WILLIAMSON
WATER & LAND ADVISORY

Muriwai Downs Golf Course Project

Appendix A - Baseline Environmental Monitoring Report

THE BEARS HOME PROJECT MANAGEMENT LIMITED

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Appendix A - Baseline Environmental Monitoring

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Contents

1. Introduction

Williamson Water & Land Advisory (WWLA) were commissioned by The Bears Home Project Management Limited (Applicant) in January 2021 to undertake environmental monitoring across the approximately 507 hectare Muriwai Downs Property (Property), located at 610 Muriwai Road. Monitoring comprised of stream and wetland water quality sampling, shallow groundwater monitoring, and flow gauging. Monitoring was carried out between late February and early August 2021.

1.1 Objective and Scope of Works

The scope of works comprised the following:

- ***Water Quality*** – collection of surface water, including Lake Ōkaihau, and shallow groundwater/wetland samples for water quality analysis;
- ***Water Quantity*** **-** Measurement of streamflow at a number of locations across the Property;
- ***Hydrological Functionality*** **-** Understanding of shallow groundwater level in wetlands or ephemerally wet areas, and fluctuation in response to different weather conditions.
- The objective of the work was to develop a comprehensive understanding of baseline environmental conditions under the current pastoral land use. This baseline understanding will in turn be compared against predictions of the likely change in environmental conditions with partial recreation land use conversion of the Property and the ongoing operation of a golf course and associated facilities.
- All aspects of the monitoring will also be used to calibrate catchment rainfall-runoff models developed as part of the Surface Water Effects Report, and to support the resource consent application for a proposed high-flow water take.

1.2 Project Overview

The Property is located approximately 3 kilometres northeast of Muriwai Beach Township, and covers approximately 507 hectares. The Property is predominantly comprised of pastoral farmland currently used for sheep and beef, as well as dairy farming. The sheep and beef operations are focused in the northern and western parts of the site, while the dairy operation is focused in the south-eastern part of the Property. The Property also contains an active sandstone quarry to the south of Muriwai Road.

In addition to the above farming land use, the Property contains pockets of significant ecological areas, outstanding natural features and a number of wetlands. These ecologically significant areas contain kauri and broadleaved forest remnants and are generally located on steeper terrain with active watercourses running through them. The Property also contains aquatic features such as Lake Ōkaihau and a large wetland complex below Toroanui Falls. Muriwai Road runs east to west through the Property, making a large part of the farming operation visible to the public.

The Applicant is proposing the establishment of a golf resort facility of international standing, including luxury short stay accommodation and a sports academy as well as areas of ecological restoration and enhancement.

This report details the baseline environmental data collection programme and will be used to support land use change analyses, and the resource consent applications for the Project.

1.3 Report Structure

The report comprises descriptions of the following:

- Introduction and Project Overview (**Section 1**);
- Environmental Monitoring Methodology (**Section 2**);
- Monitoring Sites (**Section 3**);

- Baseline Monitoring Results (**Section 4**); and
- Summary (**Section 5**).

2. Environmental Monitoring Methodology

Monitoring of surface water flows, shallow groundwater levels, and surface water quality was carried out across the Property from late February to early August 2021. Groundwater and surface water monitoring will be ongoing, while water quality sampling finished in July 2021.

2.1 Surface Water Flow

Measuring surface water flow involves continuously recording stream water level with electronic sensors. To convert the surface water level (m) into flow (m^3/s), manual stream flow monitoring (gaugings) of level and flow are concurrently undertaken over a range of flow conditions from low flow to flood flow. The manual gaugings are used to develop a rating curve that is applied to the continuously measured water levels to convert into streamflow.

Ultra-sonic water level sensors (Waterwatch LS1)[1] were installed at three stream monitoring sites (**Table 1**). The sensors continuously monitored water levels at a predefined interval of 15 minutes, and transmitted the data to the cloud, where it could be viewed remotely by the user. The locations of the stream monitoring sites are shown on **Figure 1**.

Rating curves were developed from flow gaugings measured during representative low, medium and high flow conditions. Velocity gaugings were undertaken using a handheld acoustic doppler velocimeter (ADV) (Sontek FlowTracker 2)[2].

The resulting time series of surface water flow, developed from measured water level data and rating curves, is referred to as a rated flow time series or dataset.

2.2 Shallow Groundwater

Shallow groundwater levels were measured using five stand-pipe piezometers (**Table 2**). Piezometers allowed groundwater to enter PVC standpipes through a series of slots at the base of each pipe. A permanent sensor mounted above ground at the top of each pipe measured changes in water level over time and transmitted measurement data via telemetry.

2.2.1 Installation

Piezometers 1 – 5 were installed across the site in boreholes that were excavated using a 150 mm diameter hand auger to ~1.6 m depth. A 2-metre length of prefabricated 100 mm PVC standpipe with a screen at the base (to allow water flow into and out of the pipe) was capped, fitted with a layer of filter fabric, placed in the hole and backfilled with:

1. gravel, against the screened portion; and
2. bentonite in the top 300 mm to seal the hole and prevent surface water running down the pipe into the saturated zone.

The locations of the piezometers are shown on **Figure 1**.

2.2.2 Sensors

WaterWatch LS1 ultrasonic water level sensors were mounted to the top of each piezometer. The sensors were configured to:

- measure water levels on five-minute intervals; and
- transmit data to the cloud sever every three hours.

[1] https://waterwatch.io/products/ls1-ultrasonic-level-sensor
[2] https://www.sontek.com/flowtracker2

2.3 Water Quality

Water sampling was carried out to quantify the chemical constituency of the water across the Property (see **Figure 1** for locations).

Water samples were generally collected fortnightly over the period February to June, and bi-monthly over July to August. However, the interval between sampling rounds was varied in response to rainfall events. The objective was to collect samples during both wet and dry conditions. Samples were collected from the same sites each time.

In some cases, samples could not be retrieved directly out of open channels, for instance in wetlands. In these cases, small amounts of available surface water were collected from local depressions. Occasionally it was necessary to dig a small depression in order to retrieve a sufficient volume of water for analysis[3].

Upon retrieval, all samples were immediately placed on ice in a cooled storage unit (chilly bin) and couriered to Analytica Laboratory in Hamilton within 24 hours for analysis.

[3] At each water sampling site, three bottles were filled for each of the various set of lab tests, comprising 1 L, 0.5 L, and 0.4 L containers.

3. Monitoring Sites

The locations of each stream level, groundwater level, wetland level and water quality monitoring site are presented in **Figure 1**.

Detailed descriptions of each site, why they were selected, and photographs of each location are presented in turn for the stream, groundwater and water quality monitoring sites in **Section 3.1**, **Section 3.2**, and **Section 3.3**, respectively.

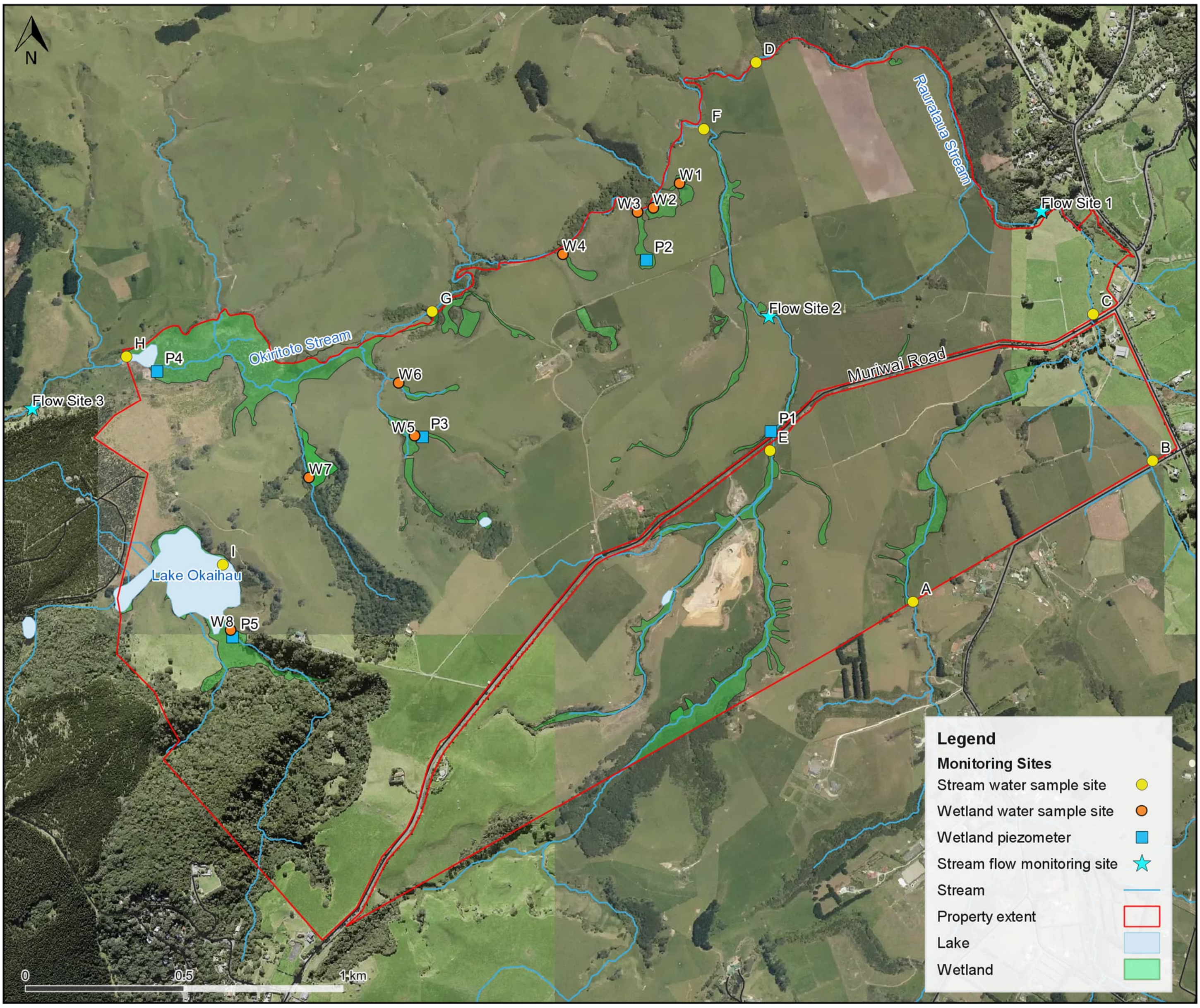

Figure 1. Overview map of environmental monitoring sites.

3.1 Surface Water - Level and Flow

Three stream flow monitoring sites were installed on the Property, representing the two main inflows; the Raurataua Stream (Flow 1), Ōkiritoto Stream upgradient (Flow 2), and the Ōkiritoto Stream downgradient as it leaves the Property (Flow 3).

These three sites were chosen as they comprise the main surface water bodies on the Property and flow perennially (all year), allowing continuous data to be recorded. The objective was to collect water level data on these streams as they entered the Property, and then again at the exit of the Property, after they had combined (within the Property) forming the Ōkiritoto Stream. This data was used to quantify the surface water volumes and dynamics on the Property as well as calibrate catchment flow models.

Descriptions and photographs of the three-stream level and flow monitoring sites are presented in **Table 1**.

Table 1. Summary of flow monitoring sites.

Site Name	Photo	Description
Flow 1		Flow Site 1 was mounted on a steel T-frame. The vertical pole was driven approximately 1.5 metres into the side of the streambank to ensure it remained stable in position. The horizontal bar extended approximately 1.2 metres out towards the centre of the stream. At this location, the streambed is irregular, but generally flat and hard rock. The stream banks are close to vertical, therefore giving a general rectangular cross-sectional profile.
Flow 2		Flow Site 2 was mounted to the downstream side of the small wooden farm bridge near the small, abandoned basalt quarry. The sensor was mounted approximately 2 metres above the streambed. The streambed is irregular and rocky at this location. Under the bridge the stream cross-sectional profile is generally rectangular with an irregular bottom. Downstream of the bridge, the stream cross-sectional profile is trapezoidal.
Flow 3		Flow Site 3 was mounted to a large Willow tree branch that has grown across the stream. The sensor was approximately 1.5 metres above the streambed. At this location, the streambed consists of firm compacted granular sediment, and the cross-sectional profile generally trapezoidal. Streambanks were overgrown with grass.

3.2 Shallow Groundwater

Monitoring sites were selected according to their proximity to shallow groundwater in areas of interest such as wetlands and streams, as well as their distribution across different parts of the Property. Sites where the water table was approximately 300 mm below ground level (mmBGL) were targeted as these locations allowed for relatively efficient piezometer set-up without the need to mobilise large and expensive drilling equipment. Since piezometers were set-up after a long dry period, some piezometers were placed close to active surface water bodies to ensure shallow groundwater would remain visible to the sensors throughout the monitoring period.

These shallow piezometers provide information on water levels (head) in the shallow aquifer, which is unconfined, meaning the top of the aquifer is at the ground surface. This means the water levels in the shallow aquifer can reach the surface under certain conditions (typically wet), and may have a direct bearing on the ecological makeup and maintenance of the wetlands they were placed in. When water levels are lower in the shallow aquifer, for instance after a dry summer, the wetlands are also likely to be drier and have less water moving through them, and vice-versa over the wetter winter months.

As alluded to above, deeper piezometers were not installed. Had they been installed, deeper piezometers would either:

1. measure groundwater levels deeper down in the same unconfined aquifer (giving the same recorded levels as the shallower piezometers, and therefore be of no additional advantage); or
2. measure head levels in a separate, partially confined or confined aquifer. The data from a confined aquifer would likely be of limited use and consequence to this study, as a confined aquifer would have limited effect on the wetlands and streams this study focuses on.

Each piezometer is depicted in **Table 2**.

Table 2. Groundwater monitoring sites – installation overview.

Site Name	Photo	Description
P1		P1 was positioned ~400 m downstream of the sandstone quarry in a fenced off site near an unnamed stream.
P2		P2 was positioned in the upper reaches of the wetland monitoring site *W3,* which flows into the Ōkiritoto Stream.

P3		P3 was positioned on the outer edge of a wetland near the *W5* water sampling site. Livestock were present at the site.
P4		P4 was positioned in the wetland area near stream sampling Site *H* where water exits the Property.
P5		P5 was positioned on the outer edge of the wetland which partly recharges Lake Ōkaihau.

3.3 Water Quality

3.3.1 Surface Water Quality Monitoring

Surface water quality sites were selected to provide insights into the effect of current land use practices on water quality as waters flowed through the Property. The monitoring locations were selected to represent sites where water entered the Property in two main upstream sections and locations downstream on the Property to enable a comparison with water quality data within the Property, and as it departed from the Property. Sites were also chosen to potentially identify influences from intensive land use activities such as the dairy milking shed adjacent to Valley Road (Site C), and the residential septic tanks along Hamilton Road (Site D).

Water quality samples were analysed for key nutrients (Nitrite-N (NO_2^-), Nitrate-N (NO_3-N), Ammonia as N (NH_3N), Filterable Dissolved Reactive Phosphorus (DRP)), Total Suspended Solids (TSS), and E. Coli (E. Coli).

A description and photograph of each monitoring site is presented in **Table 3**.

Table 3. Surface water quality monitoring sites.

Site Name	Photo	Description
A		Site A was selected to monitor water quality as it enters the Property through an unnamed stream (pictured), which feeds into the Raurataua Stream. The stream is perennial and contained consistent low flows during each round of sampling. Samples were collected close to the Property boundary under the Manuka trees depicted in the photo (left). The stream is fenced off to livestock along the reach pictured but is not fenced off to livestock in the upstream neighbouring Property.
B		Site B was selected to monitor water quality as it enters the Property through an unnamed stream (pictured), before feeding into the Raurataua Stream. The stream is perennial and is fenced off from livestock. Samples were collected from under the bridge (pictured left) along Muriwai Valley Road.
C		Site C was selected to monitor water quality in the Raurataua Stream, immediately downstream of the dairy shed. The stream is perennial with consistent baseflow, and is fenced off from livestock, though livestock throughfares run up against reaches of the stream at the sample site.
D		Site D was selected to monitor water quality in the Raurataua Stream, downstream of the septic tank discharges from residents on Hamilton Road. The stream is fenced off from livestock.
E		Site E was selected to monitor water quality immediately downstream of the quarry. The unnamed stream is perennial with an observable baseflow. The first round of sampling found visual indications of hydrocarbons on the outer widths of the stream bed.
F		Site F was selected to monitor water quality at the downstream extent of the unnamed tributary before it joins the Ōkiritoto Stream. The stream runs through a heavily grazed paddock, and functions as a source of water for livestock.

