"Achieving Outcomes by Building Capability"

Improving water quality outcomes through real-time quality monitoring

Our Land & Water National Science Challenge
Rural Professional Fund project
2021-22 Funding Round

Prepared for Our Land and Water National Science Challenge

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November 2022

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Thanks to our farmer, John Wright, who dreamed up this project to try a new technology improve his understanding of water quality dynamics and potential drivers. John has a a strong commitment to research and environmental management and loves to try new ideas, as demonstrated by his use of several innovative tools and technologies. He transparently shared the data with the local community, enabling it to be used to its full potential for applied learning, and has since purchased his own nitrate sensor.

We would also like to extend our thanks to the Our Land and Water National Science Challenge programme for the funding to trial two nitrate sensor and test the concept. The unique collaboration of a farmer, rural professionals, and environmental research scientists is the catalyst for jointing the dots, and bringing science, ideas and action together, and bringing new energy to the local catchment.

Please Read

1 Executive Summary

This project trials and evaluates the application of real-time water quality monitoring, a relatively new technology with few resources to support its use and application. Existing groundwater monitoring programmes are unable to determine the effectiveness of nitrate loss mitigations within useful timeframes or spatial resolution. Advancements in measurement technology are beneficial and increase our ability to determine the current state of Aotearoa New Zealand freshwater and the pressures on it.

Three Hydrometrics GW50 nitrate sensors were established on an irrigated dairy farm in South Canterbury to identify nitrate dynamics in shallow groundwater, comparing three groundwater sites (distributed along a flow path from top to bottom of the farm) over a year. In addition, continuous measurements of electrical conductivity and periodic nitrate-nitrogen (NO_3-N) grab samples was trialed to give an indication of nitrogen dynamics in two streams, one on the farm and another nearby.

The local community gained a stronger understanding of the dynamic of nitrates in shallow groundwater, and the case study farmer was positively engaged with the data. Peak nitrate concentrations were observed in real-time and primarily linked to large rainfall events. The considerably higher nitrate concentrations during the condensed drainage period surprised the farmer, a potential area for extension activities. It was difficult to establish relationships with farm management events in isolation; this is likely to have been improved if the project duration was longer. Linking the electrical conductivity and individual NO_3-N grab samples was also challenging, due to multiple factors.

Generally, all nitrate sensors followed a similar pattern of changes in concentrations, to a point. The middle site responded differently, indicating it may be in a different hydrological environment, have a more localised response, or be influenced by nitrogen losses from the kale crop located upstream. This highlights the complexities of groundwater, land surface recharge and nitrate sources, despite the proximity of the sites. The shallowest site, the Novaflow drain outlet, was found to be more hydrologically responsive to directed soil drainage. This site had the highest average monthly nitrate concentrations for most of the project as would be expected given its position at the bottom of the root zone. The Novaflow site helps demonstrate the potential contribution of root zone drainage to the nitrate concentration of the shallow groundwater and reinforces to the farmer how important management of higher risk soils on the property is.

Effective and reliable, continuous nitrate groundwater sensor monitoring has significant potential for application at the catchment level over several years - to help support a better understanding of the dynamic and often elevated nitrate concentration in the local groundwater and groundwater feed streams. A survey we conducted on 18 of the projects field day participants predicted that the time to near peak adoption would be 13 years with 75% of participants adopting the technology. ‘Environmental advantage’ was identified as the most significant influence on peak adoption; a large environment advantage was predicted to increase peak adoption from 75% to 88%, signalling adoption levels are likely to be higher in at risk catchments that require freshwater improvements. This project demonstrates that a successful community science programme could be developed in collaboration with scientists, project managers, and landowners to ensure the ease of use, robustness of data for research use, and analysis and dissemination of meaningful results to the community. The project also found that hard data provided a renewed focus to catchment groups. This could facilitate a refreshed approach to farm nitrogen management, supporting flexible and adaptive management responding with mitigation actions to adverse effects of farming activities observed in the results.

2 Project introduction

2.1 Background

Aotearoa New Zealand is responding to multiple pressures to reduce the impact of intensive land use on groundwater quality and stream health, with significant investment in nitrate management through national policy and standards, regional plan rules, and on-farm actions. Farms need to not only be financially, socially, and environmentally sustainable; they also need to demonstrate that they are operated in a way that also satisfies public and political interests.

