and their tributaries as would be expected given their reliance on a combination of surface water and groundwater (Appendix D).

In the upper catchment, groundwater levels show a strong seasonal influence with high levels at the end of winter and lowest levels at the end of summer (see Figure 3-9). Given that stream flows also show a seasonal pattern of highest flows in winter and lowest flows in summer, it is likely that the swamp wetlands in this area experience seasonal changes in water levels which will be largely driven by rainfall.

Since groundwater levels fluctuate less in the lower catchment, swamp water levels in the lower catchment may be more consistent than those in the upper catchment. Swamps in the lower catchment that are close to Waituna Lagoon (within 60 m based on Thompson and Ryder, 2003) may experience surface water and groundwater level changes caused by fluctuating lagoon levels.

6.2.4 Marsh

Marshes have moderate to good drainage, fed by groundwater or surface water, and are characterised by moderate to great fluctuation of water table. Marshes are often periodically inundated by standing or slowly moving water. Marshes differ from swamps by having better drainage, a generally lower water table, a usually more mineral substrate, and a higher pH. Marshes occur mainly on slight to moderate slopes, especially on valley margins, valley floors, and alongside streams, rivers and lakes (Johnson & Gerbeaux, 2004).

Marsh wetlands comprise 54 hectares in the Waituna Catchment and are a small area relative to the other wetland classes. The majority of marsh wetlands are located in the lower Carran week catchment (Appendix D). Like swamps, the marsh wetlands source water from groundwater and surface water and will thus be subject to similar seasonal and long term water variations driven largely by rainfall.

6.2.5 Fen

A fen is a wetland with a predominantly peat substrate that receives inputs of groundwater and nutrients from adjacent mineral soils. The water table is usually close to or just below the peat surface, and relatively constant. Fens have slightly higher nutrient status than bogs (Johnson & Gerbeaux, 2004).

Fen wetlands comprise the smallest area in the catchment, totalling 32 hectares. They are restricted to the lower and eastern Waituna Catchment in the Moffat Creek and Carran Creek sub-catchment but are absent from the Waituna Creek sub-catchment (Appendix D).

The occurrence of fen wetlands in the lower catchment is in part related to their need for more stable groundwater levels which is what occurs in the lower catchment but not in the upper catchment.

Table 6-1: Properties of Wetland Fragments and Wetland Class Description

From DOC GIS Layer on Wetland Fragments				Wetland Class Description From Johnson and Gerbeaux (2004)						
Wetland Class	**Area on Private Land (ha)**	**Hydrosystem[6]**	**Waituna Catchment Locations**	**Water origin (dominant)**	**Water flow**	**Drainage**	**Water table position cf. ground**	**Water fluctuation**	**Periodicity**	**Substrate**
Bog	1,993	Palustrine	Mid, Low	Rain only	~ Nil	Poor	Near or above	Slight	Wetness permanent	Peat
Unknown	384	Palustrine	Mid, Low	Similar to swamp						
Terrestrial	321	Terrestrial	Upper, Mid, Low	Similar to swamp						
Shallow Water	281	Palustrine Lacustrine Riverine	Upper, Mid, Low	Lake, river, etc., or adjacent groundwater	Nil to fast	Nil to good	Well above surface: inundated	Nil to high	Wetness almost permanent	Usually mineral
Swamp	92	Palustrine Lacustrine Terrestrial	Upper, Mid, Low	Mainly surface water + groundwater	Moderate	Poor	Usually above surface in places	Moderate to high	Wetness permanent	Peat and / or mineral
Marsh	54	Palustrine Lacustrine	Upper, Low	Groundwater + Surface water	Slow to moderate	Moderate to good	Usually below surface	Moderate to high	May have temporary wetness or dryness	Usually mineral
Fen	32	Palustrine Lacustrine	Low	Rain + Groundwater	Slow to moderate	Poor	Near	Slight to moderate	Wetness near - permanent	Mainly peat

[6] Definitions from Johnson and Gerbeaux, 2004:
Palustrine – Freshwater wetland fed by rain, groundwater or surface water but directly associated with estuaries, lakes or rivers
Lacustrine – Wetlands associated with water and beds and immediate margins of lakes and other similar open water bodies
Riverine – Wetlands associated with rivers, streams and other channels where dominant function is continually or intermittently flow freshwater in open channels

6.3 Hydrological Influences on Wetland Fragments

In terms of natural influences on water levels, rainfall is considered to be the dominant hydrological influence on known wetland fragments within the Waituna catchment. This is because rainfall that has the largest natural influence on groundwater levels and in turn it is groundwater in combination with rainfall run-off from the land surface that has the largest natural influence on surface water flows and water levels in Waituna Lagoon. It should also be noted however that the effects of rainfall on groundwater, surface water or perched water in any wetland are also influenced by local soil properties and evapotranspiration.

In terms of artificial (anthropogenic) influences on wetland extent, land drainage through the construction of tile drains and open drains are predicted to have the influence on wetland fragments because they directly affect water levels. Though it is considered that groundwater abstraction will cause localised lowering of groundwater levels and potential reductions in stream flows, the effects are considered small in relation to water inflows and outflows at a catchment level and much smaller than the impacts of land drainage.

In terms of surface water, there are no consented takes from any of the streams or drains within the Waituna Catchment. The only surface water takes are those less than 2 L/s which are classified as a permitted activity. Since Environment Southland does not know the number of permitted surface water takes it is not possible to determine the total abstracted. Though unlikely to be significant, recording this type of information on field surveys would improve the prediction of effects from surface water abstraction on wetland extent.

Wetland fragments close to Waituna Lagoon may receive water directly from the lagoon as a result of large changes in lagoon water levels. However, it appears that rainfall landing on the ground surface has a greater influence on groundwater levels, at least at distances greater than 60 m from the lagoon (Thompson & Ryder, 2003). It also appears that rainfall affects groundwater levels within hours or days compared to changes in lagoon water levels which can take weeks or months (Thompson & Ryder, 2003).

6.4 Wetland Condition

The most comprehensive information on wetlands on private land in the Waituna Catchment has been provided by the voluntary High Value Area (HVA) programme run by Environment Southland. This involves the survey of remnant areas of native biodiversity on private properties in the Southland region.[7] A HVA assessment report is produced at the conclusion of each on site survey which provides the landowners with information about the presence, conditions and relative values of indigenous biodiversity on their land.

To date HVA surveys have been conducted on 24 properties in the catchment as shown Figure 6-3. This included 10 properties that contained wetland communities. These communities were considered by the survey teams to be highly representative of the Waituna Ecological District. Some of the areas are covenanted with the QEII Trust. A summary of the ecological characteristics of these wetlands, defined by wetland class, is set out in Table 6-2.

The predominant wetland class of the sites surveyed is bog with some areas featuring small areas of swamp, fen and shallow water. The predominance of bogs in these areas is consistent with the prevalence of this wetland type across the catchment. Structurally, the bogs support a cover of manuka scrub and shrubland and wire rush rushland while the swamps tend to support flaxland.

The nationally threatened bittern and fernbird were recorded in several of the surveyed wetlands. A good population of the nationally threatened swamp mingimingi (*Coprosma pedicellata*) was recorded at one site. In addition, the presence of bog pine (*Halocarpus bidwillii*) and the cushion plant (*Donatia novae-zealandiae*) in one swamp near the Waituna Lagoon was highlighted as notable flora as bog pine

[7] HVA surveys are entirely voluntary and many landowners have yet to participate in the surveys.

is uncommon in lowland and coastal Southland while the cushion plant is rare outside of localised areas in the Waituna Scientific Reserve.

All of the surveyed wetlands were affected by invasive weed species, notably gorse, broom and blackberry. The presence of grey willow in one area and shade tolerant holly, Chilean flame creeper and Darwin's barberry at some sites is of concern in terms of their ability to displace indigenous plants and threaten the long term integrity of the wetlands.

Overall, the wetlands surveyed were considered to be in good condition with a favourable connectivity in terms of proximity of other wetlands and formally protected areas. Some are contiguous with conservation land and reserves and form an important buffering function.

6.5 Awarua-Waituna Wetlands Programme (Arawai Kākāriki)

Arawai Kākāriki is a large-scale wetland restoration programme led by the Department of Conservation. The main goal is to protect wetlands, and increase understanding of these productive environments. An important part of the programme is getting the community involved. DOC are working with partners to improve knowledge of wetland conservation issues, and build stronger relationships with iwi and regional councils.

The programme is focused on three of New Zealand's most significant wetland sites:

- Whangamarino Wetland (Waikato)
- Ō Tū Wharekai (Canterbury)
- Awarua-Waituna Wetlands (Southland).

The Awarua-Waituna Wetlands Monitoring Programme provides up to date information on the ecological conditions of wetlands on public conservation land. This includes information on threatened species, including fernbird and bittern populations, and the presence/absence of invasive weeds such as Spanish heath. This information does not extend to wetlands on private land although is relevant for adjoining or nearby landowners.

6.6 Water Quality

The water quality of wetlands on private land within the catchment is not well known, with little to no published information available. The wider context of water quality in the catchment as a whole is discussed in Section 4.

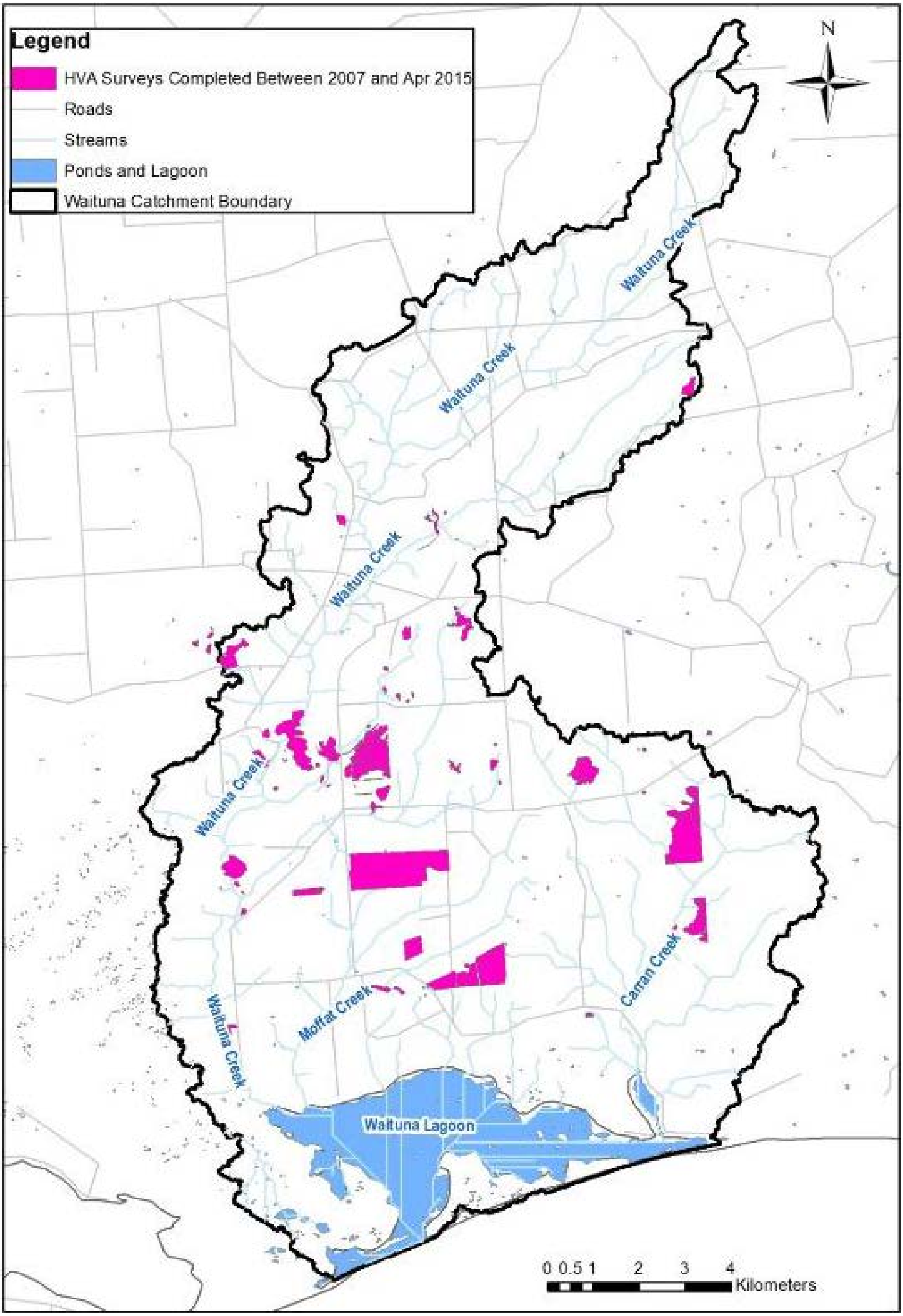

Figure 6-3: Location of HVA Surveys undertaken in Waituna Catchment

Table 6-2: Summary of HVA Assessments in the Waituna Catchment by Wetland Class

Wetland Class	Vegetation Types	Wetland Size (ha.)	Condition	Connectivity	Threatened/Notable Species	Weeds
Bog	Manuka scrub	47.1	Good examples of peatland (bog)-shrubland mosaics. Generally in good condition with the central parts retaining natural hydrology.	Variable connectivity. Some bogs are isolated and others located close to other wetlands or form a buffer to adjacent reserves.	Bittern, fernbird, black billed gull, tomtit, white-faced heron. *Coprosma pedicellata*	Mostly gorse, broom and blackberry. Some wetlands affected by Chilean flame creeper, Himalayan honeysuckle, elderberry, Tutsan, *Cotoneaster* grey willow, Acacia and Eucalyptus spp.
	Manuka/wirerush rushland	82.1				
	Manuka-bog turpentine scrub/wire rush-tangle fern shrubland	18.4				
	Manuka-bog turpentine scrub/wire rush shrubland	6.2				
	Manuka-mingimingi/wirerush shrubland	149.0				
	Manuka-Juncus-Coprosma shrubland	1.5				
	Wire rush rushland	1.1				
	Gorse/wire rushland	0.4				
	Flaxland	0.6				

Wetland Class	Vegetation Types	Wetland Size (ha.)	Condition	Connectivity	Threatened/Notable Species	Weeds
Swamp	Flax/Carex flaxland	7.1	Swamps generally in good condition with low edge effects.	Good connectivity overall. Generally situated in vicinity of wetlands managed by DOC and areas of open water.	Bog pine (*Halocarpus bidwilllii*), *Donatia novae-zelandiae*	Gorse, broom, blackberry
	Flaxland/pasture (ephemeral wetland)	2.5				
	Flaxland	2.7				
	Red tussock/ sphagnum-wrirerush mossland	1.2				
	Juncus rushland	0.9				
Fen	Manuka-red tussockland	1.3	Generally in good conditions and exhibiting reasonable floristic diversity. Modified by past fires and grazing	Limited connectivity.		Gorse, broom, blackberry elderberry, Darwins barberry, Radiata pine
	Red tussock tussockland	0.7				
	Carex sedgeland	1.1				
Open Water	NA	4.6				

7 Gap Analysis

7.1 Hydrology and Hydrogeology

Environment Southland has undertaken an intensive study of the hydrology and hydrogeology of the Waituna Catchment as part of the Surface Water Quality Study. The extensive monitoring that was undertaken during 2011 through 2013 has now ceased, but climate monitoring is continuing.

As a result of this study, a sufficient understanding of the hydrology and hydrogeology of the catchment has been developed. It is recommended that continued monitoring of groundwater levels at key bores through the catchment be continued to enable assessment of any trends. This should be undertaken in conjunction with groundwater quality monitoring.

7.2 Water Quality

The Environment Southland Surface Water Quality Study collected a significant data set for interpreting the water quality in the whole catchment. Since this time, monitoring has reduced to the State of the Environment (SOE) monitoring sites which includes the sites at the ends of the main creeks and within the Waituna Lagoon itself.

There is no ongoing monitoring of groundwater quality and minimal surface water monitoring throughout the catchment. It is recommended that monitoring be implemented at pre-existing surface water and groundwater monitoring sites to provide a record of change in water quality over the Living Water Programme duration.

7.3 Ecology

There are significant ongoing projects and monitoring of the ecology in the Waituna Lagoon and on public land within the Awarua-Waituna Wetlands being undertaken by DOC. Within the wider catchment, the sources of information are more limited and consist of High Value Area (HVA) surveys[8], wetland mapping projects and investigations of riparian habitat undertaken by DOC, Environment Southland and the Living Water Programme. Environment Southland also undertake macroinvertebrate surveys as part of their State of the Environment monitoring programme at sites in the main creeks.

Currently, the surveys are undertaken by different agencies and do not appear to be co-ordinated. It is recommended that the timing and reporting of future surveys be co-ordinated between the agencies to optimise the value of this information and to prevent duplication of effort.

The Landcare Research Land Cover Data Base (LCDB) provides information on broad-scale vegetation types within the catchment. There is the potential to use this database, which is periodically updated, to track changes in vegetation cover in the catchment over time. Alternatively, mapping could be done from aerial photography. It is recommended that this be carried out under the Living Waters project.

There is also the potential for ecological monitoring to be undertaken by interested landowners and volunteer groups working in the catchment.

7.4 Wetlands on Private Land

The following list identifies gaps in the information on wetlands, particularly those on private land.

Information gaps relevant to hydrology and hydraulics:

- Direct monitoring of groundwater and surface water at key reference points and which are tied together with any water quality or ecological monitoring.
- The DOC GIS shapefile on private wetlands could be updated to fill in missing data such as the wetland classes defined as “unknown”, or where a water source is not defined.

[8] HVA surveys are entirely voluntary and many landowners have yet to participate in the surveys.

- It would be useful to identify locate and/or quantify the extent of drainage on private properties. This involves mapping the location drains including mole drains, tile drains and open water drains. Given the difficulty in determining sub-surface drains, identifying the outlets of drains in the beds and banks of streams and open water drains would also be beneficial.
- It would be useful to determine the number of permitted surface water takes (<2 L/s) since Environment Southland Southland has no record of these.
- Quantifying the effects of land drainage on groundwater levels and stream flows.
- Quantifying the effects of returning once-drained land back to a more natural un-drained or naturally drained state.
- Quantifying the water balance of different types of wetland fragments.
- Concurrent stream gauging along the lengths of Moffat Creek or Carran Creek to determine sources of water as has been done for Waituna Creek.
- Database or map showing the location of springs. Flowing artesian bores exist in the Moffat and Carran Creek catchments (Wilson, 2011), and so it is possible that artesian springs may be present.
- Information on the extent of constructed drains in peat bog wetlands and the potential for land subsidence and changes in the stream flows.

With respect to water quality in wetlands, minimal information is available, except in the shallow water wetlands that were monitored as part of the Surface Water Quality Study. No information was found on water quality for the other wetland types. Specifically, the following information was not available:

- Wetland Water Quality – Existing surface and/or groundwater sites upstream of natural wetlands may be able to be used as a proxy, however it is recommended that the water quality of a few representative wetlands across the catchment be monitored regularly.
- Nutrient Removal – The load of nutrients removed by natural wetlands across the catchment is unknown. Modelling the potential removal rate of nutrients will indicate the impact likely on Waituna Lagoon if wetlands within the catchment are lost or restored.

Apart from the HVA survey results and the identification of wetland class from the mapping surveys, little information exists about the ecology and the condition of wetlands on private land. For all wetlands, even those where a HVA has been performed, a quantitative assessment of wetland condition, such as required to enable an understanding of changes over time is currently not available.

The following information gaps apply to private properties, particularly where HVA surveys have not been conducted:

- Verification of wetland extent.
- Information on the condition of wetlands on private properties, including vegetation condition and threats form invasive species and other habitat modifications.
- Determination of the vegetation types present.
- Presence of threatened species.
- The effects of changes to farm management practices on wetland condition.

The recommended monitoring programme addresses many of these gaps.

8 Monitoring and Management Recommendations

This section of the report sets out advice on restoration actions, monitoring and reporting to be undertaken by the Living Water Programme. The focus of the monitoring and management recommendations are wetlands that are located on private land, as there are already extensive programmes of work associated with the wetlands on public land and the Waituna Lagoon. The recommendations have been based on an understanding of the wider catchment as summarised the earlier sections of this report and are intended to address the data gaps that have been identified.

8.1 Wetland Restoration Actions

On the ground physical works should be the focus of the Living Water Programme and should be prioritised based on the benefits achieved to wetland condition, water quality and biodiversity. We recommend that that the key priorities for restoration are:

1. **Fencing** – to exclude stock and prevent loss in wetland extent
2. **Preventing and Reverting Land Drainage** – to reduce water loss and maximise water input to wetland
3. **Controlling Nutrient Run-Off** – to reduce nutrient runoff to wetlands to improve water quality and reduce weed growth.

These three actions are considered the highest priority for protecting and improving wetland extent and condition. We consider other actions, such as weed and pest control and planting, can improve biodiversity and can supplement the primary actions. These actions should be implemented in accordance with the prioritisation undertaken as part of this project and reported separately.

The physical works recommended for implementation are summarised in Table 8-1 which also identifies the measures that could be used to determine the success of the measures.

8.2 Monitoring

There is a considerable amount of information on the extent and type of wetlands in the catchment. However there is minimal information on wetland condition and quantitative information that can be used to determine change over time. Therefore, the recommended programme focuses on collecting quantitative information that can be used to determine the benefits of restoration activities over the 10 year Living Water Programme time frame.

The recommended monitoring programme includes:

- **Hydrology and Hydrogeology Monitoring.** This monitoring is focused on developing an understanding of the water system in the catchment, particularly around the wetlands, and how this may change as a result of interventions undertaken. It will inform any works to improve the water system of the wetland.
- **Water Quality Monitoring.** This will include:
  - Surface water and groundwater quality monitoring across the catchment to monitor the effect of the overall project on water quality;
  - Site-specific monitoring of surface water and/or groundwater coming into and discharged from the wetlands (dependent upon the nature of the wetland) at selected sites.
- **Ecology Monitoring.** This monitoring will focus on gathering quantitative and qualitative information wetland condition and rare species.
- **Site-Specific Wetland Monitoring.** More intensive monitoring that can be implemented at a sample of wetland fragments throughout the catchment and/or in high priority wetlands.

8.2.1 Hydrology

Changes in the hydrology in the overall catchment can be assessed using existing rain gauges and the levels recorded in groundwater monitoring bores as part of the water quality monitoring. High level changes should be compared once every five years, or more frequently if changes in wetland condition are noticed on the ground.

For high priority wetland sites, more intense monitoring may be justified, particularly if significant changes to the drainage patterns around the wetlands are proposed. Table 8-2 describes the hydrological monitoring that could be implemented at these selected wetland fragments.

8.2.2 Water Quality

The Environment Southland State of the Environment monitoring programme includes the following four sites, which are generally at the base of the Waituna Catchment:

- Carran Creek Tributary at Waituna Lagoon Rd
- Moffat Creek at Moffat Road
- Carran Creek at Waituna Lagoon Road
- Waituna Creek at Marshall Road.

The following sites were included in the Environment Southland Surface Water Quality Study in 2011 and 2012:

- Surface water:
  - Waituna Creek 1m upstream Waituna Road, in the upper catchment
  - Waituna Creek 1m upstream Rimu Seaward Downs Road
  - Carran Creek east branch u/s Waituna Gorge Road
  - Carran Creek 3km u/s Waituna Lagoon Road
- Groundwater
  - Carran sub-catchment: F47/0253, F47/0254 and F47/0258
  - Moffat sub-catchment: E47/0129, F47/0256 and F47/0262
  - Waituna sub-catchment: F46/0693 and F47/0252.

It is recommended that Living Water Programme fund the monitoring of these seven additional sites on a monthly basis similar to the ongoing State of the Environment monitoring. This could be implemented through funding the Environment Southland science team to undertake the monitoring, subject to Environment Southland agreement.

Table 8-2 describes the specific water quality monitoring that could be undertaken at selected wetland fragments to understand changes in water quality in the wetland, and provides a description of how this could be undertaken.

8.2.3 Ecology

8.2.3.1 Vegetation and Wetland Mapping

Understanding long-term changes or trends in vegetation cover across the catchment can be achieved through comparison of successive versions of the Landcare Research Land Cover Database (LCDB). The first LCDB database was released in 2000, with successive updates released through to LCDB v4.1 released in July 2015. It is likely that further updates will be released during the 10 year duration of the Living Water Programme. Although high level, this is an existing dataset which can be used to monitor long-term trends in vegetation and wetland extent over time on a catchment scale. Note that it is unlikely to detect the presence and/or loss of small wetland fragments due to the national scale of the dataset.

Mapping of small wetland fragments is being undertaken by Environment Southland. This will yield more accurate spatial definition of wetland classes and delineation of wetland extent and boundaries in the catchment. This programme should be continued to include wetlands on private land.

Utilising the LCDB in combination with detailed mapping undertaken by Environment Southland will allow future changes in vegetation cover and wetland extent to be assessed across the catchment. This should be undertaken approximately every five years and a minimum of once every 10 years.

8.2.3.2 Wetland Condition Monitoring

There are a large number of wetland monitoring methodologies available including Wetland Extent monitoring (Ward & Lambie, 1999), Wetland Condition monitoring (Clarkson, et al., 2004), WETMAK (Denyer, K.; Peters, M., 2012) and variations on these. In 2013, a wetland monitoring methodology was specifically developed for the Southland region, based on aspects of these other programmes (Clarkson, Hicks, Robertson, Rance, & Ledgard, 2013).

Wetland condition monitoring should be undertaken at statistically randomly selected wetland fragments throughout the catchment, or else on selected priority sites. The selected monitoring methodology depends upon the location, purpose and skills of the organisation or person conducting the monitoring. For consistency, wetland monitoring on private land should reflect methods already used by Environment Southland.

For selected wetland sites, a comprehensive programme based on the Environment Southland wetland monitoring methodology can be used. For other wetland fragments where less detail is justified, information collected by the HVA surveys or through WETMAK will be sufficient. The latter is particularly appropriate for use by landowners.

Wetland condition monitoring should be undertaken relatively infrequently to avoid adverse impacts on vegetation communities from trampling. It is recommended that monitoring should be undertaken approximately every five years.

8.2.3.3 Flora and Fauna

Monitoring of flora and fauna can be considered at all wetlands, with a wider suite of parameters monitored at high priority sites. The abundance of flora and fauna can be an indicator of wetland condition and restoration, and help to motivate landowners and community groups. Some of the items below can be conducted by landowners, whilst others require specialist staff and equipment.

- Five-minute bird counts – for all habitat types (Dawson & Bull, 1975).
- Aquatic macroinvertebrate monitoring – including wetland macroinvertebrate indices such as the Wetland Macroinvertebrate Community Index (Suren, Stark, Wech, & Lambert, 2010).
- Rare species – the location of any rare or threatened plant and animal species should be recorded and mapped. This information may need to be treated with caution should there be a risk of illegal collecting.

Periodically these more specialised methods should also be considered:

- Wetland bird call playback - for cryptic species especially for larger sites with dense sedgeland, rushland, raupo swamp etc.
- Herpetofauna surveys – to determine the presence/absence of skinks and geckos.
- Fish surveys – trapping is most appropriate for deep water and estuarine sites and there is unlikely to be suitable sites around the wetlands. Electric fishing can be used in wadable streams and open water wetlands.

The frequency of monitoring of these specialized flora and fauna survey will depend on the budget available, and can be one-off surveys or repeated every one to five years along with other monitoring programmes.

Table 8-1: Recommended restoration actions in order of priority

#	Action	Purpose	Priority Actions	Frequency	Measure (optional)
1	Fencing of streams, wetlands and low lying areas	Fencing for removal of stock. Prevents further wetland loss and degradation. Potential to increase wetland area. To improve the biodiversity and water quality within the wetland Currently significant wetlands are required to be fenced by Supply Fonterra. We suggest that wetlands that have been prioritised are considered to be significant and hence should be fenced.	• Existing unprotected wetlands • Low lying areas and boggy pasture • Multiple small sites	One off	Length of fencing installed per year. Total area of land retired/protected.
2	Preventing and reversing land drainage	Restore the natural hydrological regime of wetlands	Around the existing wetlands: • Avoid digging new drains • Avoid deepening of existing drains • Stage drain clearance on each farm over time • Limit water abstraction from streams and groundwater; • Remove/plug tile drains; • Infill / dam cut off drains.	Initial review and then further implementation as understanding of the hydrological regime has been obtained (2 years after monitoring start)	Changes in groundwater levels
3	Controlling nutrient runoff	Investigate management changes to surrounding land use to improve water quality.	• Create a nutrient budget (Dairy NZ) • Consider carbon sources such as woodchips or hay to absorb nitrogen • Change fertiliser use • Change stocking rates • Consider effluent treatment	Monitor annually	Water quality changes (nitrogen, phosphorus, *E.coli*)
4	Weed control	If required. Chemical/mechanical control to improve biodiversity by removing pest species to aid replacement with natives. Note - Changing hydrology can reduce weed invasion.	• Sites with rare species/habitats. • Protect sites with low weed invasion first	Every year	Weed species presence and abundance.

#	Action	Purpose	Priority Actions	Frequency	Measure (optional)
5	Animal pest control	Installation of bait stations to prevent plant losses and improve biodiversity Quarterly pest control, reducing in frequency as pest numbers decrease.	• Sites with rare species/habitats. • Site with high native plant diversity (to encourage regeneration) • Protection of new plantings.	Every year	Number of animals trapped. Volume of bait consumed. Bird species abundance and diversity.
6	Planting	If required. Mainly required if weed control creates bare open areas and/or for engagement with the community groups. This will include seed collection, propagation of stock and planting Note - Changing hydrology can improve wetland vegetation without planting. Retirement only can produce many benefits without planting.	• Open bare ground. • Weed infested sites. • Where natural regeneration is unlikely to occur. • Buffer zones next to streams and wetlands • Corridors to connect sites.	One off	Number of plants planted per year.

Table 8-2: Site-specific monitoring at selected wetland sites

Indicator	Components	Reasons for Monitoring	Type of Monitoring	Frequency
HYDROLOGY AND HYDROGEOLOGY				
Climate	• Rainfall • Temperature • Evapotranspiration	The main source of water for most of the wetland types is rainfall, and hence is a primary data source for understanding the water balance. Monitoring of climate can help to distinguish natural versus anthropogenic changes to wetlands.	Collation and interpretation of information from existing climate stations to monitor climate over time.	Annually
Groundwater / Surface Water Abstraction	• Location, use and water source of all groundwater and surface water abstraction points within or near the wetland fragment.	Groundwater and surface water abstraction have the potential to have a large effect on groundwater levels and surface water flows within a wetland fragment.	Estimate the maximum rate of take and how often abstraction occurs. Based on this, decide if further more detailed monitoring is necessary. This might involve keeping a record of abstraction from bores / surface takes which already have flow meters installed or it may	If flow meter installed, collation of data on monthly basis. If no flow meter, then obtain an estimate of flow and ask the landowner to keep a record of the pumping

Indicator	Components	Reasons for Monitoring	Type of Monitoring	Frequency
			involve installing flow meters where a site does not have one.	hours and provide on a monthly basis.
Groundwater Levels and Surface Water Flows	• Groundwater level in selected bores • Surface water level of exposed water surface in wetland and/or adjacent streams/ponds • Surface water flow in selected sites	Groundwater level and surface water flow monitoring is necessary to show: • Short-term and long-term trends in surface water / groundwater inflows/outflows to the wetland fragments, including, effects of climate changes, and effects of localised and regional surface water / groundwater abstraction, • Show different wetland types. Different classes of wetlands have different regimes in terms of groundwater level variations, surface water flows, and rainfall input. Monitoring groundwater and surface water would be a way to help identify these. • Connection between groundwater and surface water; and • Its effect on the overall water balance.	Groundwater level readings from at least one bore near the wetland identified from: • an existing private bore that is either not used or used infrequently, or • install some shallow piezometers. Surface water level readings from a staff gauge installed in the wetland, a nearby pond, or stream. Surface water flow readings from at least one stream or drain. The surface water flow monitoring will depend on wetland type as some wetlands may receive no surface water inflows. Qualitative monitoring of surface water flows and levels can be undertaken through taking photos fortnightly from a fixed known position. Overtime this will generate a visual history of flows. Spot gauging can be then used to provide more accurate estimates of flow related to the photo images. Local land-owners could monitor groundwater and surface water levels themselves. They may need to be supplied with a water level meter. Surface water flow monitoring will require a suitably skilled person with the right equipment.	Groundwater / surface water level readings should generally be taken at fortnightly intervals in order to assess long-term trends. Data loggers could also be installed in order to obtain a more detailed record. Data will need to be collated on a monthly basis. Surface water flow measurements through spot gauging fortnightly
Springs	• Location, type, and discharge rate of springs	Springs occur where groundwater discharges to the land surface and these often feed surface water. This is not necessity to monitor if groundwater levels and surface water flows / levels are being monitored.	A survey of the location, type, discharge rate and other relevant information should be undertaken to determine areas sensitive to changes in groundwater levels. Discharge rate will be measured over a v-notch weir (or similar) or can install a pipe and	One off check for presence and size of springs If large spring present, the discharge rate measured on fortnightly basis.

Indicator	Components	Reasons for Monitoring	Type of Monitoring	Frequency
		However, if there are large springs present which contribute a large percentage of the flow then these should be monitored.	measure from a bucket or measure from a channel that the spring drains into.	
Drainage	• Presence of surface and tile drains • Clearance of existing drains • Removal of drains	An understanding of any changes to the management practices around the wetland is important for interpretation of the results of the monitoring.	Identification and mapping of surface and sub-surface drains, location and frequency of drain clearance, as well as any removal of drainage.	Collation of changes on an annual basis.
SURFACE WATER AND GROUNDWATER QUALITY				
Water Quality	• Surface water quality • Groundwater quality	Wetlands have a key role in removing contaminants. This monitoring will indicate the impact of wetlands on water quality passing through the wetland and by extrapolation will indicate the importance of the wetland to water quality in the catchment as a whole. Over time, this will also enable an assessment of the impact of restoration works undertaken on water quality. The monitoring will include monitoring of the water coming into and discharged from the wetlands, including surface water and/or ground water dependent upon the wetland type.	<u>Groundwater</u> Two existing bores should be selected, one up gradient and the other down-gradient from the wetland. Levels determined and samples will be collected from the bores for analysis for the suite of parameters included in the ES SOE monitoring. <u>Surface water</u> If possible, a site representative of the incoming water to the wetland and one of the discharge from the wetland will be selected. This should be the same sites as that where water level is monitored (refer hydrology above). Samples will be collected from the sites for analysis for the suite of parameters included in the ES SOE monitoring. Sample collection will need to be undertaken by a suitably trained person or through the use of loggers. Sampling could be implemented through funding its inclusion in the ES SOE monitoring.	Monthly (manual collection) or continuous (loggers)

Indicator	Components	Reasons for Monitoring	Type of Monitoring	Frequency
TERRESTRIAL AND AQUATIC ECOLOGY				
Wetland extent	• Wetland area • Connectivity	The size and extent of the wetland is a key determinant of its ecosystem function and long-term viability.	Mapping of vegetation extent from aerial photography. Comparison in change in wetland extent over time.	Every 2-5 years
Ecosystem intactness **Dominance of native plants**	• Vegetation cover	Degree of intactness and size is important to determine the ability of a wetland to maintain its long-term viability and resilience. An increase in the intactness and in most cases size of a wetland improves habitat quality, life supporting capacity and ecological services. The degree to which native plants have been displaced by introduced plants (mostly invasive weed species) can modify wetland function.	Photopoint Monitoring (Qualitative): Fixed photo points established to illustrate visual changes in vegetation cover over time. Vegetation Monitoring (Semi-quantitative) Fixed transects positioned along environmental gradients capturing vegetation types represented in the wetland with sampling plots located along transects in each vegetation types. The size of the plots will vary depending upon the wetland type; from 2m x 2m plots in rushland, sedgeland, cushionfield vegetation to 5m x 5m plots on scrub and shrubland vegetation. Observations to include: • change in cover by dominant species and change in species abundance and composition. • change in cover and rate of regeneration of introduced species within different indigenous vegetation types.	Annually Every 2-5 years.
Predation, browsing and grazing regimes	• Damage by domestic or feral animals • Predator impacts on wildlife	Browsing pressure and trampling effects by feral and domestic animals can damage plants and soils, altering ecological functions. Predators can impact local bird, herpetofauna and invertebrate populations, including nationally and regionally threatened and at risk species.	Walk over surveys with fixed photo points to observe presence of stock, pugging, trampling of vegetation and dung and identification of scats. Pest animal monitoring through observation of pest sign and/or deployment of tracking tunnels. Five minute bird counts at fixed locations within habitat types represented in wetland.	Annually

Indicator	Components	Reasons for Monitoring	Type of Monitoring	Frequency
Aquatic fauna	• Macroinvertebrate species abundance and composition	Changes in wetland condition can affect the biodiversity of the fauna within the wetland	Aquatic macroinvertebrate monitoring using wetland MCI indices.	Every 2-5 years
Rare species	• Presence of rare flora or fauna	Presence of rare species is a key component of improved biodiversity	The location of any rare or threatened plant and animal species should be recorded and mapped. There can be targeted surveys or incidental observations during other monitoring. This information may need to be treated with caution should there be a risk of illegal collecting.	Identification during other surveys

8.3 Reporting

Reporting of restoration activities and the results of the monitoring is important to ensure to demonstrate the result of the programme and to ensure that knowledge is transferred. Reporting recommended for the project includes:

- **Annual Summary Report.** This will identify the restoration works undertaken and the monitoring carried out. Detailed analysis will not be carried out at this frequency. It should also identify the outcomes of any external projects that had been undertaken and reported during the past year. This will provide a useful ongoing identification and review of relevant information.
- **Five-Yearly Outcomes Report.** This will be undertaken approximately every five years in the middle of the project and again towards the end. It will present the findings of restoration work and monitoring undertaken, including analysis of data and recommendations for the next five years.

8.3.1 Annual Report

This report will summarise the works undertaken under on private properties in the catchment and the data collected during monitoring. The report will be prepared for each financial year of the project after the close of the year (April).

The annual report will collate data gathered on a catchment-wide and site-specific basis including:

- Climate
- Groundwater levels
- Stream flows
- Surface water and groundwater quality
- Ecology monitoring
- Site-specific wetland monitoring
- Restoration works undertaken on the ground, including dates, locations, areas, and nature of activities.
- Costs from the previous year, and projected budget for the following year.
- Results of projects that had been undertaken in the catchment by other agencies e.g. DairyNZ, other DOC departments or Environment Southland.

The annual report will not include significant analysis of the data collected, but is an identification and collation exercise to ensure that the appropriate data is being adequately collected and to ensure that data quality is being maintained.

8.3.2 Five-Yearly Report

This report will be undertaken on a five-yearly basis and will include more detailed analysis and critique of the data collected and recommendations for modifications to the programme on the basis of these results. The data collected will be analysed to identify trends and ensure that the monitoring regime is providing sufficient information and to evaluate whether certain aspects of the monitoring is required to continue. These reports will clearly identify any lessons learnt through the project in a manner which can be clearly articulated project stakeholders to ensure that this information can be passed on.

Restoration Works

The report should document what works have been undertaken on a catchment scale and within each private property. As far as possible this information should be collected in Excel and GIS format so that it can readily collated and analysed.

The report will document the extent and nature of the works completed, including:

- landowners engaged in the programme
- length of fencing, and areas of riparian or wetland habitat that have been fenced

- any drainage works that have been undertaken
- specific changes to land use practices around the wetlands
- extent of planting undertaken (e.g. numbers of plants)
- extent of weed control and animal pest control (e.g. labour hours / volume of spray / numbers of pests)
- Costs.

Climate, Hydrology and Hydrogeology

At a general level, the hydrological data should be analysed to determine:

- Trends in climate, groundwater levels and surface water flows over time
- Any trends that can be correlated with key ecological or water quality parameters
- A record of any new drains or old drains which are removed
- Processes which show how water interacts within the wetland fragments e.g. what is the effect on groundwater levels and surface water flows as a result of blocking / decommissioning surface and or tile drains.

For selected sites, a water balance can be calculated. A water balance brings climate, groundwater and surface water monitoring data together in order to assess the changes in water storage and the overall hydrological state of a wetland. The water balance for the monitored wetlands will be determined in this report in order to assess changes in the hydrological regime over time. A consistent decrease in the total change in storage may show that the wetland is under stress.

The report will identify any management required to restore hydrological regime in the wetlands that have been monitored, such as removal of tile drains, filling of cut-off drains.

Water Quality

The water quality data collected throughout the catchment through the Environment Southland State of the Environment Programme and the seven additional sites should be analysed for compliance with the relevant environmental guidelines. Any trends in surface water or groundwater quality should be identified.