G		Site G was selected to monitor water quality at Toroanui Falls pool (an important focal point for locals and Iwi). The pool is recharged by the Ōkiritoto Stream.
H		Site H was selected to monitor flow and water quality at the downstream extent of the Ōkiritoto Stream as it leaves the Property. The stream fans out into a wide wetland with no clearly defined channel.
I		Site I was selected to monitor water quality at Lake Ōkaihau. The lake is fed by stream flow from an unnamed catchment that comprises predominantly mature native bush (see *W8*).

3.3.2 Wetland Water Quality Monitoring

Wetlands typically have positive effects on water quality, particularly for receiving environments downstream of the wetland. This is achieved through reduced flow velocity and greater resident times of any water movement through wetlands and provide suitable habitat certain hydrophytic plant species. This results in varying degrees of sediment deposition and denitrification, as well as a range of other benefits such as filtering and nutrient removal effects, and adding oxygen to the water, hence improving its quality.

Quantifying existing water quality within specific catchments reveals the effects of activities occurring within those catchments. Key water quality parameters such as nutrients (typically nitrogen and phosphorus), E. Coli and suspended sediment levels can be tested and compared across different wetlands on the Property as well as with guideline values. Monitoring wetland water quality over time can identify possible effects caused by influences such as seasonality and longer-term changes in rainfall as well as land use change.

Wetland water quality monitoring sites were selected following advice provided by the Project Ecologist, Graeme Ussher from RMA Ecology. The wetland monitoring sites were selected to provide spatial coverage across the Property, and to target a combination of unfenced wetlands where sheep and cattle had direct access, as well as fenced / protected wetlands. Descriptions and photographs of the eight wetland monitoring sites are presented in **Table 4**.

Table 4. Wetland water quality monitoring sites.

Site Name	Photo	Description
W1		Wetland 1 sits within a heavily grazed paddock, with both sheep and cattle present in varying numbers over the sampling period. The wetland is adjacent to the proposed golfing area.
W2		Wetland 2 sits within a heavily grazed paddock, with both sheep and cattle present in varying numbers over the sampling period. The wetland is adjacent to the proposed golfing area.
W3		Wetland 3 sits within a heavily grazed paddock, with both sheep and cattle present in varying numbers over the sampling period. The wetland is adjacent to the proposed golfing area.
W4		Wetland 4 sits within a heavily grazed paddock, with both sheep and cattle present in varying numbers over the sampling period. The wetland is adjacent to the proposed golfing area.
W5		Wetland 5 sits within a heavily grazed paddock, with both sheep and cattle present in varying numbers over the sampling period. The wetland is adjacent to the proposed golfing area.

W6			Wetland 6 sits within a heavily grazed paddock with both sheep and cattle present in varying numbers over the sampling period. The wetland is adjacent to the proposed golfing area.
W7			Wetland 7 is fenced off, and has an upstream catchment comprised of mostly native forest. This sample site acts as a baseline comparison for the other wetland monitoring sites.
W8			Wetland 8 sits upstream of Lake Ōkaihau, with a catchment of primarily native forest, and therefore provides a baseline comparison against the unfenced / grazed wetland monitoring sites. The wetland is fenced off from other paddocks but may have small numbers of goats and deer which appear to roam through it, as well as geese.

4. Baseline Monitoring Results

The following sections present the baseline environmental flow monitoring data collected up to the time of preparing this report. It is understood the stream water level and shallow groundwater level monitoring sensors will likely remain in place to enable a longer record of collection, hence this report may be updated in the future.

The key monitoring outputs are provided as a combination of time series plots, tabulated data, and summary statistics as appropriate. General commentary and interpretation of the monitoring data is also provided where appropriate. However, full detailed analysis of the data is not presented in this report. Water quality, and the anticipated changes in catchment water quality associated with the Project is further detailed in the Water Affects Assessment report (WWLA, 2021 – Appendix C).

4.1 Surface Water Flow

As detailed in **Section 3.1**, stream water level was continuously measured on a 5-minute interval, and subsequently converted to a corresponding stream flow using a standard rated flow measurement approach. In addition, one spot gauge flow measurement was collected at the water quality monitoring sites. The results of the stream level and rated flow monitoring, and spot gauge monitoring are presented in turn below.

Both the continuous rated flow monitoring data and spot flow gauging data were used to calibrate the catchment flow models detailed in the Surface Water Affects Assessment report (WWLA, 2021 – Appendix C).

4.1.1 Continuous Level and Rated Flow Monitoring

Rated streamflow for the three continuously monitored stream level sites are presented in **Figure 2** to **Figure 4**. Monitoring data is unavailable for the first three months for Site 3, due to difficulties and delays in obtaining permission and site access at the initial recommended site, the wooden footbridge approximately 600 m downstream of the eastern Property boundary. Therefore, the location of Site 3 was moved to its present location, attached to a tree approximately 350 m downstream of the Property boundary (**Table 1**).

As expected, streamflow increases with increasing distance downstream along the catchment, as additional tributaries join, and additional groundwater baseflow enters. In general, the three sites were shown to respond quickly to heavy rainfall events, with increased attenuation of the flood peaks generally observed with increasing distance downstream.

Small, sub-daily fluctuations were observed in the measured water level record of Site 2. These were believed to be a result of temperature fluctuation impacts on the ultrasonic water level sensor. Site 1 was heavily vegetated along both stream banks, and above the stream itself, and therefore similar sensor fluctuations did not occur.

A large rainfall event (approximately 40 mm over three hours) occurred on 26 July. This resulted in a rapid rise in water levels at all three monitoring sites. Water levels rose by approximately 1 m and submerged the sensor at Site 3. A manual water level measurement was therefore collected concurrent with the flow gauging at this location.

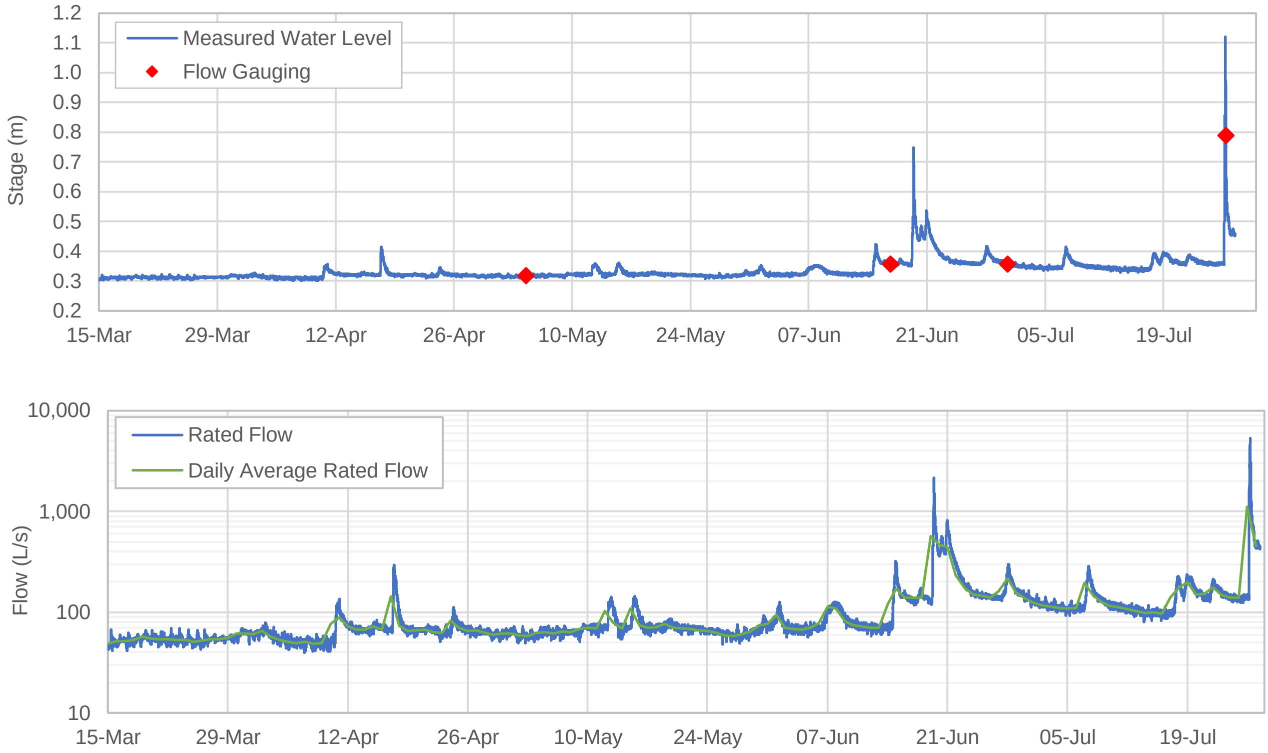

Figure 2. Flow monitoring Site 1 (top – measured stage, bottom – rated flow).

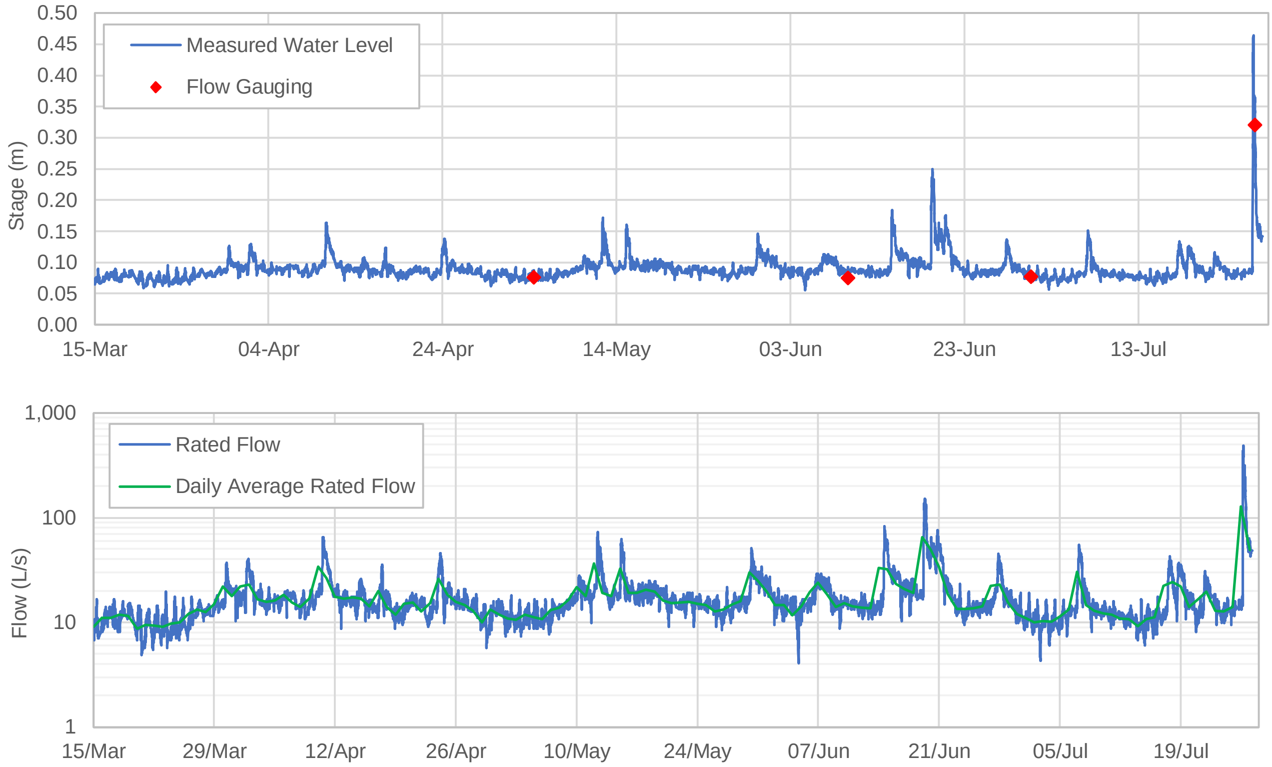

Figure 3. Flow monitoring Site 2 (top – measured stage, bottom – rated flow).

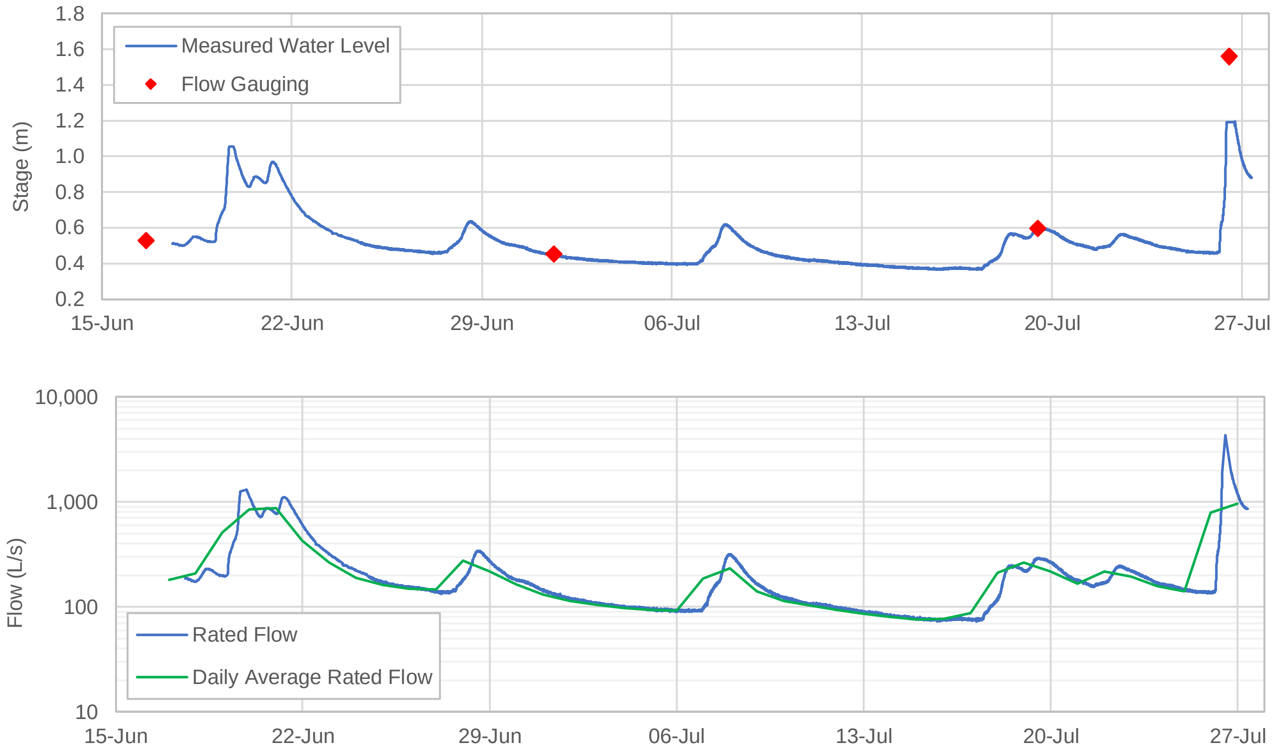

Figure 4. Flow monitoring Site 3 (top – measured stage, bottom – rated flow).

4.1.2 Surface Water Flow Monitoring (Spot Gauging)

Surface water flows were measured by taking spot gaugings at particular times. The different gaugings show the relative proportions of water that enter the site in different streams, and how water volumes in streams increase downstream as tributaries combine.