The project provides the farmers and stakeholders an insight into potential tools to take some control over their own data collection activities so they can better inform their decision making around farming system changes and mitigations, as well as engage in regulatory discussions with data to inform meaningful dialogue. As affirmed in Our Freshwater 2020: New Zealand's Environmental Reporting Series (p.2), *"understanding the current state of freshwater and the pressures on it, is essential groundwork for decisions on where to put our efforts".*

2.2 The challenge

Farm nitrogen losses are usually estimated by nutrient models, such as Overseer, for regulatory and compliance purposes. While these models estimate nitrogen lost from the soil root zone, they do not account for the fate beyond this point, of the impact on local water quality, a key component to managing and mitigating the impact of a farm on receiving waterbodies. Further, these models often incur high margins of error. A recent review of Overseer commissioned by the Ministry for the Environment (MfE) and the Ministry for Primary Industries (MPI) (2021) concluded there is a lack of confidence in the models estimates of nitrogen lost from farms for use as a standalone measure. The Government responded to the review, one of their recommendations was that there is further investigation into the feasibility of real-time monitoring of freshwater quality at the local level (MFE & MPI, 2021)

Accurate water quality data is a key principle for implementing regional policies in relation to nutrient losses from agriculture and monitoring the health of waterways. Existing groundwater monitoring programmes, predominantly designed to provide a regional-scale indication of nitrates and long-term trends, are unable to determine the effectiveness of nitrate loss mitigations within useful timeframes (i.e., 5-10 years) or spatial resolution (Our Land and Water (2021)). Consequently, the effectiveness of implementing new nitrate management approaches may not be known for several decades (and sometimes much longer). This shortfall has significant implications for stakeholders, kaitiaki, communities and regulators who care deeply about the state of freshwater.

Specifically:

- Farmers and industry making considerable financial and time investments on improving freshwater want to understand if they are on the right track, however this will take several years.

- Long term farm management and financial planning is difficult when the extent of future nitrate mitigation requirements is unknown. Uncertainty over the compatibility of some farm systems with new nutrient limits has potential knock-on effects for investment decisions and property values.

- Māori consider water to be taonga, and a significant resource of cultural, spiritual, and historic importance. The effects of land intensification on stream water quality and health have had a severe impact on cultural values, with a significant reduction in mahinga kai quality and abundance.

- High nitrate concentrations in groundwater supplies and stream health deterioration are a concern for all communities. Any lack of information on the rate of progress towards improvement exacerbates community concerns and frustration, increasing pressure on farmers' “social license to operate”.

- Regulatory bodies are unable to evaluate the effectiveness of nitrate rules and policies within the 10-year period of a regional plan. Current monitoring systems do not provide suitable information; hence the status quo approach does not support robust land and water management.

Through working with farmers, a significant increase in their interest in monitoring the health of their on-farm waterbodies has been observed. We need to know more than what we currently do – data is key! Further advancements in monitoring programmes are inevitable and beneficial.

2.3 Project aim

This project trials and evaluates the application of real-time water quality monitoring, a relatively new technology with few resources to support its use and application. The aim of this project is to:

- Rapidly improve environmental monitoring and engage catchment with local attainable data.

- Increase understanding of the dynamic of nitrates in shallow groundwater, and the potential drivers of the frequency and magnitude of seasonal nitrate concentration spikes.

- Identify nitrate detections coming from the upper to lower groundwater sites

- Inform landowners of the impact of farm management practices and climatic variation on water quality.

2.4 Project team

This grassroots project idea was instigated by a local farmer, John Wright, who has a strong commitment to research and environmental management, as demonstrated by his foresight to undertake quarterly water quality monitoring on their farm since 2013, and their use of several innovative tools and technologies to enhance environmental management and improve farm management decisions. Despite having lots of data, John knew he wouldn’t catch the immediate after-effects on nitrate levels from sudden weather events or irrigation. John has heard about real-time monitoring and believed “*it would be a big improvement in which it would capture everything*”. He explains “*quarterly sampling just didn’t provide the full picture. I don’t know if a spike or a drip was a one-off or part of the pattern. I had been looking for a solution like Hydrometrics nitrate sensor for a long time”.*

We initially pitched the project idea to the local Te Ana Wai Catchment Group. We found several farmers were already invested in the concept; about ten farmers in the catchment were conducting their own water quality monitoring programmes at their own cost using quarterly testing regimes. Many farmers offered access to their land and potential installation sites for real-time sensors. It became clear this project was of value to local farmers, who in the past have been frustrated with the lack of local data that affects their land specifically. This gave us the confidence that the project is worth pursuing and of value to local farmers, who in the past have been frustrated with the lack of local data that affects their land specifically.