The water quality information gathered at site-specific wetlands should be reviewed to determine:

- Trends in water quality over time, especially in response to physical works undertaken
- Changes in water quality across the wetlands (e.g. water quality treatment)
- Connections between water quality and level/flow information (e.g. impacts on water quantity).

Ecology

At a general level, the recorded ecological data should be analysed on a catchment scale and site-by-site basis to determine:

- Location and area of wetlands, including protected and unprotected sites
- Change in extent of native and introduced plant cover
- Presence of native flora and fauna including rare or threatened species
- Change in predator sign and/or numbers
- Any changes in management affecting the wetlands e.g. land use changes, drainage, vegetation clearance or planting
- Any other trends in wetland function that can be correlated with key ecological or water quality parameters.

The report will identify any physical works required to restore wetland fragments, establish corridors between wetlands or whether any wetland planting or pest control should be undertaken.

8.4 Living Water Outcomes

The Living Water Programme has identified a number of key performance areas, objectives and ten year outcomes. Table 8-3 identifies how the recommendations from this report will achieve the required outcomes in the Waituna Catchment.

Table 8-3: Manner in which Living Water Outcomes are achieved

Objectives	Ten Year Outcomes	Recommended Actions
Achieve biodiversity and water quality improvement		
1. *Protect aquatic values by maintaining and enhancing the water regime and water quality.*	1.1 Maintained or re-established water regime (water levels, duration and seasonality) which enhances aquatic values.	Wetland hydrological monitoring programme will determine water regime in wetlands and allow informed changes to be developed to restore aquatic values. Effects of physical works on restoring aquatic values will be monitored through the wetland monitoring programme.
	1.2. Rates of sediment deposition are minimised	The fencing and planting of wetlands will reduce the amount of sediment entering the streams. The proposed continued catchment scale monitoring programme will enable the assessment of the sediment concentrations in the main streams.
	1.3 Maintained or enhanced water quality	Catchment scale water quality monitoring will allow assessment of the overall effect on catchment and lagoon water quality throughout the project Wetland water quality monitoring programme will determine water quality in wetlands and treatment functions. Proposed land use changes and restoration works to enhance water quality is to be undertaken. Effects of restoration works to be monitored through the wetland monitoring programme
2. *Maintain or restore indigenous ecosystem condition.*	2.1 Condition of indigenous habitat is maintained or restored.	Monitoring programme allows an understanding of the habitat condition in the wetlands. Fencing, pest control and/or planting of wetlands will improve indigenous habitat.
	2.2 Current extent of indigenous habitat in the management area is maintained or increased.	Catchment vegetation mapping will determine extent of all vegetation types over the whole catchment at intervals through the project Extent of wetland habitat is to be mapped and monitored on a regular basis. Wetlands will be fenced and pest programmes implemented.
	2.3 Area of indigenous habitat under legal protection is increased (on public or private land).	The mapping, monitoring and physical works in wetlands on private land may lead to increased uptake of legal protection by land owners involved.

Objectives	Ten Year Outcomes	Recommended Actions
3. *Maintain and enhance indigenous species diversity and threatened species.*	3.1. Maintained or enhanced diversity and abundance of the representative range of indigenous species and guilds.	Wetland monitoring will enable accurate understanding of the range of species present (both plant and bird) and any changes over the project. Physical works such as fencing, and pest control and restoration of water regime will improve habitat and likely diversity and abundance of indigenous species.
	3.2. Maintained or improved abundance and distribution of target threatened species.	As for 3.1 The presence of threatened species will be recorded and mapped during monitoring.
Develop environmental sustainability on-farm and off-farm		
4. *Integrate land and water management on and off farm to improve catchment health and support production*	4.1 Project management integrates environmental, cultural, economic, social and recreational values on and off-farm	The monitoring programme and reporting of the results at stages throughout the project will allow findings to be disseminated quickly to maximise the benefit to the farming community and natural environment.
	4.1 Farmers achieve demonstrated improvements in on-farm sustainability indicators (e.g. riparian protection, biodiversity integration, nutrient balance, effluent management, water use management).	Monitoring will enable the accurate identification the various factors that can influence wetlands on the property. This will enable the identification of practices on farm and physical works which will improve the health of the wetlands.
4. Foster a close working partnership with iwi		
5. *Work with iwi, hapu & whanau to recognise and provide for the values of Mātauranga Maori.*	5.1 Iwi, hapu, whanau partnerships developed and strengthened	There are various elements of the programme where interaction and involvement of iwi is possible and would be highly beneficial.
	5.2 Cultural values recognised and protected	As 5.1
	5.3 Iwi, hapu and whanau participate in management and sustainability at the site	As 5.1
Achieve engagement and participation of stakeholders, landholders and community		
6. *Engage with other agencies, landholders, community organisations and stakeholders*	6.1 Catchment and site management actions jointly developed with agencies, farming community and stakeholders	The proposed restoration actions and monitoring on private land will be implemented in consultation and agreement with landowners.
7. *Fully involve Fonterra suppliers and other landholders in restoration initiatives*	7.1 Site management actions jointly implemented with Fonterra suppliers and other landholders.	We have identified a number of places where the programme could be implemented for efficiently through cooperation with other parties.

Objectives	Ten Year Outcomes	Recommended Actions
8. Foster community participation in conservation and sustainability initiatives	8.1 The community, public and DOC/Fonterra employees participate in conservation and sustainability management at the site.	The restoration and monitoring proposed will involve close cooperation with landowners and potentially community groups.
Promote the programme; conservation and sustainability values; and best practice management		
9. *Promote conservation, sustainable farming and the outcomes from the Living Water Programme.*	9.1. The community and visitors appreciate the conservation and sustainability values and the outcomes at the project site	The monitoring programme will enable the clear determination of the ecological condition of the wetlands and their importance to the functioning of the catchment. The proposed reporting will communicate project outcomes and enable ongoing feedback and involvement with stakeholders.
	9.2. Fonterra suppliers and employees support the conservation and sustainability values and the outcomes at the project site	The monitoring and physical works proposed has been prioritised initially to the wetlands on land owned by Fonterra suppliers. For further information on prioritised sites, please refer to the wetland prioritisation report (MWH, 2017).
10. Develop, share and communicate best practice methods for protecting and restoring aquatic ecosystems	10.1 Best practice methods (ecological and farming) developed and shared with farmers, managers and community	The monitoring and reporting will enable the dissemination of information generated by the project on an ongoing basis and facilitate the development of best practice methods.
Raise and maintain a positive profile of Fonterra and DOC		
11. Raise and maintain a positive public, shareholder and staff profile of Fonterra and DOC through the programme	11.1 Favourable public perception of DOC and Fonterra is achieved through the programme	Results of restoration and monitoring will be reported to ensure transparency with project stakeholders and the public.
	11.2 Favourable farmer perception of DOC and Fonterra is achieved through the programme	The restoration and monitoring activities proposed will involve close consultation with farmers.
	11.3 Improved employee perception of DOC/Fonterra partnership is achieved through the programme	Results of restoration and monitoring will be reported to ensure transparency with project stakeholders (including DOC/Fonterra staff) and the public.

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Holmes, R., Goodwin, E., & Allen, C. (2015). *Riparian and Tuna Habitat Quality in the Tributaries of Waituna Lagoon, Southland.* Nelson: Prepared by Cawthron Institute for the DOC/Fonterra Partnership Living Water Programme.

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Appendices

Appendix A Information Sources

Literature

Report Name and Description	Water Quantity	Water Quality	Ecology
AgResearch (2012) Potential for Controlled Drainage to Decrease Nitrogen and Phosphorous Losses to Waituna Lagoon. Prepared for Environment Southland by AgResearch Limited June 2012		Covers controlled drainage methods that may decrease nitrogen and phosphorous losses to Waituna Lagoon.	
AgResearch (2013). Science Summary and Overseer Analysis of the Waituna Catchment (RE500/2013/074). Prepared by AgResearch Limited June 2013.		Summarises sources of nutrients primarily using Overseer. Not reviewed	
Aqualinc (2014). Regional scale stratification of southland's water quality – guidance for water and land management. Prepared for Southland Regional Council by Aqualinc Research Limited.		High level regional scale study of the State of Southland's water quality. Predominantly focuses on four estuaries not Waituna Lagoon.	
Aquanet (2010). Review of state of the environment water quality monitoring programme. Prepared by Aquanet Consulting Ltd for Environment Southland.		Recommends improvements to SOE monitoring. Not reviewed	
Boffa Miskell (2010). Awarua/Waituna Wetlands. Hydrology and vegetation mapping methodology, vegetation descriptions and recommendations. Prepared for Department of Conservation by Boffa Miskell Limited and Urtica Inc. March 2010.	Discussion of wetland hydrosystems and wetland class based on various methods of mapping.		Discussion on wetland classes in the conservation estate and private land. Categorisation of wetland classes in the conservation estate to structural and vegetation class levels. Classification of the historic extent of wetlands to hydrosystem level but not wetland class level due to difficulties in aerial photography interpretation.
Burbery, L. (2012). Analysis of groundwater level data: Waituna Lagoon. Prepared for Environment Southland. Report No. 1008-2-R1.	Eigen modelling of groundwater levels in various bores in order to estimate groundwater residence times and degree of hydraulic connection between groundwater and surface water.		

Report Name and Description	Water Quantity	Water Quality	Ecology
Dairy NZ (2015). Hydrological report of Waituna Catchment. Yet to be released.	Surface water report not reviewed.		
Elliot, S. (2012). Comparison of catchment modelling approaches for the Waituna Lagoon catchment. Prepared for Environment Southland by NIWA, 27th February 2012.	Provides a description and comparison of the capabilities of two different surface water models known as SWAT and CLUES and there applicability for use in the Waituna Catchment.		
EMA. (2013). Waituna Creek Southland Rehabilitation and Enhancement Issues and Options.			Guidelines for stream rehabilitation and enhancement measures.
Environment Southland (2011). Surface water quality – Waituna Catchment. Prepared by Kirsten Meijer. June 2011		Outlines surface water quality within the Waituna Catchment based on SOE monitoring. Provide recommendations for future monitoring.	
Environment Southland (2011). Regional mapping of groundwater denitrification potential and aquifer sensitivity. Prepared by Clint Rissmann for Environment Southland November 2011.		Report models the capacity of aquifers in Southland to attenuate or remove nitrogen.	
Environment Southland (2012). The extent of nitrate in Southland groundwaters: regional 5 year median (2007-2012 (June)) technical reports. Prepared by Dr Clint Rissmann for Environment Southland in July 2012.		Summarises nitrate contamination from human sources in groundwater around Southland.	
Environment Southland (2012). Update on Waituna Drain Clearing Project. Prepared by Andy Hicks for Environment Southland		Summary of water quality results following two drain clearing events.	
Environment Southland (2013). Waituna science bibliography February 2013.	Summary of scientific and technical reports on Waituna Catchment with some of the reports specifically focused on groundwater and surface water processes at a catchment scale.	Summary of scientific and technical reports relating to Waituna Lagoon – little information specifically relating to water chemistry	Summary of scientific and technical reports relating to Waituna Lagoon with some reports on aquatic flora, aquatic plant dynamics and vegetation sequences.

Report Name and Description	Water Quantity	Water Quality	Ecology
Environment Southland (2013). Nitrogen, phosphorous and sediment losses from rural land uses in Southland. Prepared by Environment Southland in August 2013.		Report predicts nitrogen, phosphorous and sediment losses from various land uses. Not reviewed.	
Environment Southland (2013). Ecological Guidelines for Waituna Lagoon. Prepared by Environment Southland in December 2013.		Document provides management guidelines for Waituna Lagoon including water quality targets.	
GNS Science (2014). The suitability of in situ filters and bioreactors for treating nutrient discharges in Southland. Prepared by GNS Science for Environment Southland February 2014.		Outlines the use of denitrifying bioreactors and phosphorous sorbent filters and proposes a pilot study for trials in Southland.	
Jackson, R., Phillips, C., and Ekanayake, E., (2001). Hydrology of the Waituna Lagoon. Prepared for Department of Conservation by Landcare Research, report number LC0001/139, July 2001.	Report provides a discussion on the effects of water levels changes in Waituna Lagoon on soil moisture levels in adjacent farmland. Key finding was that Lagoon is not well coupled to the drainage of farmland and that the largest effect on drainage is rainfall.		
Lincoln Environmental and MWH (Morgan, M., Evans, C.) (2003). Southland Water Resources Study – Stages 1 to 3. Report prepared for Venture Southland. Report No. 4597/1.	Region wide report on water resources in Southland looking at the potential long term water requirements, capacity to meet requirements, water resources that would come under the most stress and reliability of supply.		
Lincoln Agritech in Press. Proposal to undertake a hydrogeological and hydrological review of the waituna catchment.	Surface water and groundwater report not reviewed.		
Liquid Fuels Trust Board (LFTB). 1986. Ashers-Waituna deposit. Resource definition, geotechnical, hydrology and mine planning studies. Prepared by Liquid Fuels Trust Board for the Ministry of Economic Development. Coal Report Series CR2543. New Zealand.	Groundwater report. Not found for review.		

Report Name and Description	Water Quantity	Water Quality	Ecology
NIWA (2012). The effect of drain clearing on water quality of receiving environments. Prepared for Andy Hicks, Environment Southland by NIWA.		Summarises effects from drain clearing, including elevated TSS and TP. Recommends best practice approaches.	
NIWA, (2013). Assessment of potential constructed wetland sites within the Waituna Catchment. Prepared for Environment Southland and DairyNZ. Report No. HAM2013-071.	Investigate options and costs for constructed wetlands. Some background information on the major streams.	Mainly focuses on appropriate sites for constructed wetlands, some generally information about loads within Waituna and Moffat Creeks	Investigate options and costs for constructed wetlands. Information provided on suitable wetland vegetation, locations and construction approaches
Opus (2010). Southland water 2010: our ecosystems technical report for lakes and lagoons. Prepared for Environment Southland by Opus International Consultants Limited.		Includes water quality trends for Waituna Lagoon and assesses the possibility of the lake ‘flipping’.	
Thompson R.M & Ryder G.R (2003). Waituna Lagoon: summary of existing knowledge and identification of knowledge gaps. Prepared by Thompson and Ryder for the Department of Conservation January 2003.		Summarises available information about Waituna Lagoon, identifies gaps of knowledge at the time of writing and makes recommendations for future research and management.	Summarises available information about Waituna Lagoon, identifies gaps of knowledge at the time of writing and makes recommendations for future research and management including further botanical and faunal surveys.
Rekker, J.H., (1994). Southland regional groundwater resource; scoping study. Report to Southland Regional Council from AquaFirma Ltd.	Regional study of groundwater in Southland at a time when groundwater usage was starting ton increase. Very little reference to Waituna Catchment.	Regional study of groundwater quality in Southland at a time when groundwater usage was starting to increase. Very little reference to Waituna Catchment.	
Rekker, J.H., (1997). Hydrological Studies into the groundwater contribution to streams and rivers in Southland. Prepared for Southland Regional Council by AquaFirma Limited, Dunedin. 48p.	Hydrological study into the groundwater contribution to streams and rivers in Southland. No reference made to Waituna Catchment but work was done in the neighboring Waihopai Catchment.		

Report Name and Description	Water Quantity	Water Quality	Ecology
Rissmann, C., Wilson, K., and Hughes, B. (2012). Waituna Catchment groundwater resource. Technical report. Prepared for Environment Southland.	Summary of groundwater quantity, quality processes, trends and monitoring within the Waituna Catchment.	Includes characterization of groundwater based on hydrochemistry including identifying anthropogenic signatures, effects of redox and assessment of water quality compared with ANZECC and NZDWS.	
Ryder Consulting (2008). Waituna Lagoon – review of existing information relating to opening regime. Prepared by Ryder Consulting by the Department of Conservation, Southland Conservancy in October 2008.		The report compiles existing information at the time of writing that was relevant to the existing opening regime of the lagoon. Not reviewed	
Ryder Consulting (2013). Environmental Effects of Activities within the Riparian Zone. Prepared by Ryder Consulting for Environment Southland March 2013.		Report identifies positive and negative effects of various riparian margin activities. Not reviewed	Report identifies effects of various riparian margin activities on aquatic biodiversity and habitat quality.
Ryder, G. (2013). Waituna Catchment. Stocktake exercise: Science component. Prepared for Waituna Partners Group November 2013.	Summary of a number of papers on surface water and groundwater related to Waituna Lagoon and the Waituna Catchment with contributions from Waituna Technical Strategy.	General summary of other projects to date – little helpful water quality information.	Summary of several papers on macrophyte monitoring and effects of eutrophication on aquatic flora in the Waituna Lagoon.
Ryder, G. (2013). Waituna Creek Rebattering. Assessment of ecological effects. October 2013			Report characterising the existing Waituna Creek environment and assessing potential effects of rebattering works on Waituna Creek ecosystems
Southern Geophysical (2014). Geophysical investigation: Waituna Catchment, Southland. Report prepared for Environment Southland and NZ Dairy.	Geophysical investigation to determine the near surface geophysical character of the Waituna Catchment to assist in the modelling of the groundwater infiltration paths.		

Report Name and Description	Water Quantity	Water Quality	Ecology
Wilson, K.L. 2011. Groundwater in the Waituna Catchment. Environment Southland Technical Comment, 23rd March 2011. 23p.	This report provides a compilation of available groundwater information and subsequent analysis in order to identify potential impacts on surface water and groundwater resources within the Waituna Catchment.	Some comment on groundwater quality in the catchment with reference to sample results.	
Wilson, K.L. 2011. Update on groundwater activities and proposed projects in the Waituna Catchment. Environment Southland Technical Comment, 21st June 2011. File reference 218/04/12. 11p.	Groundwater report. Not reviewed.	Generally outlines research questions that need further work.	

Data Used for Hydraulic Modelling

Source	Water Quantity	Water Quality
Department of Conservation	• Map of the lower Waituna Creek 1962. • Waituna Creek Historic Maps. • ESRI GIS shapefile on private wetland fragments including information on wetland hydrosystems, wetland classes and sources of water.	
Environment Southland	• Bore logs • Groundwater levels • Bore construction details • Aquifer type • Aquifer test and specific capacity data • Consented groundwater takes • Groundwater level monitoring site details • No data on consented surface water takes as there are no consented takes within the Waituna Catchment apart from those less than 2 L/s which are a permitted activity. • Surface water flow monitoring sites and electronic copies of the time series data. • Water level data for Waituna Lagoon. • Climate station data from Lawsons Road and Waghorns Road.	• Groundwater quality data • Surface water quality data • Waituna Lagoon platform telemetry data • Waituna Lagoon water quality data
GNS	• Regional groundwater model (model under construction).	

GIS Data

A summary of all data available and collated for the purposes of this investigation is provided below.

Name	Source	Description	Metadata	National	Regional	Local
BASE INFORMATION						
Aerial photos 0.4m 2013-2014	LINZ	Aerial photography	Imagery flown for ES summer 2013-2014			✓
Aerial photos 0.75m 2005-2011	LINZ	Aerial photography	LINZ dataset			✓
Cadastral boundaries	LINZ	Property boundaries in and around Waituna	LINZ dataset			✓
NZ Coastlines Topo 1500k	LINZ	NZ coastline	LINZ dataset	✓		
NZ Mainland Contours Topo 150k	LINZ	20m contours	LINZ dataset			✓
NZ Mainland Topo 50 Maps	LINZ	Topographical map 1:250,000 scale	LINZ dataset			✓
NZ Mainland Topo 250 Maps	LINZ	Topographical maps 1:50,000 scale	LINZ dataset			✓
NZ Roads Centerlines Topo 1500k	LINZ	Local roads in and around Waituna	LINZ dataset			✓
Shademodel	LINZ	Digital elevation, topography	LINZ dataset	✓		
Waituna Catchment Boundary Oct 13	DOC	Waituna Catchment boundary	Unknown			✓
HYDROLOGY & WETLANDS						
Awarua Rivers	DOC	Rivers and streams within or near the Waituna Catchment	NZM260 topographical maps			✓
NZ Mainland Lake Polygons Topo 150k	LINZ	NZ freshwater lakes. Includes the Waituna Lagoon, farm ponds and some wetlands.	LINZ dataset	✓		
NZ Mainland River Centerlines Topo 150k	LINZ	Rivers in and around Waituna. Less extensive than “Awarua Rivers” dataset.	LINZ dataset			✓

Name	Source	Description	Metadata	National	Regional	Local
NZ Mainland River Polygons Topo 150k	LINZ	Major rivers in NZ	LINZ dataset	✓		
NZ Mainland Swamp Polygons Topo 150K	LINZ	Swamps from topographical maps. Loactions and some names.	LINZ dataset	✓		
QEII Wetland Waituna	DOC	Location of QEII covenanted wetlands within and near the Waituna Catchment	DOC dataset			✓
Wetlands Current Waituna	DOC	Location and extent of current wetlands with details of vegetation types, soil type etc.	Unknown	✓		
Wetlands Historic Waituna	DOC	Location and extent of historic wetlands and wetland type	Unknown			✓
Wetland Private Waituna	DOC	Location and extent of wetlands and watercourses on private land	Boffa Miskell & Urtica 2008 survey			✓
2012 Private Wetlands	DOC modified by MWH	Location and extent of wetlands and watercourses on private land, with wetlands identified as "gone" in the "Waituna Wetland Loss" removed	Generated by MWH from DOC data			✓
Wetland Public Waituna	DOC	Location and extent of wetlands and watercourses on DOC land	Unknown			✓
Waituna Wetland Loss	DOC	Location and extent of wetlands within and near Waituna Catchment (note: shows more wetlands than "Wetlands Historic Waituna") includes identification of status in 1990 and 2012	DOC dataset			✓
HYDROGEOLOGY						
All Bores	MWH	Summary of all ES bores within the Waituna Catchment. Includes bore ID, location, depth.	ES data			✓
Aquifer Drawdown	MWH	Location of all ES consented wells within a 2km radius of the Waituna Catchment, showing the extent of drawdown in the surrounding groundwater in the unconfined aquifer	Generated by MWH from ES data			✓
Climate Stations	MWH	Location of climate stations monitored by Environment Southland and NIWA Cliflo	Compilation of data from existing reports			✓
Consented GW Takes All Clip	MWH	All consented GW takes within a 2km radius of the Waituna Catchment boundary as of April 2015.	ES Consents excel spreadsheet			✓
Groundwater Dipping Data	Environment Southland	Groundwater levels in wells monitored by ES within the Waituna Catchment (15/01/1997 – 18/12/2014	ES data			✓

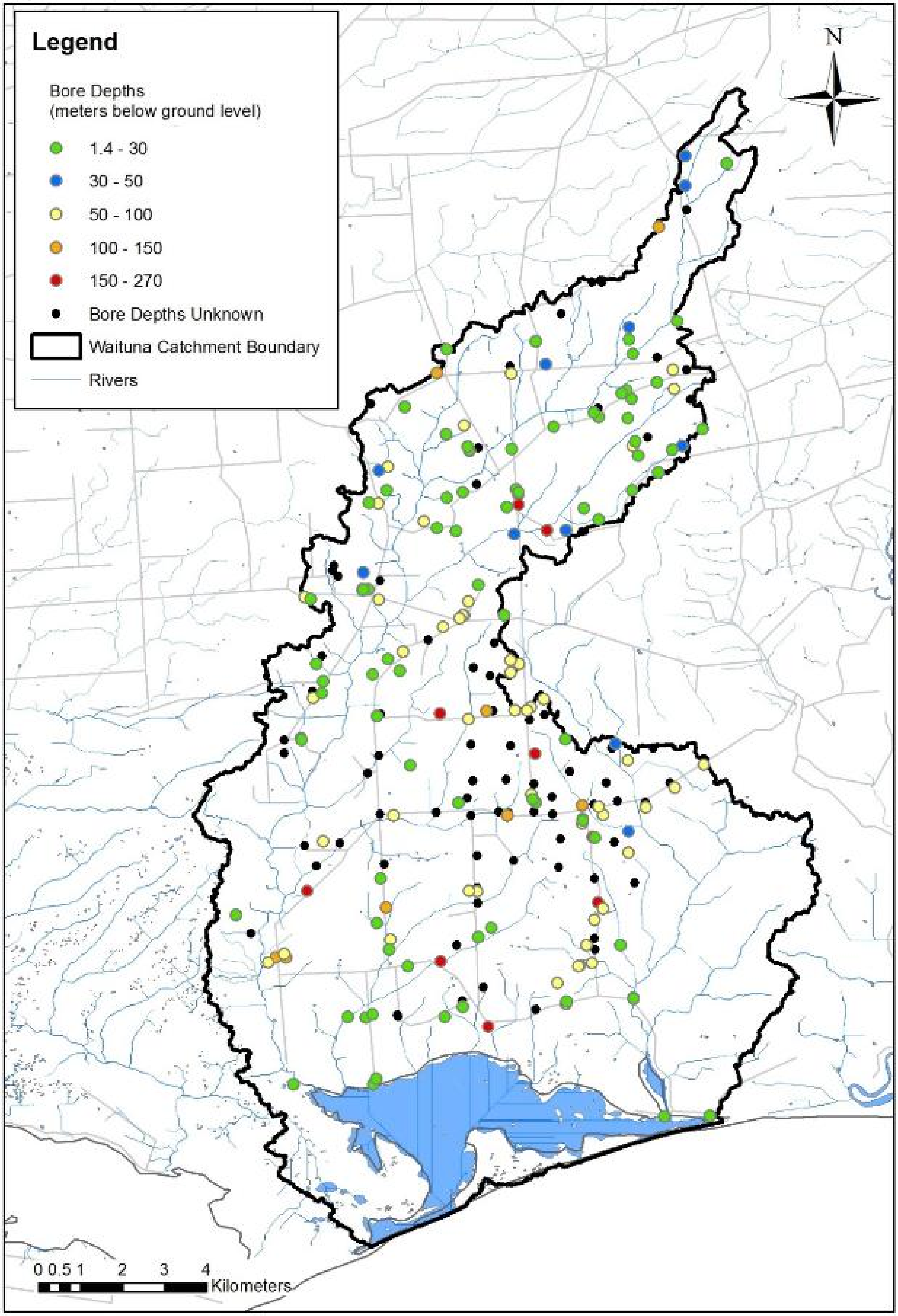
Name	Source	Description	Metadata	National	Regional	Local
GW Levels Bores Greater 30m	MWH	Bores within the Waituna Catchment >30m in depth from Groundwater Dipping Data	Generated by MWH from ES data			✓
GW Levels Bores Less than 30m	MWH	Bores within the Waituna Catchment <30m in depth from Groundwater Dipping Data	Generated by MWH from ES data			✓
Highest GW Levels	MWH	Highest GW level for bores <30m deep (unconfined aquifer)	Generated by MWH from ES data			
Lowest GW Levels	MWH	Lowest GW level for bores <30m deep (unconfined aquifer)	Generated by MWH from ES data			✓
Physiographic survey	Environment Southland	Broad zones of different physical and chemical properties of groundwater, relating to soil types.	Rissmann et al. (2012)		✓	
QMAP Murihiku	GNS Science	1:250,000 geological maps of NZ. Murihiku covers Southland, Gore, Invercargill, Stewart Island.	GNS Science data		✓	
Waituna Catchment Bore Log Data	Environment Southland	Location, depth, lithology and strata recorded at groundwater bores within the Waituna Catchment. No date of data.	ES data			✓
Surface Water Flow Continuous Monitoring Sites	Environment Southland	Continuous stream flow monitoring data.	ES data		✓	
AQUATIC ECOLOGY						
ES Monitoring Sites	ES	ES State of the Environment “ecosystem sites” monitored annually for macroinvertebrates, periphyton, sediment and fish. Location of annual EFM surveys.			✓	
ES Fish Monitoring	ES	ES fish monitoring sites. Location of annual EFM surveys.			✓	
FENZ_v1	Landcare	Collation of all FENZ layers (below)	FENZ	✓		
FENZ_v1_lakes	Landcare	National lake data based on lake polygons: • Lake catchments: catchment size & attributes • Lake classification: lake type based on physical environment attributes and expert knowledge • Lake pressures & rankings: lake quality ranking based on human pressures e.g. vege cover, nitrogen, exotic macrophytes, exotic fish, dams	FENZ	✓		

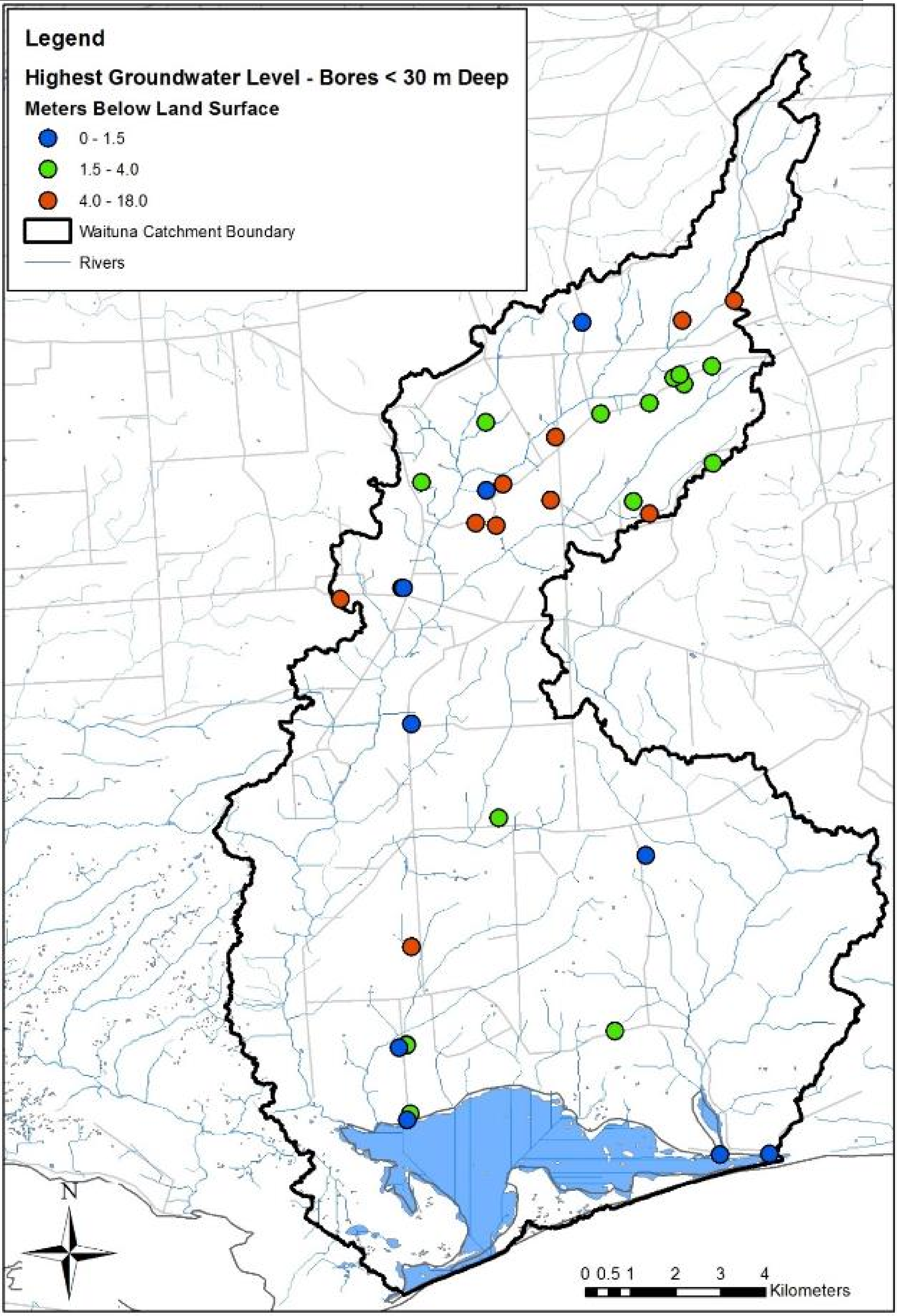
Name	Source	Description	Metadata	National	Regional	Local
FENZ_v1_rivers	Landcare	National river and stream data layers based on REC flow lines and catchments: • River predictors: physical environment data • Predicted fish distributions based on NZFFD • Predicted invertebrate distributions • River & stream classification: groups rivers that have similar environmental and biological attributes • River & stream pressures: human pressures on aquatic systems including exotic fish, mines, dams, vege, impervious surfaces, nitrogen • River & stream rankings: conservation rankings	FENZ	✓		
FENZ_v1_wetlands	Landcare	National wetlands data (mostly larger wetlands). • Wetland classification: Six wetland types adapted from Johnson and Gerbeaux (2004) • Historic wetlands typology: historic extent • Current wetlands sites: current wetland extent and pressures • Currently wetland typology: wetland types within each current wetland	FENZ and Ausseil et al (2008)	✓		
NZFFDA_2015_04_28	NIWA	NZ Freshwater Fish Database records fish species, abundance, size, sampling methods, location and physical description of fish sample sites.	NIWA NZFFD downloaded 28/04/15	✓		
WONI Biogeographic Provinces	DOC	Waters of National Importance for biodiversity (province boundaries)	FENZ Database	✓		
WONI Biogeographic Units	DOC	Waters of National Importance for biodiversity (unit/region boundaries)	FENZ Database	✓		
TERRESTRIAL ECOLOGY						
Extent Fire	DOC	Location and date of fires within and near the Waituna Catchment. Only one small fire recorded in the Waituna Catchment.	DOC dataset			✓

Name	Source	Description	Metadata	National	Regional	Local
HVA Surveys Completed 2007 to 29 April 2015	Environment Southland	Survey of High Value Areas	Ground-based surveys completed by DOC		✓	
Threatened Environments Classification 2012	DOC	NZ Threatened Environment Classification (threat classification criteria)	Landcare dataset	✓		
Land Environments New Zealand LENZ Level 4 Polygons	Online Database	NZ Threatened Environment Classification (LENZ Level 4 polygons only)	Landcare dataset	✓		
LCDB v40 Land Cover Database Version 40	Online Database	Land Cover Database v4.0 (LCDB v4.0) existing vegetation cover	Landcare dataset	✓		
Bioweb Herpetofauna Database	DOC	The BioWeb Herpetofauna Database includes species taxonomy information, species observation records and marked-animal observation records.	DOC Bioweb Database	✓		
Bioweb Threatened Plant Database	DOC	BioWeb Threatened Plants database contains national records of threatened plant species - distribution and abundance, and identification including pictures and alternative names.	DOC Bioweb Database	✓		
WATER QUALITY						
ES Groundwater Quality Monitoring Sites Waituna	Environment Southland	Location of ES groundwater monitoring sites cropped to the Waituna Catchment	ES data		✓	✓
L&M Groundwater Quality Monitoring Sites	MWH Reports	Location of eight groundwater monitoring sites monitored on behalf of L&M to collect baseline data.	L&M data			✓
L&M Surface Quality Monitoring Sites	MWH Reports	Location of two baseline surface water monitoring sites monitored on behalf of L&M.	L&M data			✓
ES Surface Water Quality Monitoring Sites	Environment Southland	Location of ES State of the Environment surface water monitoring sites cropped to the Waituna Catchment	ES data			✓

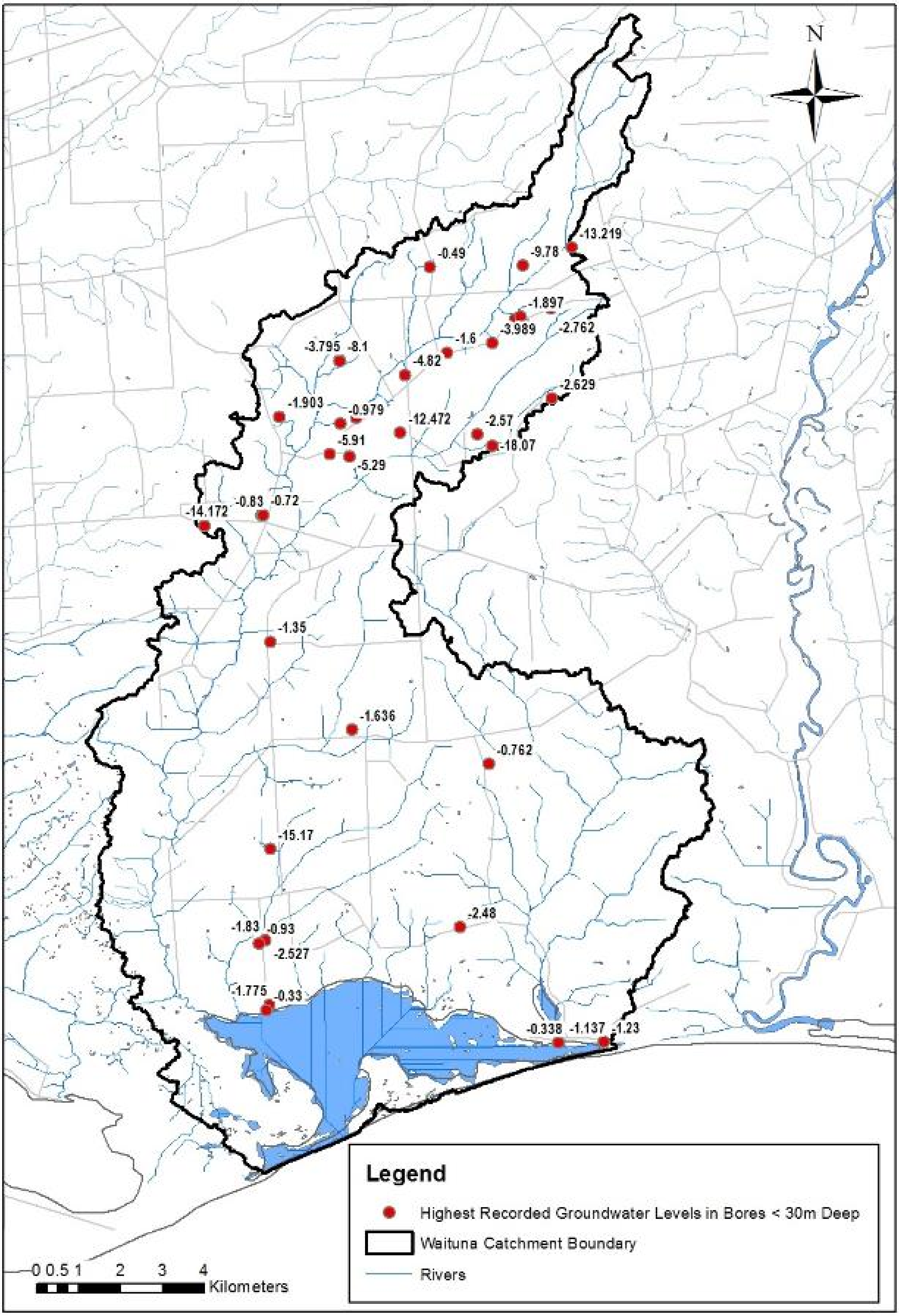
Appendix B Hydrology and Hydrogeology Data

Figures


Legend
Bore Depths
(meters below ground level)
1.4 - 30
30 - 50
50 - 100
100 - 150
150 - 270
Bore Depths Unknown
Waituna Catchment Boundary
Rivers
N
0 0.5 1 2 3 4
Kilometers



Legend
Highest Groundwater Level - Bores < 30 m Deep
Meters Below Land Surface
0 - 1.5
1.5 - 4.0
4.0 - 18.0
Waituna Catchment Boundary
Rivers
N
0 0.5 1 2 3 4
Kilometers