Spot gaugings were carried out at the seven water quality monitoring sites, plus Flow Site 1 on 8 and 9 June 2021, concurrent with water quality samples collected at each site. The spot flow gaugings are summarised in **Table 5**. Note that due to dense in-stream vegetation and very low flow, a gauging was not possible at Site B.

The results show that the stream at Site A transmits a larger volume of water through the Property than Site B or E (note that these sites are plotted on the map in **Figure 1**). Additionally, the spot gaugings indicate where streams gain or lose water as it travels across the Property. The results suggest that an increase of ~3 L/s occurs between Site E (upstream) and F (downstream), an increase of ~5.8 L/s between Site C (upstream) and D (downstream), and a significant increase of ~65.2 L/s between Site D (upstream) and G (downstream). This suggests that water is entering the main streams from a combination of small surface water tributaries, and wetland and/or groundwater baseflows.

Table 5. Spot flow gaugings.

Site ID	Date/Time	Flow (L/s)
A	9/06/2021 13:48	49
B	9/06/2021 13:00	-
C	9/06/2021 12:36	61
D	9/06/2021 10:24	66.8
E	9/06/2021 11:22	10
F	9/06/2021 9:28	13
G	8/06/2121 14:30	132

4.2 Shallow Groundwater

Figure 5 to **Figure 9** show groundwater levels and rainfall from 11 March to 2 August 2021. Rainfall data was retrieved for the Muriwai Golf Course rain gauge site from Auckland Council's Environmental Data Portal. Groundwater levels were recorded by WWLA.

The groundwater levels generally responded to rainfall recharge, with increases in groundwater level after rainfall, and receding groundwater levels during dry spells. However, the signal between recorded rainfall and groundwater level was not always consistent. It is worth noting that variation in rainfall can occur over small distances. This means that the rainfall received at the Muriwai Golf Course rain gauge (shown in **Figure 5** to **Figure 9**) may have been different to that received in the vicinity of the piezometers on the Property. Despite this, the data is adequate to determine groundwater levels across the monitoring period and gauge the effect of rainfall at each monitoring site. To reduce the small high-frequency sensor noise in groundwater levels (small spikes), 12-hour rolling averages were applied to the raw data from each sensor, providing a smoother line and a clearer view of the groundwater level trends. Small spikes were caused by thermal fluctuations during the day, but do not affect the longer-term average accuracy of the data.

Groundwater level data from Piezometer 1 (P1) is shown in **Figure 5**. P1 shows relatively small fluctuations in response to rainfall recharge, particularly when compared to piezometers 4 and 5.

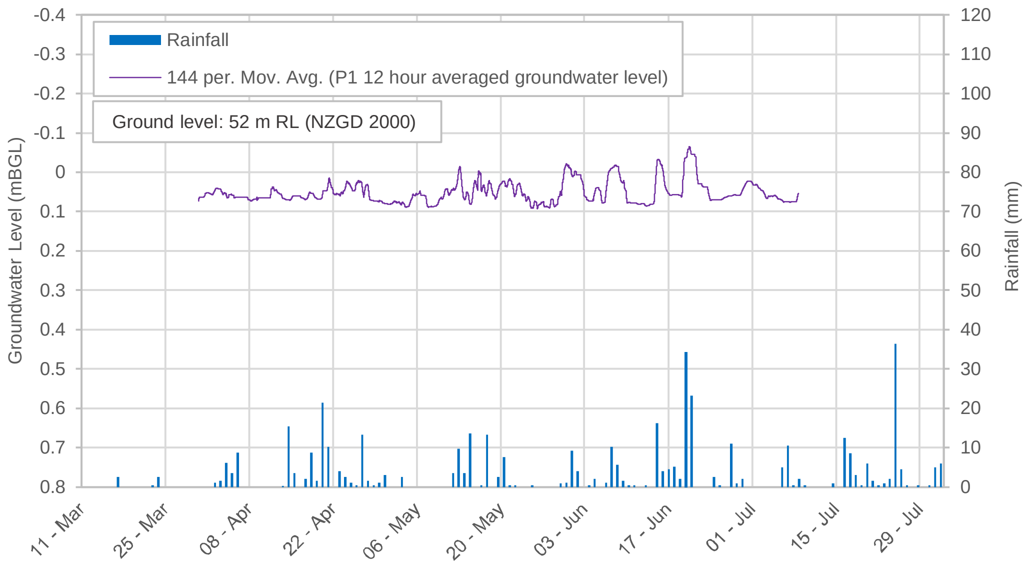

Figure 5. P1 Groundwater level monitoring data and rainfall.

Groundwater levels in Piezometer 2 (P2) are shown in **Figure 6**. The location of P2 was changed in April due to challenges with the telemetry system in the sensor, hence the monitoring in for this site began on 25 April 2021. The new location had improved cellular reception which enabled data to be transmitted to the cloud directly from site.

The data in this wetland location shows a strong relationship between rainfall and groundwater levels. After large rainfall occurred on 19 and 20 June 2021, the shallow groundwater reached the ground surface. The wetland appears to have held the high water levels for over two weeks, before dropping below the ground surface on 12 July 2021 for 5 days until 17 July 2021, when two days of rainfall totalling 21 mm caused the water level in the wetland to rise above the ground level again where it remained until the end of the recording period on 2 August 2021.

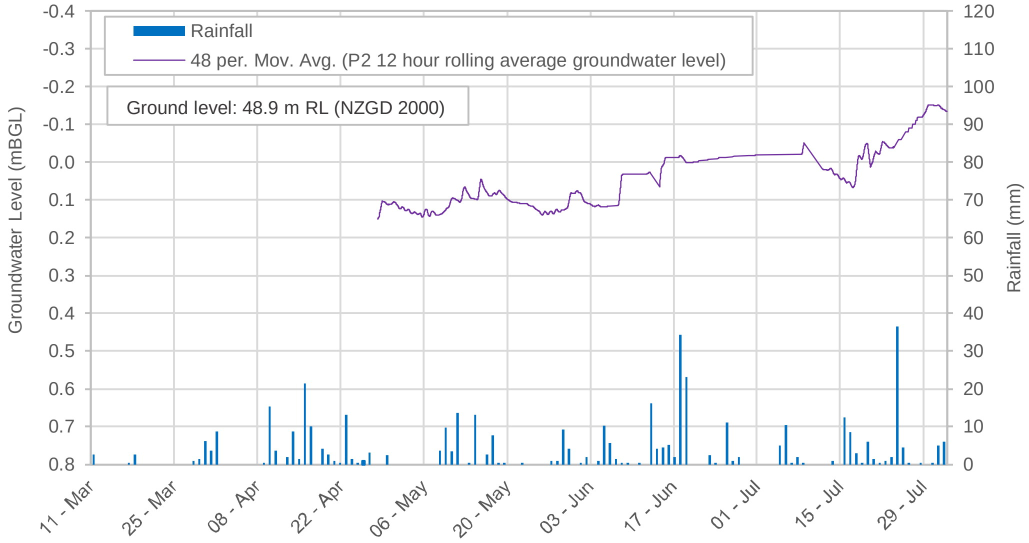

Figure 6. P2 Groundwater level monitoring data and rainfall.

Groundwater levels in Piezometer 3 (P3) are shown in **Figure 7**. This wetland location shows a subdued response to rainfall, meaning the magnitude of the groundwater response is generally smaller compared to the other piezometers. This is a typical response of piezometers in close proximity to a stream. Streams can reduce groundwater fluctuations if the water table is at a higher elevation than the stream, as the stream can act as a pressure release point for the groundwater within its vicinity.

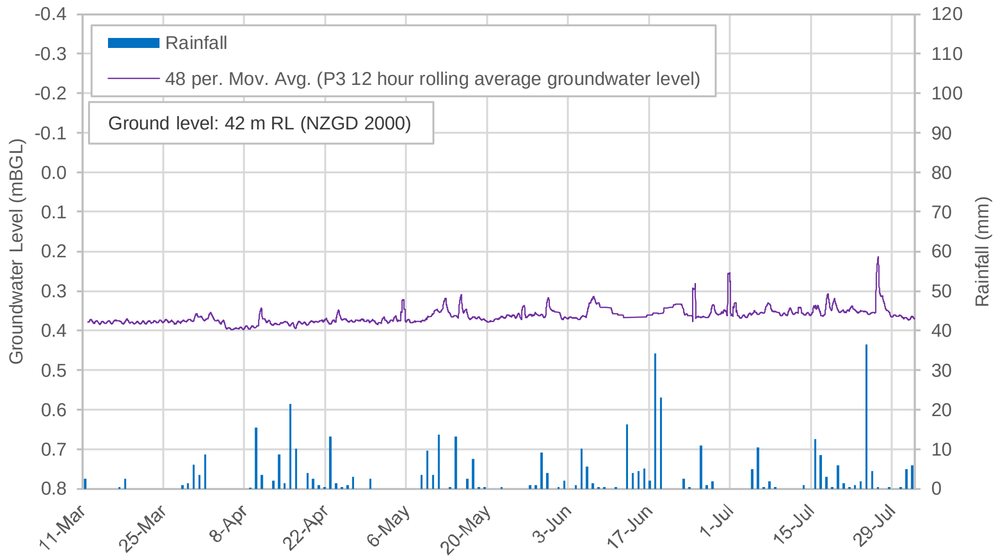

Figure 7. P3 groundwater level monitoring data and rainfall.

Groundwater levels in Piezometer 4 (P4) are shown in Figure 8. Groundwater levels at this wetland location show a strong response to rainfall, with the magnitude of the fluctuation generally in proportion to the depth of recorded rainfall.

The two largest rainfall events in the monitoring period occurred on 19 to 20 June 2021 and 26 July 2021, with totals of 47.4 mm and 36.5 mm respectively recorded. These two events stand out in the groundwater monitoring data, and in both cases the water levels rose above the ground surface. In this sensor location, the large increase in water level may be partly attributable to surface water flooding, as the piezometer was located within the flood plain.

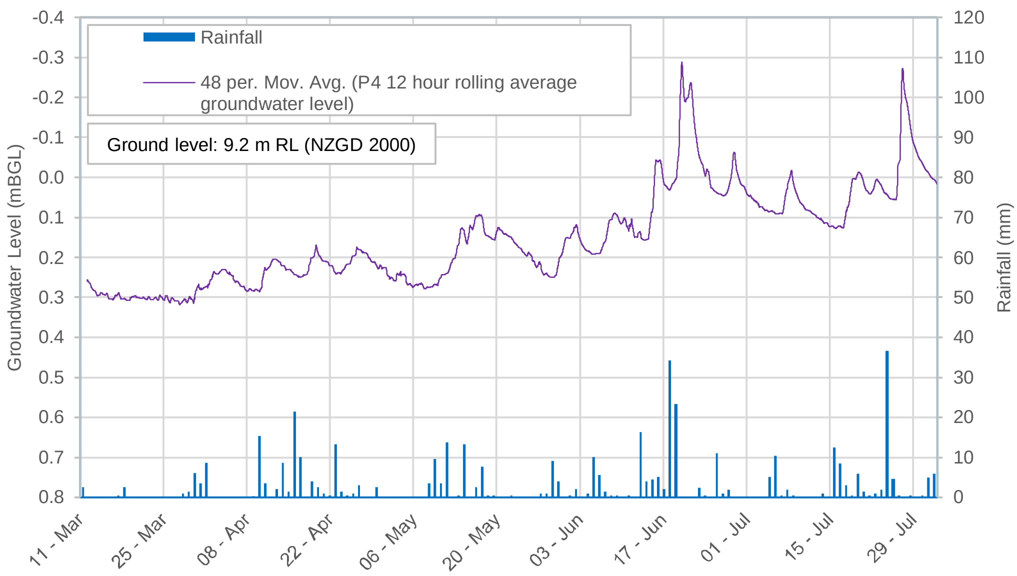

Figure 8. P4 groundwater level monitoring data and rainfall.

Groundwater levels in Piezometer 5 (P5) are shown in **Figure 9**. Groundwater levels at this wetland location show a strong response to rainfall. Similar to P4, the magnitude of the groundwater level fluctuation is generally in proportion to the depth of rainfall, with the exception of the large increase in water levels on 2 and 3 of May, and again on 17 and 18 May. These two anomalous increases in groundwater level were reflected strongly in P4 and more subtly in P1, 2, and 3. This may indicate that appreciable rainfall occurred on and closely preceding these days but was not recorded at the Muriwai Golf Course rain gauge.

Similar to P4, the two largest rainfall events in the monitoring period generated large and rapid increases in shallow groundwater. At P5, the groundwater level briefly reached the ground level on 27 July 2021 before receding over the following 5 days.

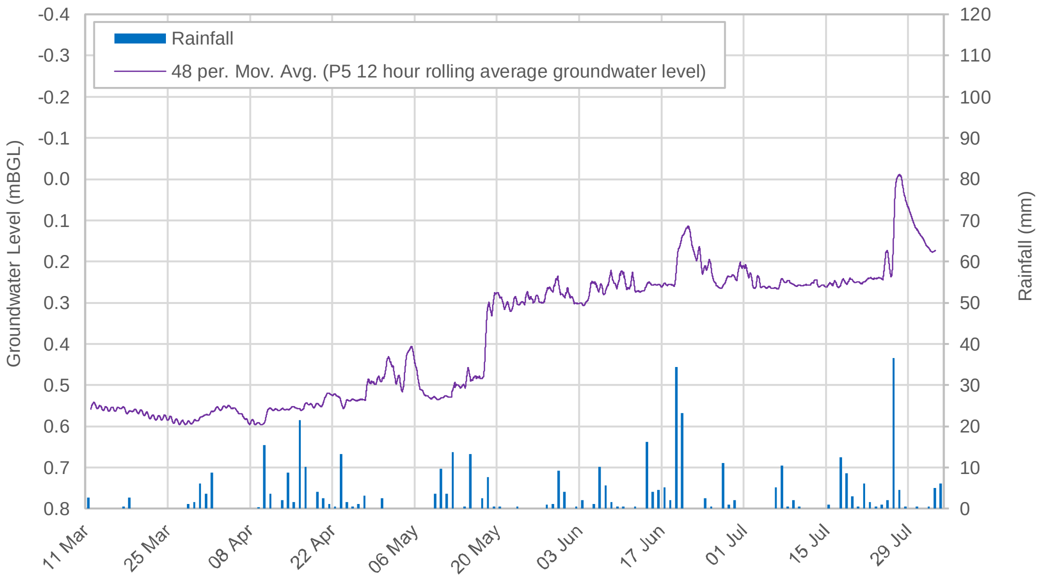

Figure 9. P5 groundwater level monitoring data and rainfall.

4.3 Water Quality

Water quality results are summarised in this section. The recorded levels of each test parameter are compared, where applicable, to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council, 2000). Not all parameters are referenced in these guidelines, and the guidelines do not categorise the water quality into categories such as "poor," "average," or "acceptable." Rather, the guidelines refer to trigger levels relative to the 95% protection level for "healthy" aquatic ecosystems in slightly to moderately disturbed conditions.

This statistically derived approach uses a probability distribution of aquatic toxicity endpoints, which aims to protect a pre-determined percentage of species (usually 95%). The 95 percent protection level is most often applied to ecosystems that could be classified as slightly to moderately disturbed (Australian and New Zealand Environment and Conservation Council, 2000).

4.3.1 Surface Water Monitoring Sites

Surface water quality results are presented in **Appendix A**. and the range in concentrations recorded at each site for context, is summarised in **Table 6**. The key water quality parameters presented include Nitrite-N (NO_2^-), Nitrate-N (NO_3-N), Ammonia as N (NH_3N), Filterable Dissolved Reactive Phosphorus (DRP), Total Suspended Solids (TSS), and E. Coli (E. Coli). These parameters have been highlighted in **Table 6** because they are generally accepted by Land Air Water Aotearoa (LAWA, 2021) to be the most crucial to defining stream or river water quality. Moreover, given the current land use as a sheep and beef farm, it is these parameters that were presumed to be most affected by the current land use.