We engaged with catchment stakeholders early, including the catchment groups (South Canterbury Catchment Collective, Te Ana Wai, Upper Opihi), Opuha Water Limited (the local irrigation company), the local Environment Canterbury mahinga kai facilitator, and industry groups. They have been very willing to collaborate and support us throughout the project. These key people each take leadership in driving continual improvement in land management, and have effectively assimilated the project findings across South Canterbury and wider regions.

The project team (**Figure 1**) has diverse skill sets, including farm systems, nutrient, hydrology, and water quality knowledge.

Project Role	Name	Business	Role
Project Lead	Jon Manhire	The AgriBusiness Group, Lincoln	Managing Director
Project Manager	Charlotte Senior	Agri Intel, Lincoln	Consultant and Director
Farmer	John Wright	Wainono Farm, 318 Talbot Road, Fairlie, Canterbury	Shareholder and Managing Director (Richard Green and John Mackenzie are the other Directors)
Scientist	Dr Blair Miller	Lincoln AgriTech, Lincoln	Group Manager, Environmental Research
Technical Support	Darcy Aker	Lincoln AgriTech, Lincoln	Hydrometrics Application and Sales Engineer
Project Implementation and Assistance	Nicole Halliday	Carrfields, Pleasant Point	South Canterbury Catchment Collective Secretary
	Kate Moorhead	Ballance Agri-Nutrients, Canterbury	Farm System Sustainability Senior Consultant
	Julia Crossman	Opuha Water Limited, South Canterbury	Environmental Manager
	Jared Panther	Opuha Water Limited, South Canterbury	Water Scientist

Figure 1: The project team. From left – Jon Manhire, Dr. Blair Miller, John Wright, Nicole Holliday, Darcy Aker, and Charlotte Senior

2.5 Case study farm

Wainono Dairy Limited is located on the southern border of Fairlie Township, Canterbury. Two decades prior, the farm was converted from a dryland sheep to two irrigated milking platforms. **Appendix 1** summarises key farm system information.

The location of Wainono Farm, at the bottom of the Upper Opihi catchment and just upwards of the Opihi Gorge where all the basins groundwater empties through, means that the sensors are well-placed to track the health of this catchment. It is important that water quality is closely monitored and improvements are made in this intensively farmed catchment, as it has been identified as a high nitrogen concentration risk zone due to the elevated levels of nitrate observed in groundwater (**Appendix 2**). Wainono Dairy borders the hill fed Opihi River which has a braided gravel bed, and the farm contains numerous tributary streams and has several existing bores and infiltration galleries within the unconfined aquifer, therefore offers numerous potential monitoring sites. In addition, the unique impermeable mudstone layer underneath the farm provides an opportunity to monitor the impact of all land-surface recharge, as drainage is captured in the shallow groundwater above this layer. All water takes are at shallow depths in the upper non-confined aquifer perched on a mudstone aquitard at approximately eight metres below the surface across the property.

The farm has rich existing data and an overall objective of continuous environmental improvement, making it an ideal case study. Some initiatives include:

- Implementation of a Farm Environment Plan, which describes the farm system, risks, and effects of farming practices on the environment and sets actions to mitigate adverse environmental effects. This is independently audited, receiving an ‘A’ grade at the most recent audit in January 2021.

- Water quality sampling data for nearly 10 years, at the upper and bottom entry points of the farm.

- The application of EMS soil mapping and variable rate irrigation (VRI) on pivot irrigation systems to ensure that irrigation water is applied at optimal efficiency, in accordance with soil types and crop requirements. Applications to non-target areas (i.e., waterways and lanes) are avoided.

- Regular measurements on soil moisture status to assist in irrigation, effluent and fertiliser scheduling, via Aquaflex (Onfarm Data, NZ) telemetry sensors across seven sites which represent a range of irrigation and soil types.

- MitAgator risk mapping to illustrate and identify nutrient contaminant hotspots.

- Use of alternative pasture species, a scientifically proven nitrogen loss mitigation.