N
-13.219
-0.49
-9.78
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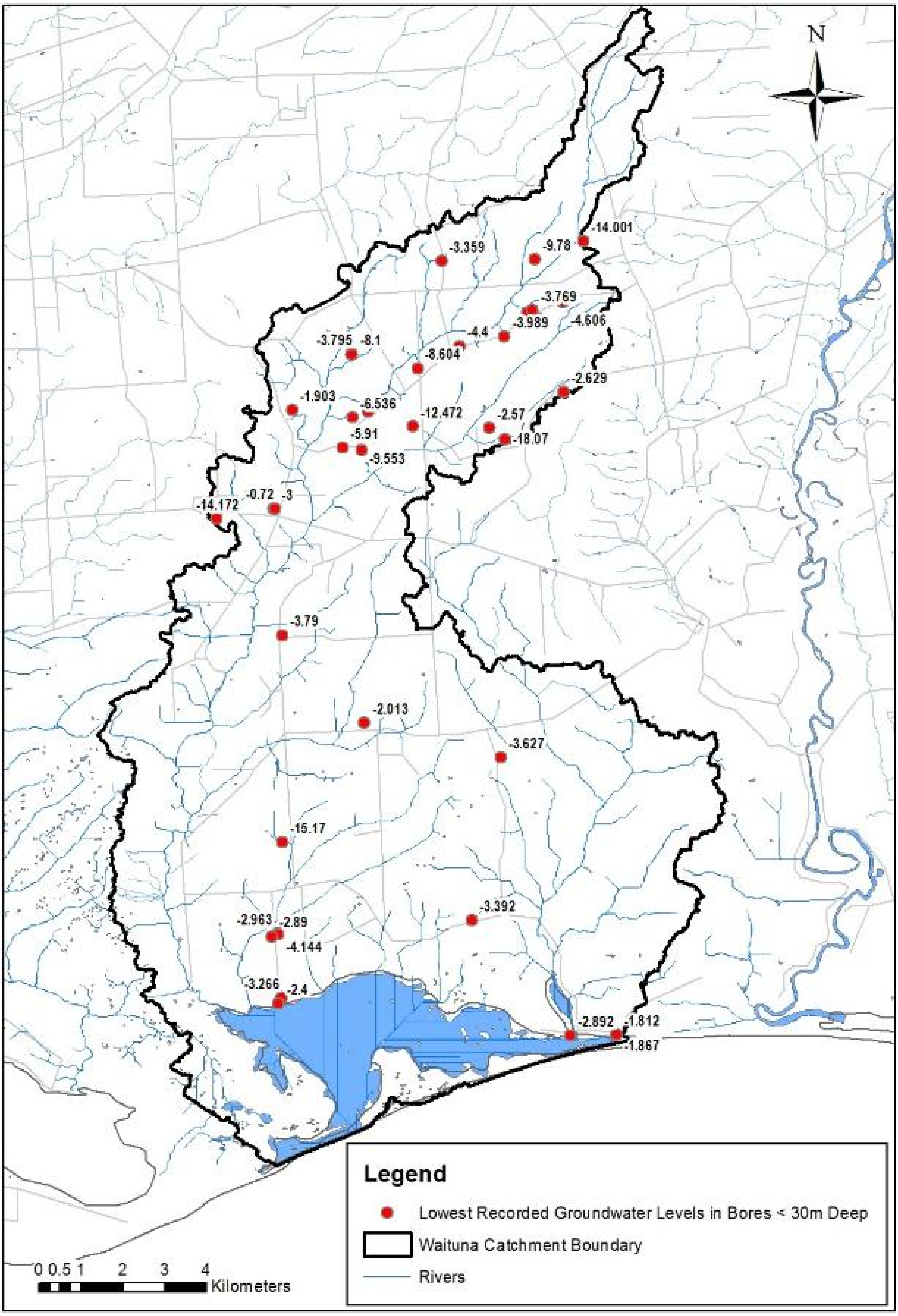
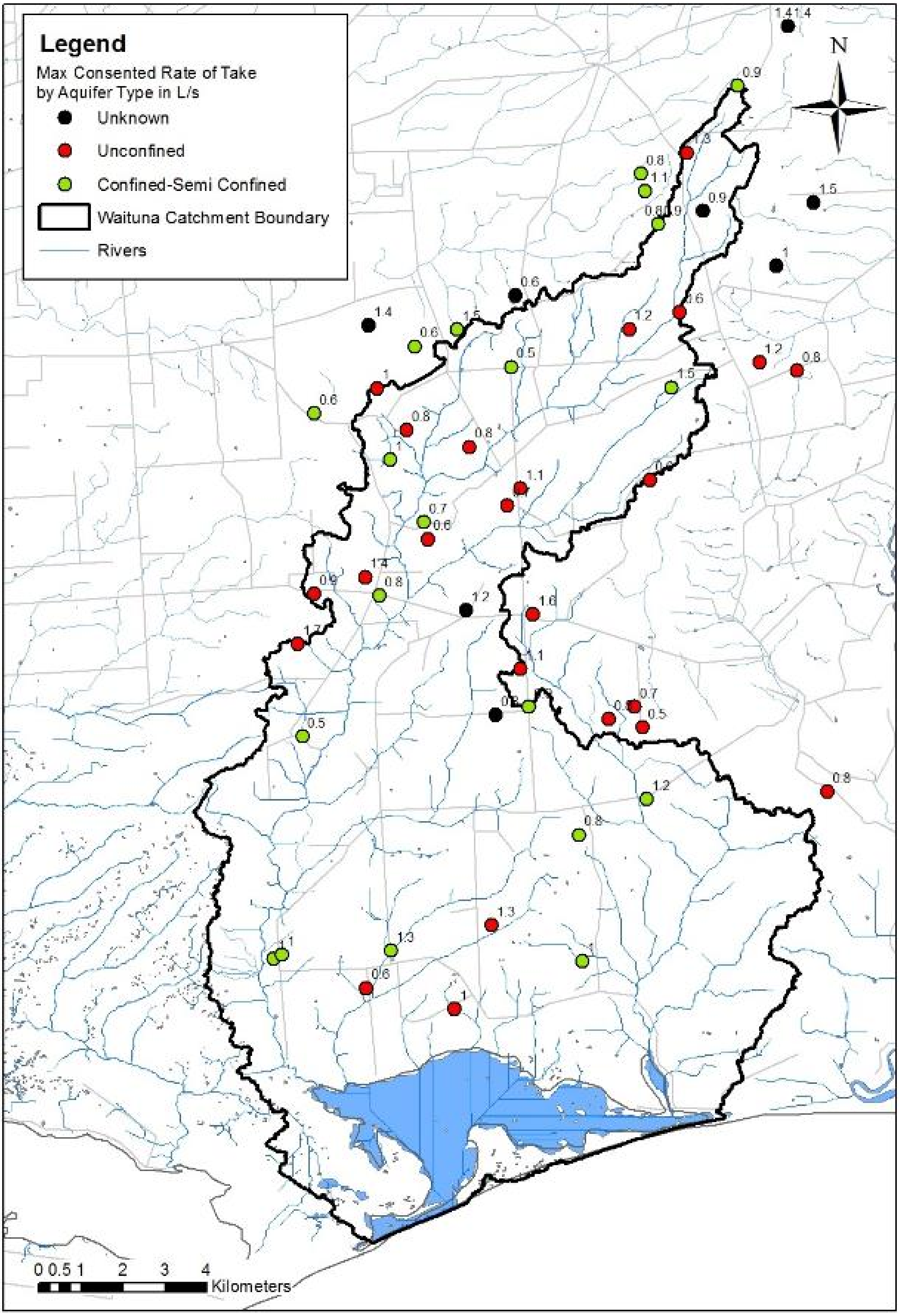
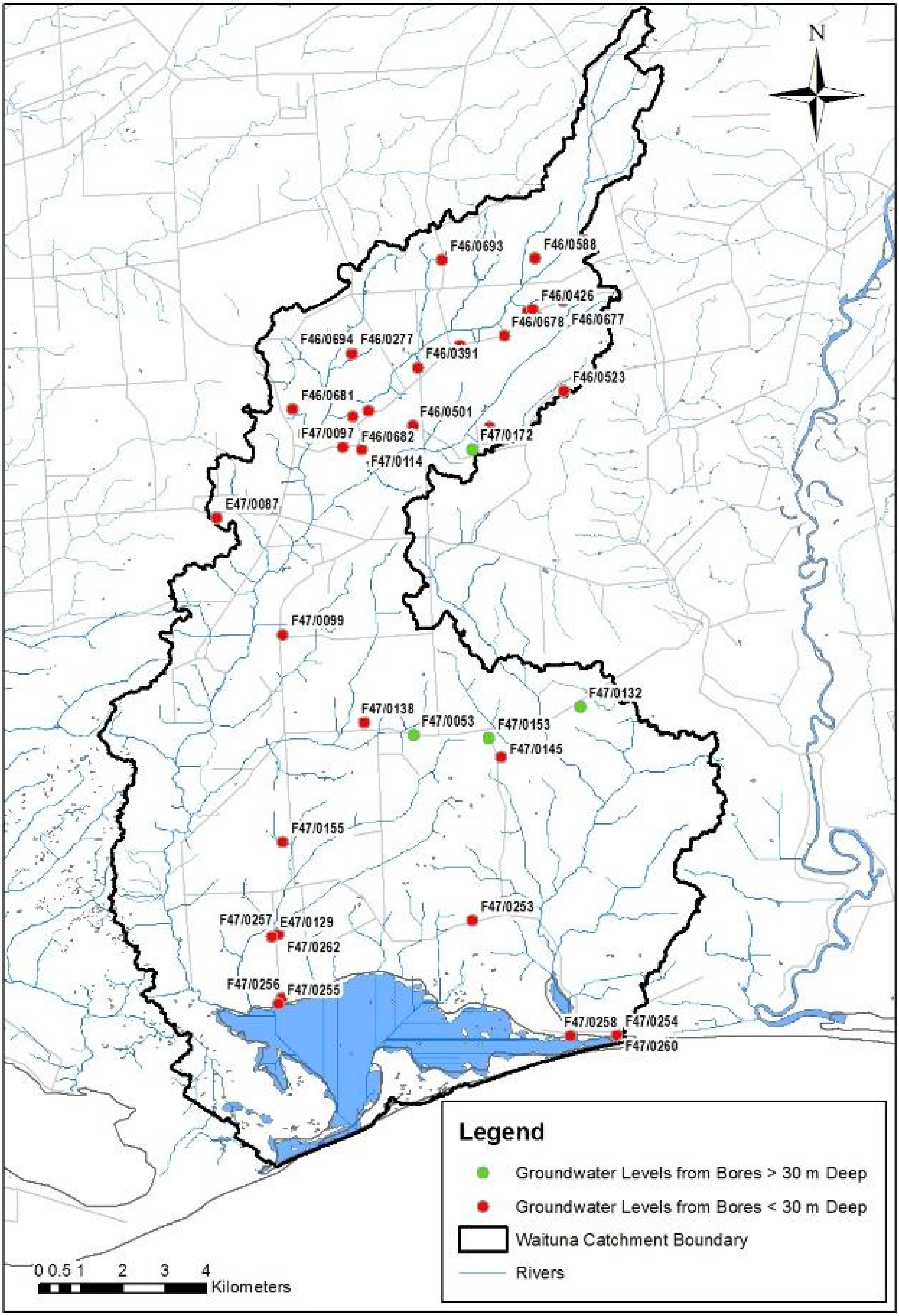
-3.989
-2.762
-3.795
-8.1
-1.6
-4.82
-2.629
-1.903
-0.979
-12.472
-2.57
-5.91
-18.07
-5.29
-0.83
-0.72
-14.172
-1.35
-1.636
-0.762
-15.17
-2.48
-1.83
-0.93
-2.527
-1.775
-0.33
-0.338
-1.137
-1.23
Legend
Highest Recorded Groundwater Levels in Bores < 30m Deep
Waituna Catchment Boundary
Rivers
0 0.5 1 2 3 4
Kilometers


N
-14.001
-9.78
-3.359
-3.769
-3.989
-4.606
-4.4
-3.795
-8.1
-8.604
-2.629
-1.903
-6.536
-12.472
-2.57
-5.91
-18.07
-9.553
-0.72
-3
-14.172
-3.79
-2.013
-3.627
-15.17
-3.392
-2.963
-2.89
-4.144
-3.266
-2.4
-2.892
-1.812
-1.867
Legend
Lowest Recorded Groundwater Levels in Bores < 30m Deep
Waituna Catchment Boundary
Rivers
0 0.5 1 2 3 4
Kilometers


Legend
Max Consented Rate of Take by Aquifer Type in L/s
Unknown
Unconfined
Confined-Semi Confined
Waituna Catchment Boundary
Rivers
N
0 0.5 1 2 3 4
Kilometers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F46/0693
F46/0588
F46/0426
F46/0678
F46/0677
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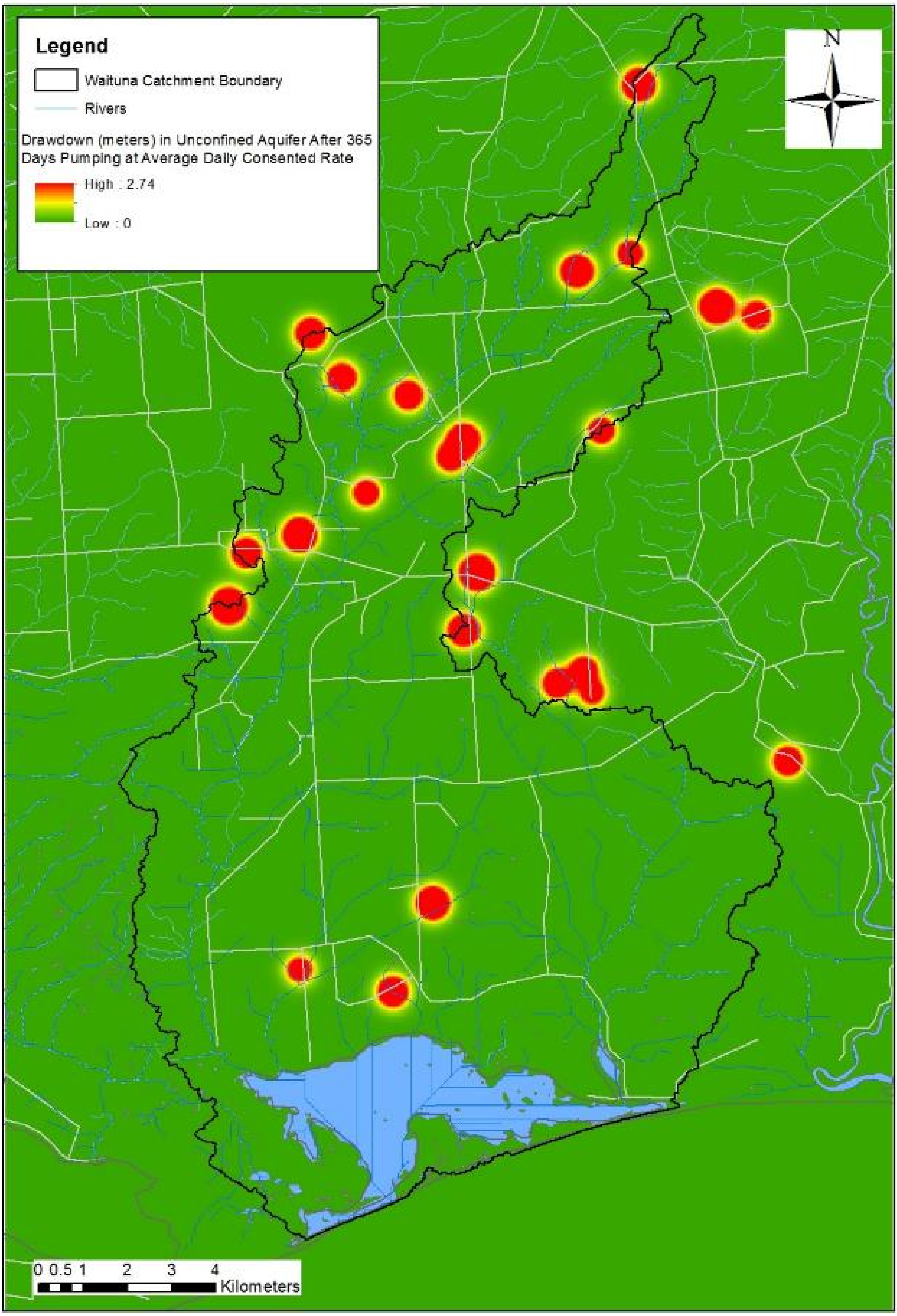
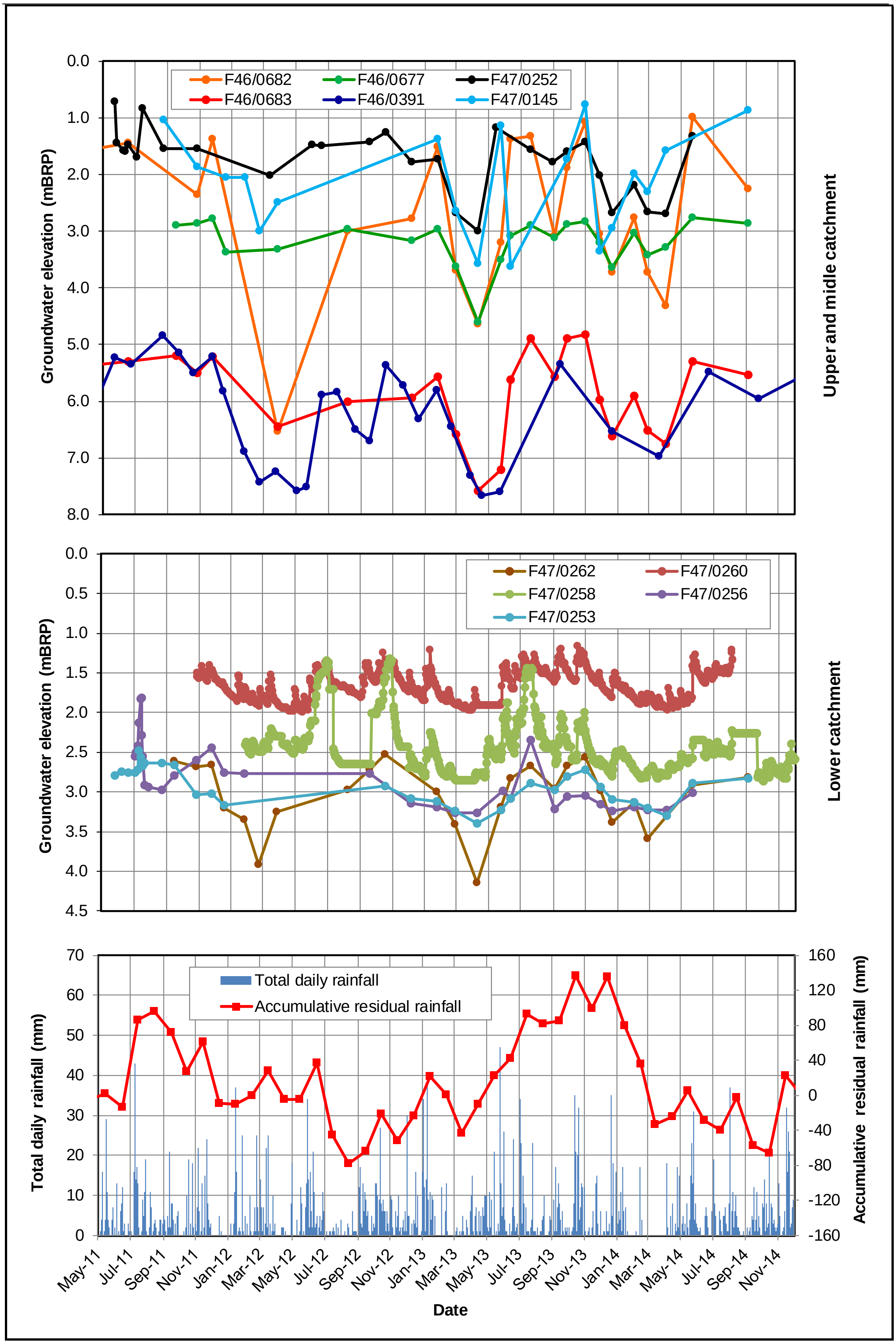
F46/0277
F46/0391
F46/0523
F46/0681
F46/0501
F47/0097
F46/0682
F47/0172
F47/0114
E47/0087
F47/0099
F47/0132
F47/0138
F47/0053
F47/0153
F47/0145
F47/0155
F47/0253
F47/0257
E47/0129
F47/0262
F47/0256
F47/0255
F47/0258
F47/0254
F47/0260
Legend
Groundwater Levels from Bores > 30 m Deep
Groundwater Levels from Bores < 30 m Deep
Waituna Catchment Boundary
Rivers
0 0.5 1 2 3 4
Kilometers


Legend
Waituna Catchment Boundary
Rivers
Drawdown (meters) in Unconfined Aquifer After 365 Days Pumping at Average Daily Consented Rate
High : 2.74
Low : 0
N
0 0.5 1 2 3 4
Kilometers


F46/0682
F46/0677
F47/0252
F46/0683
F46/0391
F47/0145
Groundwater elevation (mBRP)
Upper and midle catchment
F47/0262
F47/0260
F47/0258
F47/0256
F47/0253
Groundwater elevation (mBRP)
Lower catchment
Total daily rainfall
Accumulative residual rainfall
Total daily rainfall (mm)
Accumulative residual rainfall (mm)
May-11
Jul-11
Sep-11
Nov-11
Jan-12
Mar-12
May-12
Jul-12
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Date

Consented Groundwater Takes (May 2015)

a) Consented groundwater takes for bores screening the water table or <50m deep

Consent	Location of Consented Groundwater Take		Bore ID(s)	Maximum Daily Rate	Average Daily Rate Based on Maximum Seasonal Volume	Maximum Seasonal Volume
	Easting	Northing		L/s	L/s	m^3/yr
203300	1262296	4836134	F47/0136	1.0	0.8	24,528
204329	1260169	4846440	E47/0086 & F47/0181	1.4	1.1	34,748
204578	1263868	4848550	F46/0380	1.1	0.9	28,616
302360	1261162	4849946	F46/0277 & F46/0278	0.8	0.7	20,849
207385	1263192	4838138	F47/0232	1.3	1.0	32,120
300589	1267855	4856567	F46/0306	1.3	1.0	31,536
300760	1260192	4836629	E47/0129	0.6	0.4	14,016
301168	1263569	4848149	F46/0501	0.7	0.6	17,520
301313	1261669	4847344	F47/0114	0.6	0.5	15,768
203254	1264176	4845548	F47/0022	1.6	1.3	40,880
204702	1271197	4841325	F46/0734	0.8	0.7	21,024
206358	1265983	4843049	F47/0185	0.8	0.7	20,989
Unknown	1266463	4852360	F46/0588	1.2	1.0	30,660
205701	1258571	4844834	E47/0126	1.7	1.3	42,048
206376	1262665	4849549	F46/0809	0.8	0.7	21,024
300070	1260459	4850945	F46/0055	1.0	0.8	24,528
300433	1266971	4848757	F46/0226	0.6	0.5	16,294
301591	1267663	4852763	F46/0680	0.6	0.5	15,768
301727	1258969	4846036	E47/0087	0.9	0.7	22,776
202758	1266784	4842851	F45/0248	0.5	0.4	12,264
203491	1270469	4851368	F46/0436	0.8	0.6	18,980
204848	1269568	4851566	F47/0202	1.2	1.2	36,500
Unknown	1266583	4843351	F46/0304	0.7	0.6	17,520
206062	1263878	4844246	F46/0463	1.1	0.9	28,032
Unknown	1270250	4859580	F46/0421	1.4	1.1	35,040
Totals	-	-	-	**24.5**	**20.0**	**624,028**

b) Consented groundwater takes for bores screened within a confined / semi-confined aquifer or >50m deep.

Consent	Location of Consented Groundwater Take		Bore ID(s)	Maximum Daily Rate	Average Daily Rate Based on Maximum Seasonal Volume	Maximum Seasonal Volume
	Easting	Northing		L/s	L/s	m^3/yr
302575	1266840	4855648	F46/0563	1.1	0.9	28,032
202344	1260791	4837532	F47/0041	1.3	1.0	31,536
202709	1258959	4850341	E46/0728	0.6	0.5	16,352
203482	1263662	4851453	F46/0255	0.5	0.4	12,060
204054	1267158	4854864	F46/0636	0.8	0.6	20,440
204128	1262358	4852351	F46/0598	1.5	1.2	37,230
204157	1260764	4849244	F46/0645	1.0	0.8	24,487
204327	1261568	4847744	F47/0180	0.7	0.5	16,936
301802	1266755	4856065	F46/0744	0.8	0.7	20,989
205583	1267467	4850961	F46/0689 & F46/0759	1.5	1.2	38,544
205924	1257988	4837325	E47/0205	1.0	0.8	26,280
207422	1258188	4837425	E47/0107	1.0	0.8	24,528
300009	1258676	4842632	E47/0091	0.5	0.4	12,965
300098	1265276	4840287	F45/0152	0.8	0.6	20,148
300596	1266889	4841149	F47/0221	1.2	0.9	29,784
300669	1261358	4851948	F46/0274	0.6	0.4	14,016
300762	1267158	4854864	F46/0636	0.9	0.7	22,776
300177	1269053	4858172	F46/0741	0.9	0.7	22,776
301215	1260520	4845997	F47/0118	0.8	0.7	21,024
301282	1265346	4837266	F47/0120 & F47/0238	1.0	0.8	26,280
302137	1264080	4843350	F47/0283	0.9	0.7	22,776
Totals	-	-	-	**19.4**	**15.3**	**489,959**

c) Consented groundwater takes with insufficient information to determine the likely aquifer source.

Consent	Location of Consented Groundwater Take		Bore ID(s)	Maximum Daily Rate	Average Daily Rate Based on Maximum Seasonal Volume	Maximum Seasonal Volume
	Easting	Northing		L/s	L/s	m^3/yr
302018	1262574	4845644	F46/0086 & F46/0089	1.2	0.9	29,784
Unknown	1263758	4853155	Unknown	0.6	0.5	15,768
203182	1268228	4855186	F46/0875	0.9	0.8	23,944
206216	1260256	4852446	F46/0736	1.4	1.1	35,040
300700	1263280	4843143	F47/0151	0.8	0.7	20,989
204766	1269963	4853869	F45/0528	1.0	0.8	24,528
205578	1270860	4855373	F47/0188 & F47/0206	1.5	1.2	37,668
Unknown	1270250	4859580	F46/0422 & F46/0421	1.4	1.1	35,040
Totals	-	-	-	**8.8**	**7.1**	**222,761**

Climate Station Monitoring Site Details

Site Owner	Site Name	Easting	Northing	Location	Data Recorded
NIWA	Invercargill Aero - 5814	1241143	4848920	18 km from catchment	Daily rainfall (1939 to present) Raised pan (1972 to present) Sunken Pan (1966 to 1978) Evaporation (1960 to 2010)
NIWA	Tiwai Point - 5823	1245749	4830551	11 km from catchment	Evaporation (1991 – 2010)
NIWA	Awarua Plains - 5821	1245425	4838823	11 km from catchment	Rainfall (1917 – 1991)
NIWA	Woodlands - 5804	1259644	4857450	6 km from catchment	Rainfall (1971 – 1986)
ES	Lawsons Road	1267507	4833743	Within catchment	Rainfall (from December 2009)
ES	Waghorns Road	1260404	4843589	Within catchment	Air temp, solar radiation, barometric pressure, wind direction, wind speed, relative humidity (from May 2011)

Notes: Easting and northing are in NZTM2000 map projection

Environment Southland Historical Groundwater Level Monitoring Sites

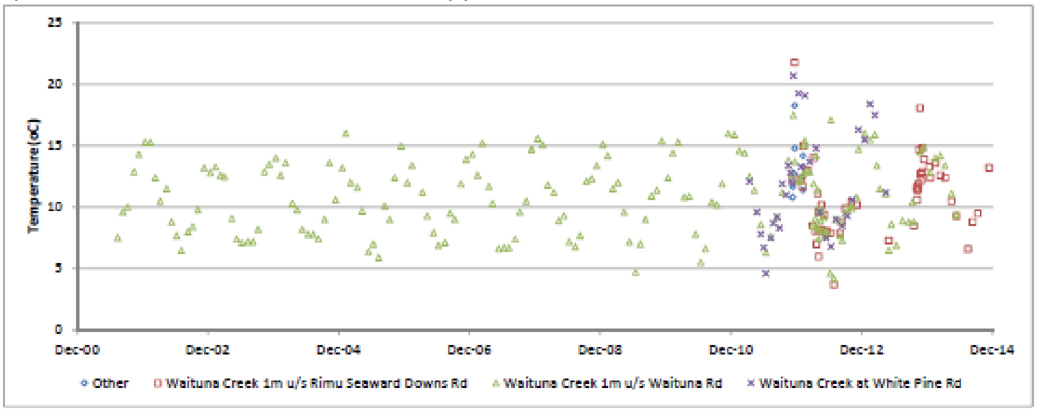
Site Owner	Bore ID	Easting	Northing	Bore Depth (mBGL)	Screened Interval (mBGL)	Monitoring Frequency
ES	F46/0391	1263704	4849590	18	Unknown	Monthly
ES	F46/0677	1267173	4851182	8	Unknown	Monthly
ES	F46/0682	1262160	4848414	10	Unknown	Monthly
ES	F46/0683	1262536	4848552	8.5	Unknown	Monthly
ES	F47/0053	1263605	4840836	131	60.4 - 73	Monthly
ES	F47/0145	1265702	4840304	7.9	Unknown	Monthly
ES	F47/0252	1260279	4846240	7	Unknown	Continuous
ES	F47/0253	1265016	4836404	7.35	Unknown	Monthly
ES	F47/0256	1260477	4834557	6	5 - 6	Continuous
ES	F47/0258	1267355	4833658	6	Unknown	Monthly
ES	F47/0260	1268446	4833667	6	Unknown	Continuous
ES	F47/0262	1260386	4836092	10.6	8.9 - 10.6	Monthly

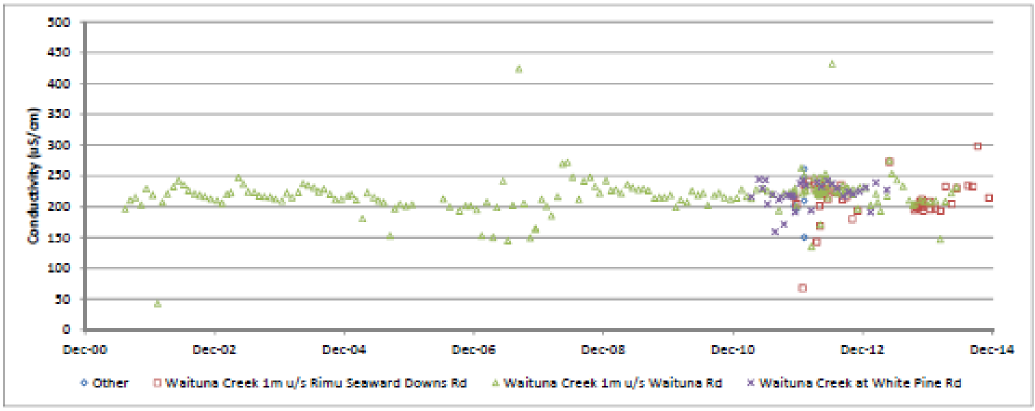
Notes: Easting and northing are in NZTM2000 map projection. mBGL is meters below ground level

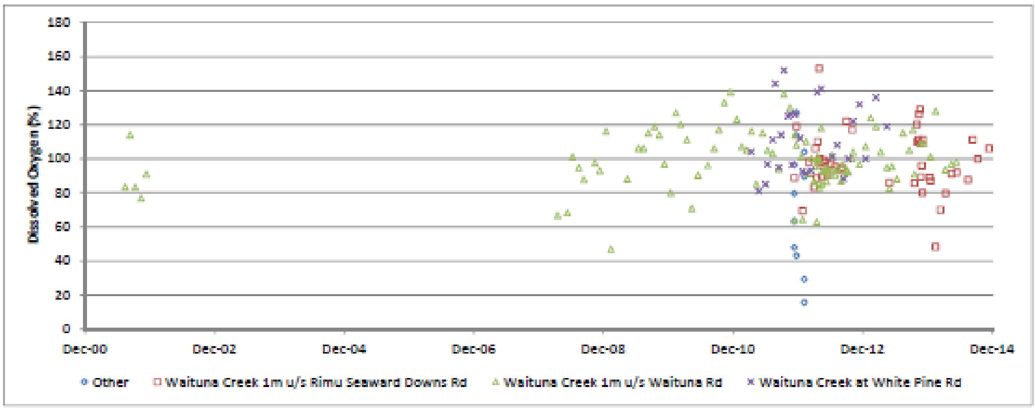
Appendix C Water Quality Monitoring Data

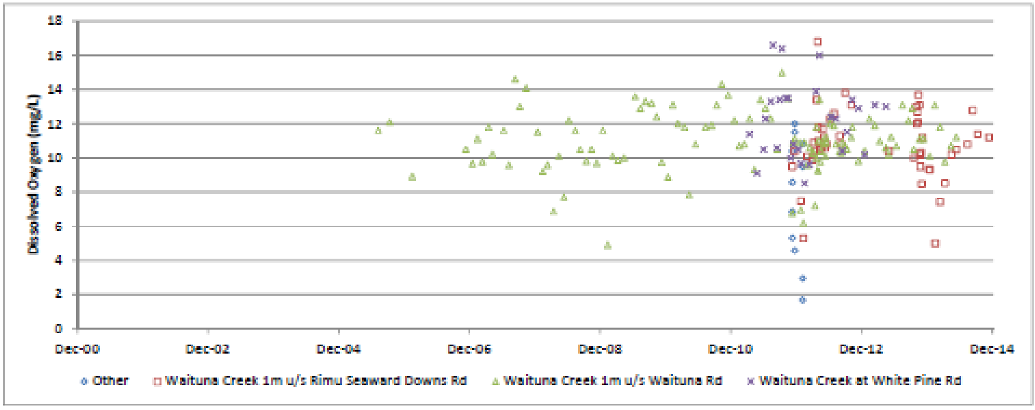
Surface Water Quality Graphs

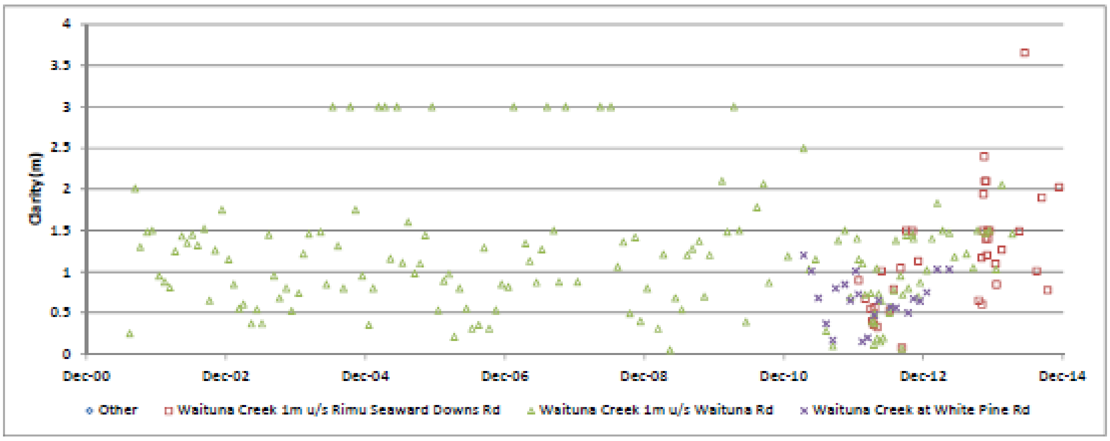
a) Waituna Creek Surface Water – Upper Catchment

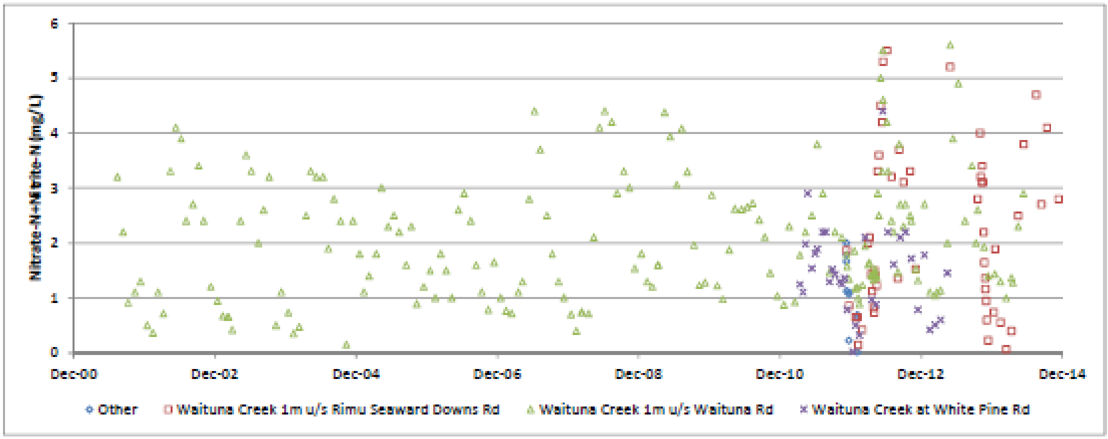


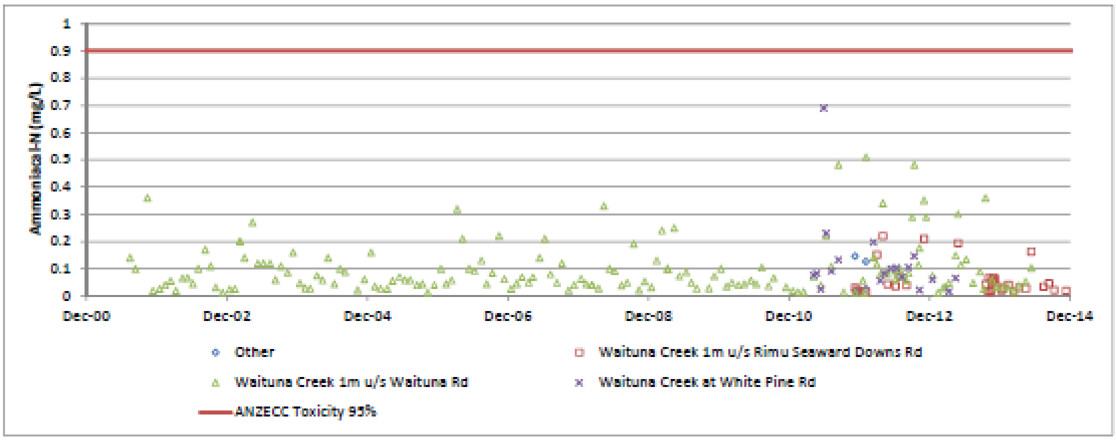


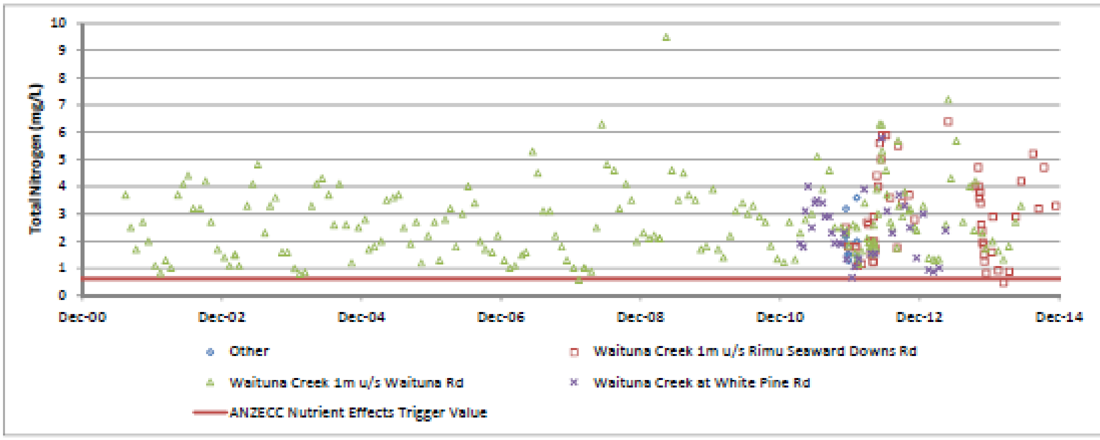


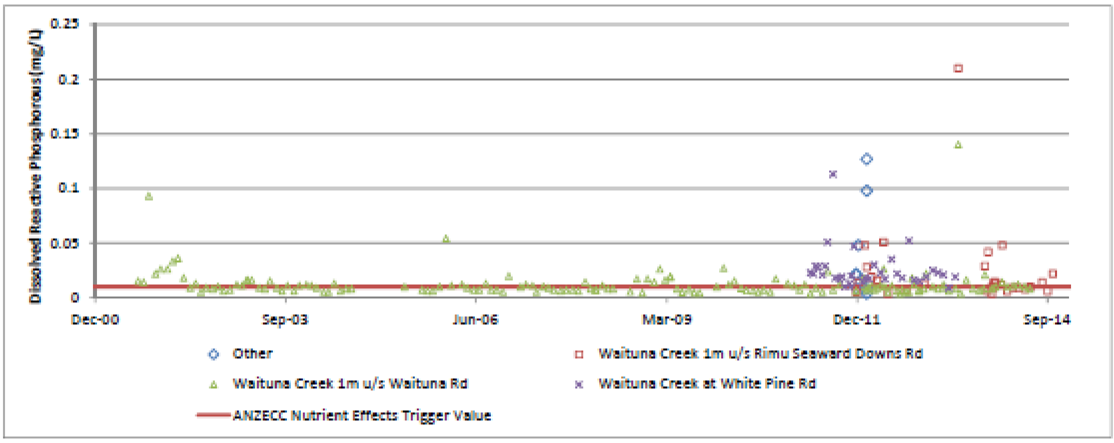



Clarity (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd

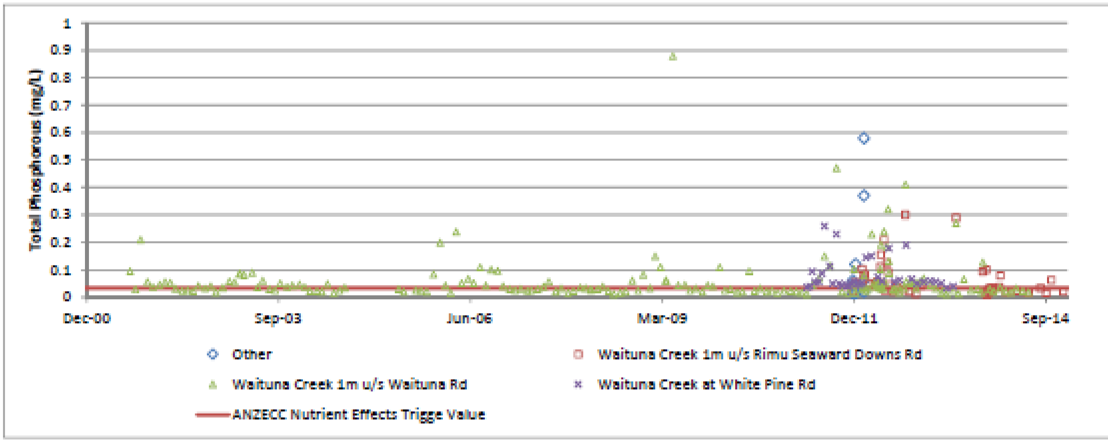

Nitrate-N+Nitrite-N (mg/L)
0
1
2
3
4
5
6
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd


Ammoniacal-N (mg/L)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd
ANZECC Toxicity 95%

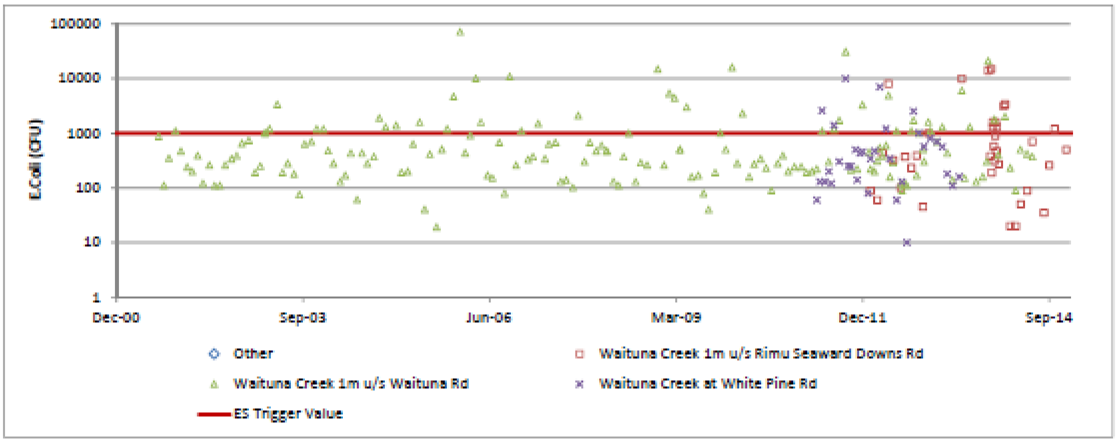

Total Nitrogen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd
ANZECC Nutrient Effects Trigger Value



Dissolved Reactive Phosphorous (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Dec-00
Sep-03
Jun-06
Mar-09
Dec-11
Sep-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd
ANZECC Nutrient Effects Trigger Value

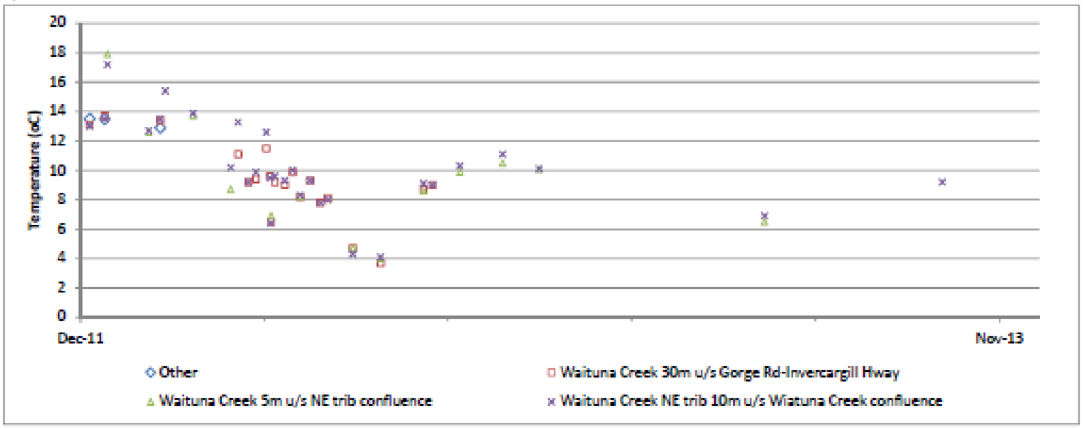


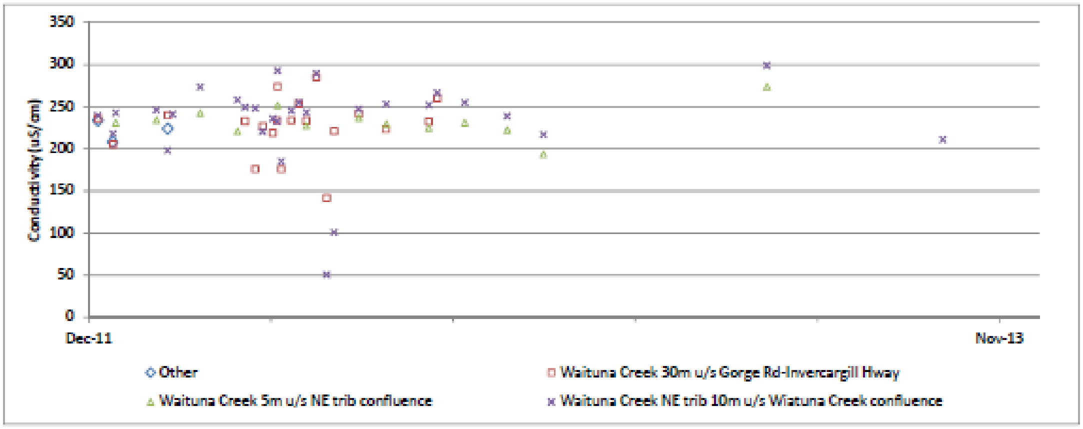
Total Phosphorous (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Dec-00
Sep-03
Jun-06
Mar-09
Dec-11
Sep-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd
ANZECC Nutrient Effects Trigge Value

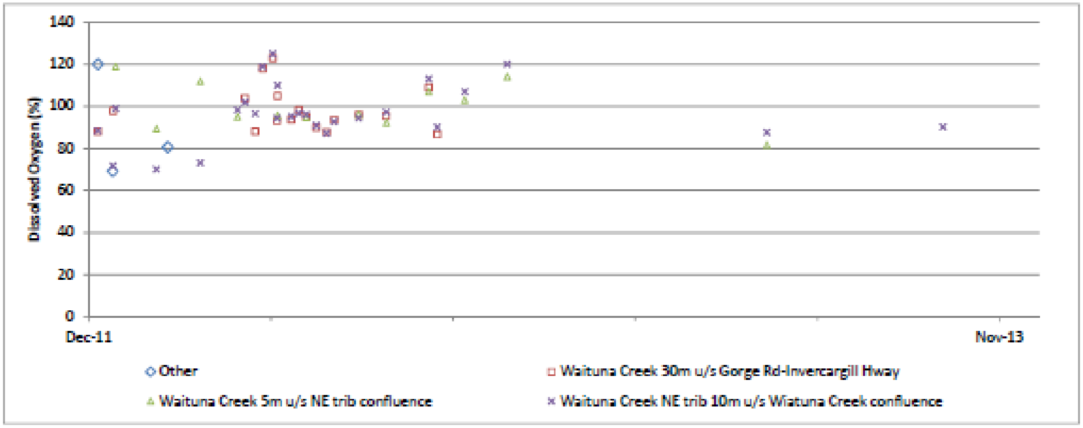


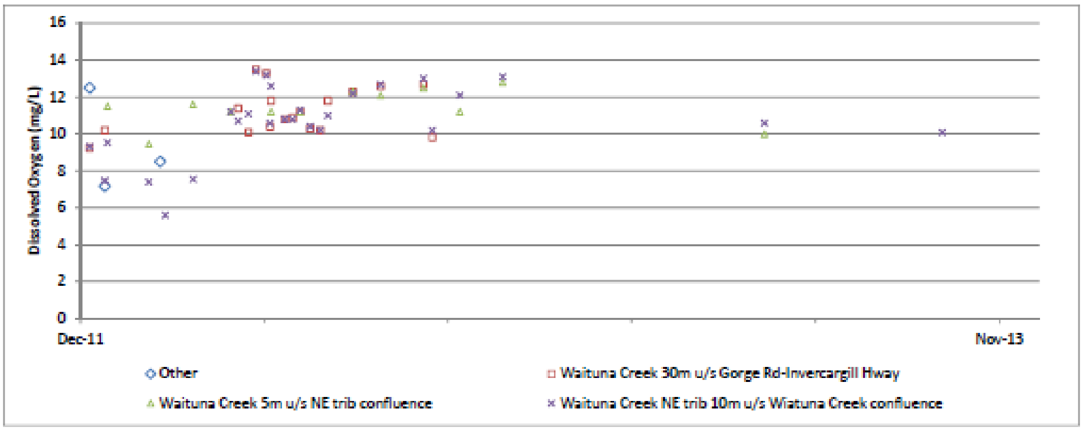
E.Coli (CFU)
100000
10000
1000
100
10
1
Dec-00
Sep-03
Jun-06
Mar-09
Dec-11
Sep-14
Other
Waituna Creek 1m u/s Rimu Seaward Downs Rd
Waituna Creek 1m u/s Waituna Rd
Waituna Creek at White Pine Rd
ES Trigger Value

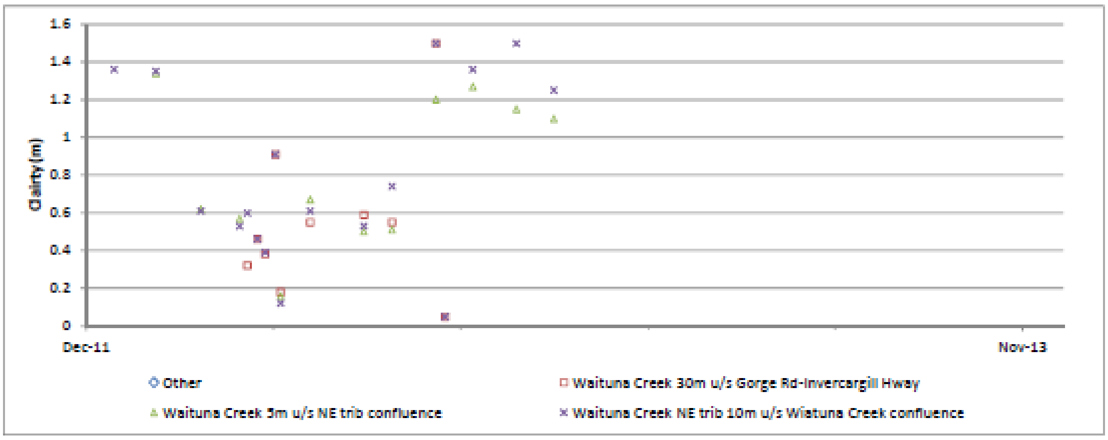
b) Waituna Creek Surface Water – Mid Catchment

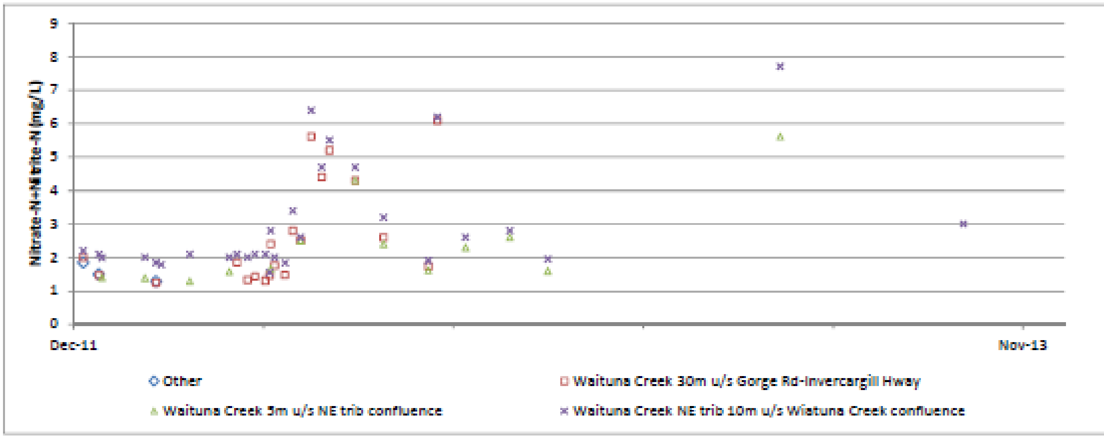


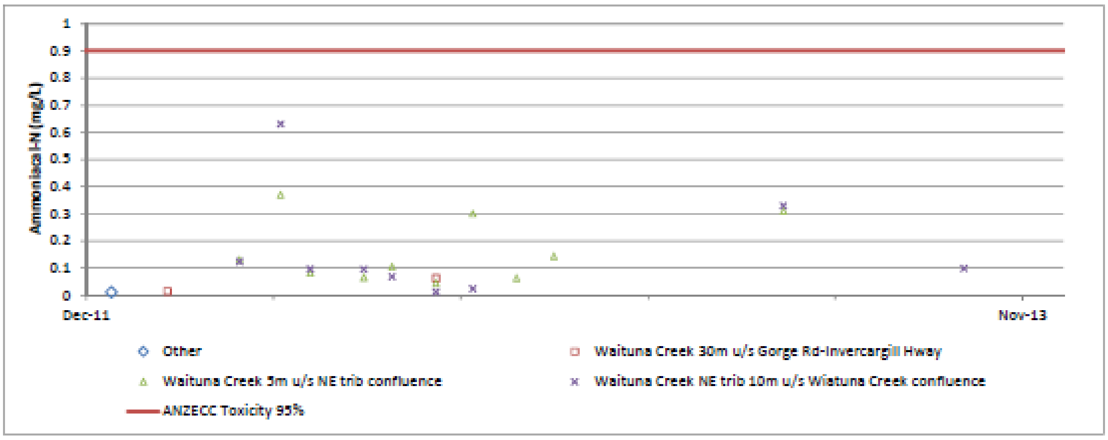


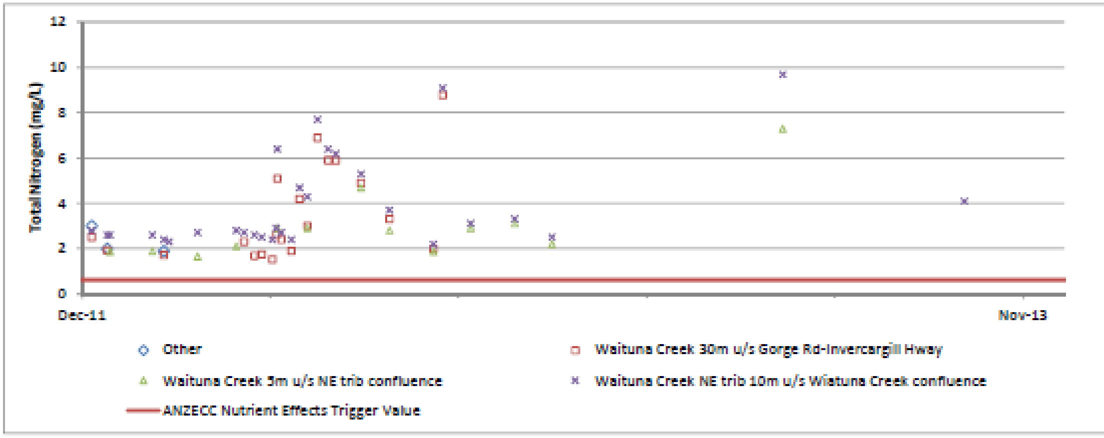


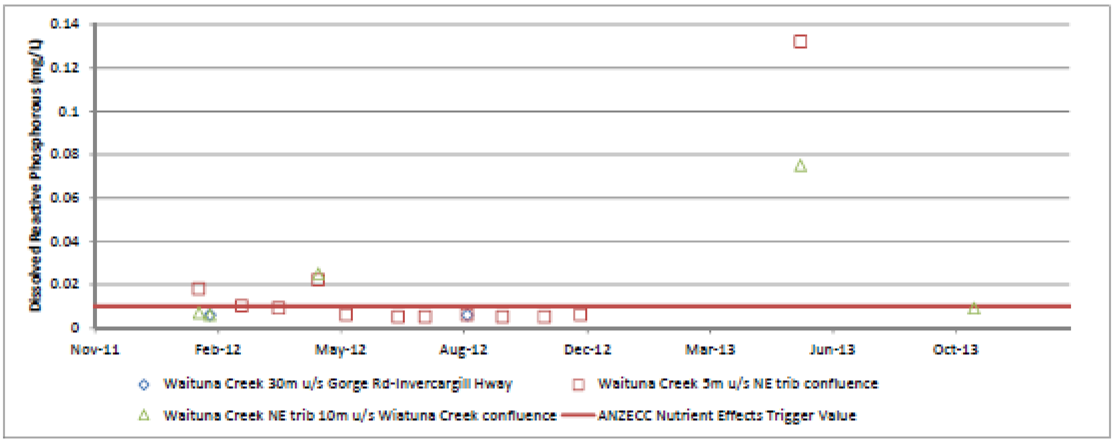


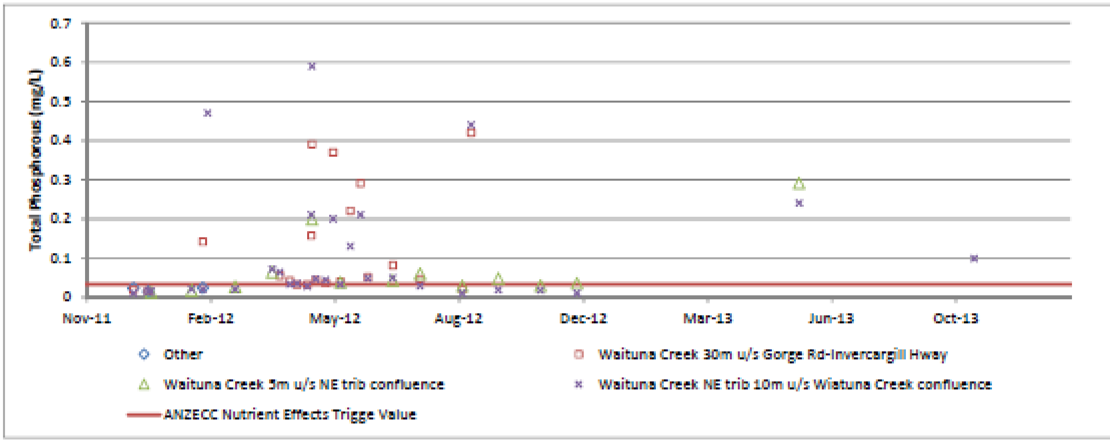

Clarity (m)
Dec-11
Nov-13
Other
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence

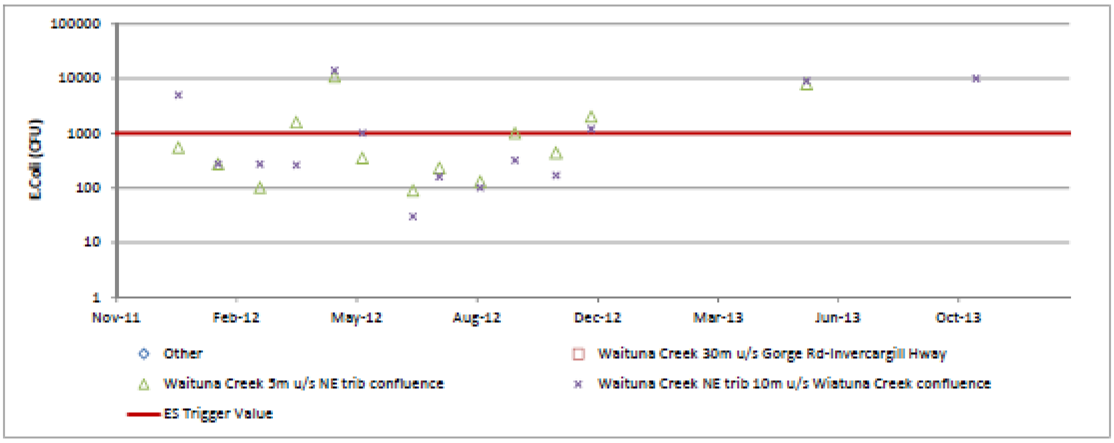

Nitrate-N+Nitrite-N (mg/L)
Dec-11
Nov-13
Other
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence


Ammoniacal-N (mg/L)
Dec-11
Nov-13
Other
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence
ANZECC Toxicity 95%

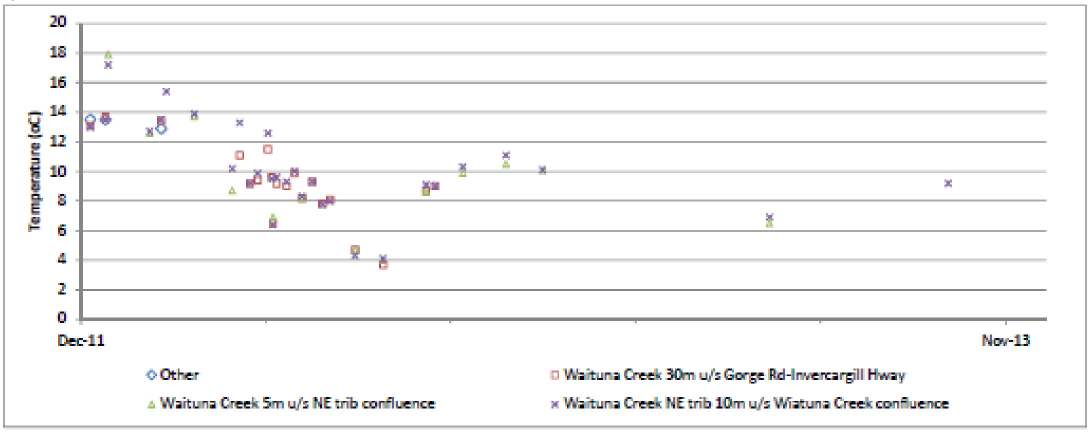

Total Nitrogen (mg/L)
Dec-11
Nov-13
Other
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence
ANZECC Nutrient Effects Trigger Value

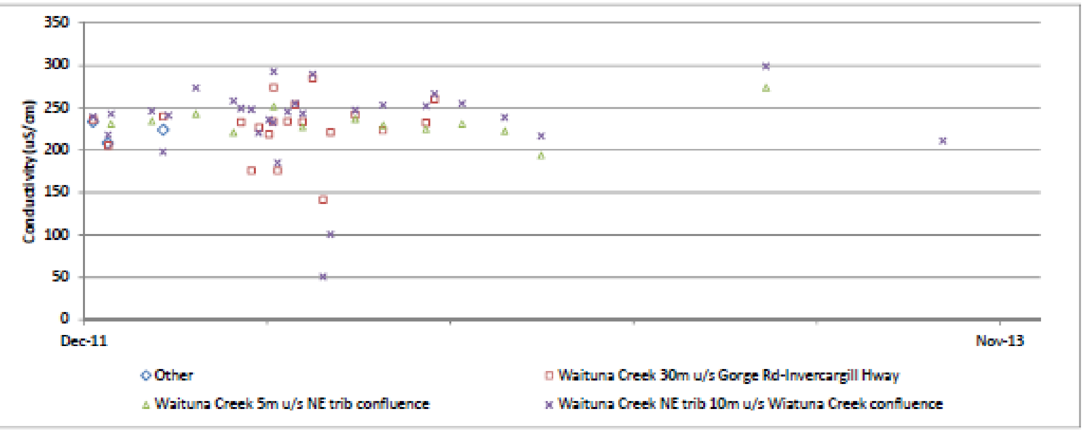

Dissolved Reactive Phosphorous (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Nov-11
Feb-12
May-12
Aug-12
Dec-12
Mar-13
Jun-13
Oct-13
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence
ANZECC Nutrient Effects Trigger Value

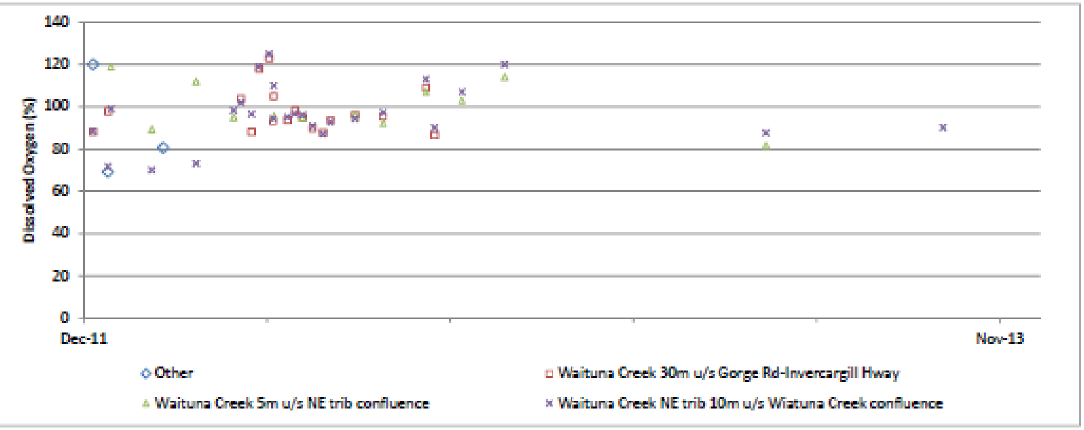

Total Phosphorous (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Nov-11
Feb-12
May-12
Aug-12
Dec-12
Mar-13
Jun-13
Oct-13
Other
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence
ANZECC Nutrient Effects Trigge Value

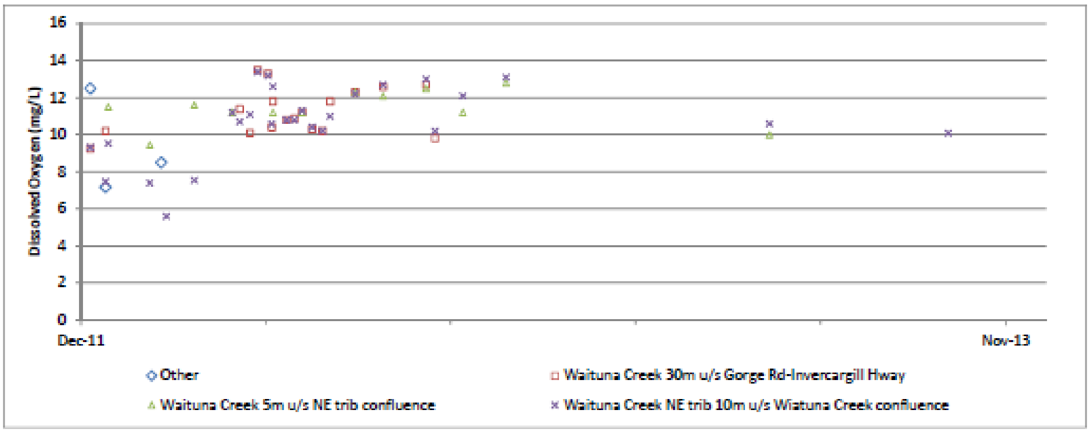

E.Coli (CFU)
100000
10000
1000
100
10
1
Nov-11
Feb-12
May-12
Aug-12
Dec-12
Mar-13
Jun-13
Oct-13
Other
Waituna Creek 30m u/s Gorge Rd-Invercargill Hway
Waituna Creek 5m u/s NE trib confluence
Waituna Creek NE trib 10m u/s Wiatuna Creek confluence
ES Trigger Value

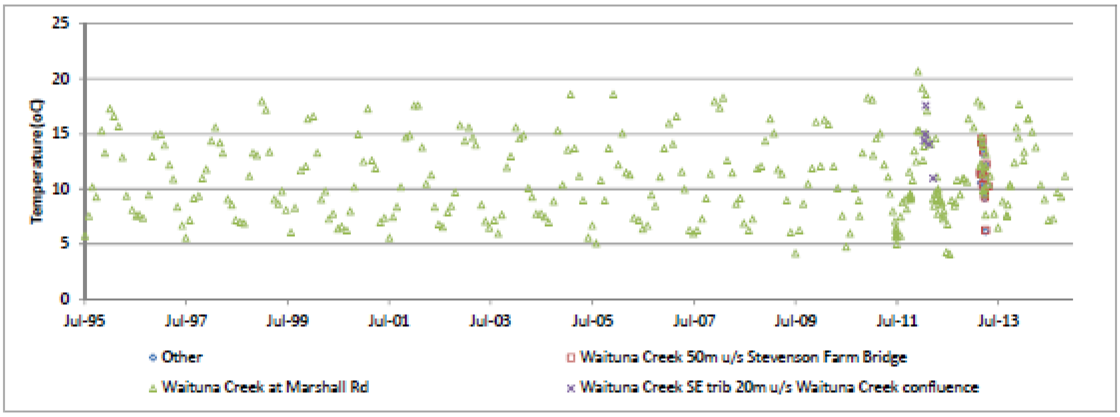
c) Waituna Creek Surface Water – Lower Catchment

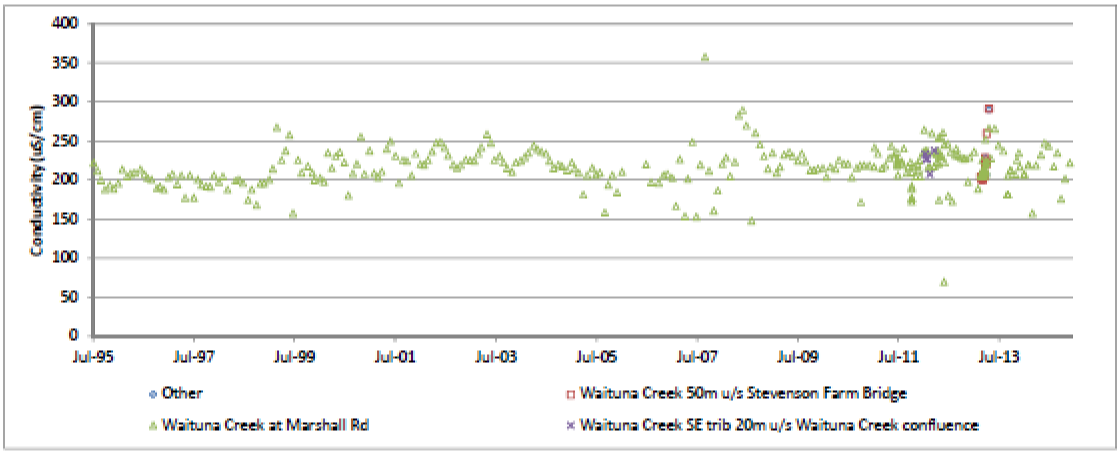


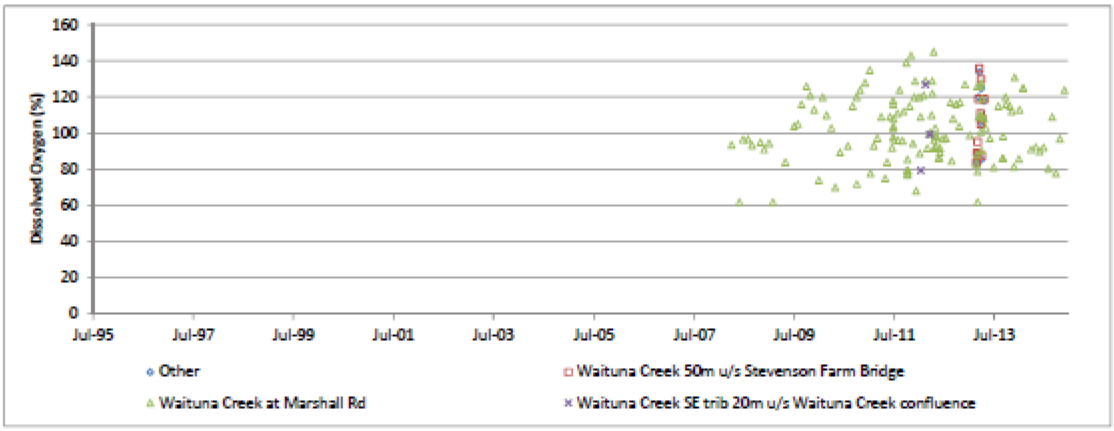


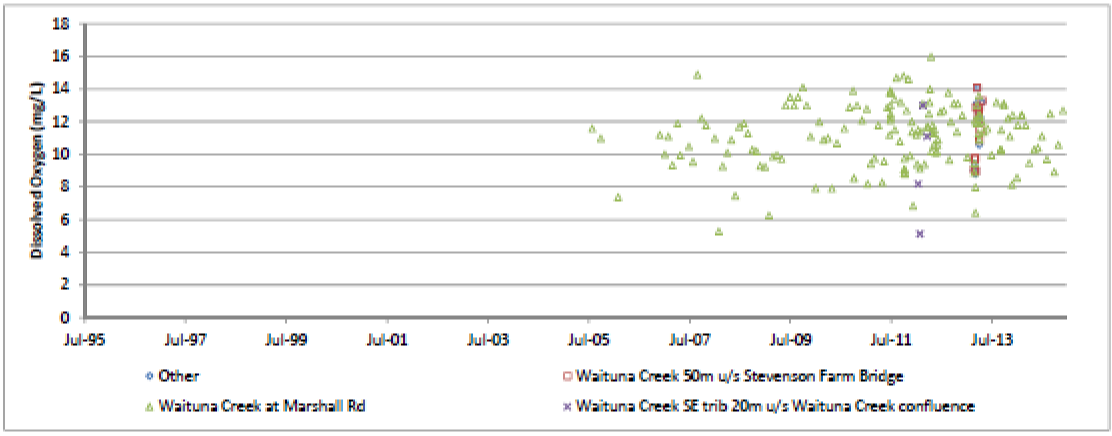


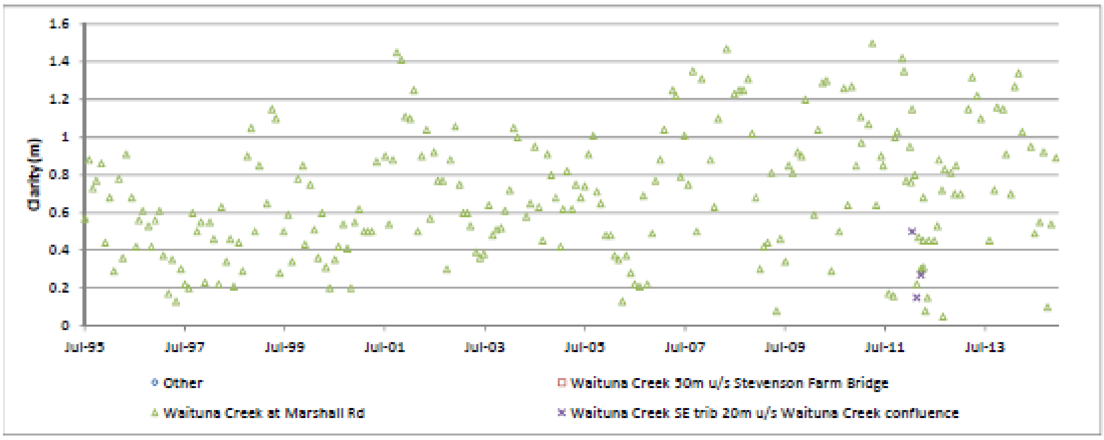


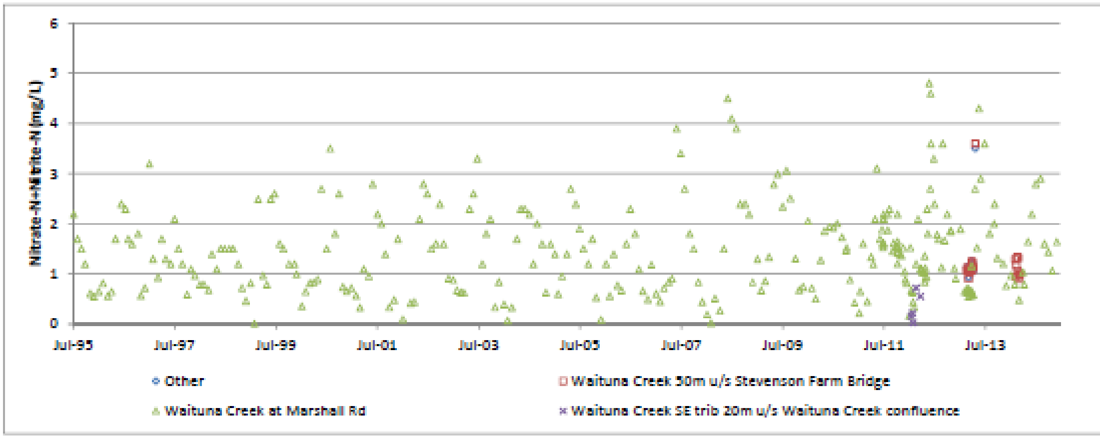

Temperature (oC)
0
5
10
15
20
25
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence

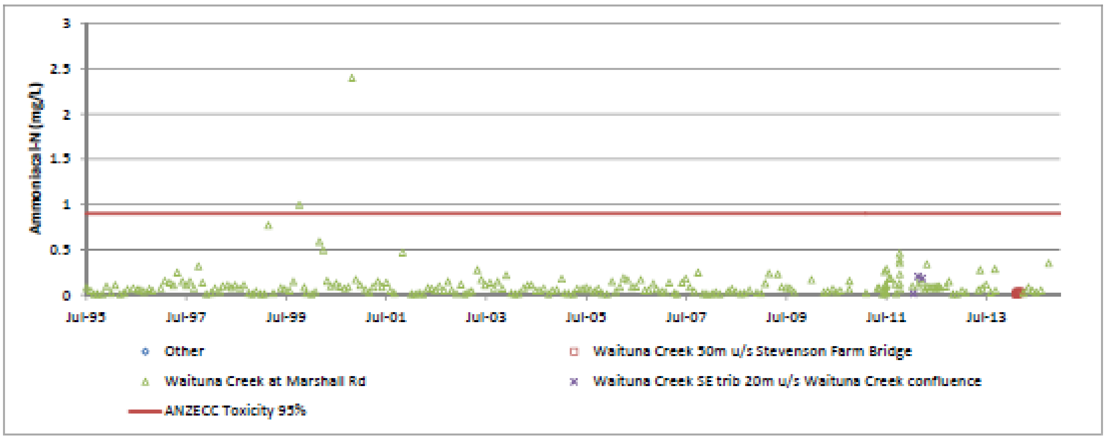

Conductivity (uS/cm)
0
50
100
150
200
250
300
350
400
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence

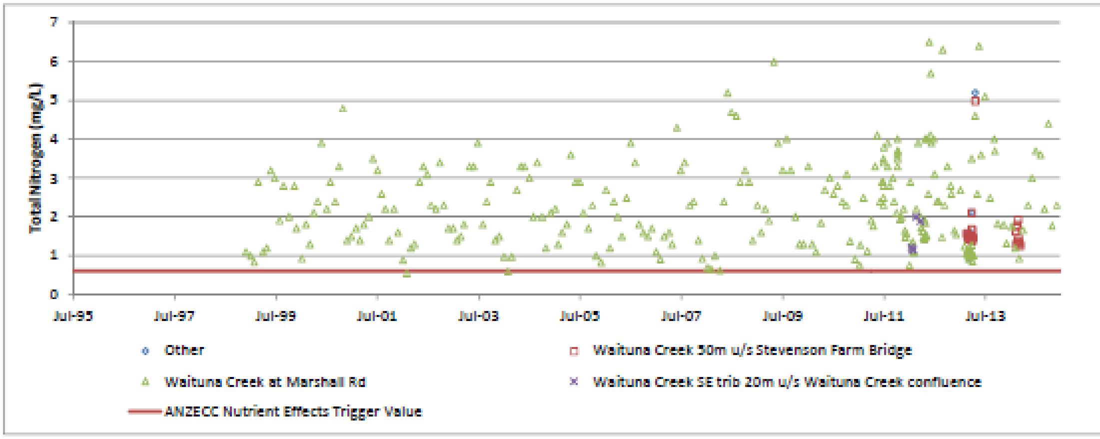

Dissolved Oxygen (%)
0
20
40
60
80
100
120
140
160
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence

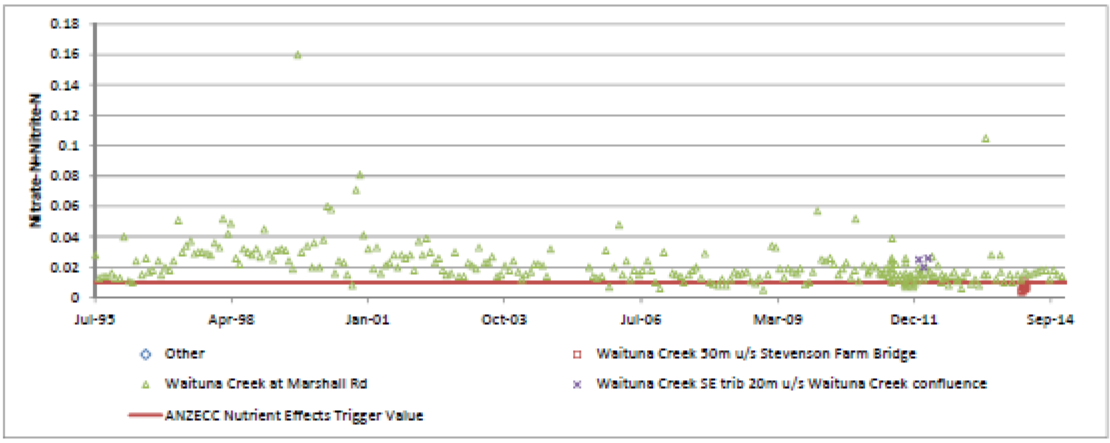

Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
14
16
18
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence

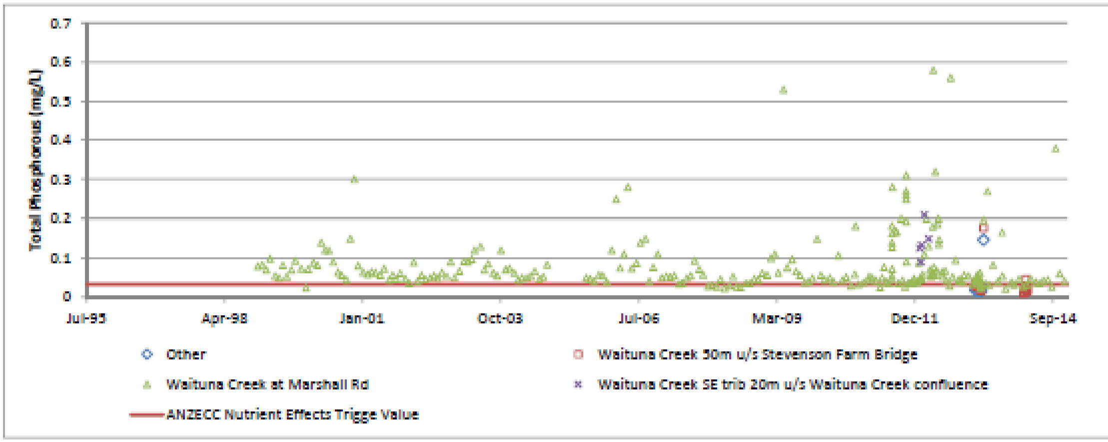

Clarity (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence

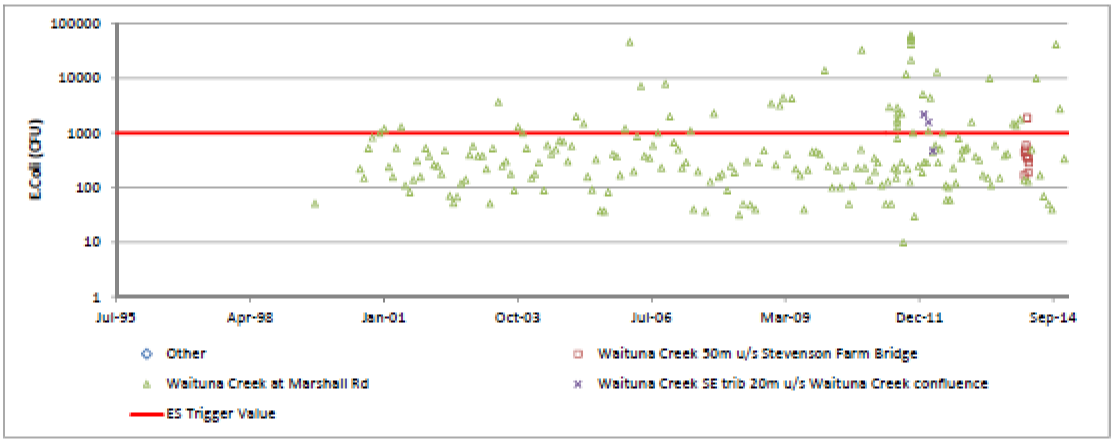

Nitrate-N+Nitrite-N (mg/L)
6
5
4
3
2
1
0
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence


Ammoniacal-N (mg/L)
3
2.5
2
1.5
1
0.5
0
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence
ANZECC Toxicity 95%

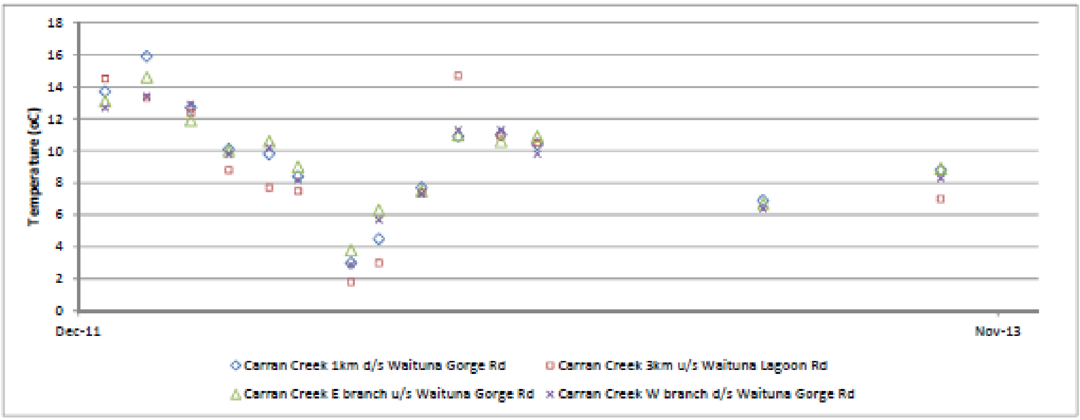

Total Nitrogen (mg/L)
7
6
5
4
3
2
1
0
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence
ANZECC Nutrient Effects Trigger Value

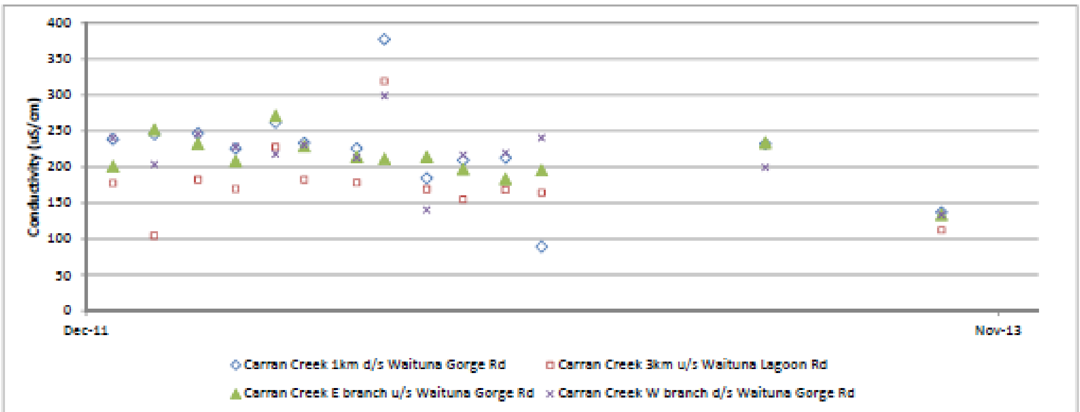

Nitrate-N+Nitrite-N
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence
ANZECC Nutrient Effects Trigger Value

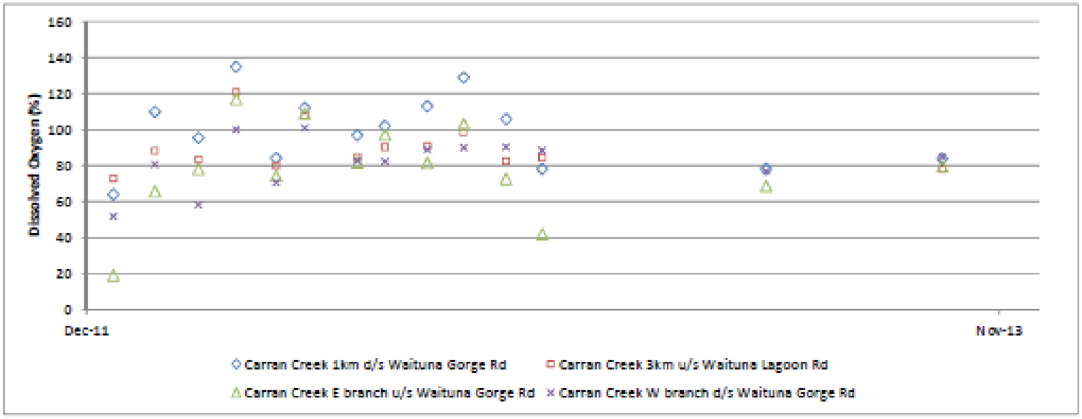

Total Phosphorous (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence
ANZECC Nutrient Effects Trigge Value

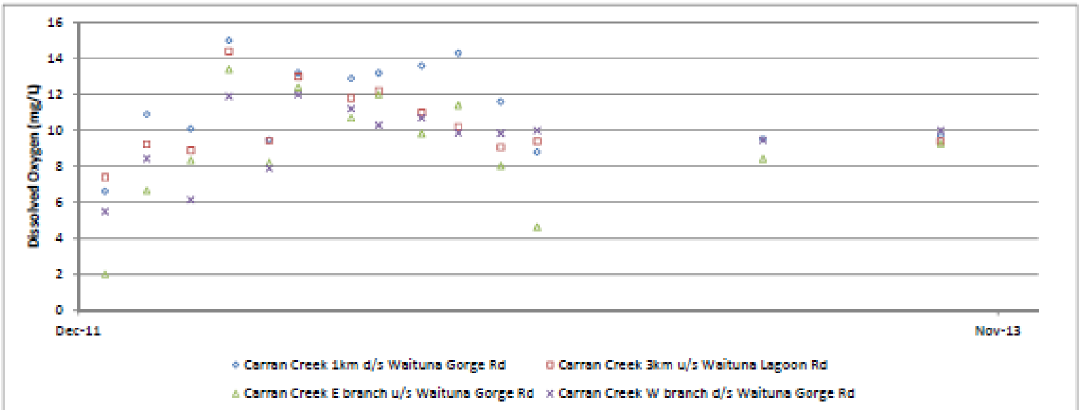

E.Coli (CFU)
100000
10000
1000
100
10
1
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Other
Waituna Creek 50m u/s Stevenson Farm Bridge
Waituna Creek at Marshall Rd
Waituna Creek SE trib 20m u/s Waituna Creek confluence
ES Trigger Value

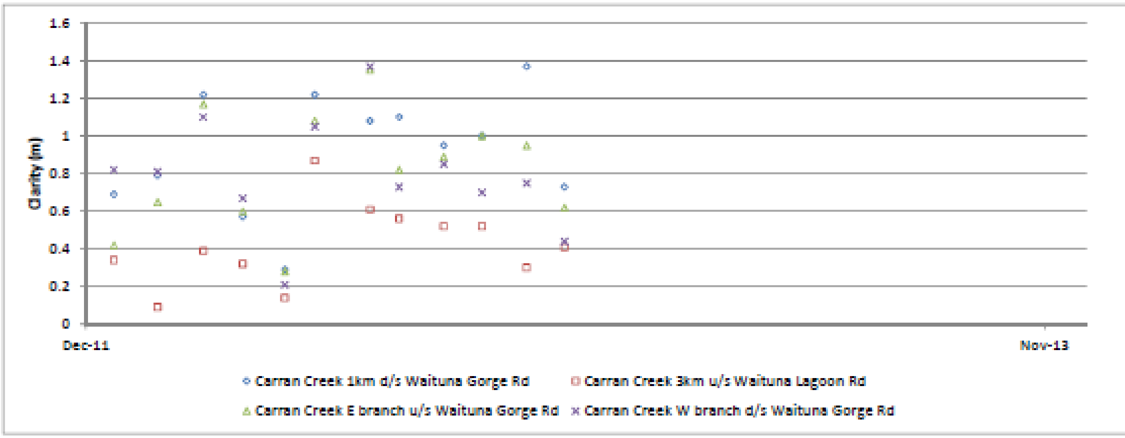
d) Carran Creek Surface Water – Upper Catchment

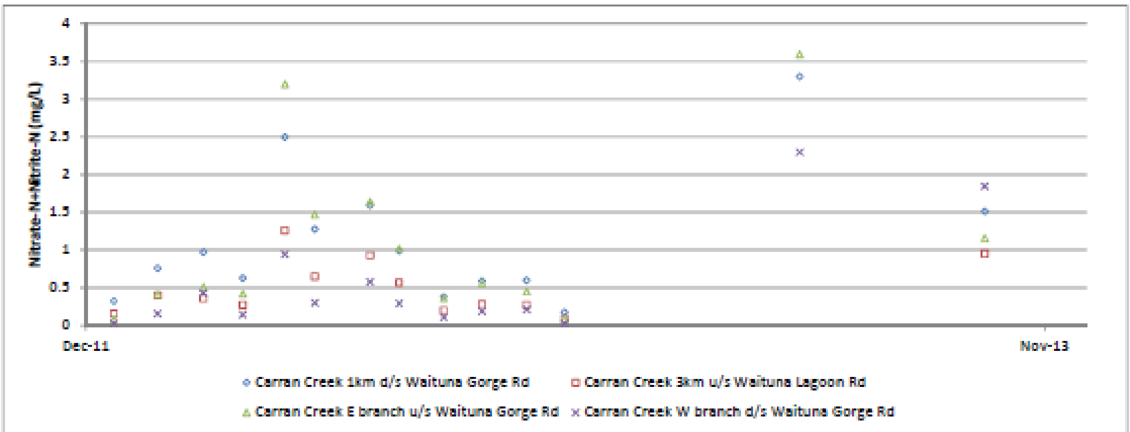


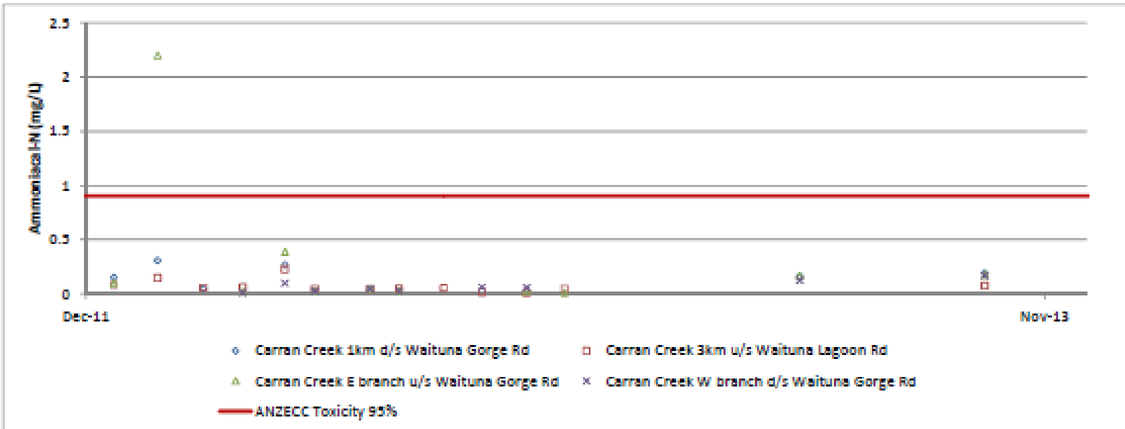


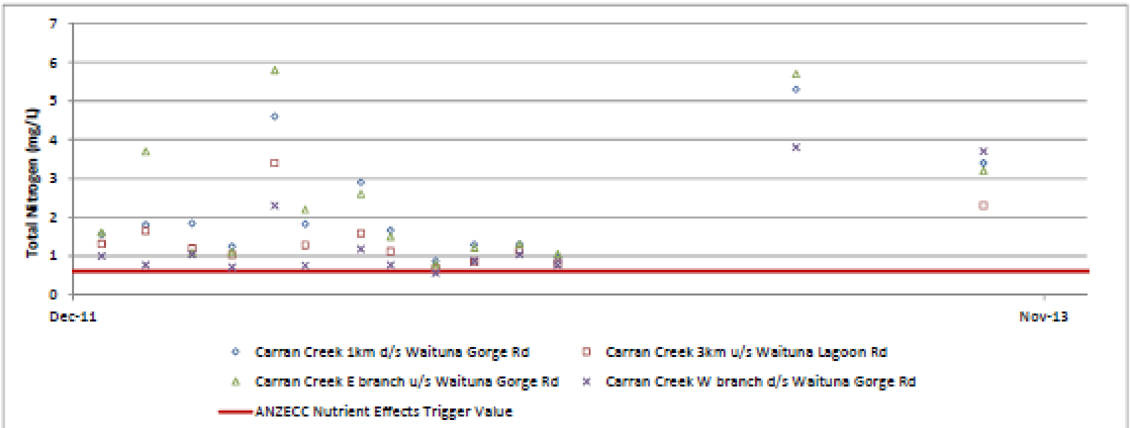


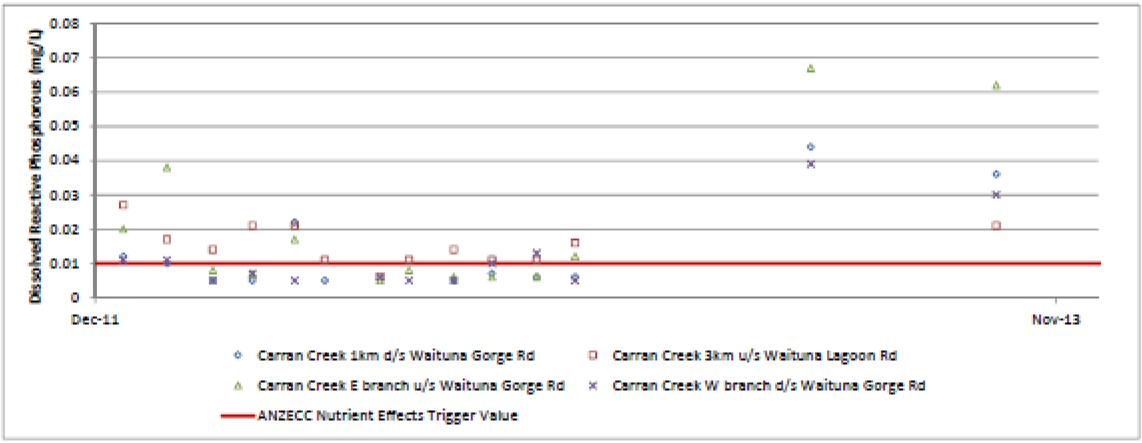


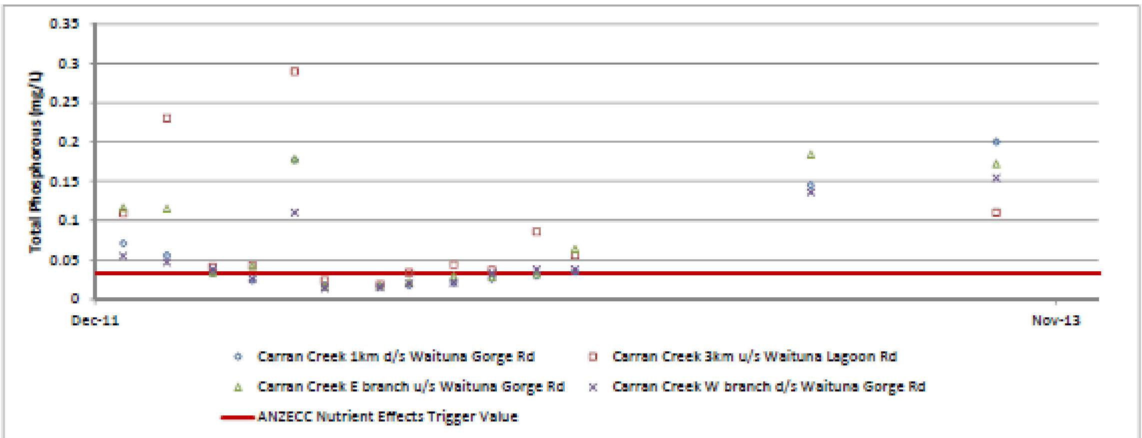

Clarity (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd

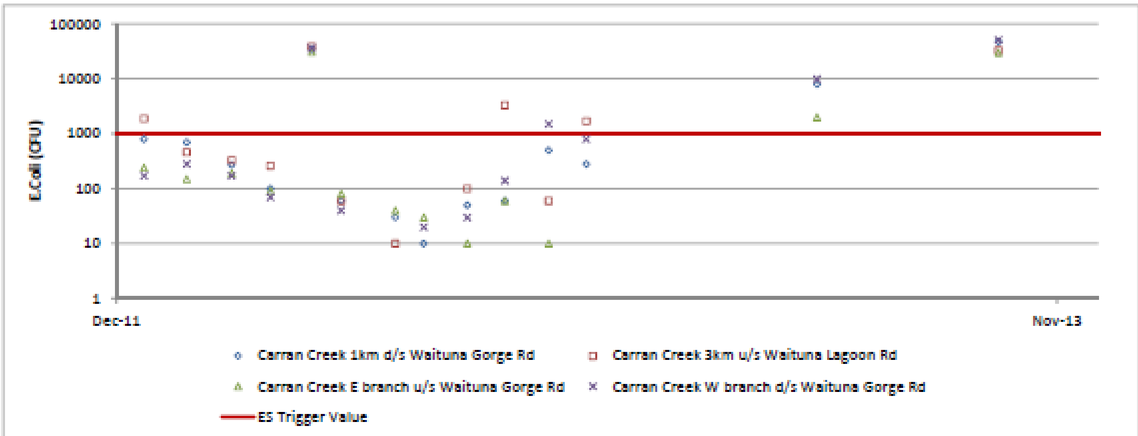

Nitrate-N+Nitrite-N (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd


Ammoniacal-N (mg/L)
2.5
2
1.5
1
0.5
0
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd
ANZECC Toxicity 95%

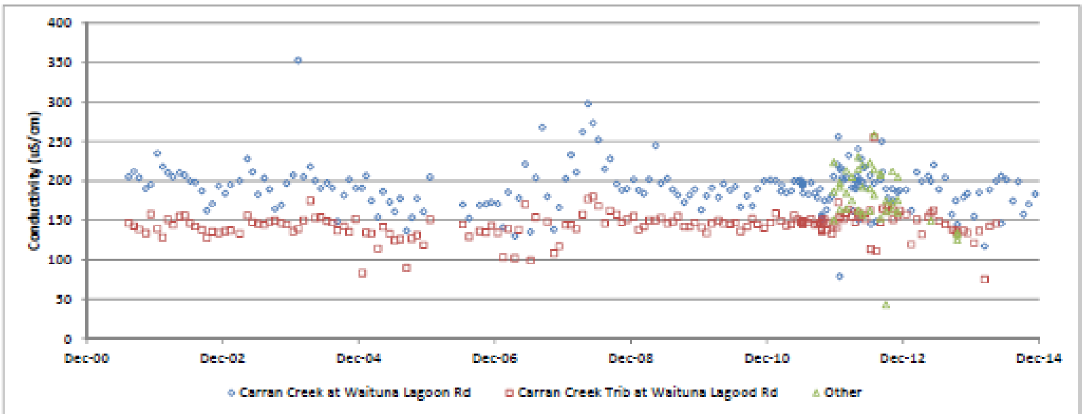

Total Nitrogen (mg/L)
7
6
5
4
3
2
1
0
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd
ANZECC Nutrient Effects Trigger Value

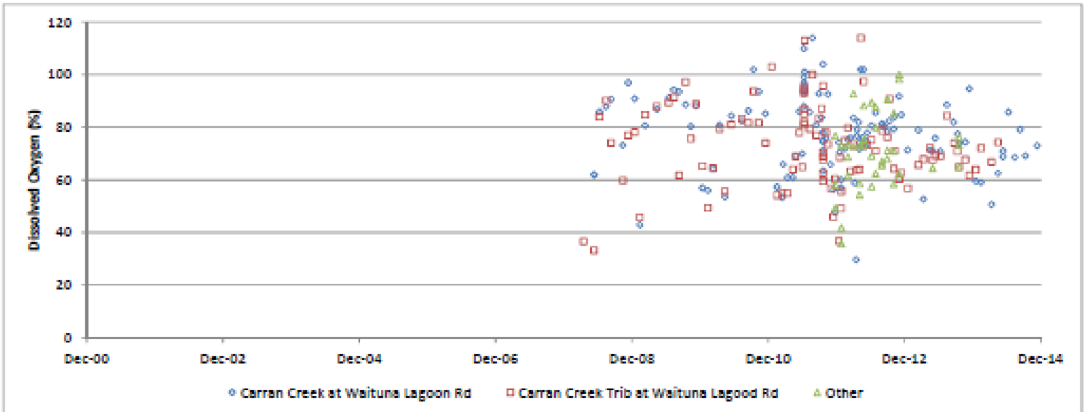

Dissolved Reactive Phosphorous (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd
ANZECC Nutrient Effects Trigger Value

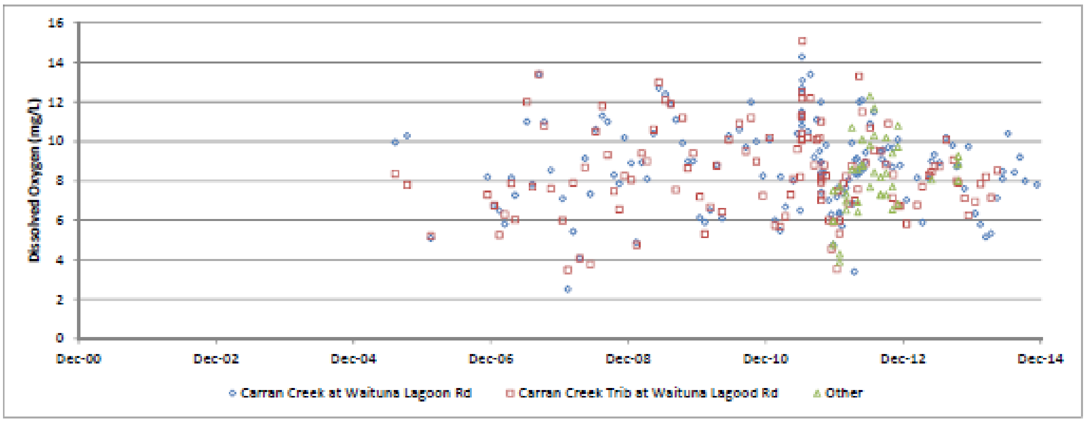

Total Phosphorous (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd
ANZECC Nutrient Effects Trigger Value

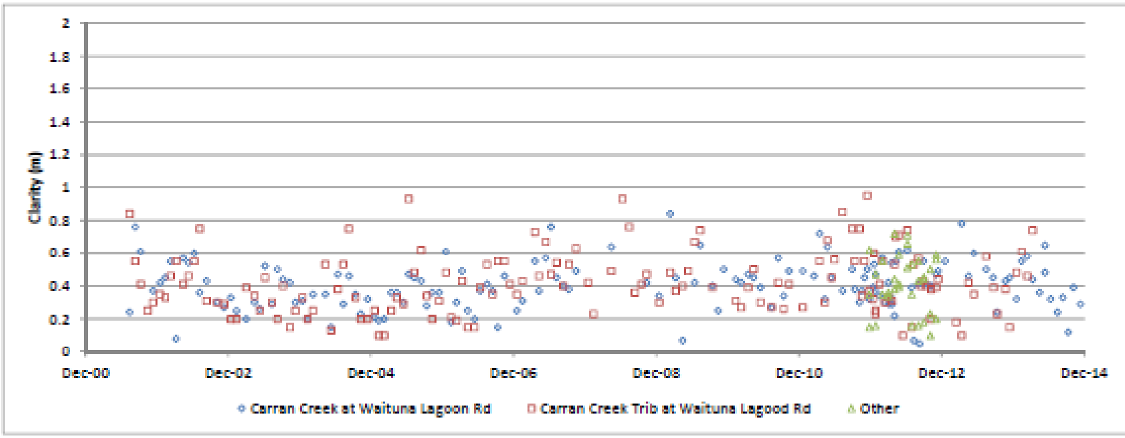

E.Coli (CFU)
100000
10000
1000
100
10
1
Dec-11
Nov-13
Carran Creek 1km d/s Waituna Gorge Rd
Carran Creek 3km u/s Waituna Lagoon Rd
Carran Creek E branch u/s Waituna Gorge Rd
Carran Creek W branch d/s Waituna Gorge Rd
ES Trigger Value

e) Carran Creek Surface Water – Lower Catchment

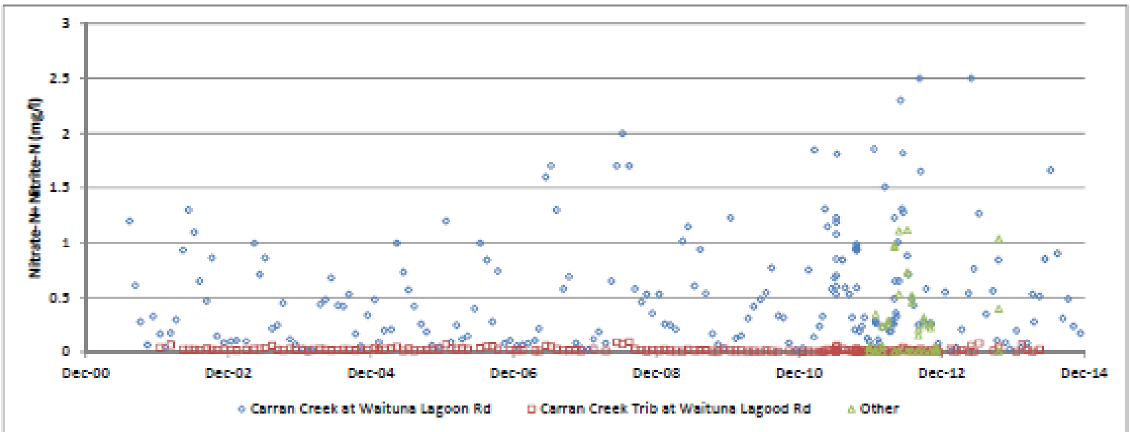




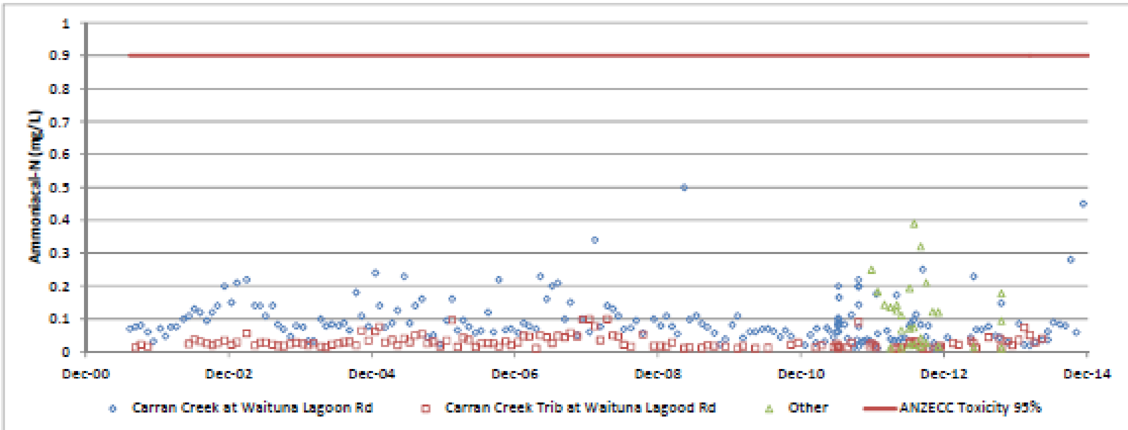




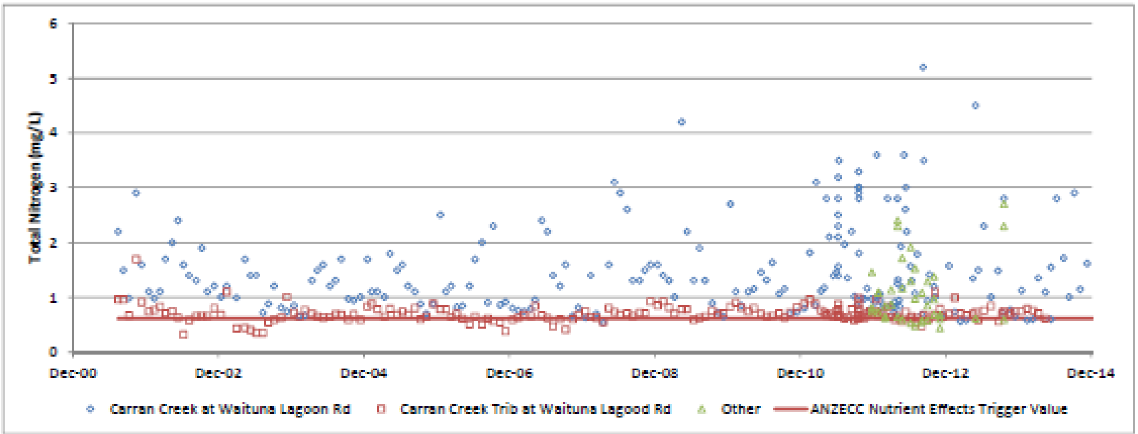
Clarity (m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other



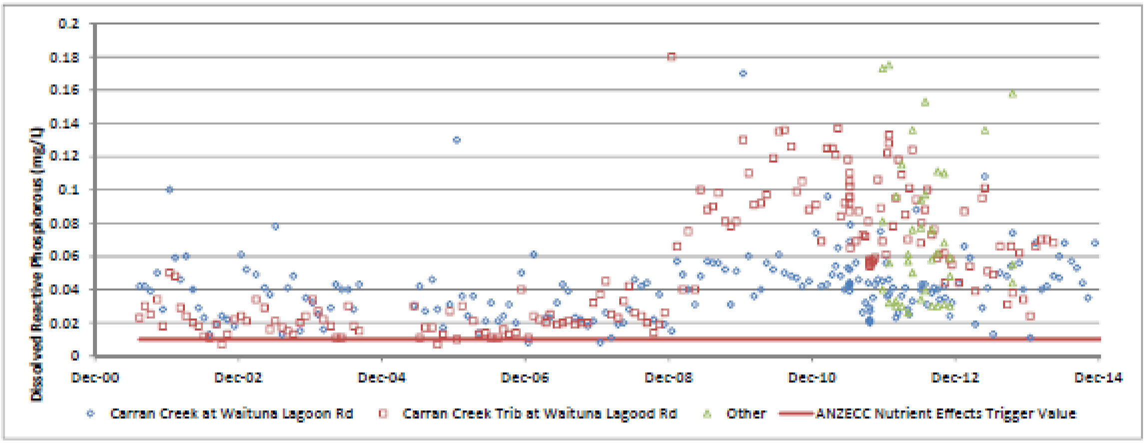
Nitrate-N+ Nitrite-N (mg/l)
3
2.5
2
1.5
1
0.5
0
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other

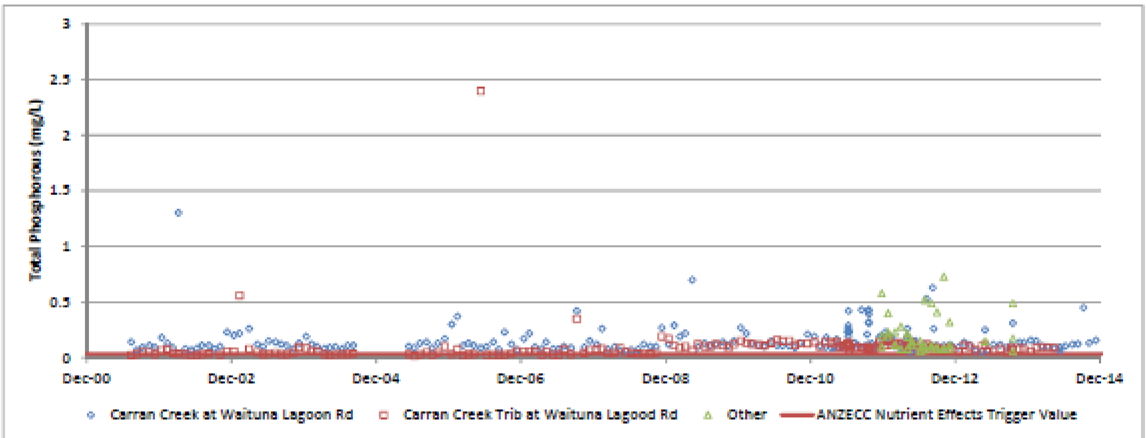


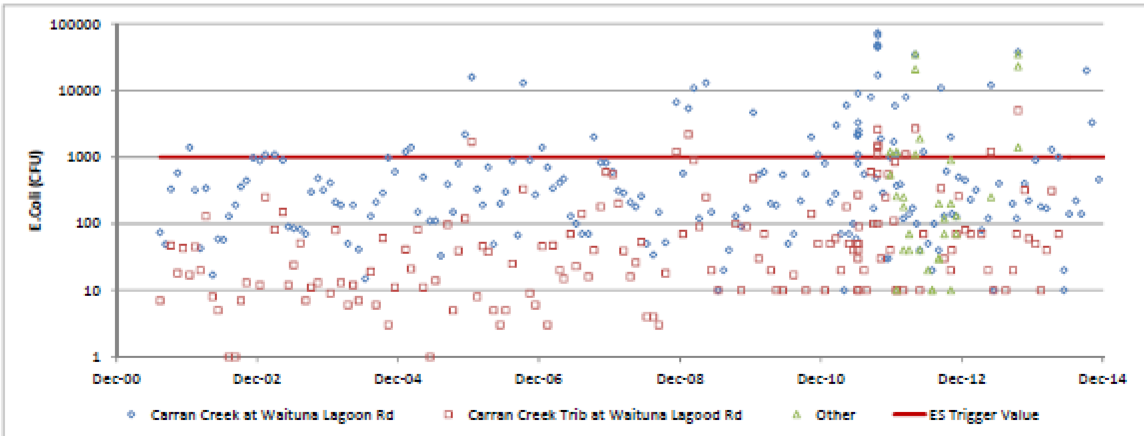
Ammoniacal-N (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other
ANZECC Toxicity 95%



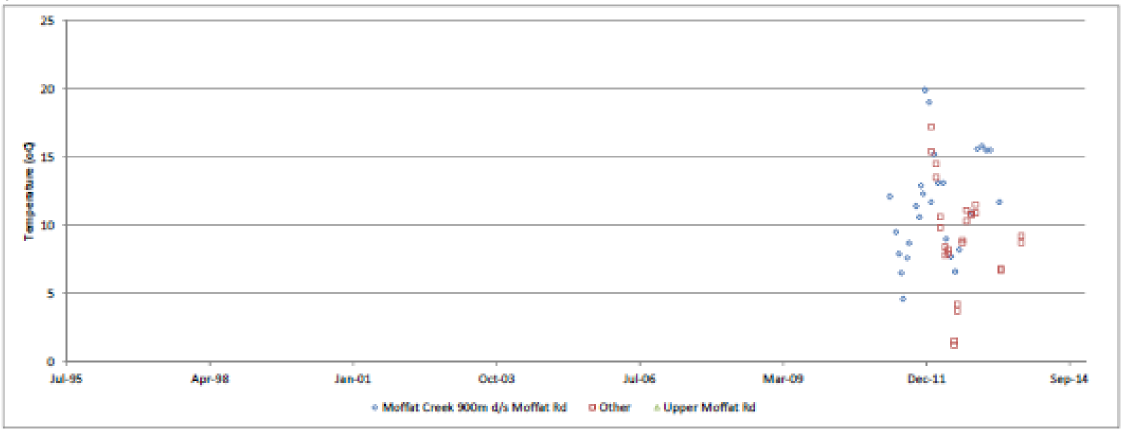
Total Nitrogen (mg/L)
6
5
4
3
2
1
0
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other
ANZECC Nutrient Effects Trigger Value