Table 6. Range in constituent concentrations recorded at each site.

Para*	A	B	C	D	E	F	G	H	I
NO_2^--N	0.001 - 0.0014	0.001 - 0.0045	0.001 - 0.002	0.001 - 0.0025	0.001 - 0.0014	0.001 - 0.0036	0.001 - 0.002	0.001 - 0.189	0.001 - 0.0034
NO_3-N	0.0972 - 0.361	0.002 - 0.894	0.0445 - 0.504	0.0047 - 0.48	0.002 - 0.141	0.0028 - 0.334	0.0022 - 0.452	0.002 - 0.371	0.002 - 0.343
NH_3-N	0.005 - 0.008	0.005 - 0.03	0.005 - 0.01	0.005 - 0.12	0.005 - 0.01	0.005 - 0.04	0.005 - 0.008	0.005 - 0.22	0.005 - 0.1
DRP	0.002 - 0.002	0.002 - 0.007	0.002 - 0.007	0.003 - 0.065	0.002 - 0.002	0.002 - 0.002	0.002 - 0.003	0.002 - 0.106	0.002 - 0.002
TSS	3 - 4	3 - 17	3 - 264	3 - 227	3 - 64	3 - 41	3 - 4	3 - 2470	7 - 31
E. Coli	110 – 2,100	53 – 4,600	70 - 15,000	60 – 4,600	40 – 1,500	20 – 3,400	40 – 5,300	30 – 90,000	100 – 8,000
Notes: * values in mg/L except E. Coli, which is cfu/100ml.									

Key observations from the surface water sites across the Property for each parameter, and with consideration for the external catchment influences, are summarised as follows:

Nitrite-N (NO2-)

- The range in NO_2^- values was between 0.001 and 0.0045 mg/L across surface water sample sites, with the exception of Site H (furthest downstream location), which recorded an appreciably higher maximum level of 0.189 mg/L on 23 April 2021.
- There was a subtle trend of increasing NO_2^- concentrations over the monitoring period (winter) across most stream sample locations, including Lake Ōkaihau. Elevated concentrations tended to occur when samples were collected after rainfall.
- Sites A and B recorded water as it entered the Property. When samples were collected in the wetter period, Site B tended to have appreciably higher NO_2^- concentrations than Site A.
- No clear relationship between NO_2^- concentrations and stream gradient were observed.

Nitrate-N (NO_3-N)

- $N0_3$-N concentrations tended to steadily rise over the monitoring period (winter) in most stream sites, namely Sites A, B, C, D, E, F, and G.
- The highest N03-N concentration recorded was 0.894 mg/L at Site B, where water enters the Property, on 15 June 2021.
- Two downgradient sample Sites (H and I) tended on average to record lower concentrations of $N0_3$-N, even during wetter months, as compared to upgradient sample sites.
- Sample Site E (immediately downstream of the quarry) tended to record lower concentrations of $N0_3$-N than sample Sites A and B, which originate from different catchments.
- Relative to the ASNZ Guidelines for Fresh and Marine Water Quality (2000), section 3.4 (Aquatic Ecosystems, water quality guidelines for toxicants, New Zealand), the levels of stream concentrations for $N0_3$-N were generally below the 95% species protection trigger value of 0.158 g/m^3 during the dry months, and generally above the trigger limit in the wetter months.

Ammonia as N (NH_3-N)

- NH_3-N concentrations were elevated sporadically across the monitoring period. In Streams B, C, E, G and I, there is a slight increase over time, which tends to suggest higher concentrations during wetter periods (i.e. winter). However, in Streams D and H, high concentrations were recorded at the beginning of the monitoring period, particularly on the 11 March 2021 sampling round (round 2).

- NH_3-N concentrations were slightly higher at site B than in the separate catchments through which samples B and E originated as they entered the Property.
- The highest NH_3-N concentrations tended to occur in low energy reducing environments, namely site H (very slow flow) and site I (Lake Ōkaihau), which are also downgradient sample sites.
- Relative to the ASNZ Guidelines for Fresh and Marine Water Quality (2000), section 3.4 (Aquatic Ecosystems, water quality guidelines for toxicants, New Zealand), the stream monitoring ammonia results were all under the 95% species protection trigger value of 0.9 mg/L.

Dissolved Reactive Phosphorus (DRP)

- DRP concentrations were generally low in concentration and relatively uniform through time in the stream monitoring sites, with the exception of Site D and Site H where one and three samples respectively showed elevated concentrations of DRP.
- Relative to the National Policy Statement for Freshwater Management 2020 (NPS-FW) numeric attribute state values for DRP, 94% and 85% of surface water monitoring samples collected were below the Attribute Band A[4] (the highest band) 95th percentile and median DRP concentration limits, respectively. Three samples (of the total 81 samples) exceeded the numeric attribute state value for Attribute Band B[5] (1 sample from Site D and 2 from Site H). However, it is noted that 5-years of monthly samples are required to determine a sites numeric attribute state, and thus the above is considered indicative only.

Total Suspended Solids (TSS)

- TSS concentrations remained relatively low and consistent across all monitoring sites, with the exception of Site H, where several samples recorded elevated TSS concentrations.
- RMA Ecology Ltd., 2021 (AEE Report – Appendix 11), suggests that streams within the grazing areas tended to have degraded beds containing soft sediment, which contributes to higher TSS levels.
- Sample Site G, the pool below Toroanui Falls, had low TSS levels as the pool acts as a settling pond for sediment.
- The highest TSS concentrations were recorded where loose fine sediments were present close to the water surface. In some cases, fine sediments may have become entrained in the water column due to sampling disturbance (i.e. standing in or near the wetland and placing a sample bottle in the water).
- No clear relationship between TSS concentrations and stream gradient or sampling season (i.e. summer or winter) were observed.

E. Coli

- E.Coli counts stayed relatively constant across the sampling period, with the exception of Site H on 11 March 2021, where extremely high levels (compared to other sampling rounds) were recorded at 90,000 CFU/100 ml. It is unknown what caused the elevated E. coli sample for Site H on 11 March 2021, and it is considered an outlier in comparison to the other eight samples collected at this site.
- E. Coli counts were elevated across several surface water sites (A, B, C, E, F, and I) on 12 May 2021. This round of sampling occurred after a long dry period of almost two-weeks followed by several wet days.
- No clear relationship between E. Coli counts and stream gradient or sampling season (i.e. summer or winter) were observed, with the exception of sample Site H, which tended to record sequentially lower E. Coli counts into the wetter months.

[4] Attribute Band A – Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.

[5] Attribute Band B – Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions.

4.3.1.1 Key Observations and Conclusions for Water Quality

- In general, the water quality meets with the applicable water quality guidelines for ammonia, as all recordings were below the 95% exceedance threshold. However, Nitrate-N was generally below the exceedance threshold in the dryer months only, with consistent exceedances in the wetter months.
- On average, water quality does not change significantly as it travels across and exits the Property, nor does it become progressively poorer or improved as it moves downstream. Rather, there are variations in recorded levels of each parameter across the sample sites, which suggests some sections of stream receive cleaner water and other sections receive poorer quality water.
- All nitrogen parameters tended to record higher levels in the wetter winter months than in the summer months. Moreover, the levels of nitrogen relevant to water quality guidelines (Nitrate-N and Ammonia as N), remained generally below the guideline exceedance limits in dry seasons and generally above the limits in the wet months.
- No appreciable differences in concentration levels for any parameters could be attributed to upgradient sample locations compared to downgradient sample locations, with the exception of NH_3-N, which recorded its highest levels in low energy Sites H and I.
- There were minor variations in concentrations corresponding to the nature of each sample site, namely the velocity of flow through at the sample location. In the narrow, fast flowing Sites (A – G), the TSS results were lower than the wide sluggish stream Site H. However, this was not true at Lake Ōkaihau, which had no flow.
- Sample Site B generally has higher Nitrite-N (NO2-), Nitrate (NO3-N) and Ammonia as N (NH3-N) concentrations than other sperate streams from discrete catchments, namely Site A where water enters the Property, and Site E where water has travelled through only a short section of the Property.

4.3.2 Wetland Monitoring Sites

Wetland water quality results are presented in **Appendix B**. and the range in concentrations recorded at each site for context, is summarised in **Table 7**. Like the stream monitoring regime, the key water quality parameters depicted in this report are Nitrite-N (NO2-), Nitrate-N (NO3-N), Ammonia as N (NH3N), Filterable Dissolved Reactive Phosphorus (DRP), Total Suspended Solids (TSS), and E. Coli Count (E. Coli). As above, these parameters have been selected because they are generally accepted by Land Air Water Aotearoa (LAWA, 2021) to be the most crucial to defining water quality in this environment and could be altered by the existing land use.

Table 7. Range in constituent concentration recorded at each site.

Para*	W1	W2	W3	W4	W5	W6	W7	W8
NO_2-N	0.001 - 0.0117	0.001 - 0.0523	0.001 - 0.003	0.0011 - 0.00591	0.0011 - 0.299	0.001 - 0.0116	0.001 - 0.0049	0.001 - 0.0204
NO_3-N	0.002 - 0.126	0.002 - 0.134	0.002 - 0.0056	0.002 - 0.0188	0.002 - 1.74	0.002 - 0.444	0.475 - 0.83	0.002 - 0.228
NH_3-N	0.005 - 4.14	0.005 - 0.21	0.005 - 0.53	0.005 - 0.1	0.005 - 0.15	0.005 - 0.26	0.005 - 0.01	0.005 - 0.1
DRP	0.001 - 0.012	0.002 - 0.013	0.002 - 0.002	0.002 - 0.002	0.002 - 0.02	0.002 - 0.002	0.04 – 0.019	0.002 - 0.003
TSS	35 – 17,900	2,612 – 13,356	370 – 3,750	18 – 19,090	1,000 – 11,628	253 – 13,370	3 - 21	82 – 40,540
E. Coli	110 - 2,700,000	100 – 7,000	1 – 1,200	20 – 86,000	60 – 9,000	30 – 1,200	2 – 10,000	300 – 9,000

Notes: * values in mg/L except E. Coli, which is cfu/100ml.

Key trends identified in the wetland sites are summarised as follows:

Nitrite-N (NO_2-N)

- All wetland sample sites had relatively consistent NO_2-N concentrations with the exception of W5, which returned notably higher than average concentrations on four testing rounds compared to other wetlands on the Property including the wetland maximum of 0.299 g/m^3 on 11 March 2021.
- No clear seasonal trends were observed, or between dry and wet sampling rounds.
- The lowest NO_2-N concentrations were recorded in W3 and W7. It was noticed that W3 generally had an appreciable flow of trickling water moving through it, even in relatively dry times, as did W7.

Nitrate-N (NO_3-N)

- $N0_3$-N concentrations tended to stay relatively consistent across most wetland sites over the sampling period, with a subtle rise in concentrations during the wetter season, particularly noticeable in W1, 2, and 6.
- W7 had a significantly higher minimum NO_3-N concentration of approximately 0.75 g/m^3 compared to all other wetland sites, which all had minimum concentrations of 0.001 g/m^3.
- Despite the high baseline in W7, the highest recorded concentration was at W5, as was the case for NO_2-N concentrations. W5 returned multiple high NO_3-N concentrations in comparison to other wetlands.
- W1 – 4, in close proximity to one another, returned consistently low concentrations compared to other sites.

Relative to the ASNZ Guidelines for Fresh and Marine Water Quality (2000)[6], section 3.4 (Aquatic Ecosystems, water quality guidelines for toxicants, New Zealand), the wetland nitrate results were mostly under the 95% species protection trigger value of 0.158 g/m^3 with some exceedances, particularly W7 which remained above the exceedance level for the duration of the sampling period.

Ammonia as N (NH_3-N)

- Adjacent sample sites, W1 and 2, recorded the high levels of NH_3-N on 12 May 2021, with W1 returning the maximum recorded concentration of 4.14 g/m^3.
- Levels were relatively consistent across the monitoring period and across all wetland sites, with the exception of W1, which had significantly elevated concentrations on 12 May 2021 and 9 June 2021 compared to levels recorded at other times across the monitoring period.
- No clear seasonal trends were observed, or between dry and wet sampling rounds.
- Similar to the stream sample sites, NH_3-N concentrations were elevated sporadically in wetlands across the monitoring period.

Relative to the ASNZ Guidelines for Fresh and Marine Water Quality (2000), section 3.4 (Aquatic Ecosystems, water quality guidelines for toxicants, New Zealand), the wetland ammonia results were mostly under the 95% species protection trigger value of 0.9 mg/L except for W1 which recorded two exceedances, 4.14 mg/L on 12 May 2021 and 1.24 mg/L on 9 June2021.

Dissolved Reactive Phosphorus (DRP)

- DRP concentrations were typically low and relatively uniform through time at all wetlands monitoring sites with the exception of W7, which consistently had higher DRP concentrations in comparison to the additional seven wetland monitoring sites. No obvious reasons were observed that may have caused elevated DRP concentrations at W7 in comparison to the other monitoring sites.
- While the NPS-FWM (2020) does not provide specific numeric attribute state criteria for wetlands, all wetland samples were below the Attribute Band A (the best) 95th percentile value.

[6] These trigger values were designed for slightly to moderately disturbed systems

Total Suspended Solids (TSS)

- TSS concentrations were highly variable across the wetland sample sites.
- W7 had consistently low TSS concentrations across the monitoring period, while W8 had several high TSS concentrations, including a maximum of 40,540 on 23 April 2021.
- TSS concentrations tended to be generally lower in wetland sites which contained low consistent flows, namely W3 and W7
- No clear relationship between TSS levels and sampling season or rainfall were observed.

E. Coli

- E. Coli counts were variable and sporadic in the wetlands, with some sample sites returning counts as low as 1 CFU/100ml, and one sample from W1 recording a count of 2,700,000 CFU/100ml on 12 May 2021. The W1 sample location bordered a heavily used pond from which livestock would drink.
- E. Coli counts were lowest on average in W3, W6, and W7, which tended to contain higher baseflows than other wetland sample sites.
- No clear relationship between E. Coli counts and sampling season (i.e. summer or winter) or dry or wet weather were observed.
- Key general observations and conclusions are summarised as follows: Overall, the water quality results suggest that in most cases, the waters are suitable for more than 95% of aquatic life.
- Occasional spikes in recorded Nitrate-N and Ammonia as N levels most likely reflect the variability in sampling conditions across the monitoring period. For example, samples were taken during intensive grazing within wetlands by sheep and/or cattle, sometimes in combination with very low standing water levels, which is likely to drive higher nutrient and E. Coli levels in the available waters. In other cases, samples were taken after a period of days or weeks where no livestock animals had been present in the wetlands, and when groundwater levels were sufficiently high to recharge baseflows, which would likely drive lower nutrient and E. Coli levels.
- Nitrite (NO3-N) tended to record slightly higher concentrations in the wetter winter months than in the summer months, but not as a rule and only by a small margin.
- No appreciable differences in concentration levels for all other parameters could be attributed to seasonality or weather conditions.
- There were minor variations in concentrations corresponding to the nature of each sample site, namely the observed flow volumes through the sample location. In the sites with slightly higher and more consistent water flows (namely sites W3 and W7), the TSS concentrations and E. Coli counts were lower on average.
- W7, whose catchment is majority native bush, had more consistent nutrient concentrations over the monitoring period, and consistently high NO_3-N concentrations compared to other sites. In general, the nutrient concentrations were lower in W7 than in the other majority native bush catchment W8. However, these wetlands did not return significantly lower nutrient concentrations than the other wetland sample sites.

4.3.3 General Observations Comparing Surface Water and Wetland Sampling Results

- Wetlands generally had poorer water quality than streams on site. This is not surprising given:
    a) seven out of nine wetlands were in paddocks with grazing livestock in them, while streams were largely fenced off; and
    b) wetlands naturally act as settling areas for sediments entrained in runoff, noting that sediments generally contain the elements which contribute to poor water quality.
- NO_2-N concentrations were generally higher in wetland samples compared to stream samples.
- NO_3-N concentrations in wetland sites were more variable and sporadic across the monitoring period compared to stream sites.