3 Methodology

3.1 Sensor selection

Three sensors were used. The ‘Our Land and Our Water National Science Challenge’ funded the lease of two sensors and the farmer purchased an additional sensor. The Hydrometrics GW50 Nitrate sensor (Figure 2) was selected for project use, as:

- The relatively low price point is more likely to be feasible for farmers than alternative continuous monitoring sensors on the market.
- It has been designed for installation in a standard 50mm bore to accurately measure nitrate nitrogen concentrations as frequently as 15 minutes if required.
- Maintenance requirements are low - it has a water jet for an effective method for cleaning the sensor, resulting in significant reduction in the need for manual cleaning.
- It has remote data logging capability.

This sensor has been developed by Hydrometrics, a division of Lincoln Agritech. Lincoln Agritech completed the installation of the sensors and provided maintenance and supported analysis of the data collected.

Figure 2: A Hydrometrics GW50 Nitrate Sensor

3.2 Monitoring layout

On the 15th October 2021, we completed our initial site visit to identify the three sites potential sites for the installation of the three nitrate sensors. A survey of the depth in numerous wells on and surrounding the farm allowed the direction of groundwater flow to be determined and confirmed our initial estimation of flow direction.

The sites were selected along the general flow direction allow comparison of upper, middle and lower farm nitrate concentrations and dynamics. The general flow direction as well as the three Hydrometrics GW50 Nitrate Sensor (Lincoln Agritech, NZ) are shown in **Figure 3**. O'Neils and Paddock 2 sensors were installed in wells connected to galleries, with the Novaflow sensor being installed at the discharge of a drain coil located down the farm (**Figure 4**).

In addition to the groundwater installations, Diver conductivity and level probes (Van Essen Instruments, Neitherlands) were installed in PVC shrouds to give an indication of nitrate dynamics (relationship to be developed with periodic grab sample data) in Glenfield and Strathconan Streams (**Figure 5**)

A new weather station (Truesense, NZ) was also installed beside the bore at Paddock 2 (**Figure 6**) to provide climatic information, a key consideration for the nitrate readings.