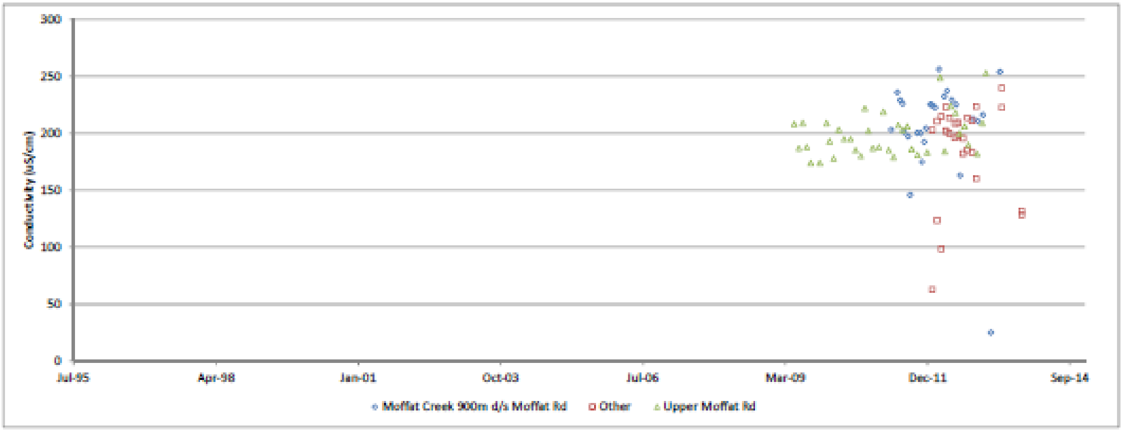

Dissolved Reactive Phosphorous (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other
ANZECC Nutrient Effects Trigger Value

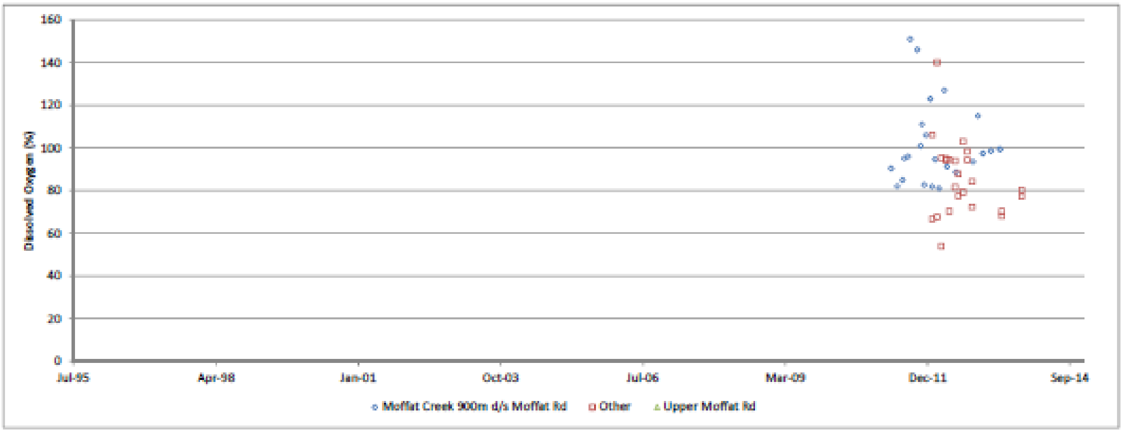

Total Phosphorous (mg/L)
3
2.5
2
1.5
1
0.5
0
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other
ANZECC Nutrient Effects Trigger Value

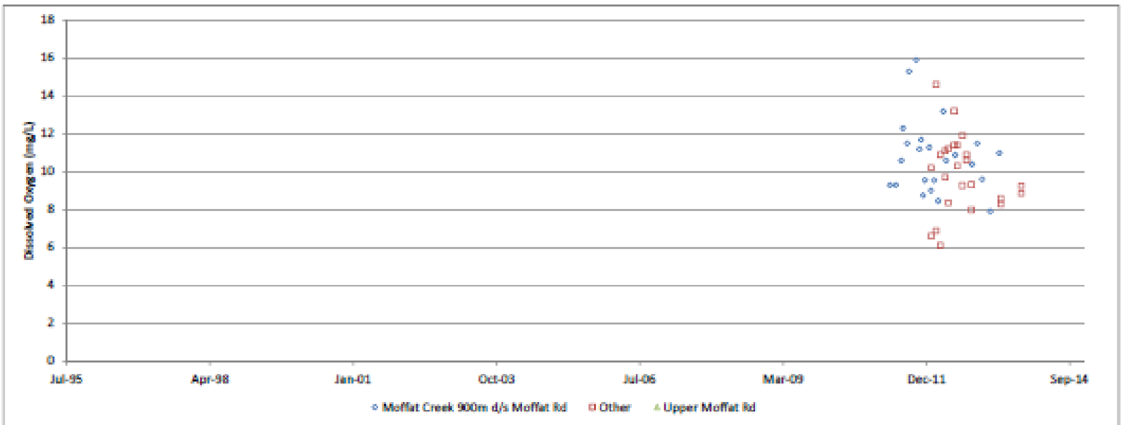

E.Coli (CFU)
100000
10000
1000
100
10
1
Dec-00
Dec-02
Dec-04
Dec-06
Dec-08
Dec-10
Dec-12
Dec-14
Carran Creek at Waituna Lagoon Rd
Carran Creek Trib at Waituna Lagood Rd
Other
ES Trigger Value

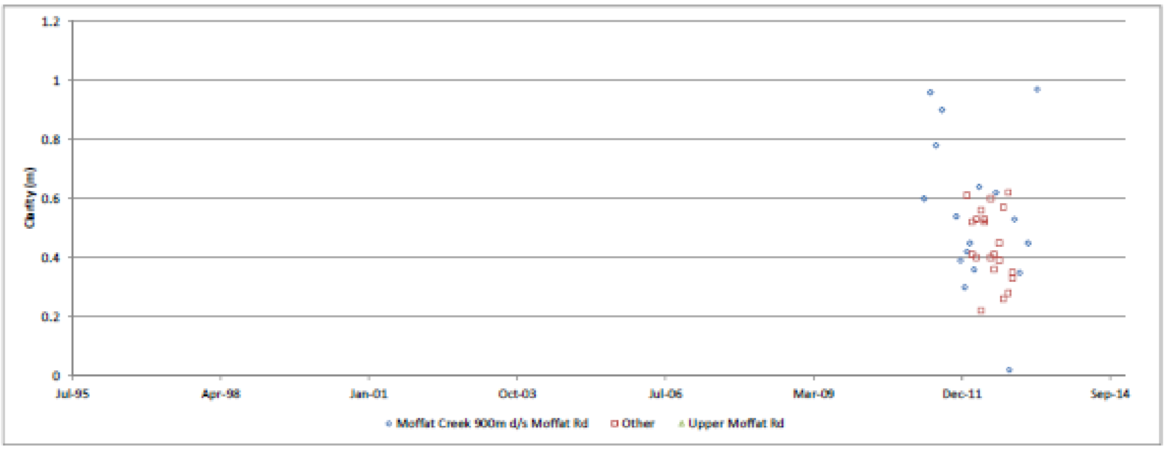
f) Moffat Creek Surface Water

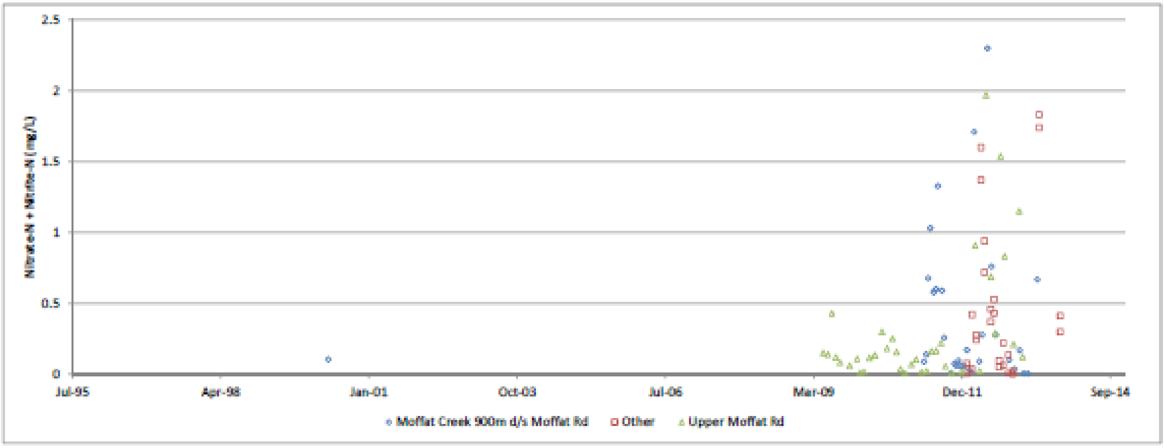


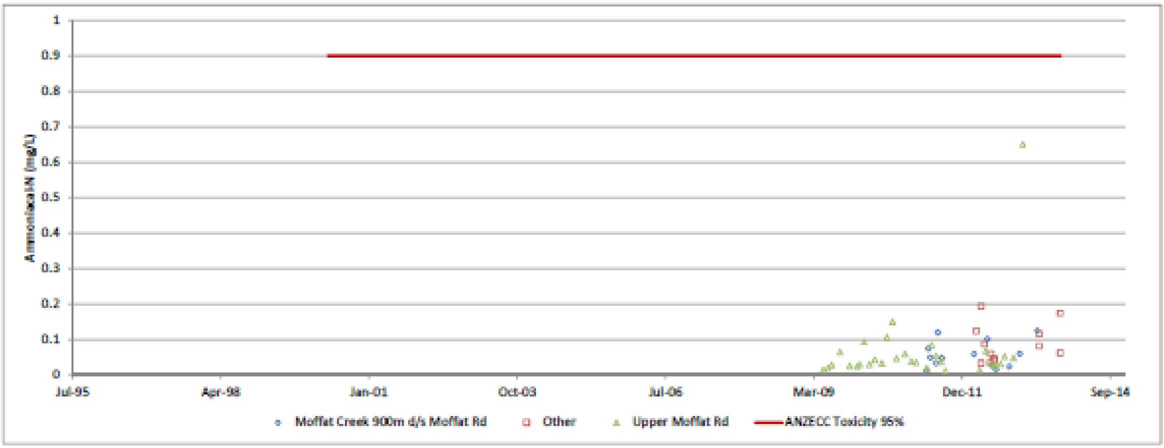


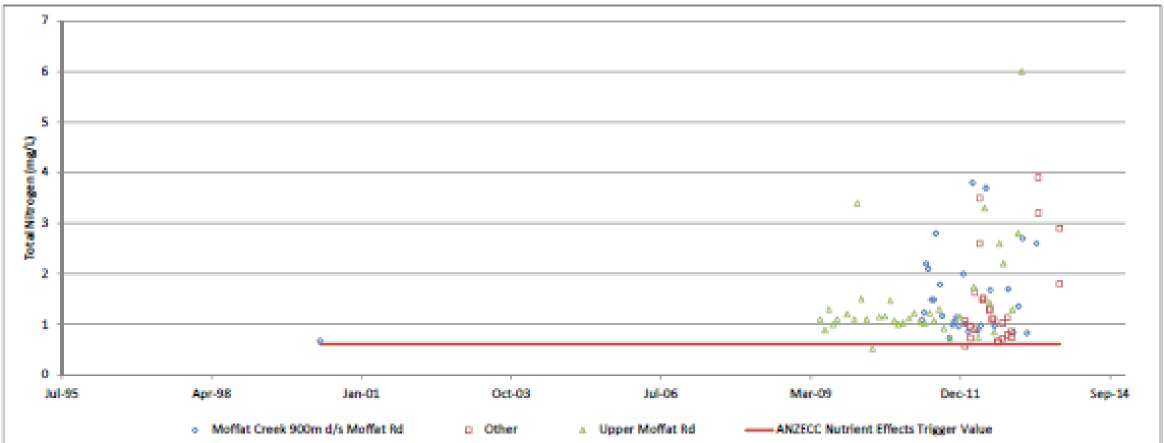


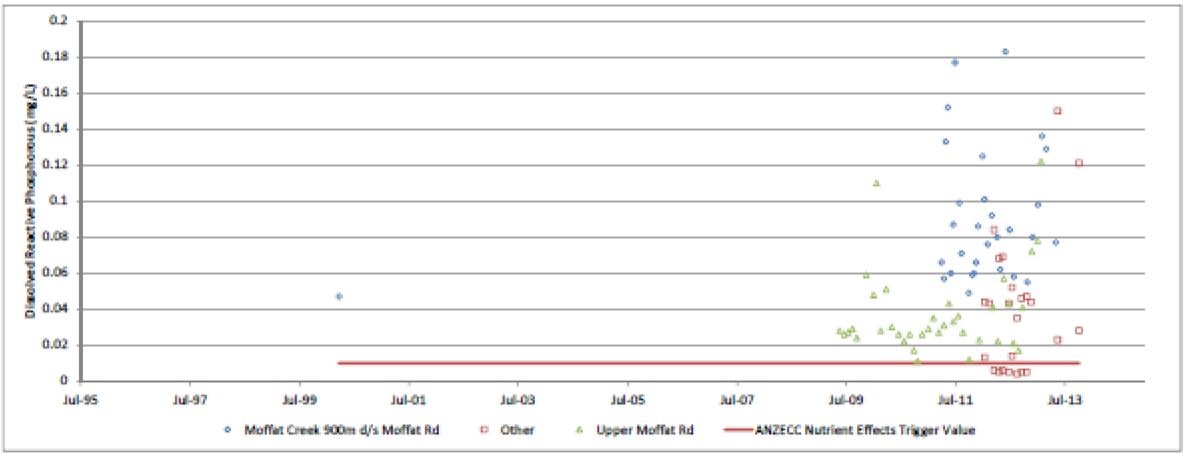


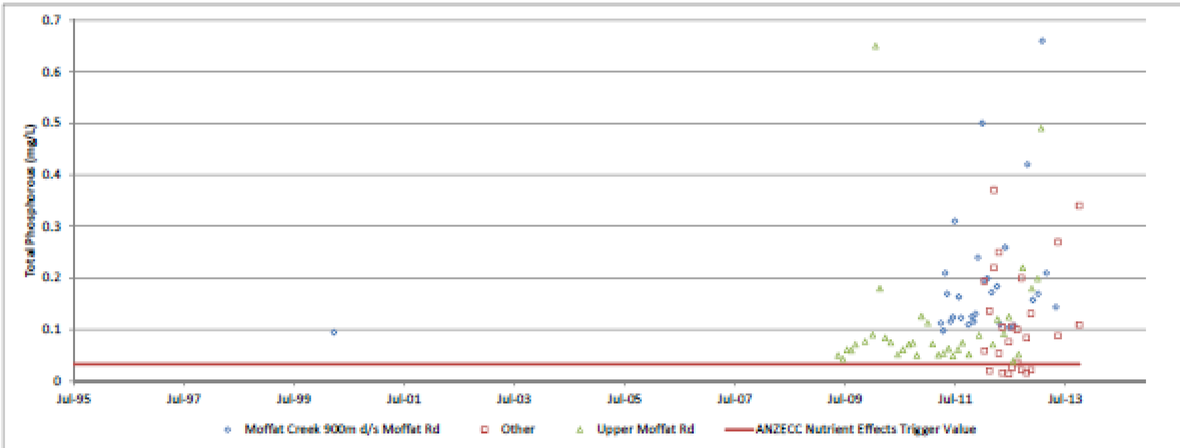

Clarity (m)
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd

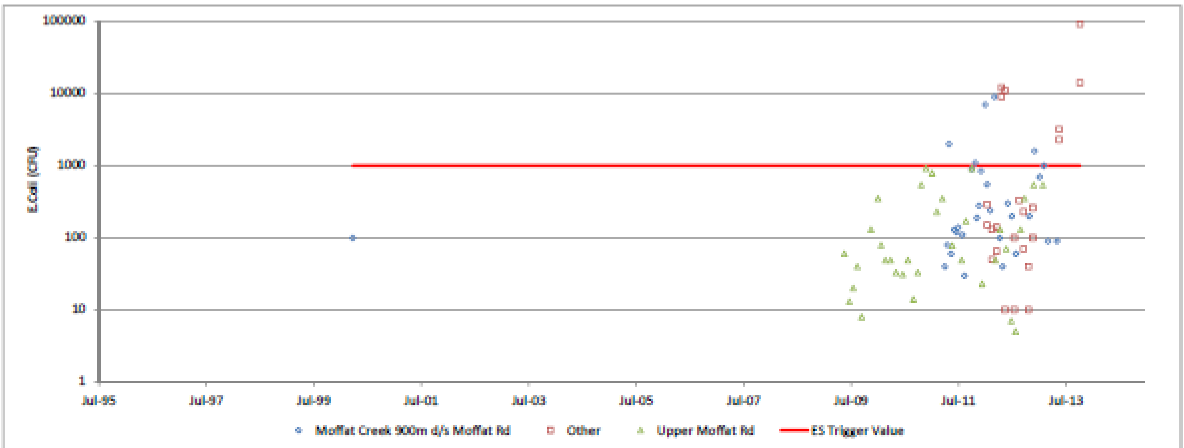

Nitrate-N + Nitrite-N (mg/L)
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd


Ammoniacal-N (mg/L)
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd
ANZECC Toxicity 95%


Total Nitrogen (mg/L)
Jul-95
Apr-98
Jan-01
Oct-03
Jul-06
Mar-09
Dec-11
Sep-14
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd
ANZECC Nutrient Effects Trigger Value

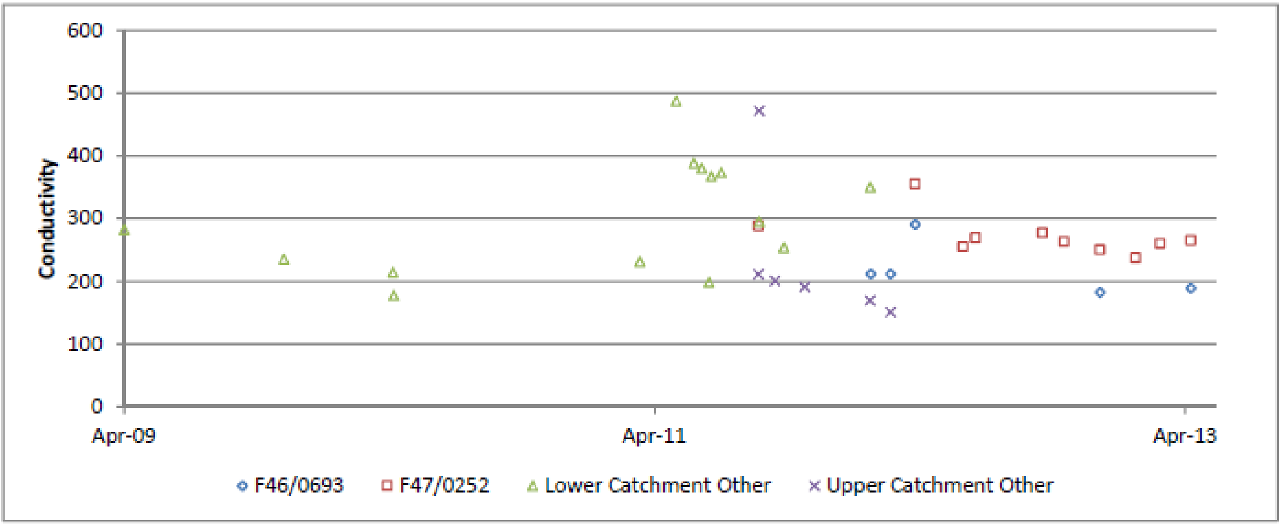

Dissolved Reactive Phosphorous (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd
ANZECC Nutrient Effects Trigger Value

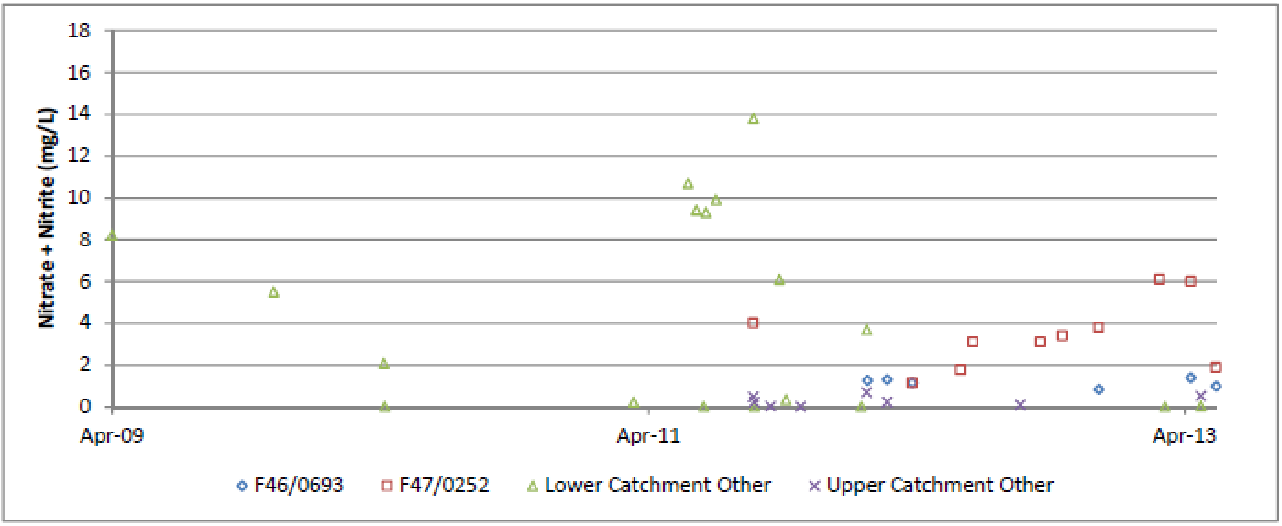

Total Phosphorous (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd
ANZECC Nutrient Effects Trigger Value

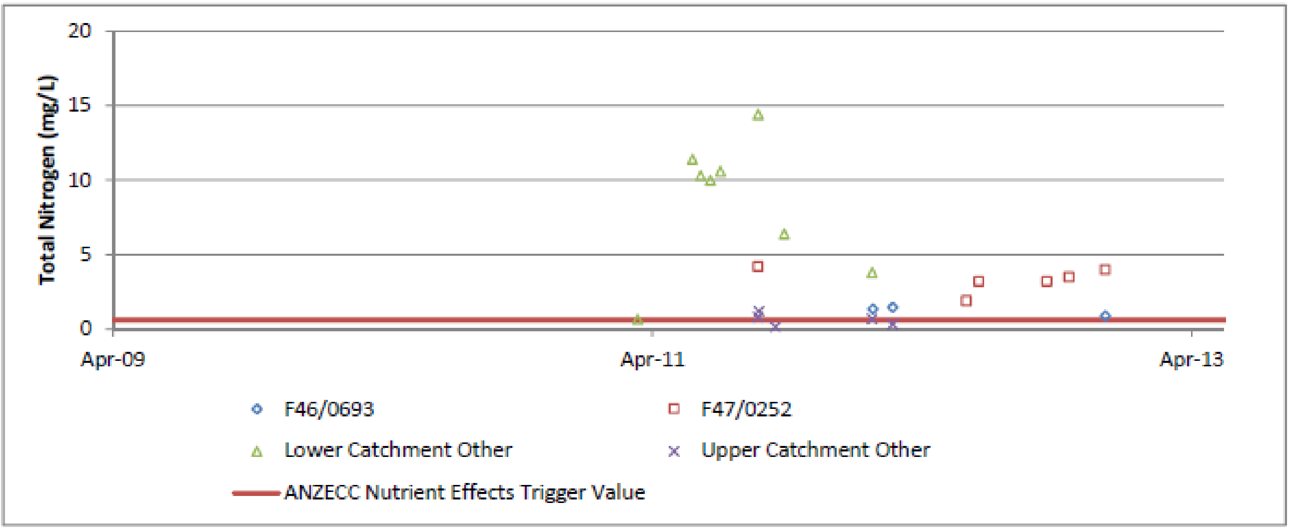

E.Coli (CFU)
100000
10000
1000
100
10
1
Jul-95
Jul-97
Jul-99
Jul-01
Jul-03
Jul-05
Jul-07
Jul-09
Jul-11
Jul-13
Moffat Creek 900m d/s Moffat Rd
Other
Upper Moffat Rd
ES Trigger Value

Groundwater Quality Graphs

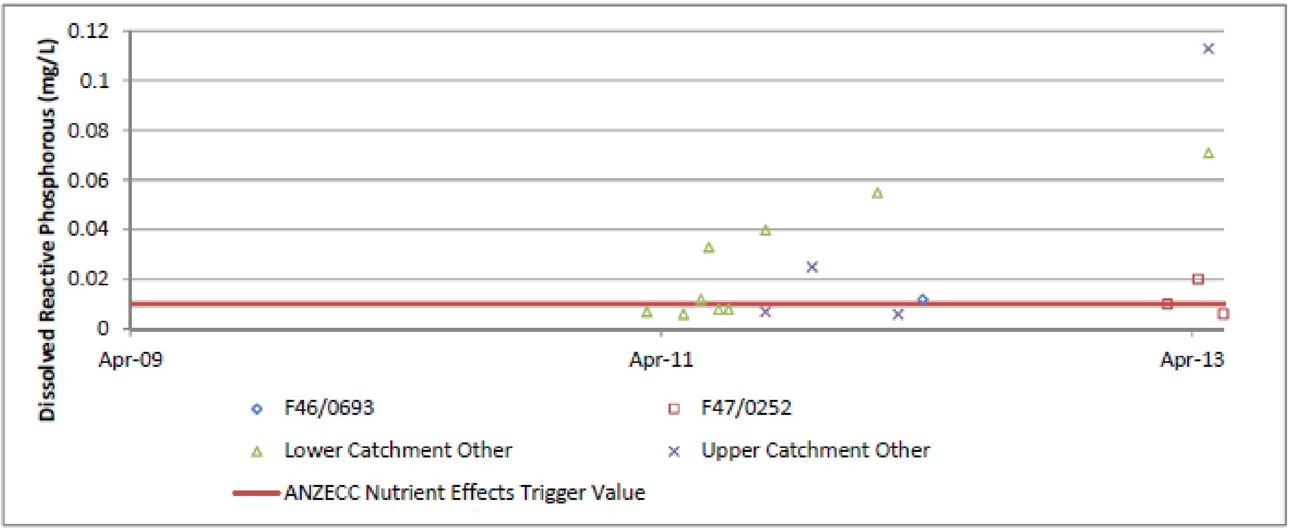
a) Waituna Creek Groundwater



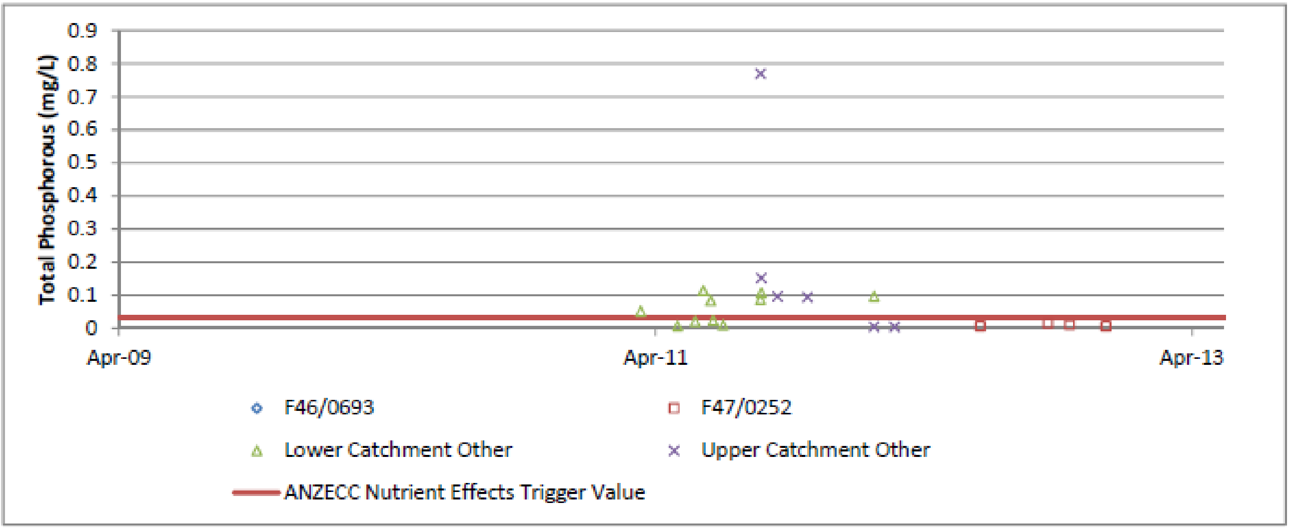




Total Nitrogen (mg/L)
20
15
10
5
0
Apr-09
Apr-11
Apr-13
F46/0693
F47/0252
Lower Catchment Other
Upper Catchment Other
ANZECC Nutrient Effects Trigger Value

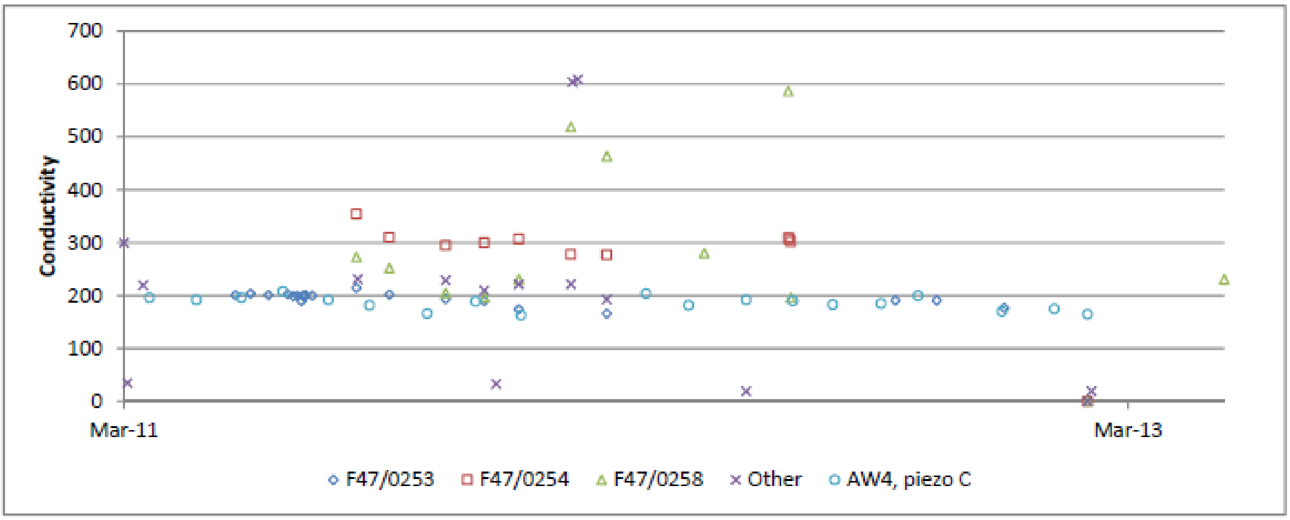


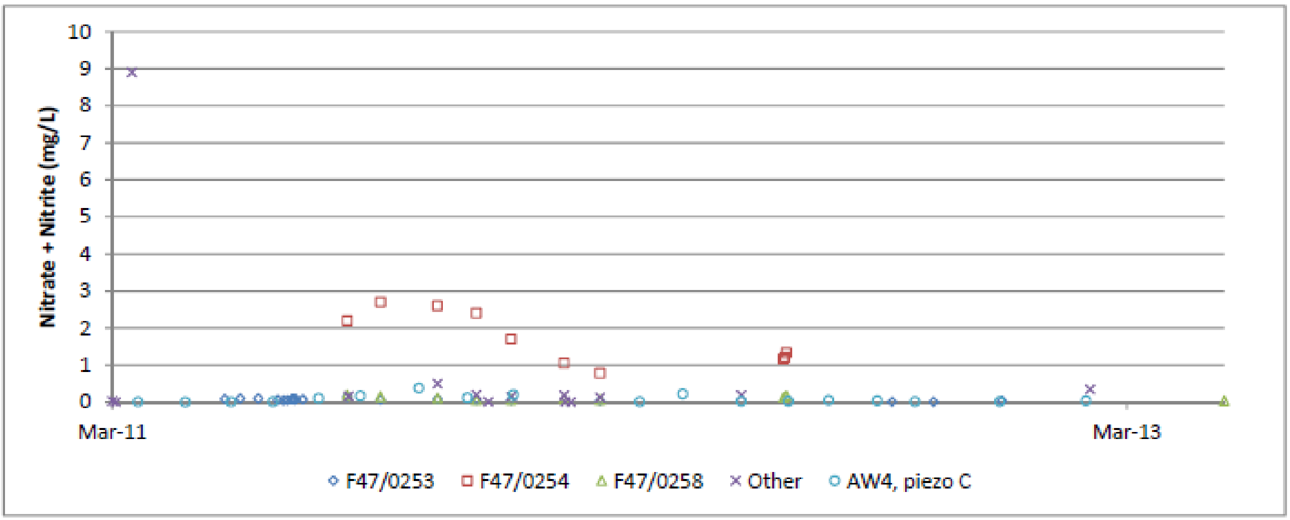
Dissolved Reactive Phosphorous (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Apr-09
Apr-11
Apr-13
F46/0693
F47/0252
Lower Catchment Other
Upper Catchment Other
ANZECC Nutrient Effects Trigger Value

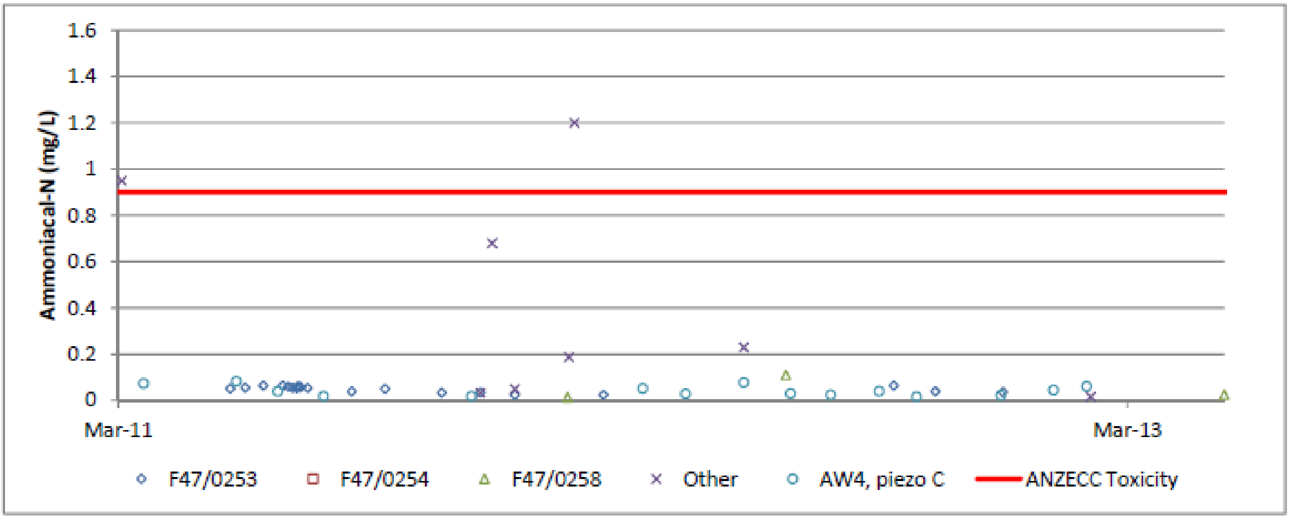


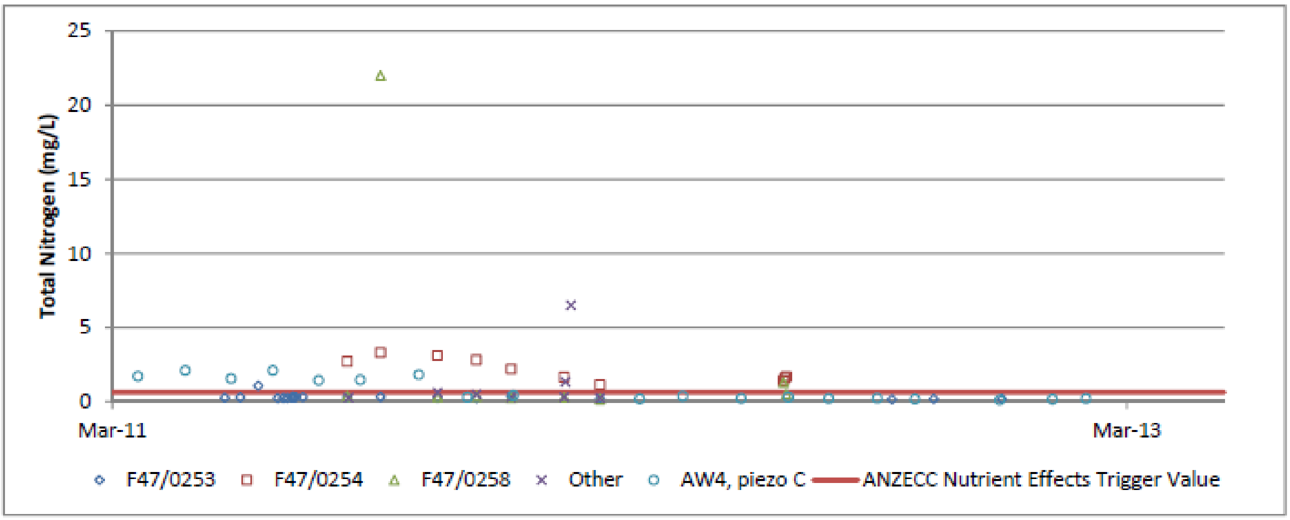
Total Phosphorous (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Apr-09
Apr-11
Apr-13
F46/0693
F47/0252
Lower Catchment Other
Upper Catchment Other
ANZECC Nutrient Effects Trigger Value

b) Carran Creek Groundwater

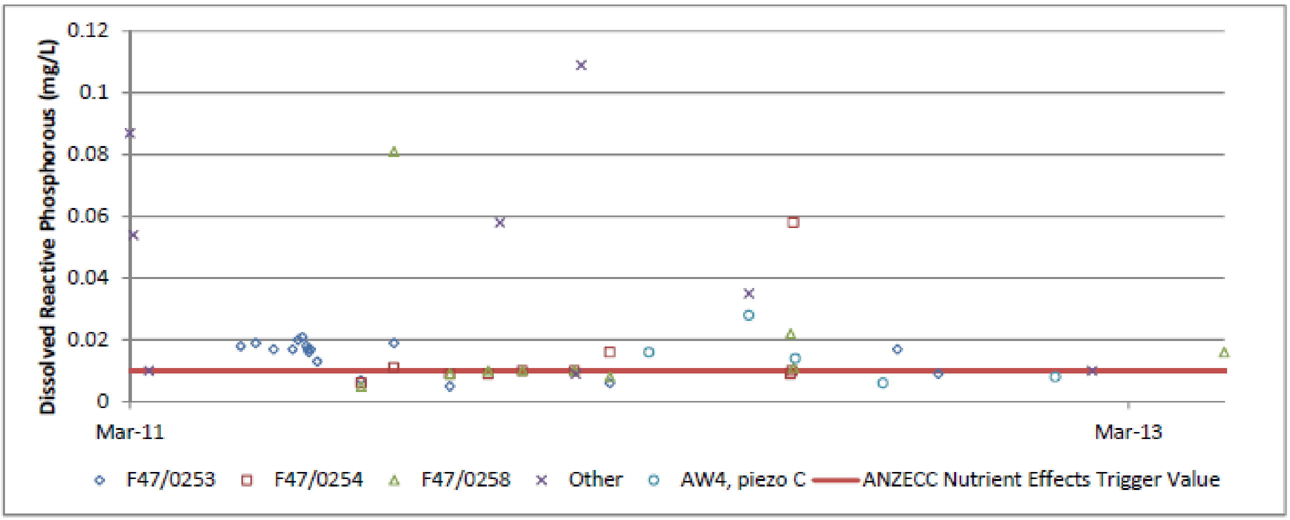




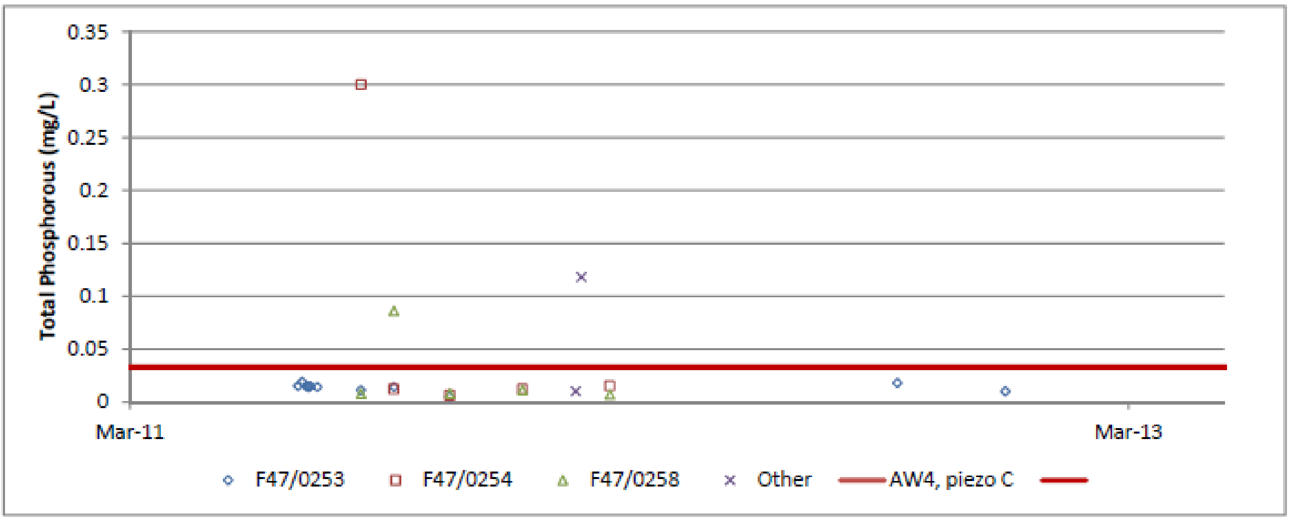




Total Nitrogen (mg/L)
25
20
15
10
5
0
Mar-11
Mar-13
F47/0253
F47/0254
F47/0258
Other
AW4, piezo C
ANZECC Nutrient Effects Trigger Value