- NH_3-N concentrations were generally similar between streams and wetlands, albeit the wetlands recorded slightly higher average and peak concentrations.
- TSS concentrations were significantly higher in wetlands than stream sites.
- E. Coli counts were generally higher in the wetlands than in the streams.

5. Summary

The following key conclusions were drawn from the baseline monitoring programme:

- **Surface Water Flow Monitoring**
  - A rated flow dataset was developed through monitoring of water levels and site rating curves developed from manual velocity gauging measurements.
  - The rated flow dataset showed the three monitoring sites tended to respond quickly to large rainfall events, with both water level and flow rising in response to rainfall.
  - Site 3, at the downstream extent of the Property, typically exhibited a slower hydrograph receding limb in comparison to the other two sites. This means water levels recede slower (i.e. are attenuated) at this site, in comparison to the two upstream sites. This was likely due to the presence of the large and dense wetland a short distance upstream.
- **Shallow Groundwater Monitoring**
  - Shallow groundwater monitoring suggests groundwater levels correlate strongly with rainfall, generally rising with rainfall and receding in the absence of rainfall.
  - A long-term trend of increasing groundwater levels over the monitoring period can be seen in P2, P4 and P5.
  - The magnitude of short-term groundwater level increases was generally observed to be in proportion to the volume of rainfall which fell within the catchment of the piezometers. P1 and P3 show a flatter long-term trend.
- **Water Quality Monitoring**
  - Water quality monitoring suggests that on average, the streams tend to show more consistent nutrient concentrations across the monitoring period, while the wetland nutrient levels were more sporadic.
  - Across most parameters, both the average and peak concentrations tend to be higher in the wetlands than in the streams.
  - The streams tended to show a steady increase in Nitrate-N (NO_3-N) levels over the monitoring period, with higher levels after wetter weather conditions.
  - Wetland sites did not record the same clear seasonal effect.
  - Stream sample Site B tended to have higher nutrient concentrations as it entered the Property compared to Site A and E which originated from different catchments.
  - Stream and wetland water quality varied somewhat across the monitoring period, and, for the parameters which could be compared to relevant aquatic ecology guidelines, water quality was generally well below the trigger values set for 95% protection level for “healthy” aquatic ecosystems in slightly to moderately disturbed conditions.

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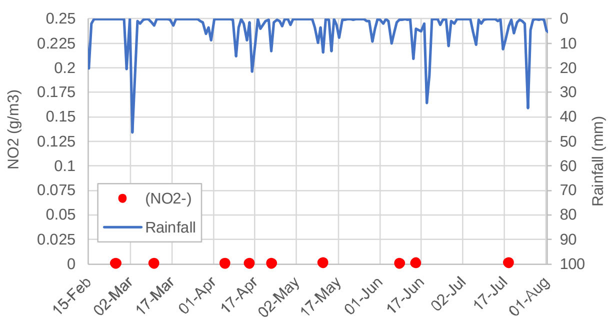
Appendix A. Stream Water Quality Results

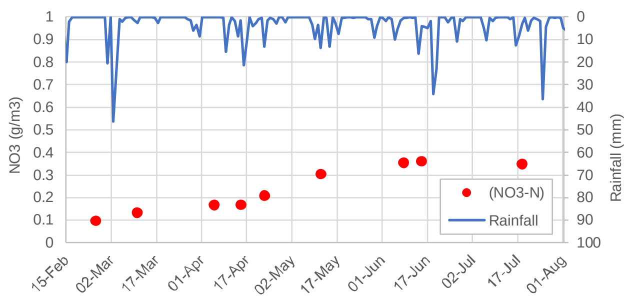
Stream Water Quality Results are presented below.

Stream sample location 'A'.

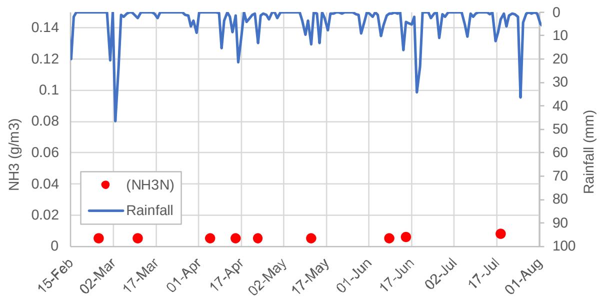
N02



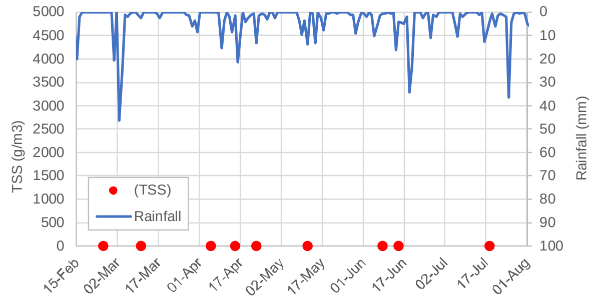
N03



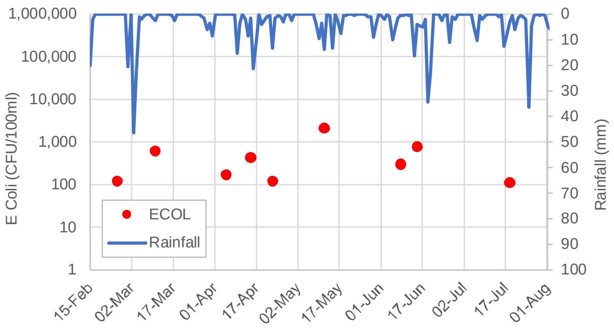
NH3



TSS

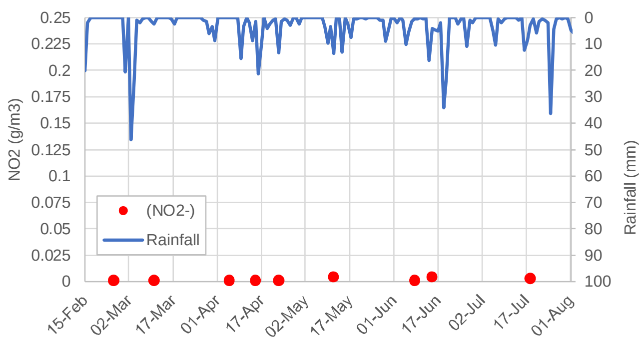


E. Coli



Stream sample location 'B'.

N02



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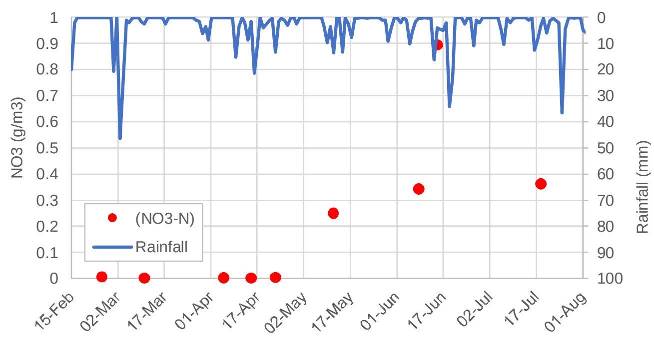

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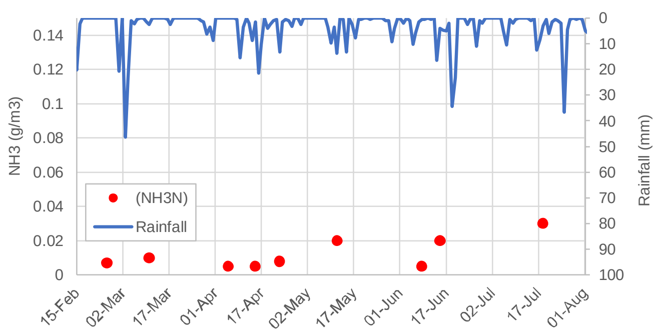

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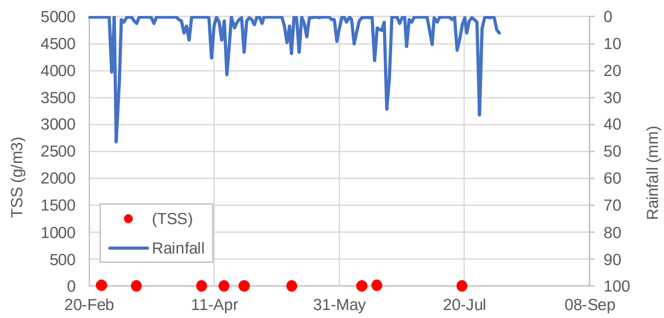
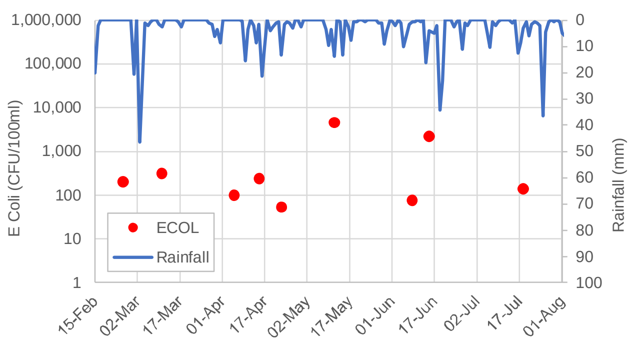
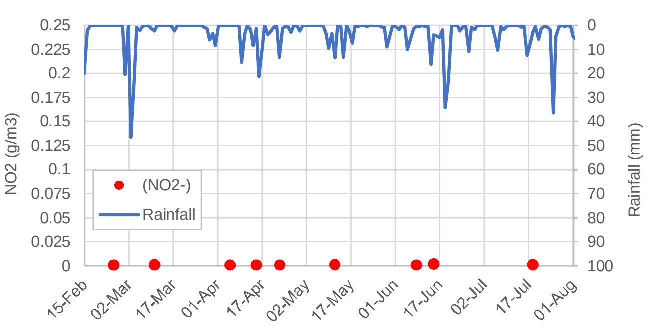


E. Coli



Stream sample location 'C'.

N02



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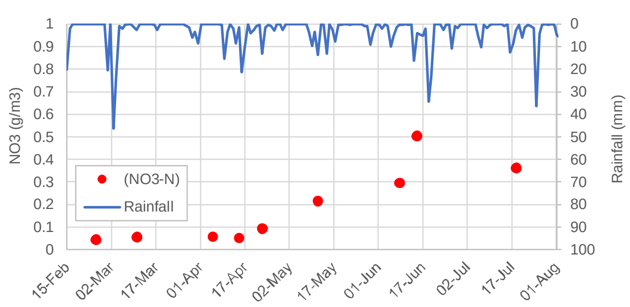
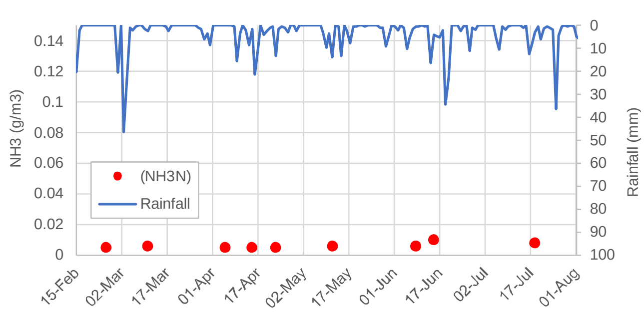
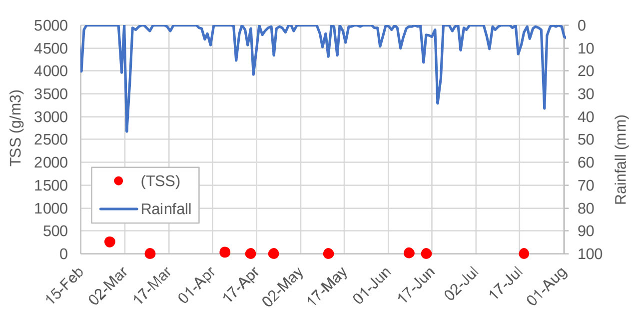


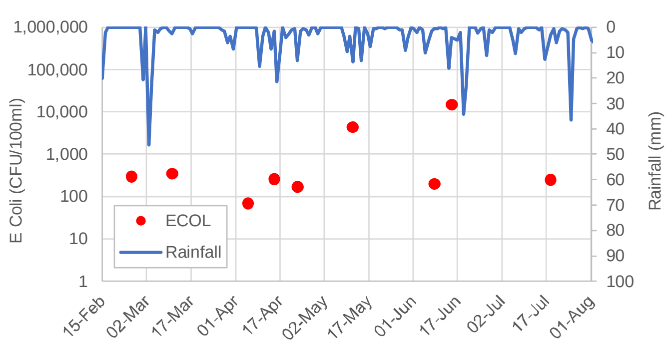
NH3



TSS

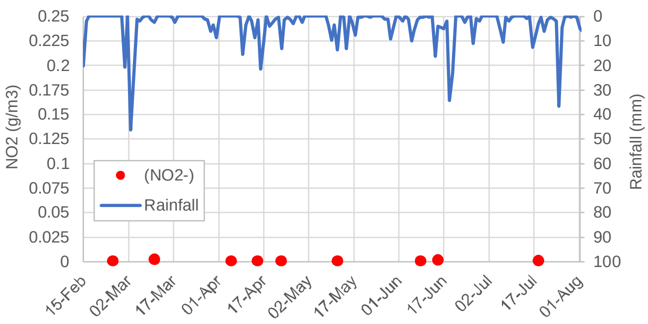


E. Coli



Stream sample location 'D'.