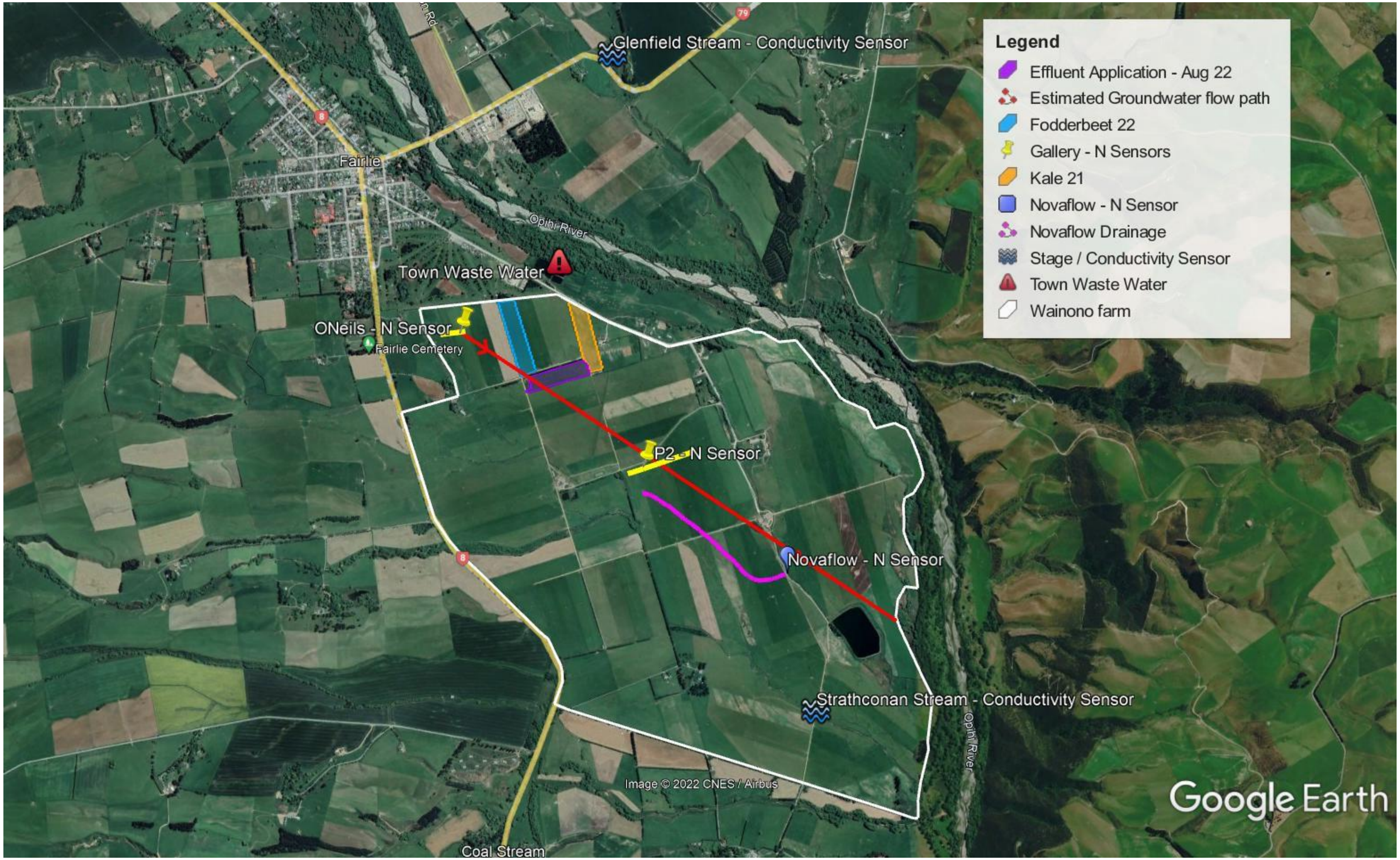

Figure 3: Locations of sensor installation at Wainono Farm. The Novaflow surface drainage is shown as the purple line, and the gallery takes is the yellow line

Figure 4: From left to right: Installations at O'Neils, Paddock 2 and Novaflow.

Figure 5: Strathconan (left) and Glenfield (right) streams Diver water level and conductivity.

Figure 6: Truesense IOT climate station installed by Paddock 2 gallery.

3.3 Data collection

Measure	Source
Groundwater nitrate concentrations	Data was uploaded to a data portal hosted by Hydrometrics for programme partners and approved stakeholders to access in near real time.
Rainfall and irrigation drainage events	The new weather station (Truesense, NZ) installation provided information to analyse rainfall and potential evapotranspiration (PET). Irrigation pumping data was collected. With the calculation of PET and measured rainfall, as well as a synthesized irrigation record, a simple water balance model was used to estimate drainage events.
Soil moisture	The farm already has seven Aquaflex soil moisture sensors (Onfarm Data, NZ)
Nitrate dynamics in Glenfield and Strathconan Streams	Two Diver conductivity and level probes (Van Essen Instruments, Netherlands) were installed and manually downloaded. The host farmer collected periodic grab samples at the same locations. These samples were frozen and analysed for nitrates at the end of the programme to determine if there is enough of a relationship between conductivity and nitrate concentration to draw any conclusions on the behavior of these streams. Opuha Water Limited were sampling nitrate at the same location, this information was also used. While Glenfield Stream was not on Wainono, it has recorded elevated nitrate concentrations in recent years and the community was interested to see if we could estimate concentrations using this low-cost methodology
Nitrogen fertiliser applications	Fertiliser applications were recorded by paddock using GPS proof of placement.
Effluent applications	Effluent applications near the sensors were reported. There were few effluent applications near the sensors, as it is usually applied on the bottom terrace. The nutrient content of the effluent was not measured.
Stock grazing regime	There was limited reporting on actual pastoral paddock grazing dates. The feed wedge was determined by weekly pasture measurements (CDEX tow-behind), the grazing rotation was typically 19 to 23 days.
Crop information	2021-22 crop information was collected, including paddock history (years in pasture), cultivation and sowing dates, crop yield, grazing dates and management, date back to pasture. These crops were then modelled using Overseer nutrient modelling.
Farm nitrogen hotspots	Farm systems modelling (Overseer nutrient modelling and MitAgator contaminant risk maps) and soil mapping was completed to reflect the current farming operation and assist with spatial identification of nutrient hotspots on the farm, in particular in the vicinity of the sensors.
Community adoption	A survey was conducted at the final field day to evaluate stakeholder perceptions on the relative value and potential for the adoption of real time water quality monitoring as demonstrated by the project. The survey method is outlined in **Appendix 3**.

4 Results and Discussion

4.1 Farmer experience

John has been positively engaged with the data, and accesses data after every rainfall event. "*I access the data every three or four days and always before and after a weather event*," he says. "*It's easy, efficient, and straightforward to understand."* The significant rise in nitrate concentrations over the winter drainage period surprised John. He finds that the data usually provides "*more questions than answers",* and often theorises the likely cause of changes with the project team.