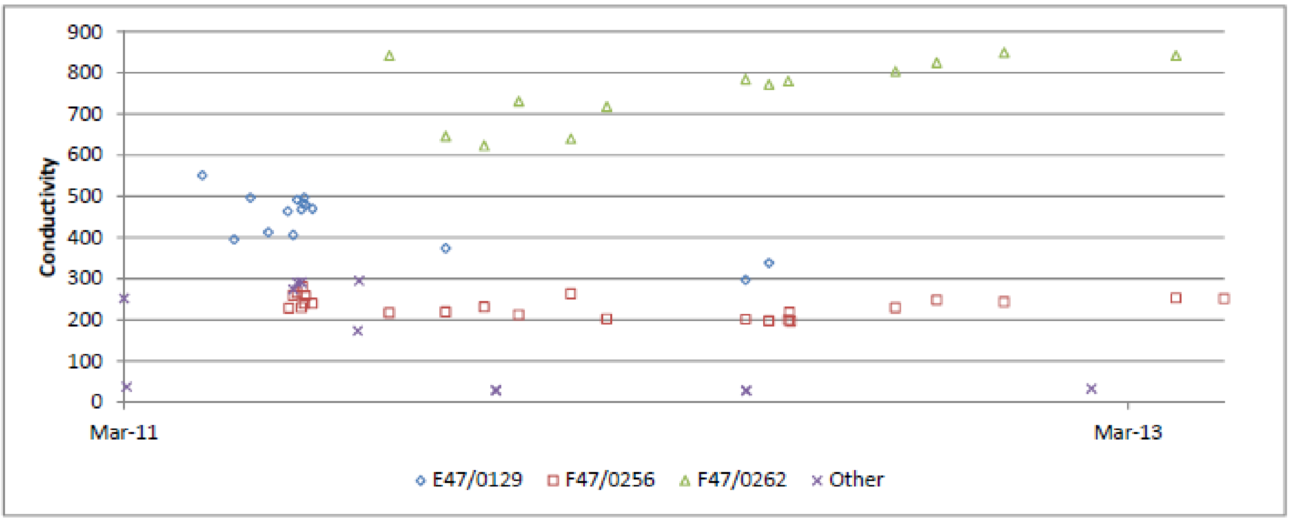


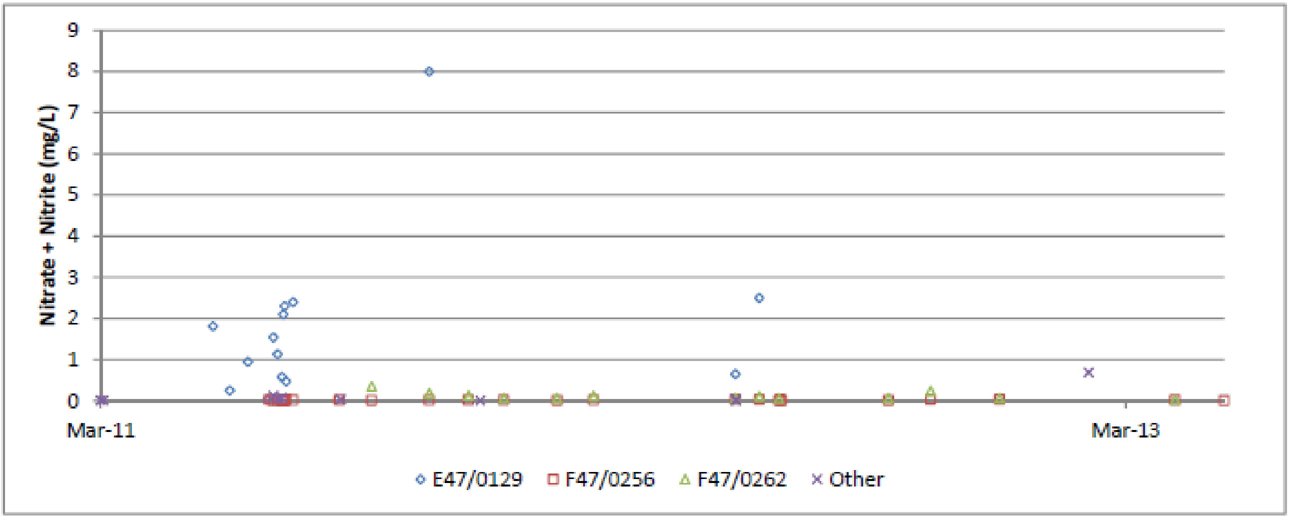
Dissolved Reactive Phosphorous (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Mar-11
Mar-13
F47/0253
F47/0254
F47/0258
Other
AW4, piezo C
ANZECC Nutrient Effects Trigger Value

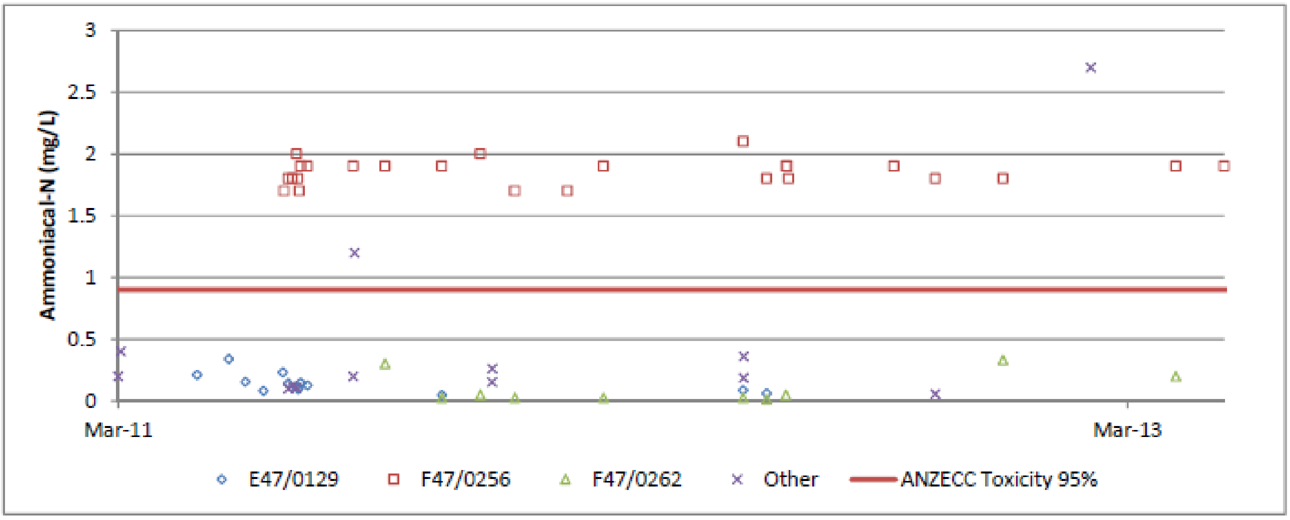


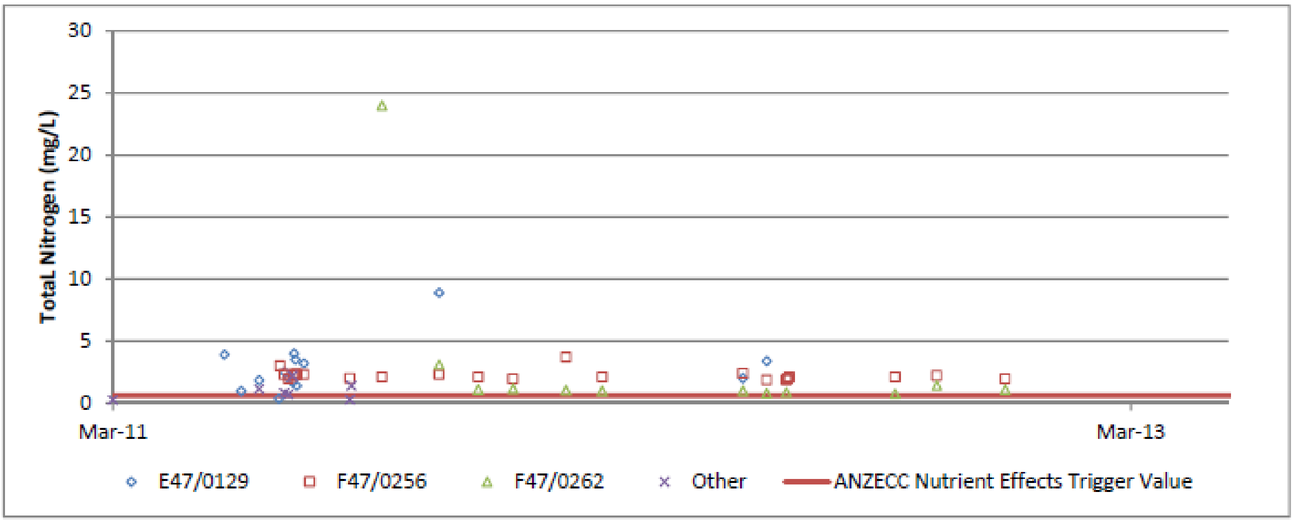
Total Phosphorous (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Mar-11
Mar-13
F47/0253
F47/0254
F47/0258
Other
AW4, piezo C

c) Moffat Creek Groundwater

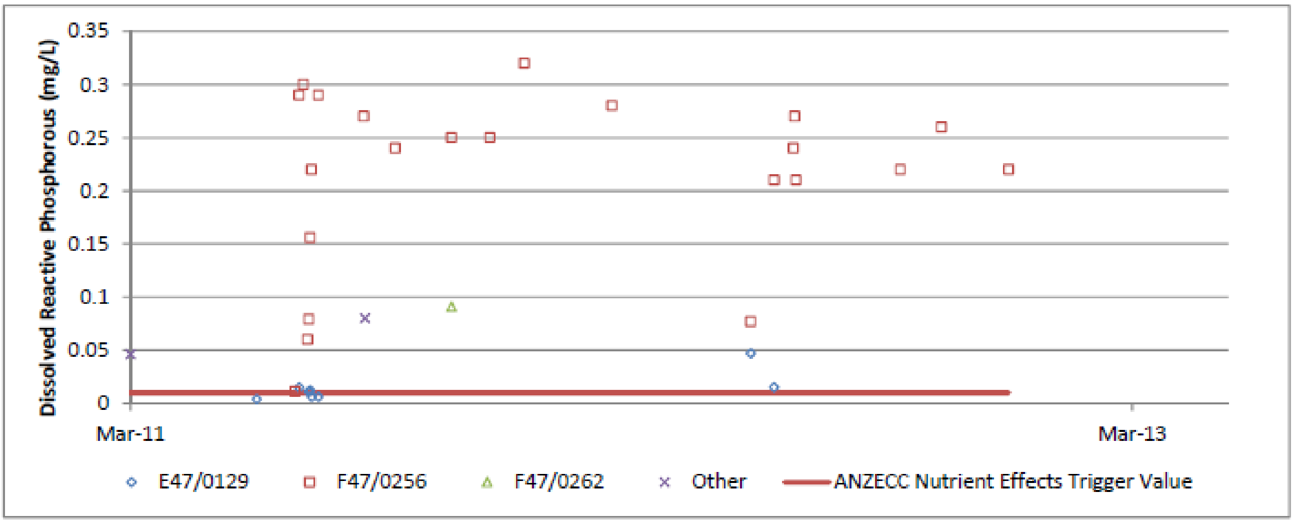




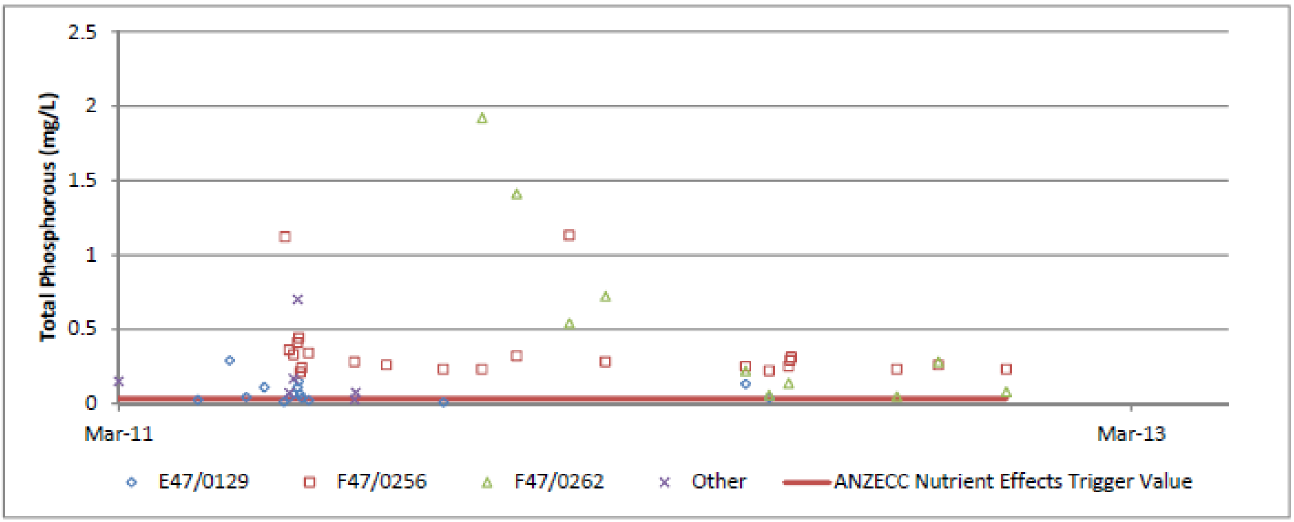




Total Nitrogen (mg/L)
30
25
20
15
10
5
0
Mar-11
Mar-13
E47/0129
F47/0256
F47/0262
Other
ANZECC Nutrient Effects Trigger Value



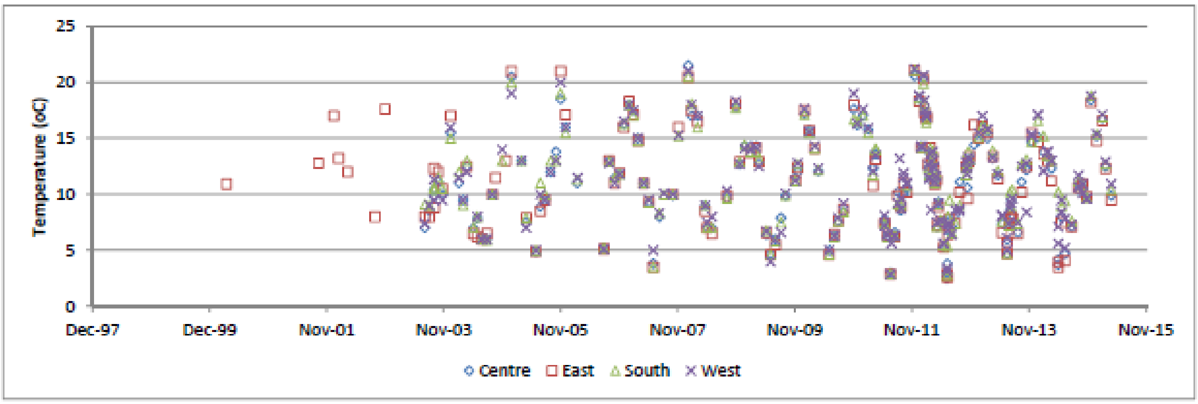
Dissolved Reactive Phosphorous (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Mar-11
Mar-13
E47/0129
F47/0256
F47/0262
Other
ANZECC Nutrient Effects Trigger Value

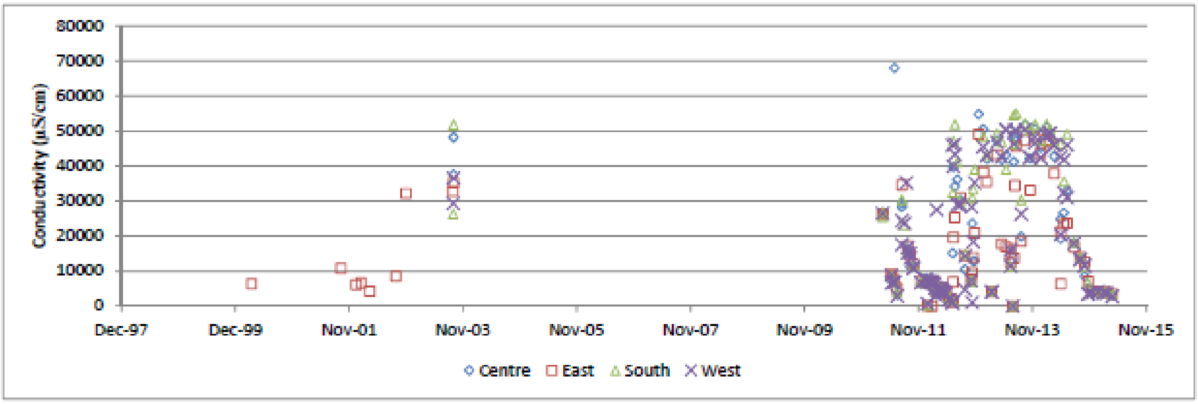


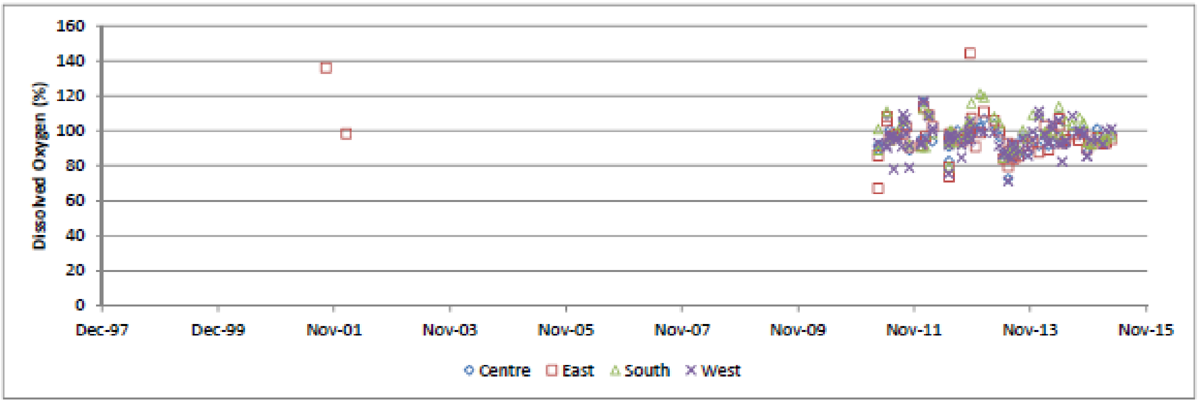
Total Phosphorous (mg/L)
2.5
2
1.5
1
0.5
0
Mar-11
Mar-13
E47/0129
F47/0256
F47/0262
Other
ANZECC Nutrient Effects Trigger Value

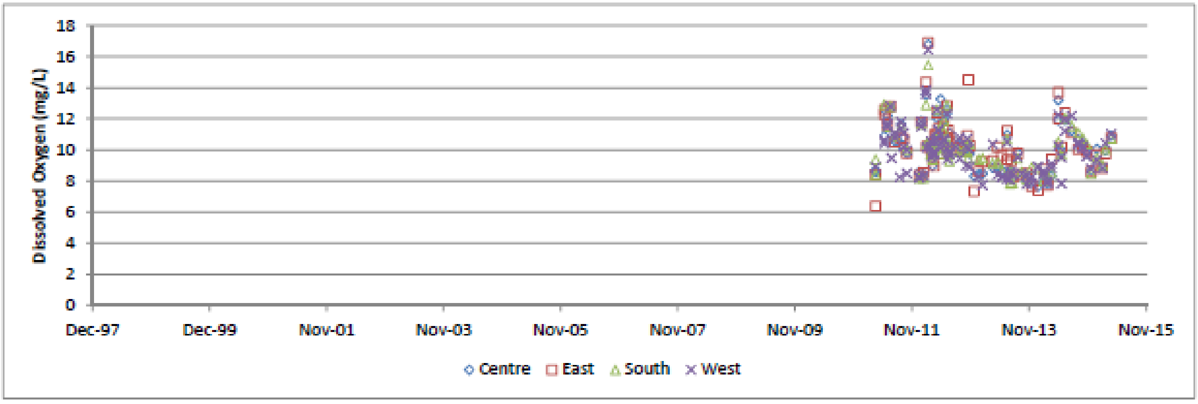
Waituna Lagoon Water Quality Graphs

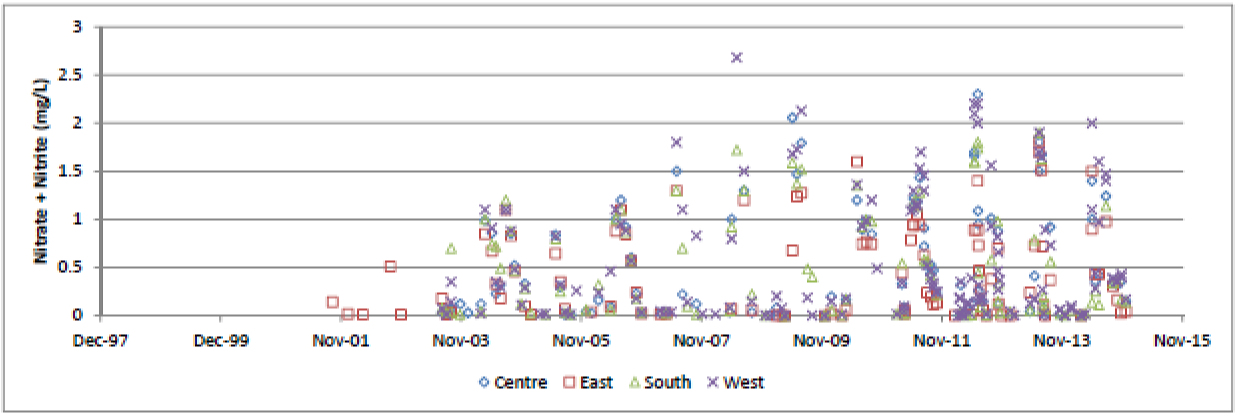
a) Waituna Lagoon Surface Water Quality

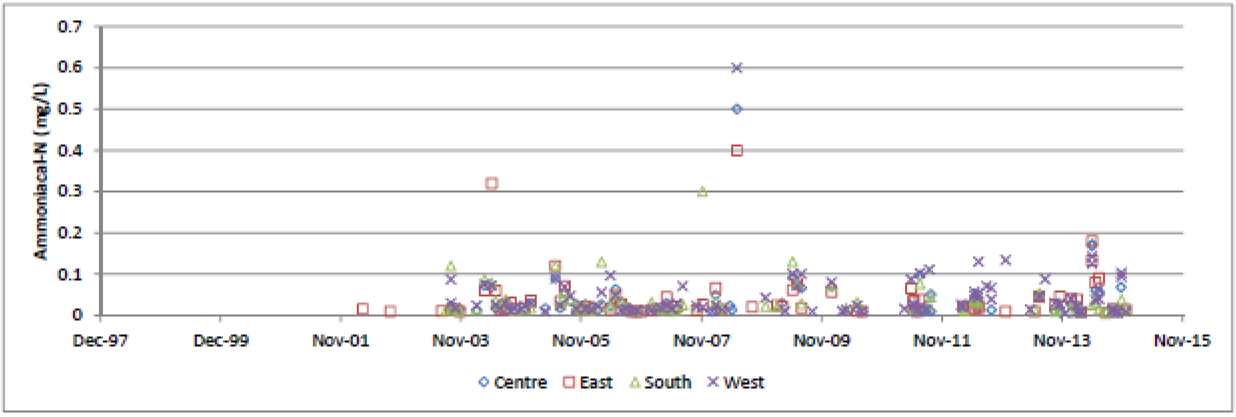


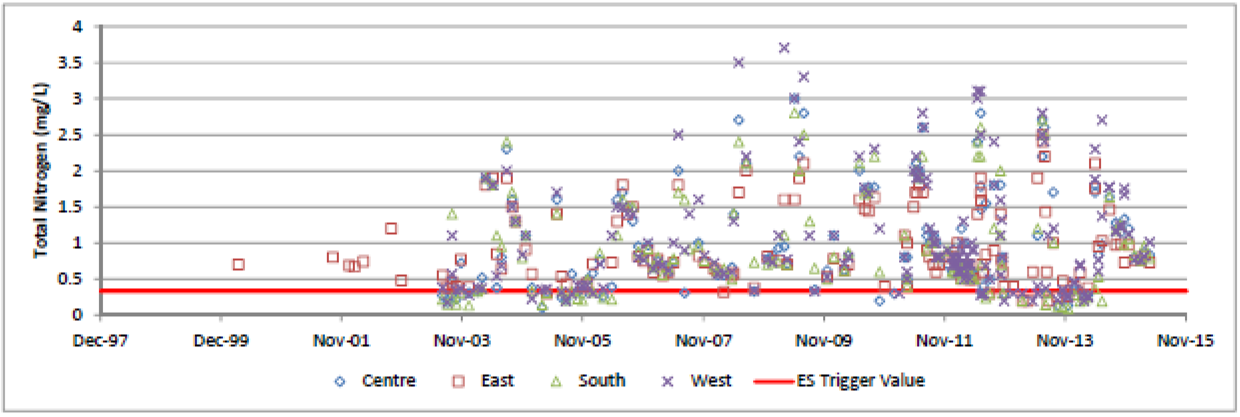


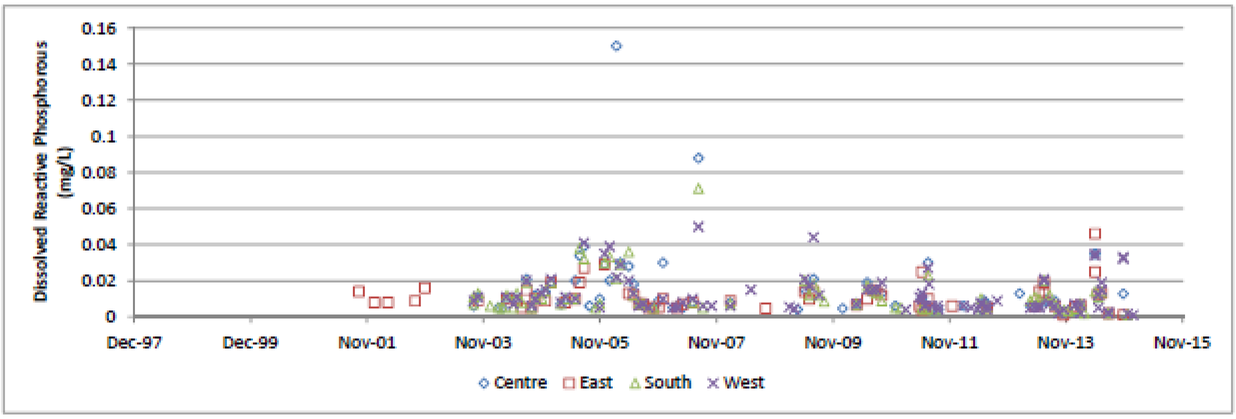


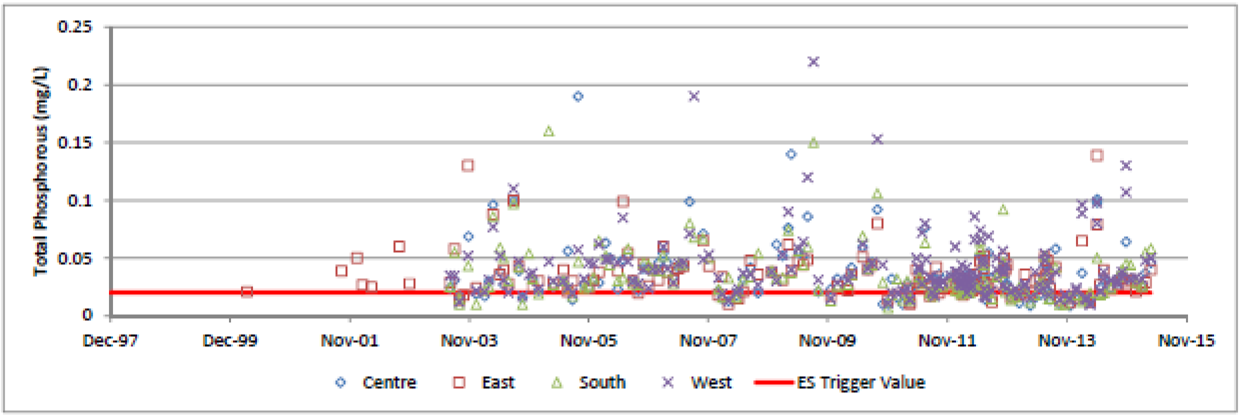


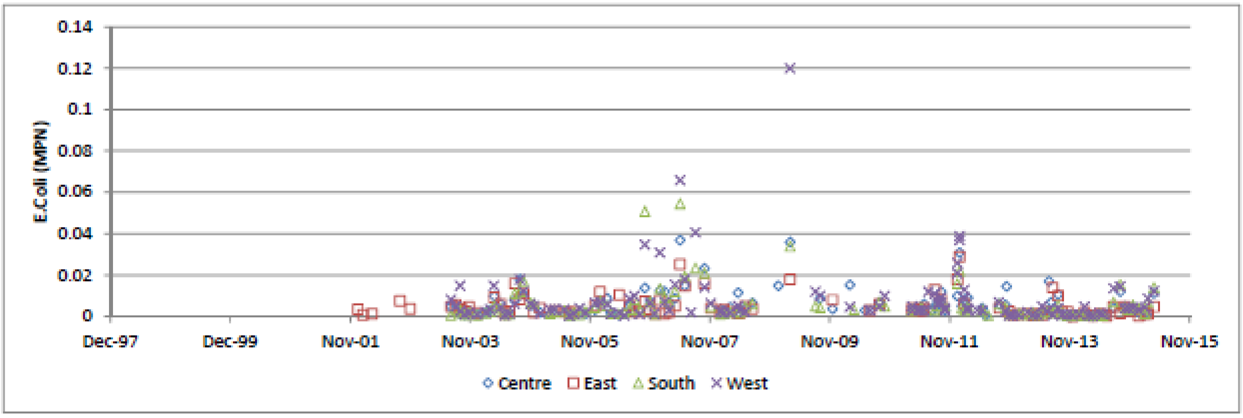

Nitrate + Nitrite (mg/L)
3
2.5
2
1.5
1
0.5
0
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West

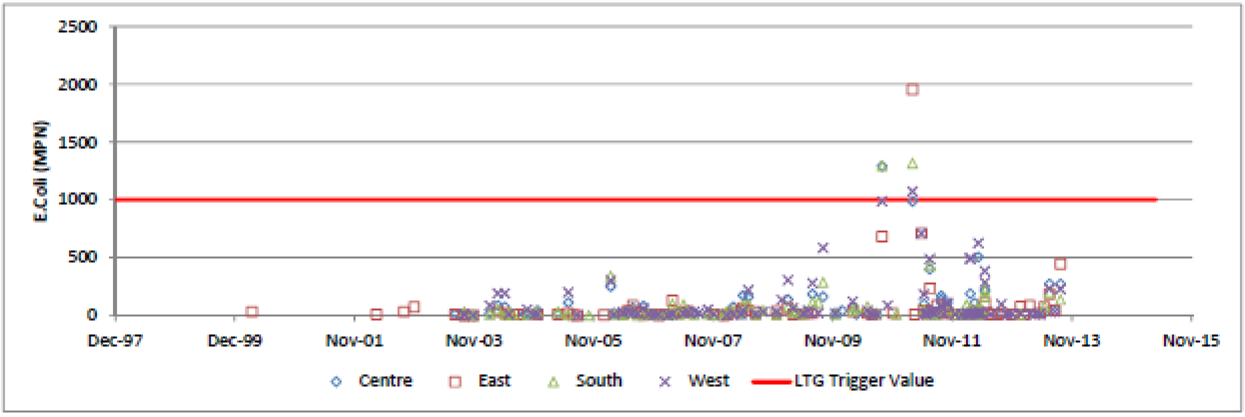

Ammoniacal-N (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West


Total Nitrogen (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West
ES Trigger Value

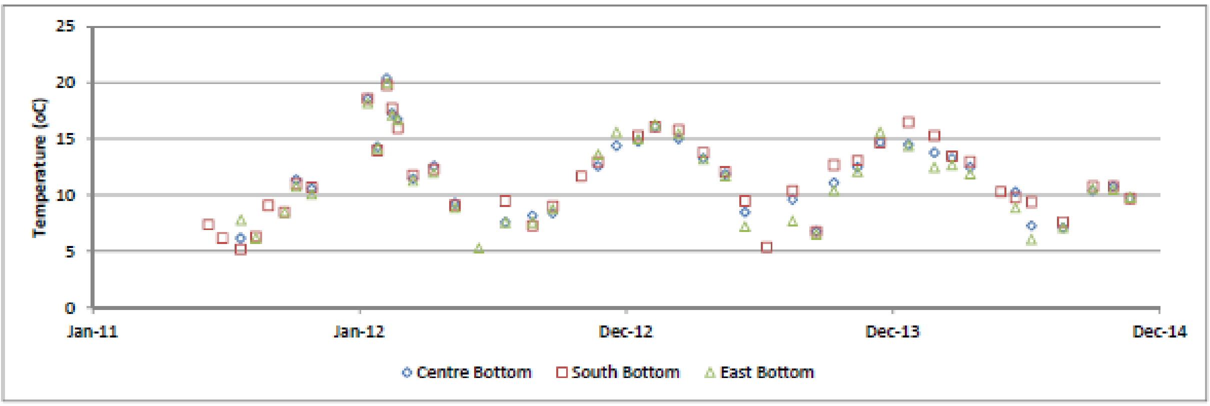

Dissolved Reactive Phosphorous (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West

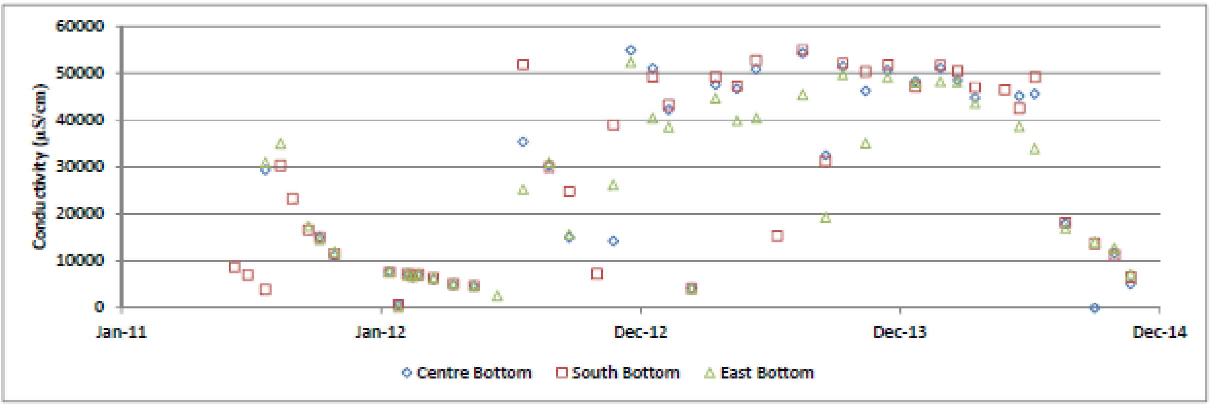

0.25
0.2
0.15
0.1
0.05
0
Total Phosphorous (mg/L)
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West
ES Trigger Value

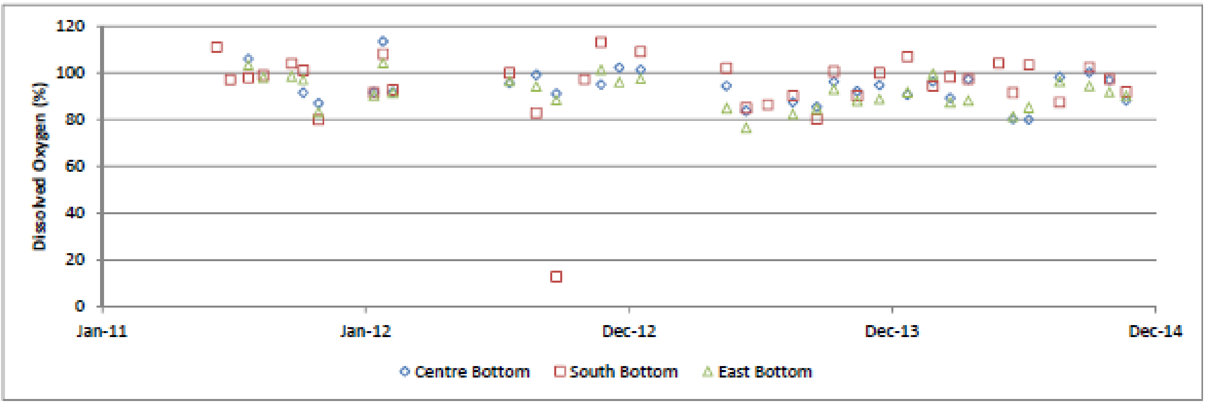

0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
E.Coli (MPN)
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West

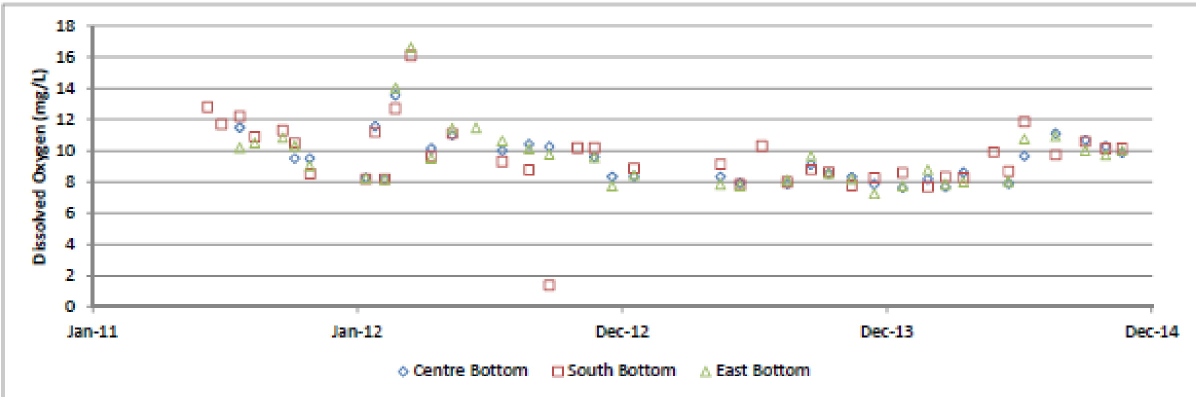

2500
2000
1500
1000
500
0
E.Coli (MPN)
Dec-97
Dec-99
Nov-01
Nov-03
Nov-05
Nov-07
Nov-09
Nov-11
Nov-13
Nov-15
Centre
East
South
West
LTG Trigger Value