N02



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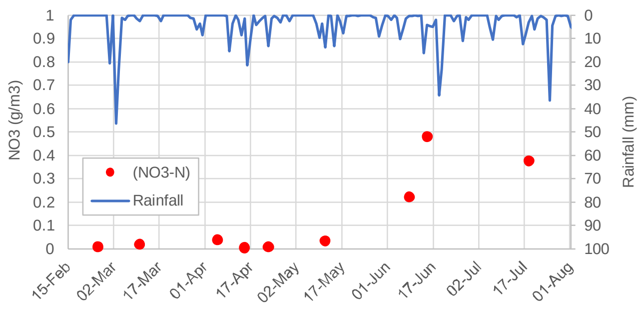

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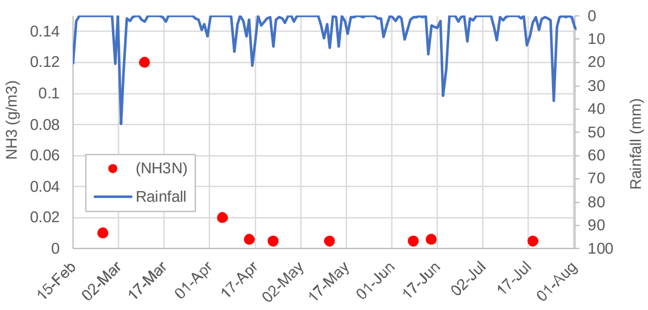
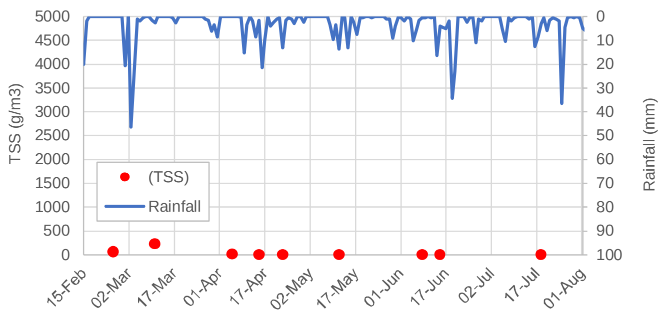
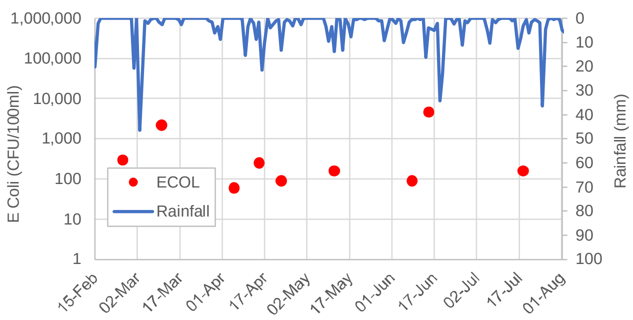


TSS

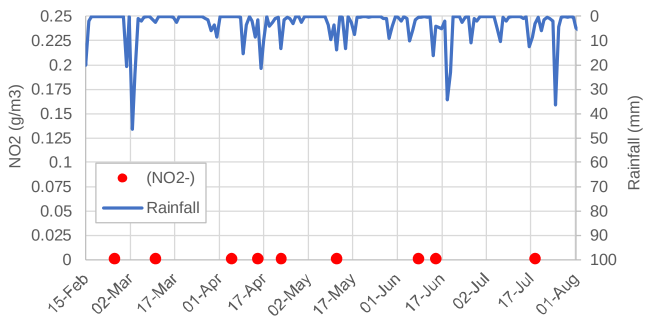


E. Coli



Stream sample location 'E'

N02



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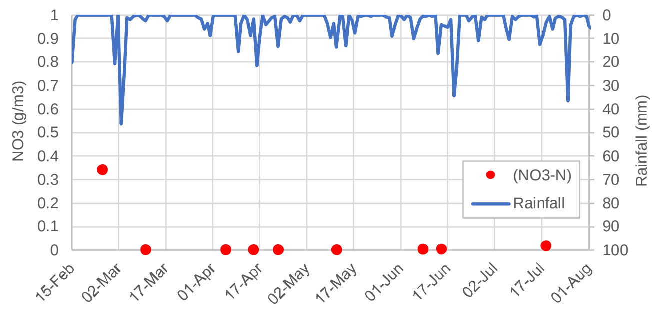

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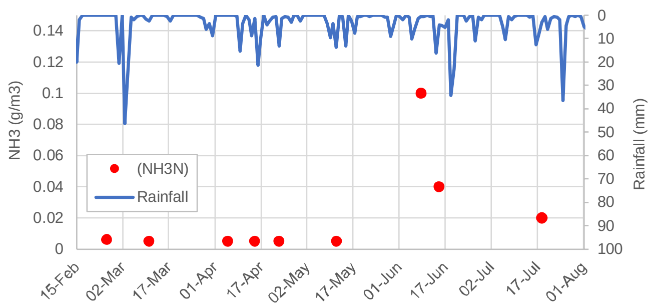
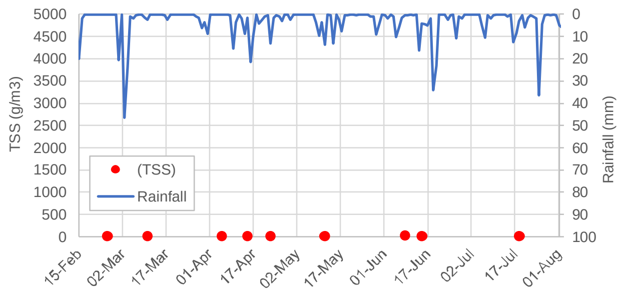
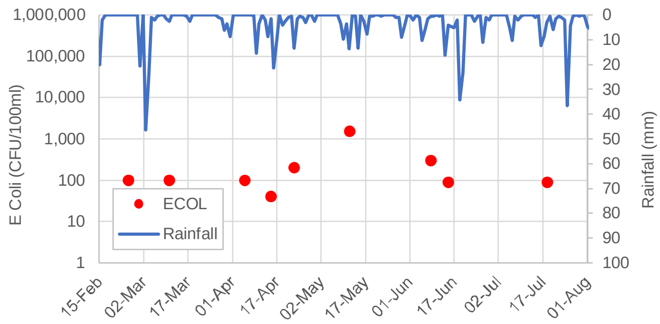


TSS

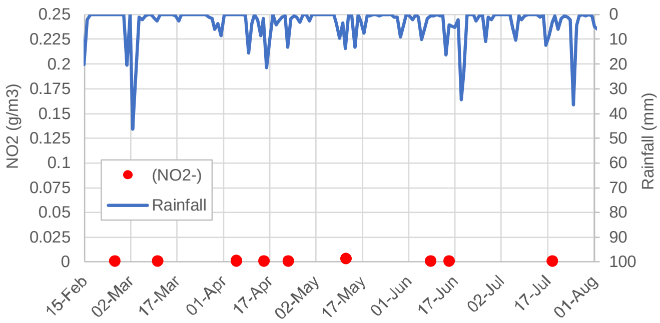


E. Coli



Stream sample location 'F'.

N02



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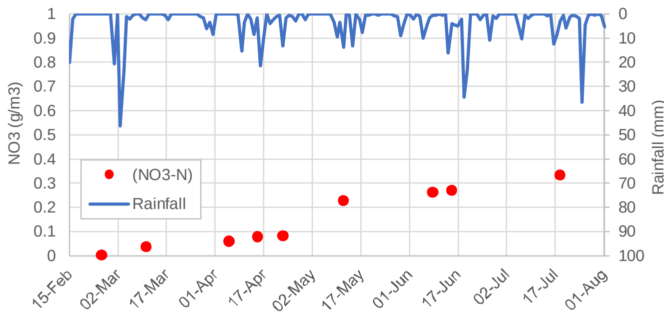
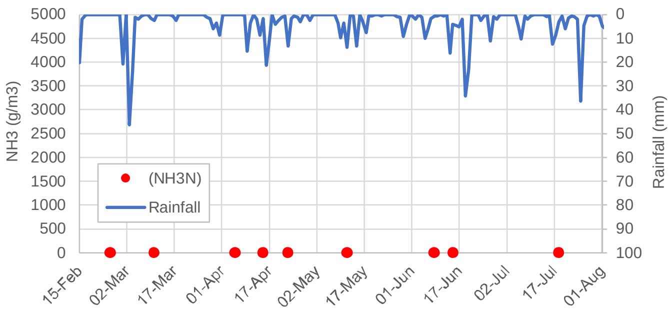


NH3



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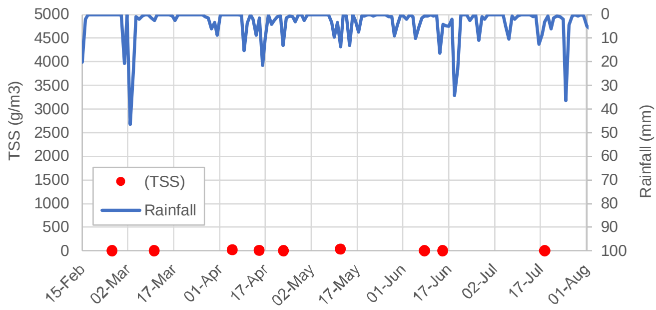
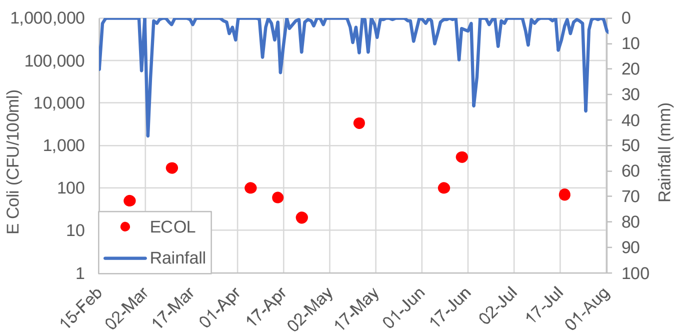
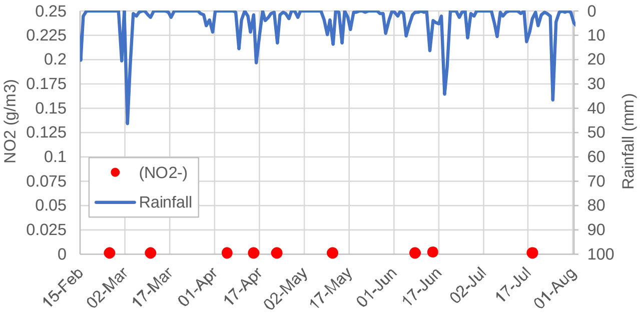


E. Coli

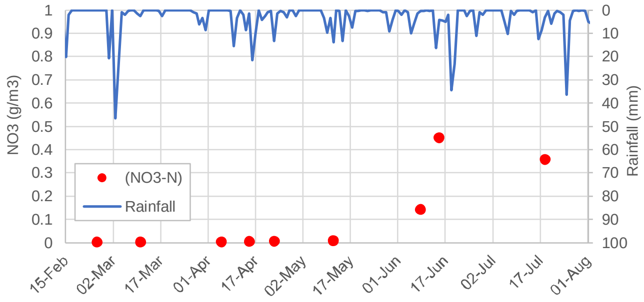


Stream sample location 'G'.

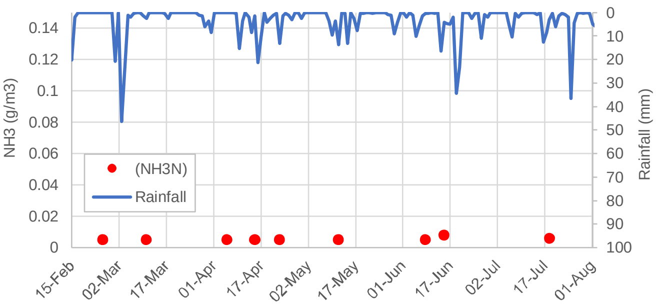
N02



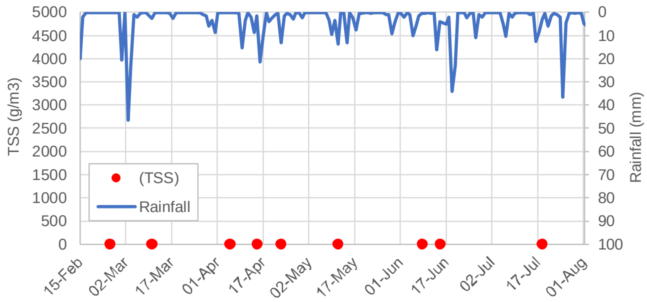
N03



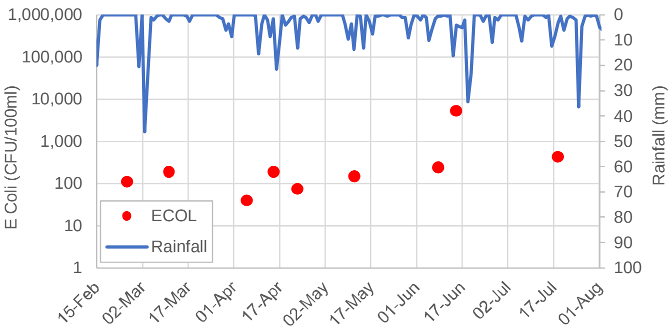
NH3



TSS

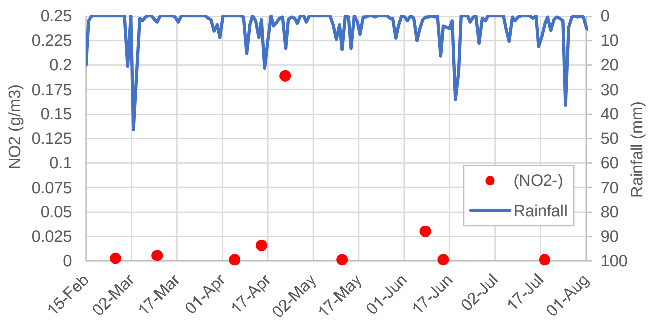


E. Coli

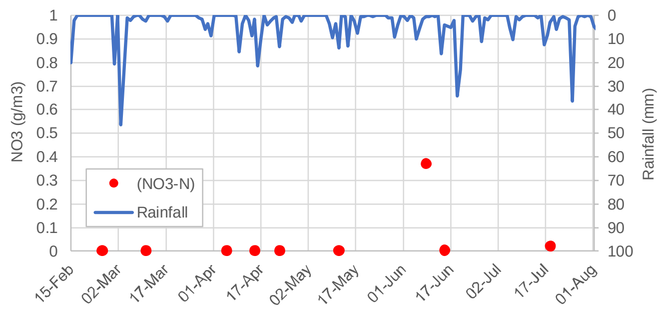


Stream sample location 'H'.

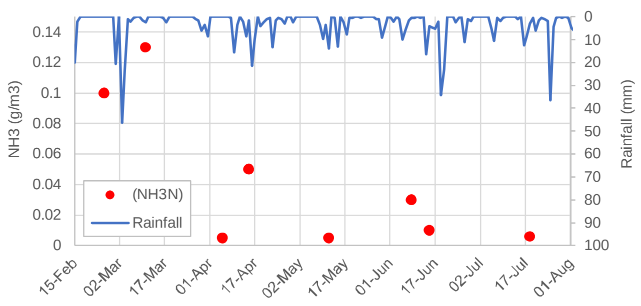
N02



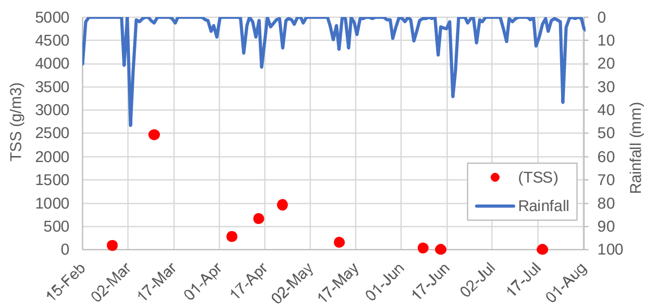
N03



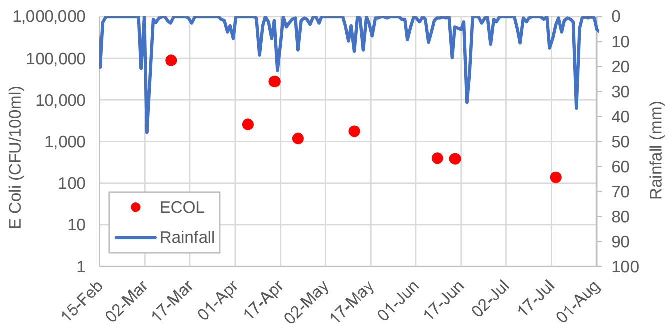
NH3



TSS

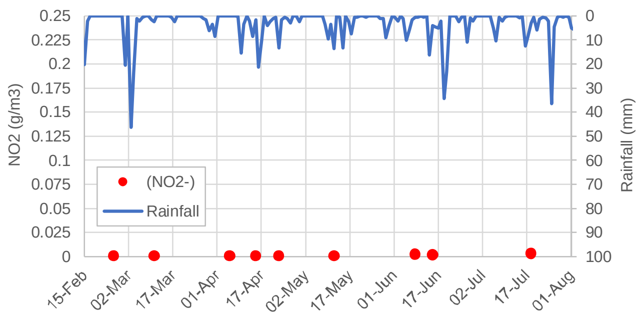


E. Coli



Stream sample location 'I'.