John can see the power of real-time data collection. "*Levels are going up and down quite a bit, as we suspected from the quarterly spot samples we took previously, but now we can go much further and identify trends. I can already see the potential in terms of how we manage our grazing and when and where we fertilise*". The farm is located at the bottom of the Upper Opihi catchment prior to Opihi Gorge; John is really interested in detecting nitrogen levels in groundwater coming from the catchment above his farm and wants to ensure groundwater quality is not deteriorating because of his farming practices.

4.2 Groundwater nitrate real-time monitoring

4.2.1 Sensor functionality

In general, the Hydrometrics GW50 performed well in this application. Some issues occurred which resulted in removal of data after reviewing the raw sensor output and determining the data was unsuitable for further analysis. While generally running clear, the Novaflow site occasionally got bio-fowling that could signal degradation if it was not removed, which would then impact the sensor's reliability. Turbidity could be an issue after heavy rainfall at the Novaflow site as well. The sensors did have automatic water cleaning jets installed, but all sites required some additional cleaning to keep the sensor working correctly.

The two galleries where GW50 nitrate sensors were installed (O'Neils and Paddock 2) developed biofouling of the optics when the pumps were not running regularly. The sensors were originally installed in an 80mm PVC pipe inserted down into 600mm diameter casing installed at the head of the gallery. This was designed to protect the sensors from the cabling and turbulence rated to the submersible pump installed in the casing. During cleaning of the sensor, it was noticed that water in the protective pipe had a slightly different $N0_3$-N concentration compared to the main casing, probably resulting from the limited number of holes drilled not allowing water to equilibrate in the highly biologically active casings. The casing was not covered and light could enter which may have contributed to the biological activity and increased fowling during non-pumped periods. Later in the project the sensors were installed directly into gallery casing to avoid the risk of non-representative readings relating to poor hydraulic connection. Immediately the interference levels dropped, confirming the theory.

4.2.2 Continuous Nitrate Sensor Readings

The upper non-confined aquifer is perched on a mudstone aquitard at approximately eight metres below the surface across the property. While it may be fractured in places both land surface recharge and water moving across the boundary are essentially confined within this narrow band. The galleries and Novaflow do not pierce the aquitard and therefore capture water drained to the aquifer from the land above or water moving through this shallow unconfined aquifer from up gradient in the catchment.

The nitrate accumulated in the vadose zone (i.e., the unsaturated zone between the bottom of the root zone and the water table) may have been relatively low (compared to a typical season) when the project started in October 2021, following the extreme rainfall and corresponding significant drainage event in Canterbury in late May 2021 where significant flushing occurred. This indicates that there could have been a lower-than-normal risk of nitrate losses to groundwater during the project, until significant drainage events in July 2022.

Figure 7 presents the continuous nitrate readings at the three sites, with rainfall, calculated drainage, and irrigation events. The dynamic nature of nitrate concentrations across the three sites is clear, as the magnitude and duration of fluctuations vary spatially and temporally. Generally, all sites follow a similar pattern, to a point.

During January, there was a total of 70mm and four rainfall events exceeding 12mm per day. A steady increase and similar patterns in nitrate concentrations in the upper and lower sites were observed. Conversely, this rainfall had a negligible impact on the Paddock 2 (middle) site as nitrate concentrations trended downwards. While this site is in the theoretical groundwater flow path, it could be in a different hydrological environment, have a more localised response, or have a different nitrogen source from farm inputs such as the kale crop located upstream. This makes it difficult to identify pulses of nitrate concentrations from above the farm, flowing through the three sites. It highlights the complexities of ground and surface interconnections, despite the proximity of the sites.

We analysed the lag period and the correlation between O'Neils and both Paddock 2 and the Novaflow site. Additionally, as a sense check, cumulative rain has been assessed against the three sites, to investigate if local recharge is the key driver. There is a 73% correlation between O'Neils and Paddock 2 at 32 days lag. However, this lag is significantly greater than the lag between O'Neils and the Novaflow which responds within seven days and has a 75% correlation. This perhaps suggests the correlation between O'Neils and Paddock 2 is coincidental rather than real. All sites are well correlated to rainfall; however, Paddock 2 responds later with a maximum correlation at 8 days lag, rather than 0 days for the O'Neils and Novaflow. It seems as though Paddock 2 may be responding to a separate leachate site immediately up gradient, however, more data would be required to confirm.