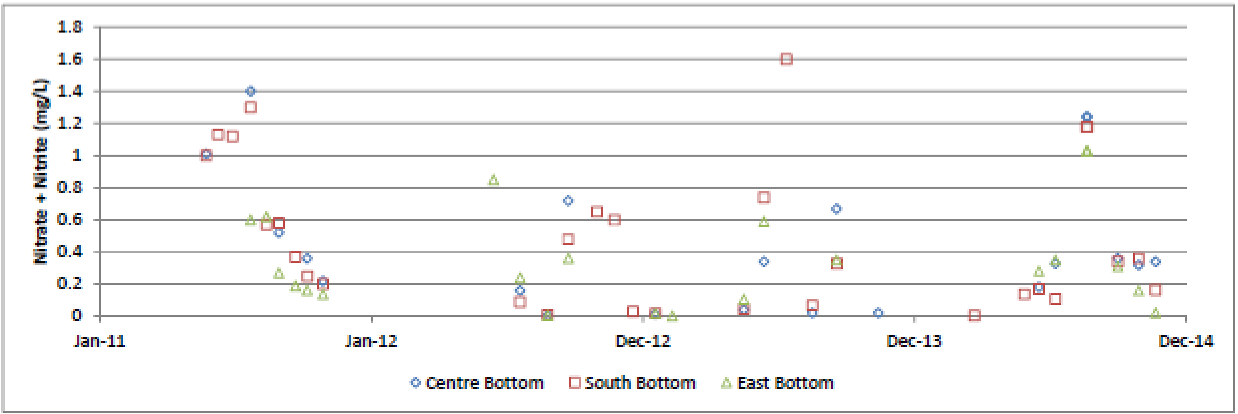
b) Waituna Lagoon Bottom Water Quality

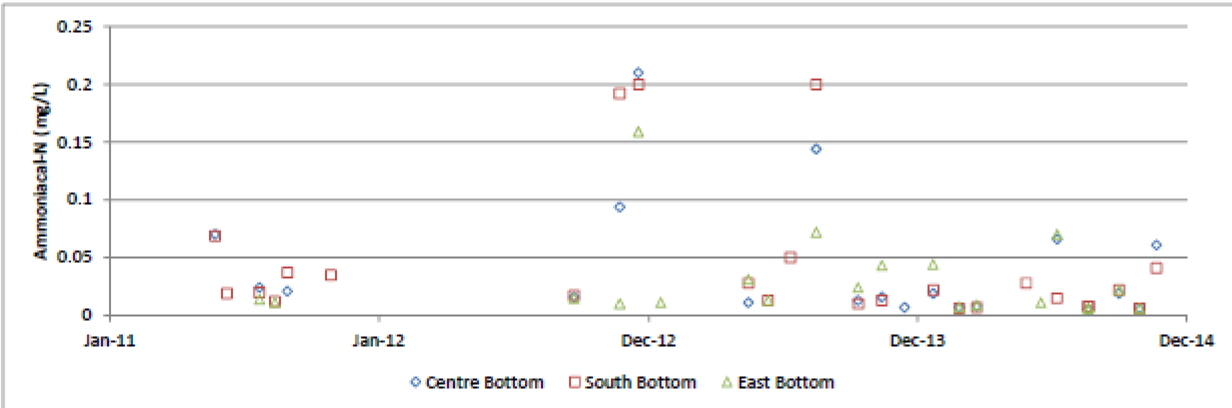


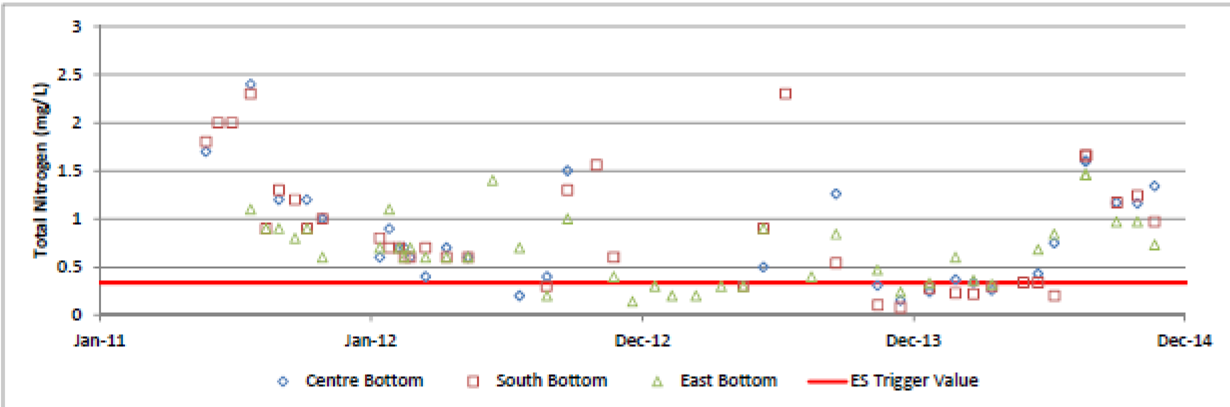


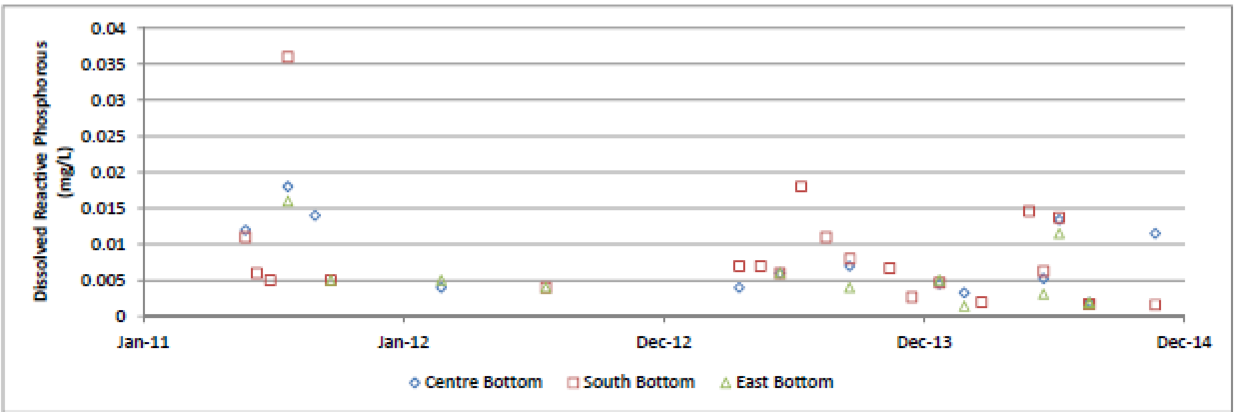


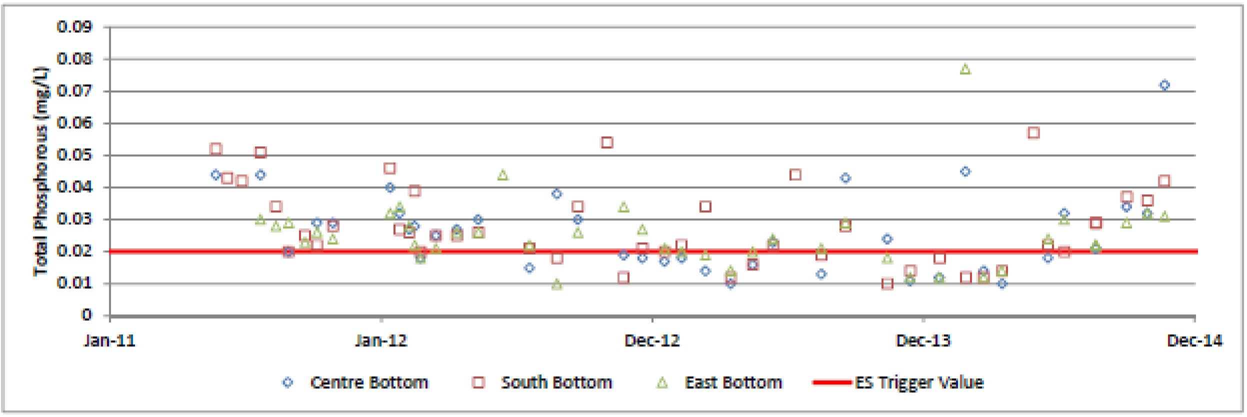


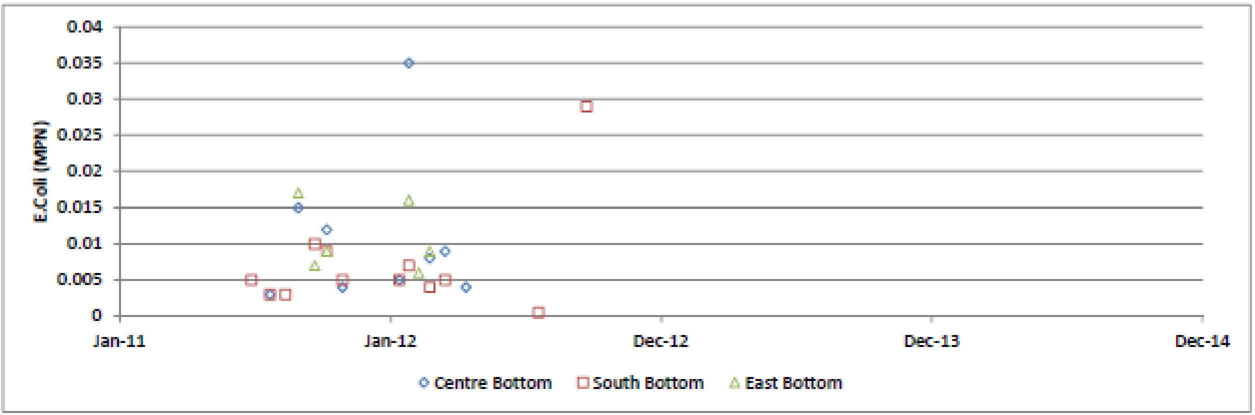

Nitrate + Nitrite (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom

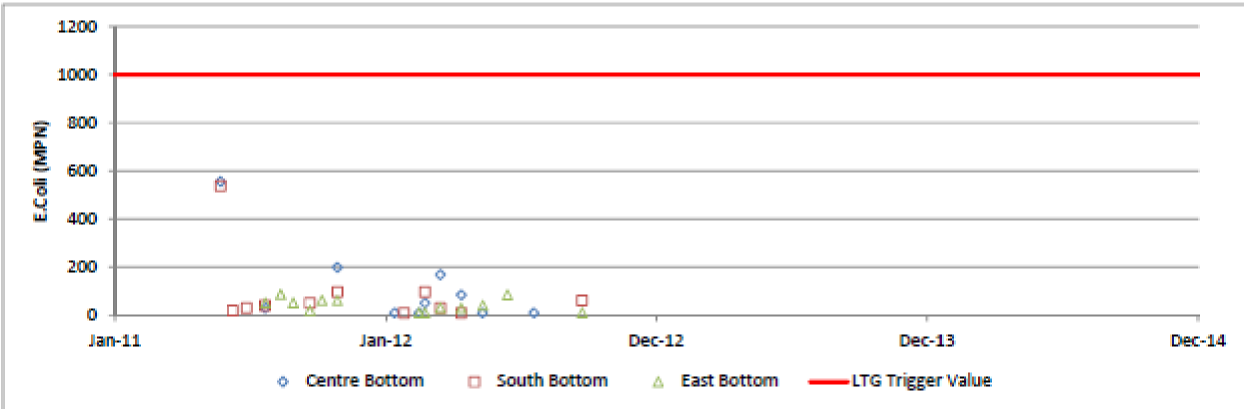

Ammoniacal-N (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom


Total Nitrogen (mg/L)
3
2.5
2
1.5
1
0.5
0
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom
ES Trigger Value

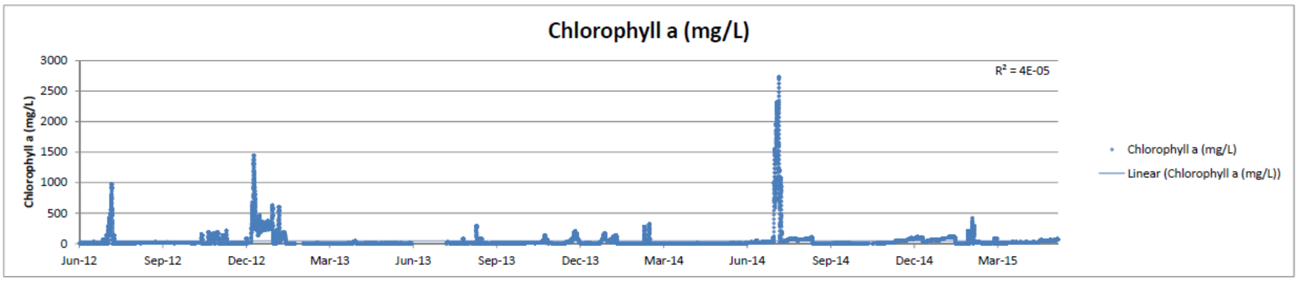

Dissolved Reactive Phosphorous (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom

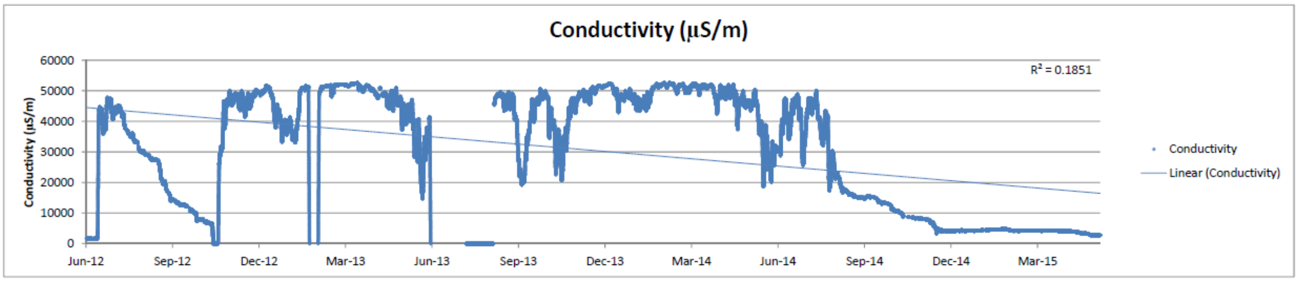

0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Total Phosphorous (mg/L)
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom
ES Trigger Value

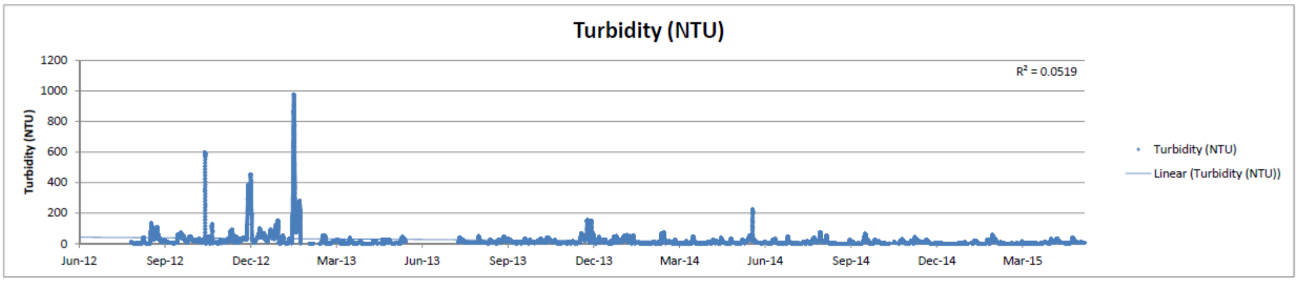

0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
E.Coli (MPN)
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom

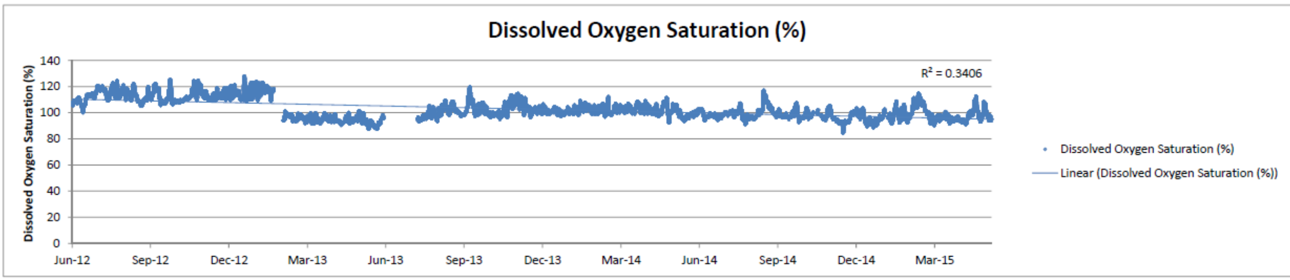

1200
1000
800
600
400
200
0
E.Coli (MPN)
Jan-11
Jan-12
Dec-12
Dec-13
Dec-14
Centre Bottom
South Bottom
East Bottom
LTG Trigger Value

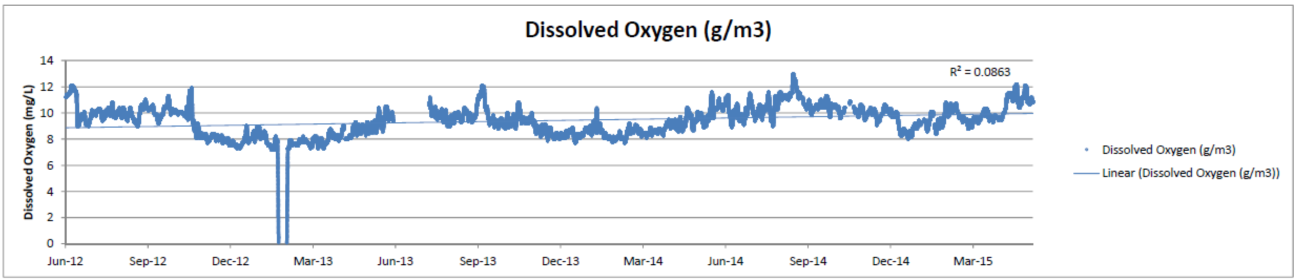
c) Waituna Lagoon Telemetered Water Quality Monitoring (Pontoon)

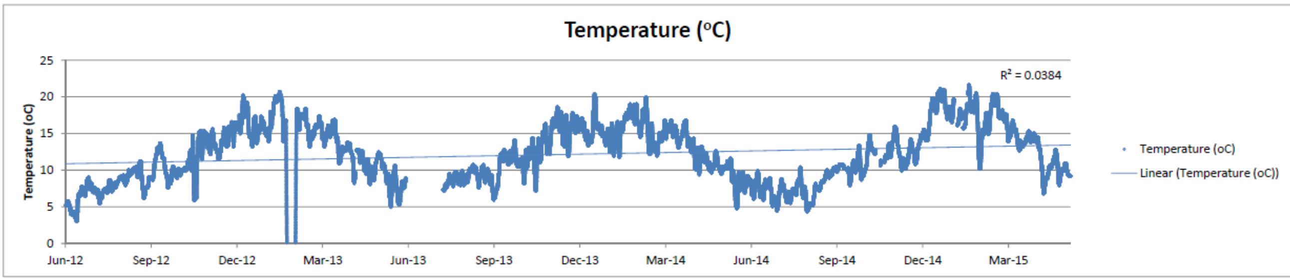




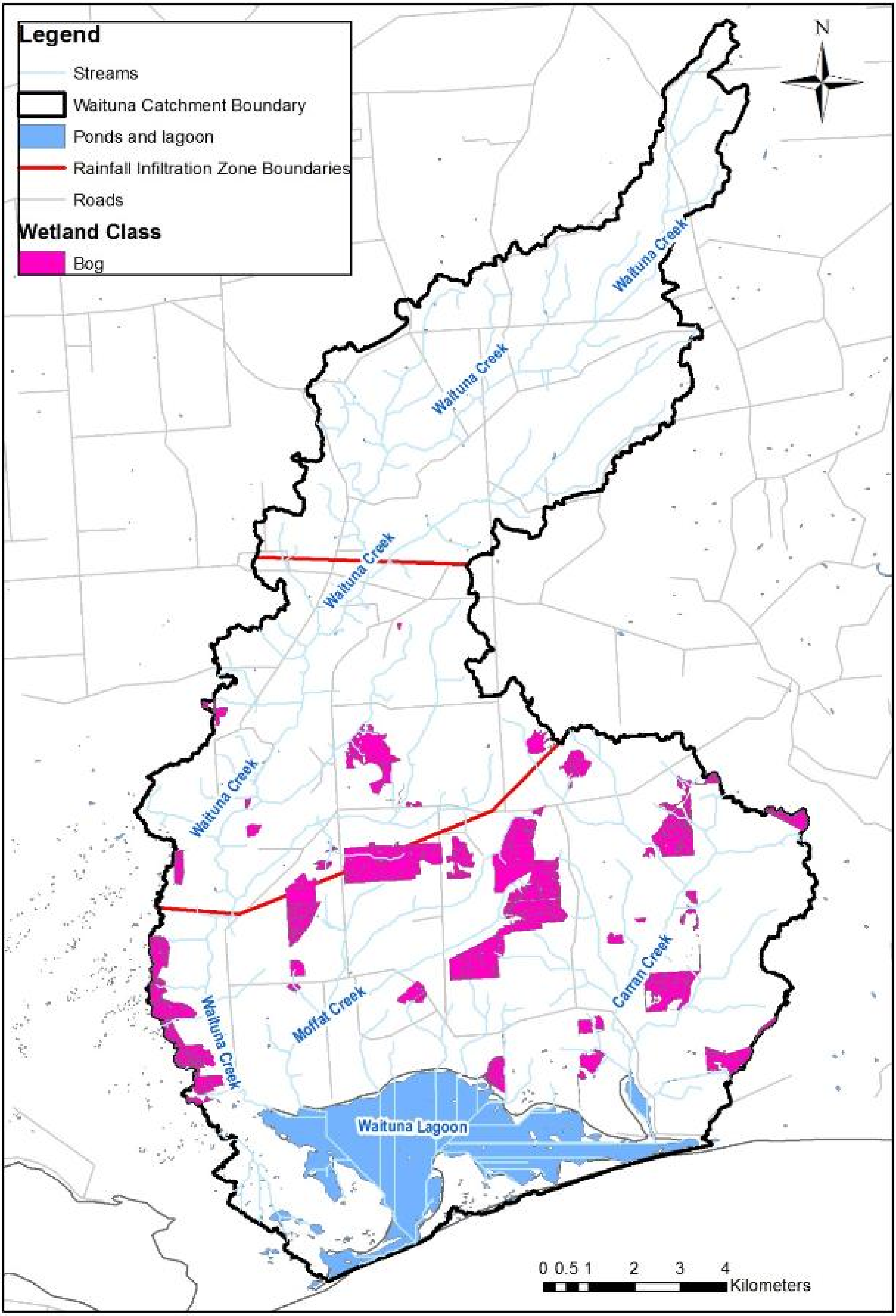


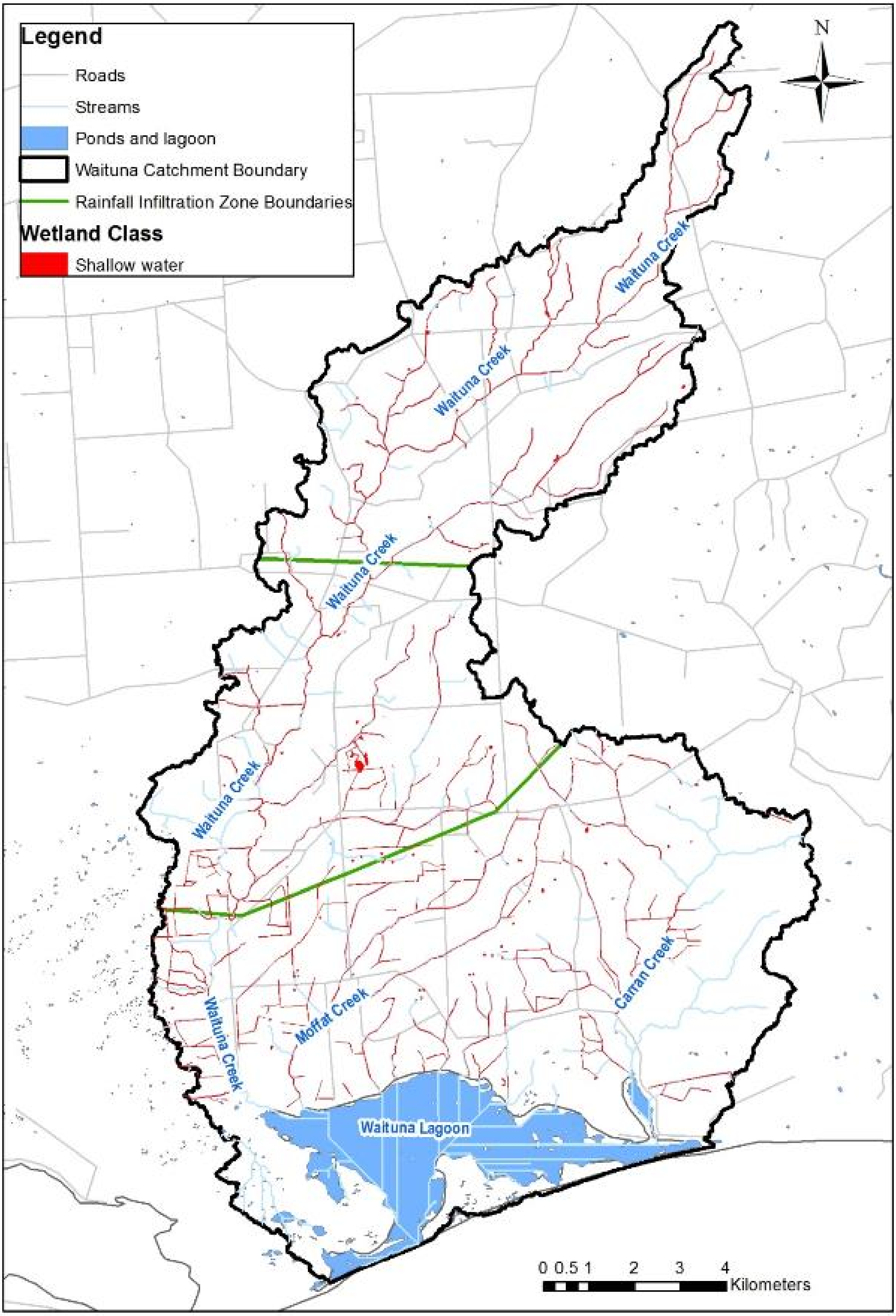

Dissolved Oxygen Saturation (%)
Dissolved Oxygen Saturation (%)
140
120
100
80
60
40
20
0
Jun-12
Sep-12
Dec-12
Mar-13
Jun-13
Sep-13
Dec-13
Mar-14
Jun-14
Sep-14
Dec-14
Mar-15
R² = 0.3406
Dissolved Oxygen Saturation (%)
Linear (Dissolved Oxygen Saturation (%))

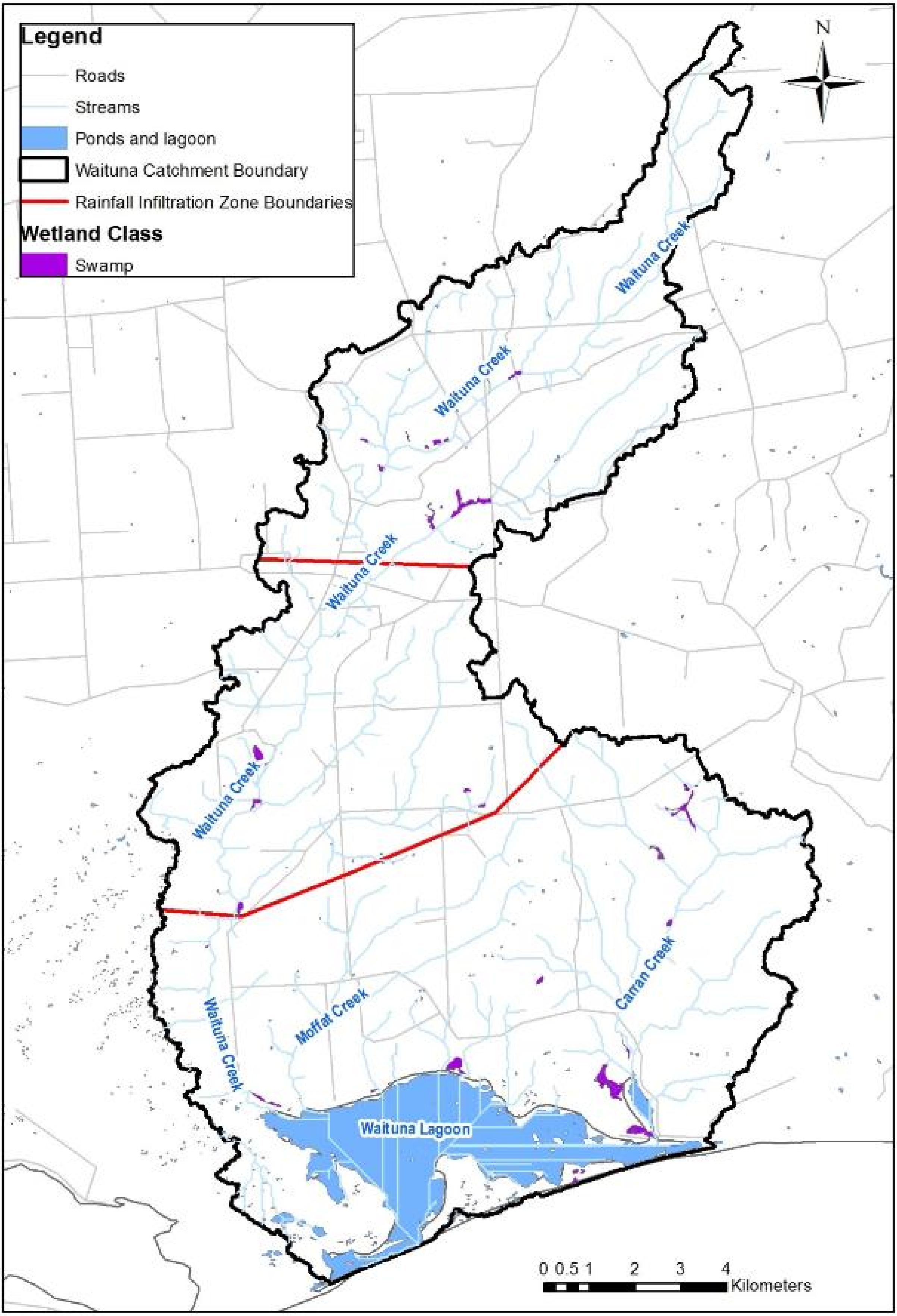

Dissolved Oxygen (g/m3)
Dissolved Oxygen (mg/L)
14
12
10
8
6
4
2
0
Jun-12
Sep-12
Dec-12
Mar-13
Jun-13
Sep-13
Dec-13
Mar-14
Jun-14
Sep-14
Dec-14
Mar-15
R² = 0.0863
Dissolved Oxygen (g/m3)
Linear (Dissolved Oxygen (g/m3))

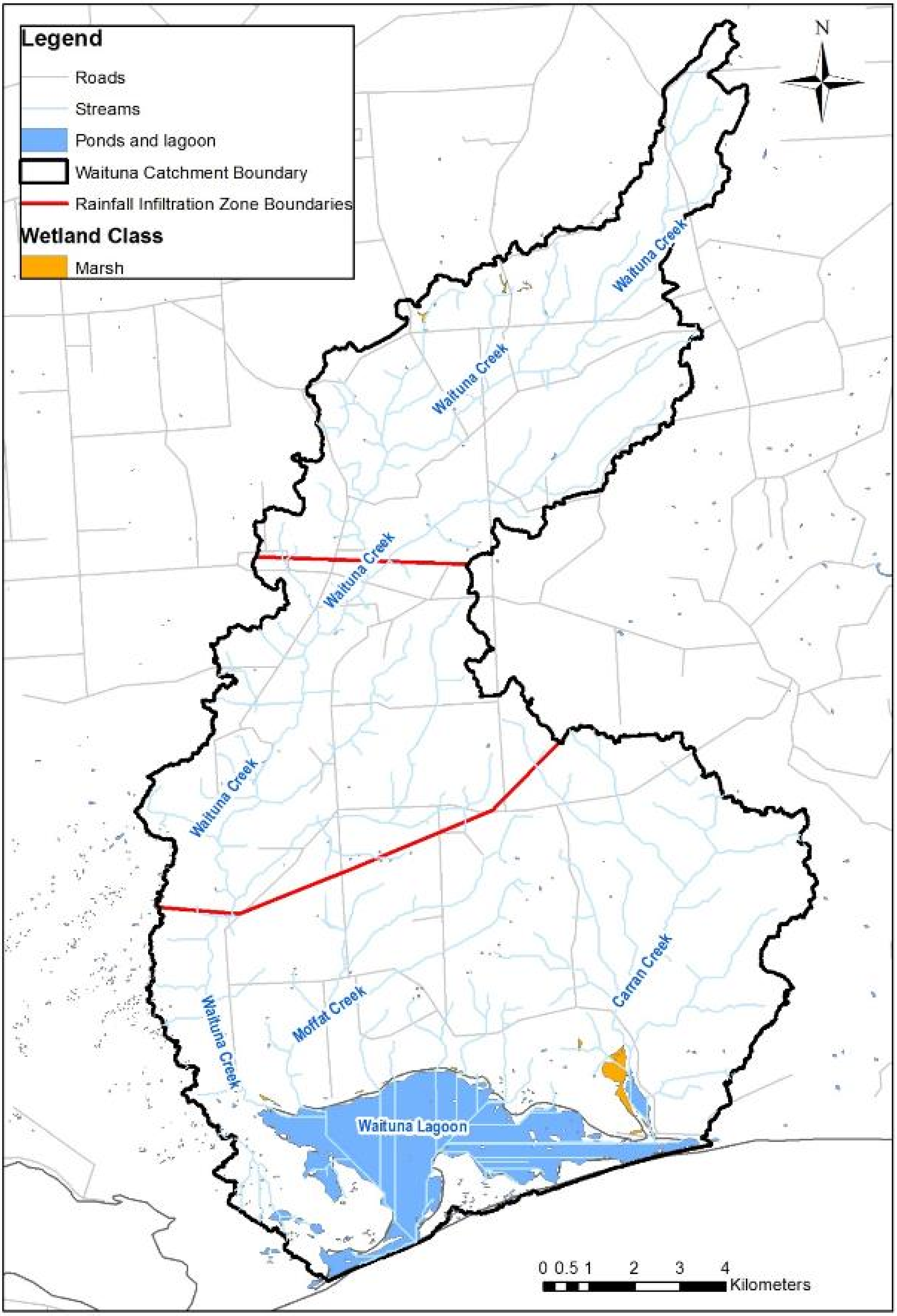

Temperature (°C)
Temperature (oC)
25
20
15
10
5
0
Jun-12
Sep-12
Dec-12
Mar-13
Jun-13
Sep-13
Dec-13
Mar-14
Jun-14
Sep-14
Dec-14
Mar-15
R² = 0.0384
Temperature (oC)
Linear (Temperature (oC))

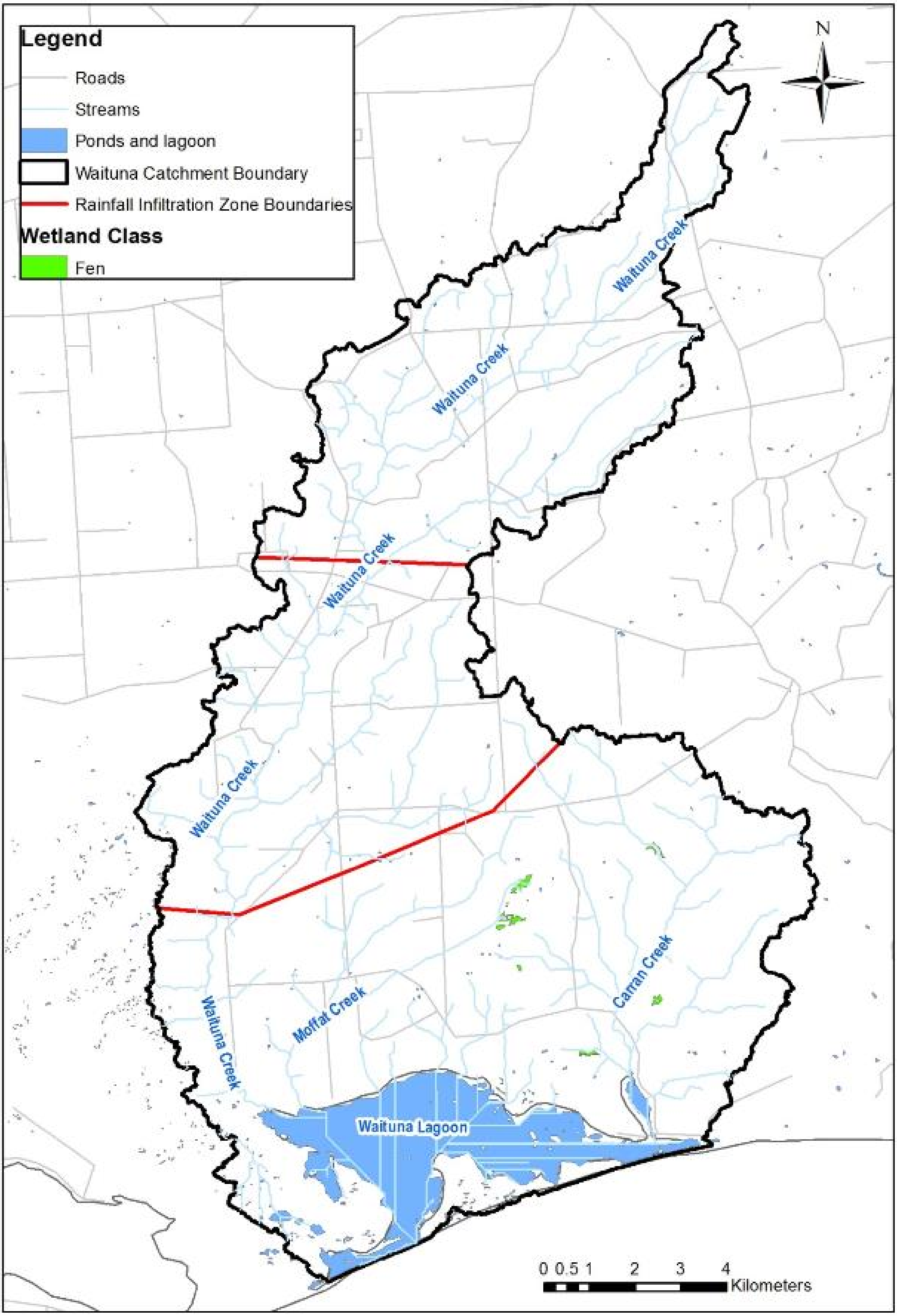
Appendix D Maps of Wetland Types in the Waituna Catchment


Legend
Streams
Waituna Catchment Boundary
Ponds and lagoon
Rainfall Infiltration Zone Boundaries
Roads
Wetland Class
Bog
N
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Moffat Creek
Carran Creek
Waituna Lagoon
0 0.5 1 2 3 4
Kilometers


Legend
Roads
Streams
Ponds and lagoon
Waituna Catchment Boundary
Rainfall Infiltration Zone Boundaries
Wetland Class
Shallow water
N
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Moffat Creek
Carran Creek
Waituna Lagoon
0 0.5 1 2 3 4
Kilometers


Legend
Roads
Streams
Ponds and lagoon
Waituna Catchment Boundary
Rainfall Infiltration Zone Boundaries
Wetland Class
Swamp
N
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Moffat Creek
Carran Creek
Waituna Lagoon
0 0.5 1 2 3 4
Kilometers


Legend
Roads
Streams
Ponds and lagoon
Waituna Catchment Boundary
Rainfall Infiltration Zone Boundaries
Wetland Class
Marsh
N
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Moffat Creek
Carran Creek
Waituna Lagoon
0 0.5 1 2 3 4
Kilometers


Legend
Roads
Streams
Ponds and lagoon
Waituna Catchment Boundary
Rainfall Infiltration Zone Boundaries
Wetland Class
Fen
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Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Waituna Creek
Moffat Creek
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Waituna Lagoon
0 0.5 1 2 3 4
Kilometers

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