N02



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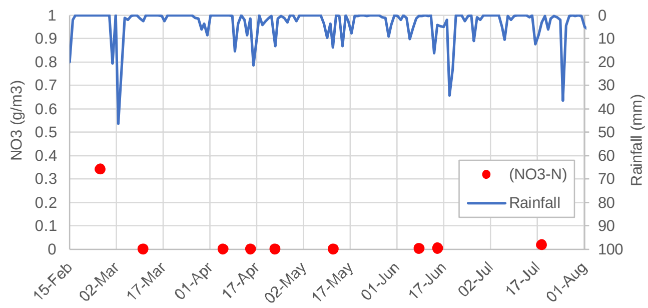
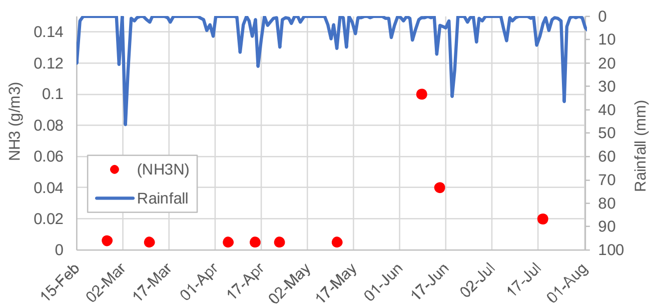
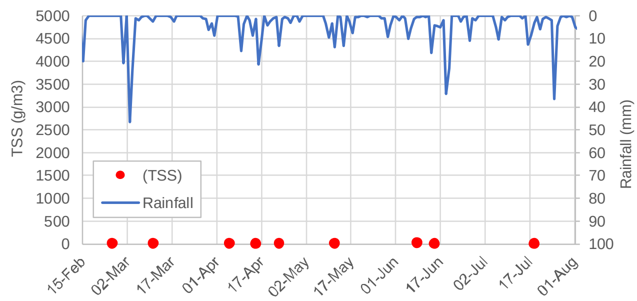


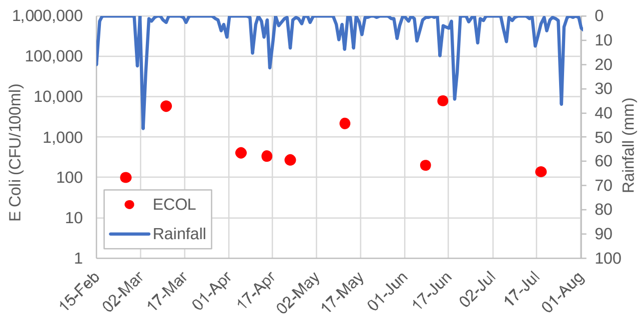
NH3



TSS



E. Coli

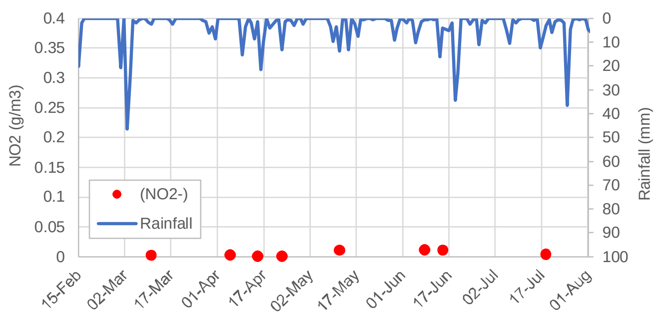


Appendix B. Wetland Water Quality Results

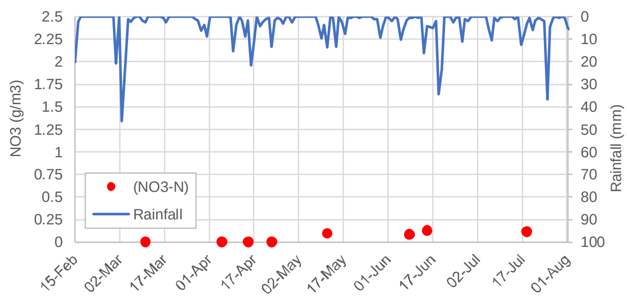
Wetland Water Quality Results are presented below.

Water quality results from Wetland 1 (W1)

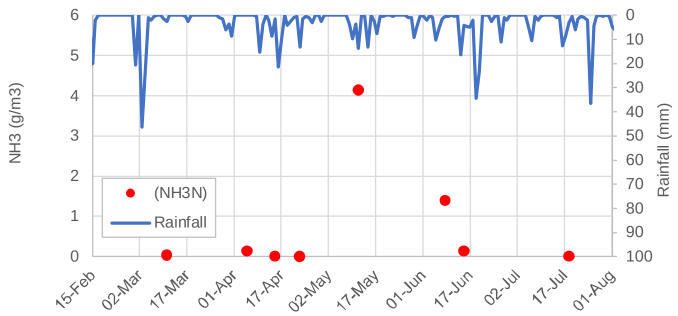
N02



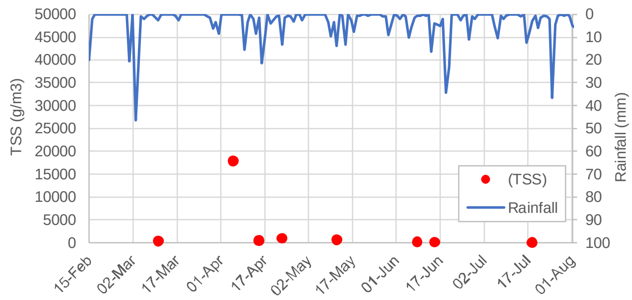
N03



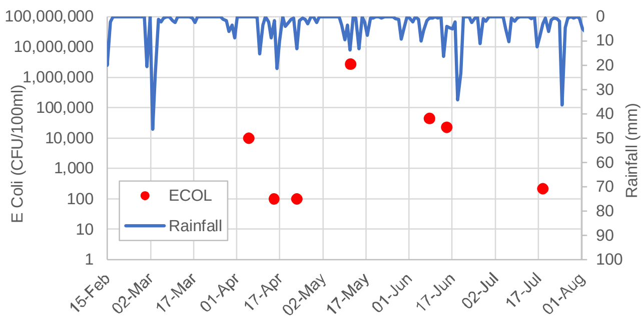
NH3



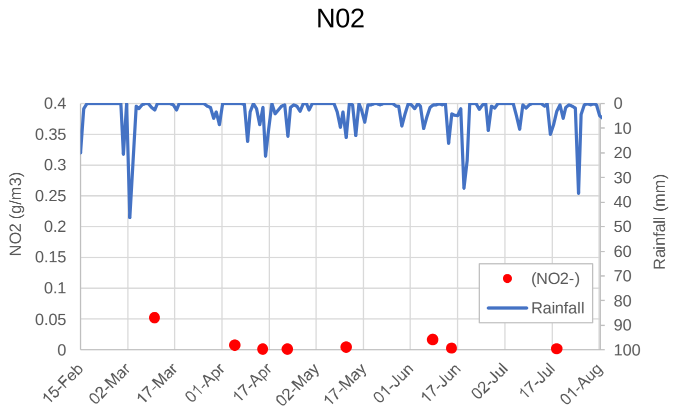
TSS

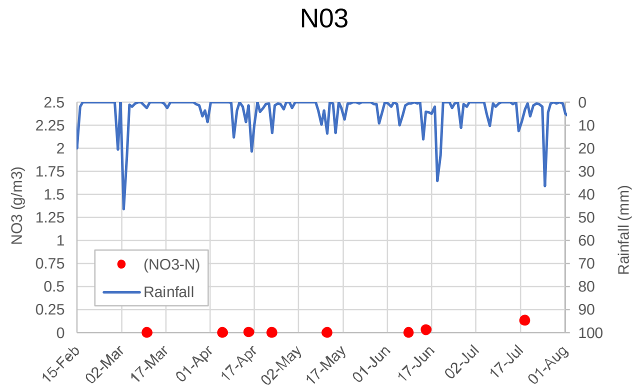


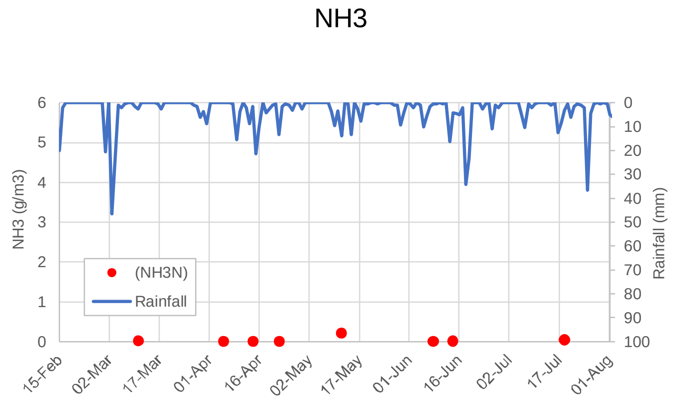
E. Coli

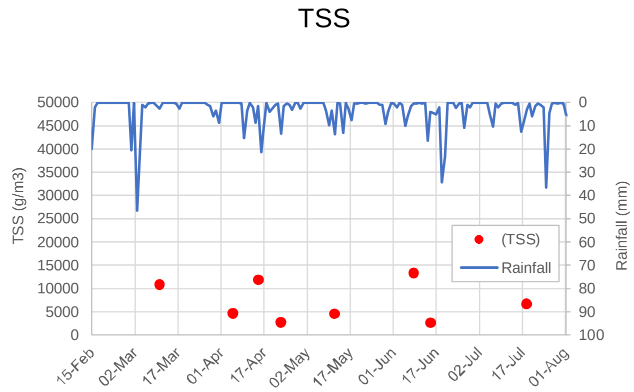


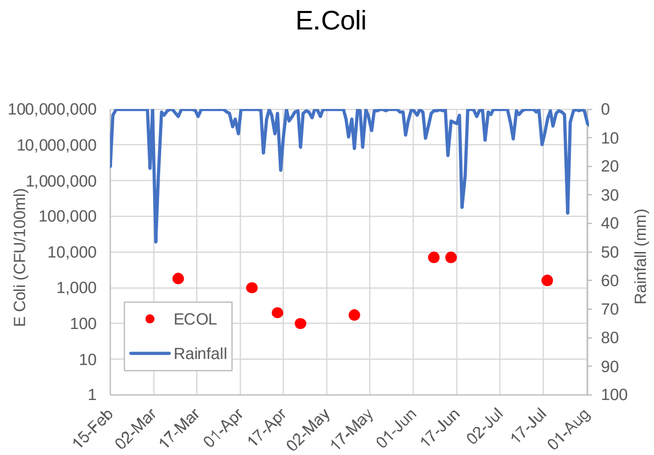
Water quality results from Wetland 2 (W2)



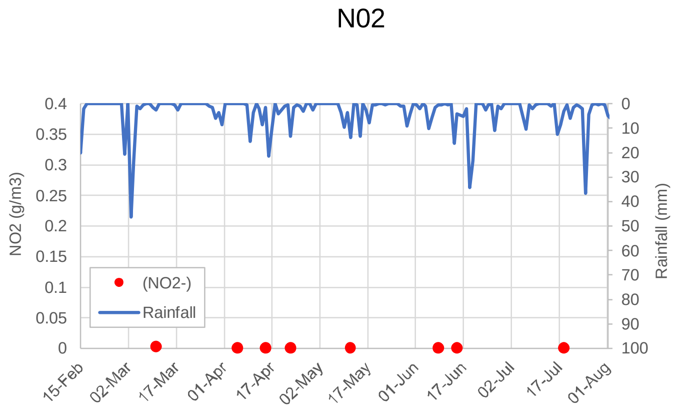


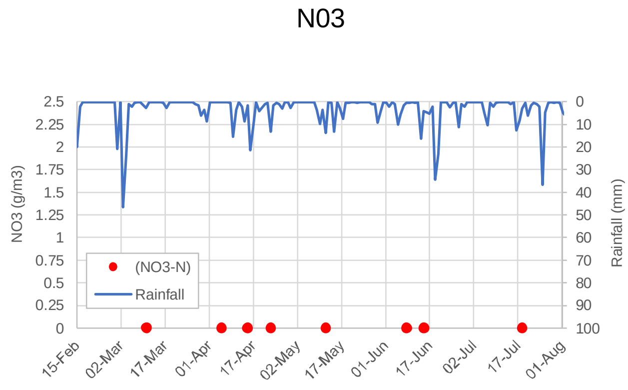


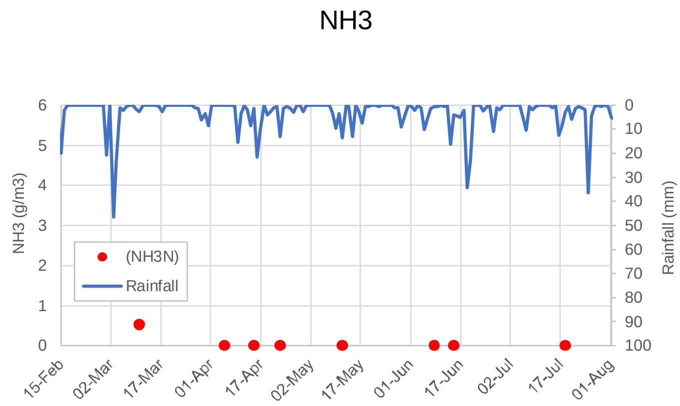


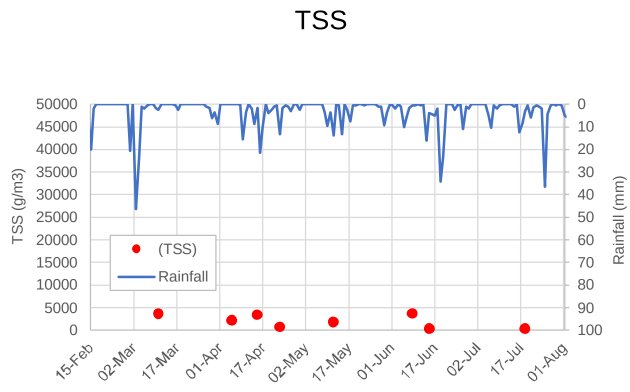


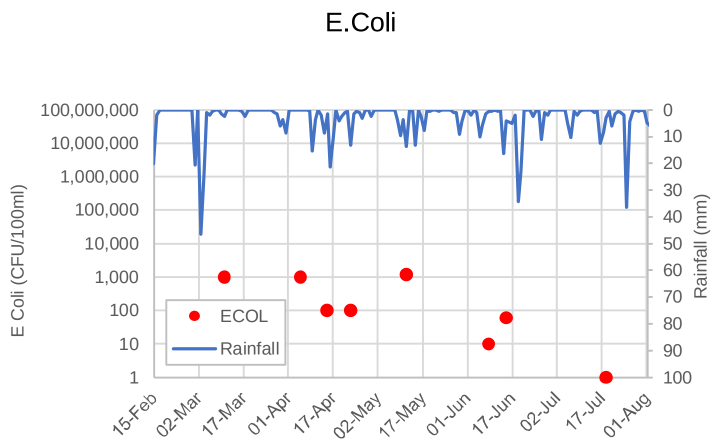
Water quality results from Wetland 3 (W3)





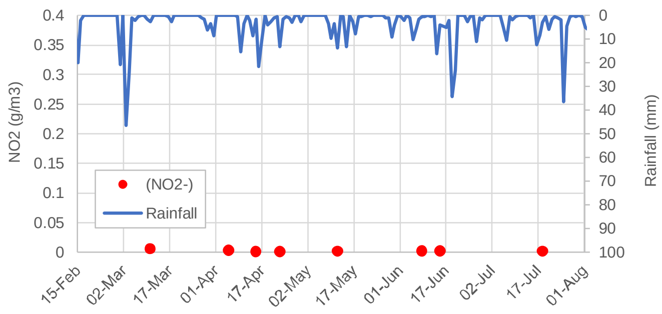




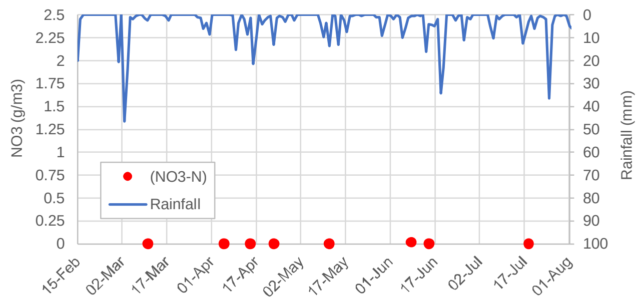


Water quality results from Wetland 4 (W4)