The Novaflow outlet site is shallower than the galleries and was therefore more hydrologically responsive to directed soil drainage and shallow groundwater. This site had the highest average monthly nitrate concentrations for most months (excluding July and August when the Paddock 2 (middle) site was the highest). It also demonstrated the most rapid response to land surface recharge. For example, on the 5th and 8th of November, the pivot irrigator malfunctioned with the nelson valve not shutting of when the pivot stopped and was watering for a few hours while stationary (**Figure 8**). A reduced nitrate concentration was detected. Generally, the Novaflow experiences sharp increases in nitrate concentrations following significant rainfall events; and then falls back to pre-rainfall levels in about two days. For example, on July 12th there was 36mm rainfall, causing the first significant drainage event (estimated 35mm) since the project commenced. Hourly nitrate concentrations in the Novaflow increased steadily from 10am to 6pm, from 4.1 to 10.4mg/L (2.5x), and then decreased to 7.3mg/L by 11am the following day. The initial rainfall response was delayed by a further five hours on the upper site and nine hours on the middle site; both these sites had a similar response of a steady increase in nitrate concentrations over nine hours, by +39% (upper site) to +27% (middle site).

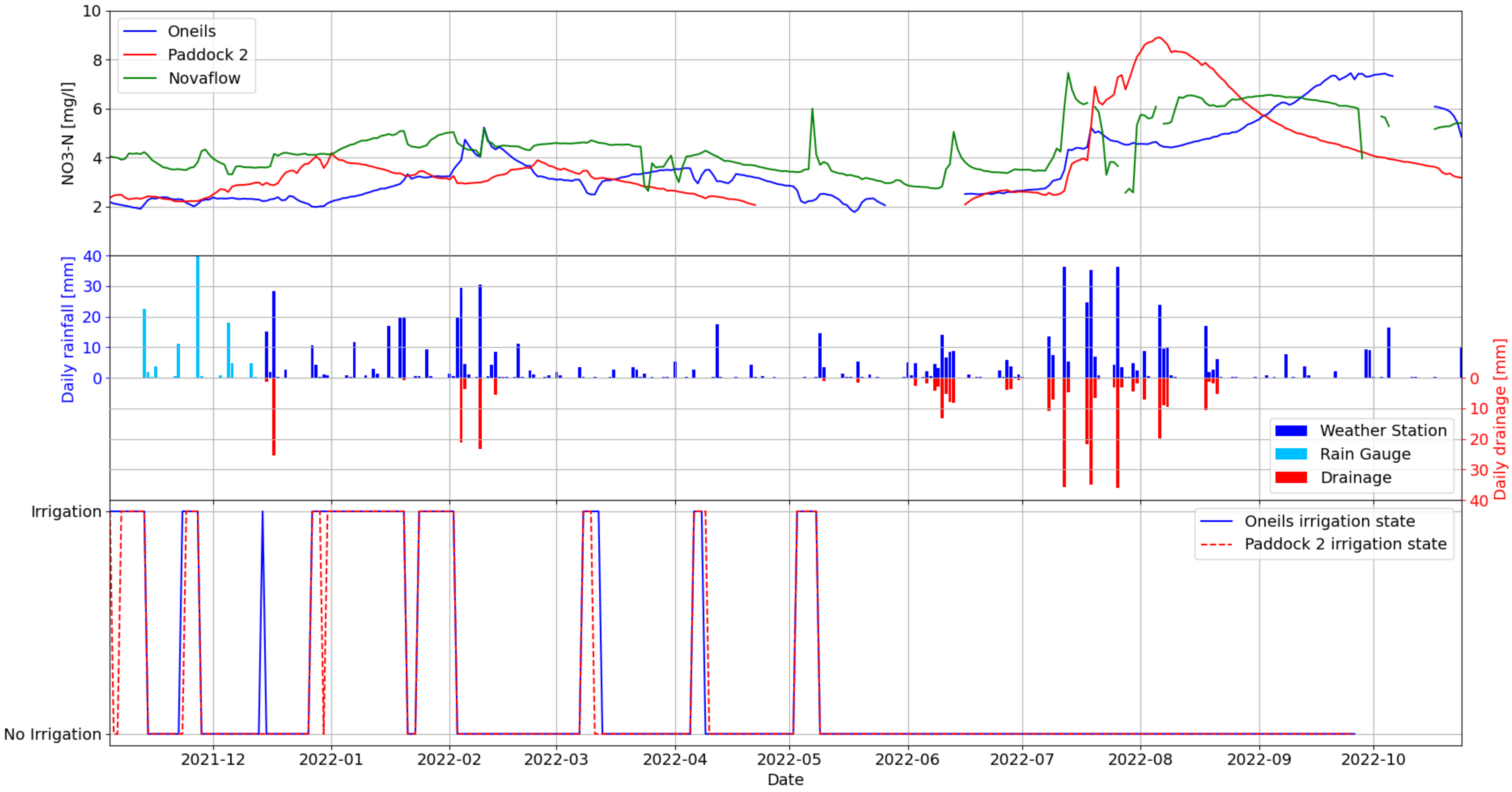