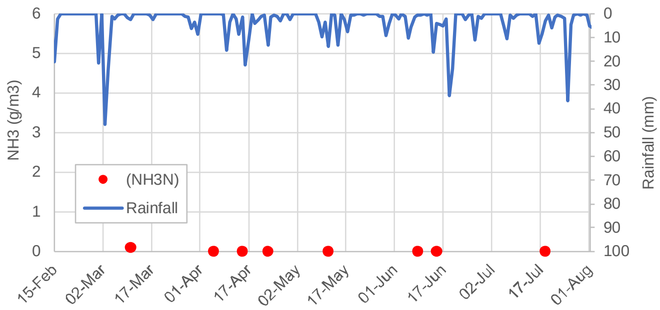
N02



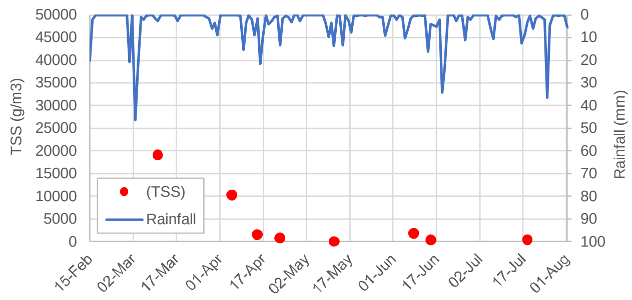
N03



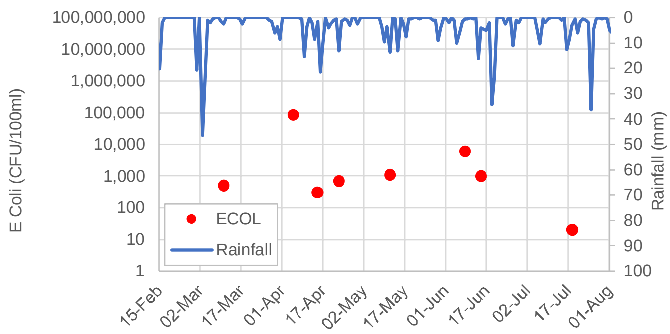
NH3



TSS

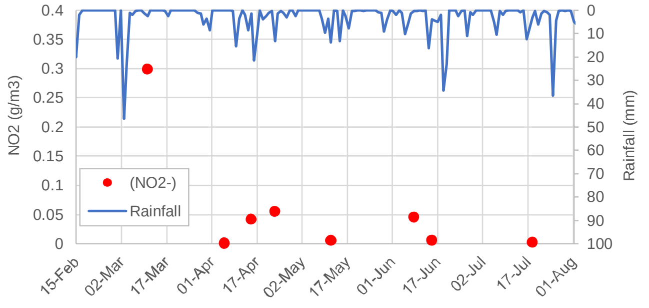


E. Coli



Water quality results from Wetland 5 (W5)

N02



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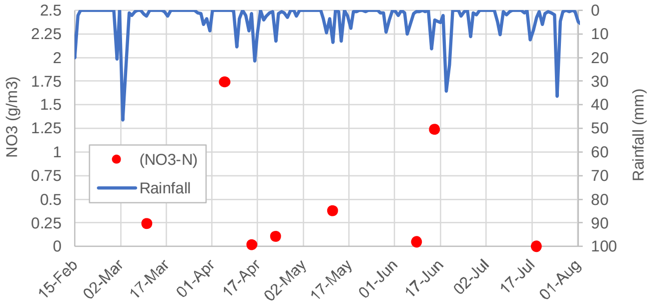
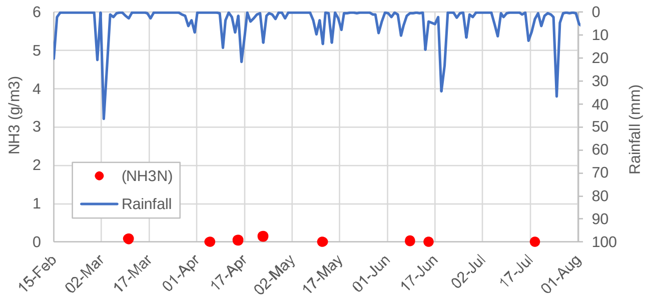
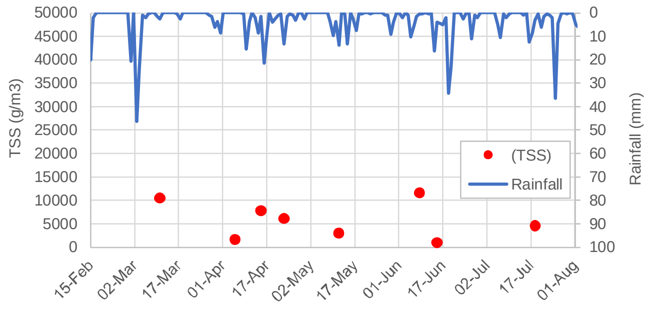


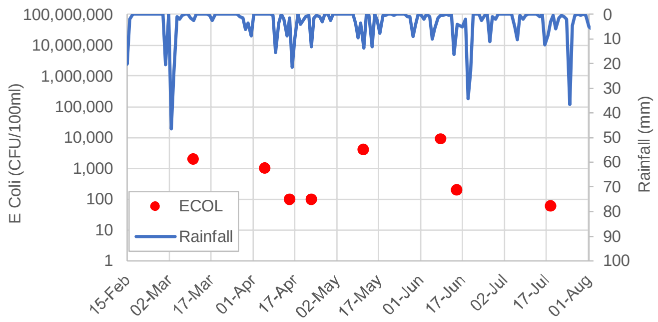
NH3



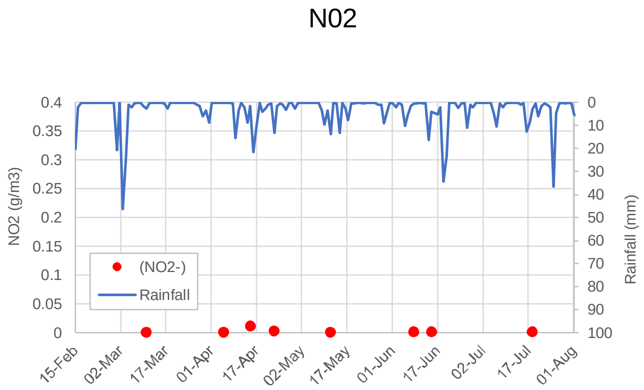
TSS

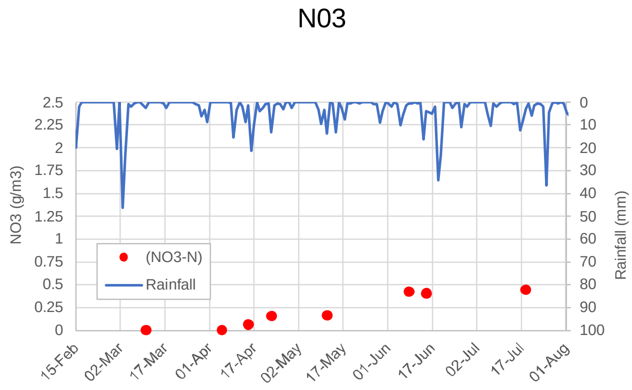


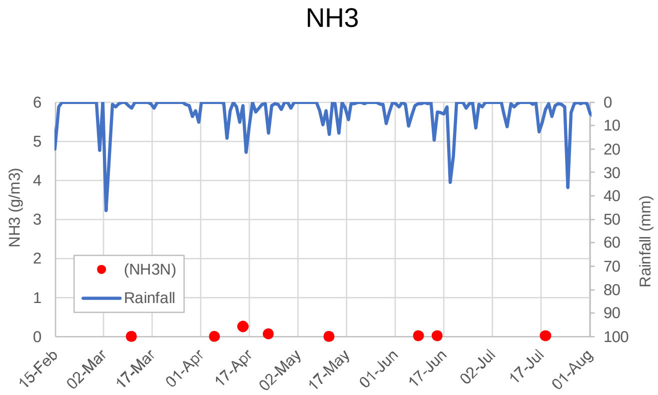
E.Coli

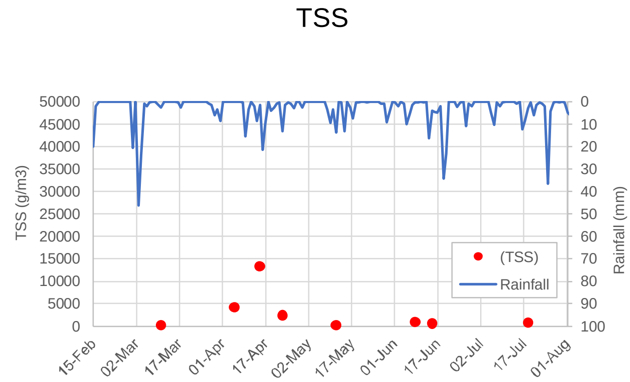


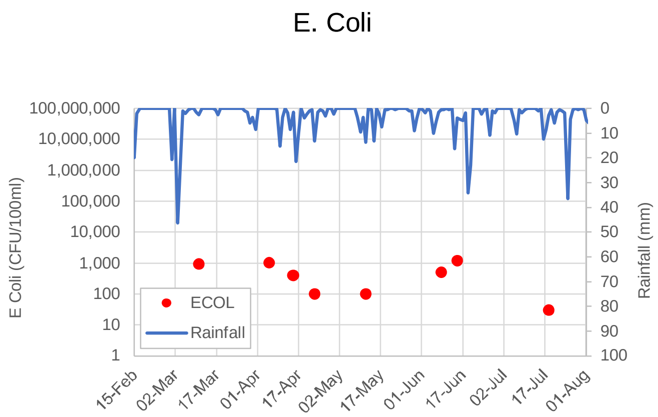
Water quality results from Wetland 6 (W6)





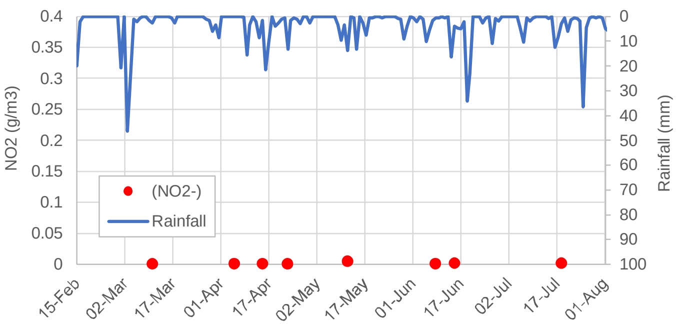




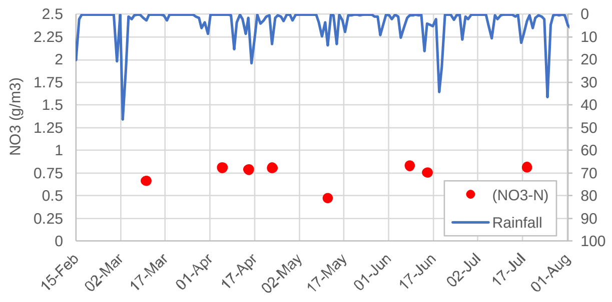


Water quality results from Wetland 7 (W7)

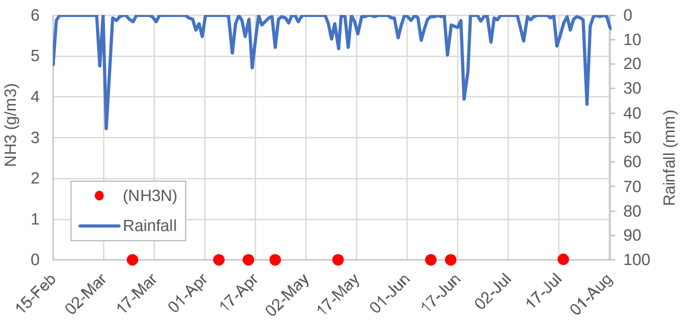
N02



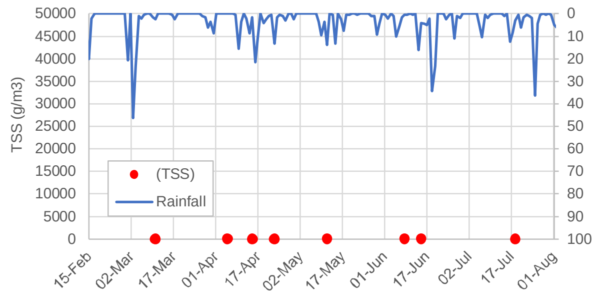
N03



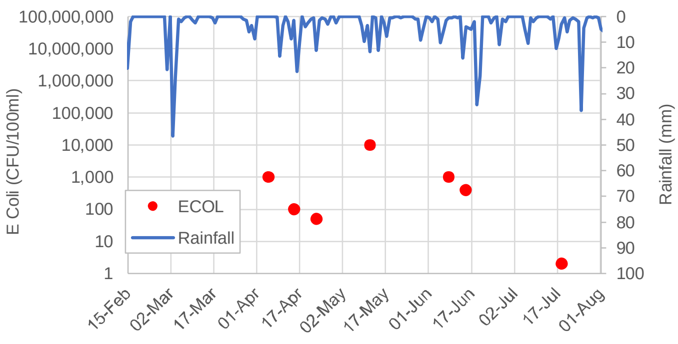
NH3



TSS

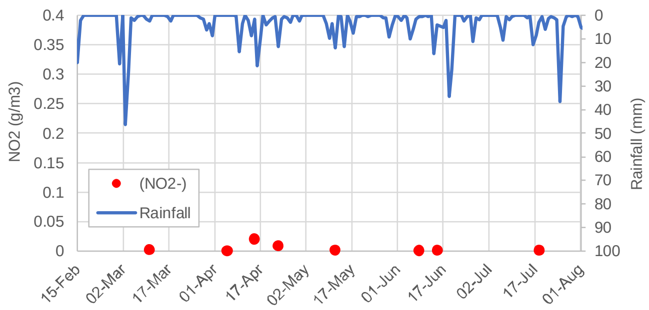


E. Coli

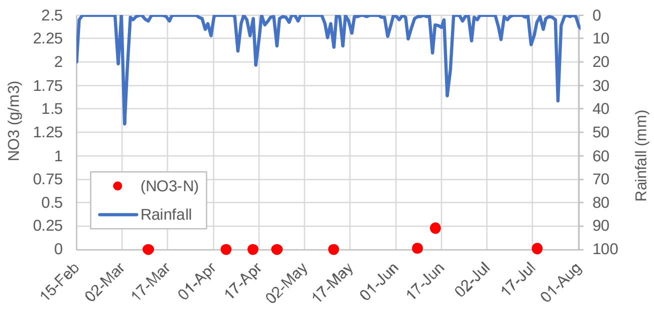


Water quality results from Wetland 8 (W8)

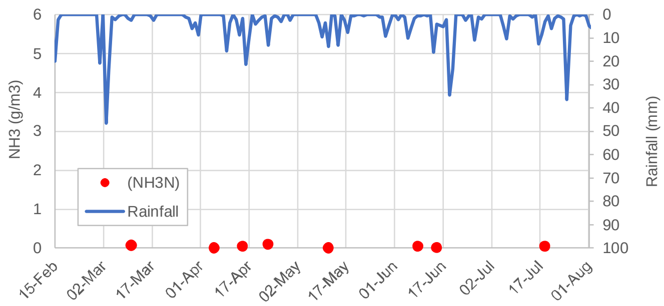
N02



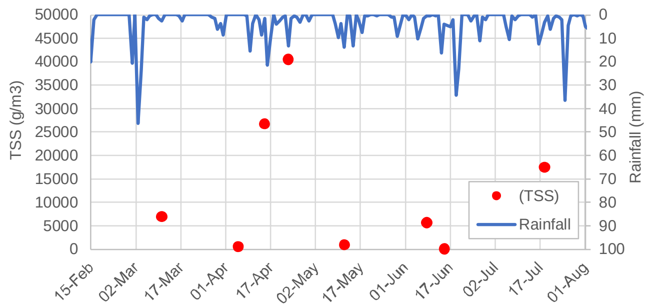
N03



NH3



TSS



E. Coli