Figure 7: Continuous Nitrate measurements from the three sites at Wainono Farm, with rainfall and calculated drainage, as well as periods of irrigation presented. The upper, middle and lower sites are O'Neils, Paddock 2 and Novaflow, respectively.

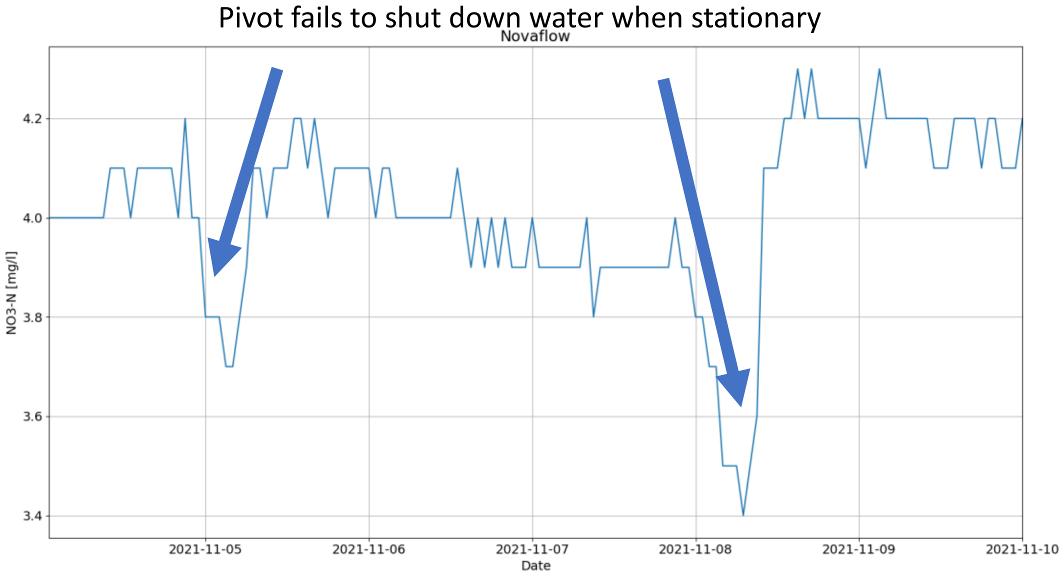

Figure 8: Novaflow hydraulic connection

The 2022 drainage season was very late and condensed, as the three largest drainage events (>35mm/day) occurred during three weeks in July. Nitrate concentrations increased from June to August across all sites and were at their highest levels during July and August. **Table 1** provides a comparison of average nitrate concentrations, rainfall, and drainage during the summer and winter/early spring months. Both periods had similar total rainfall volumes, however from July to September drainage levels were almost three times higher, coinciding with higher average nitrate concentrations across all sites. The local irrigation company, Opuha Water Limited, also found that the July rainfall event caused a significant increase (+285 to +475%) in nitrate concentrations in the Lake Opuha tributaries (Ribbonwood Creek, Station Creek and North Opuha River).

Table 1: Comparison of average nitrate concentrations at the three nitrate sensor sites, rainfall, and drainage during the summer and winter/early spring months.

	Average Nitrate (mg/L)	Rainfall (mm)	Drainage (mm)
Summer (Dec-Feb)			
Upper	3.0		
Middle	3.3		
Lower	4.4		
Average	3.6	298	81
Mid-winter – early spring (Jul-Sep)			
Upper	3.6		
Middle	5.7		
Lower	5.5		
Average	4.9	296	234
% change			
Upper	+20%		
Middle	+73%		
Lower	+25%		
Average	+36%	-1%	+289%

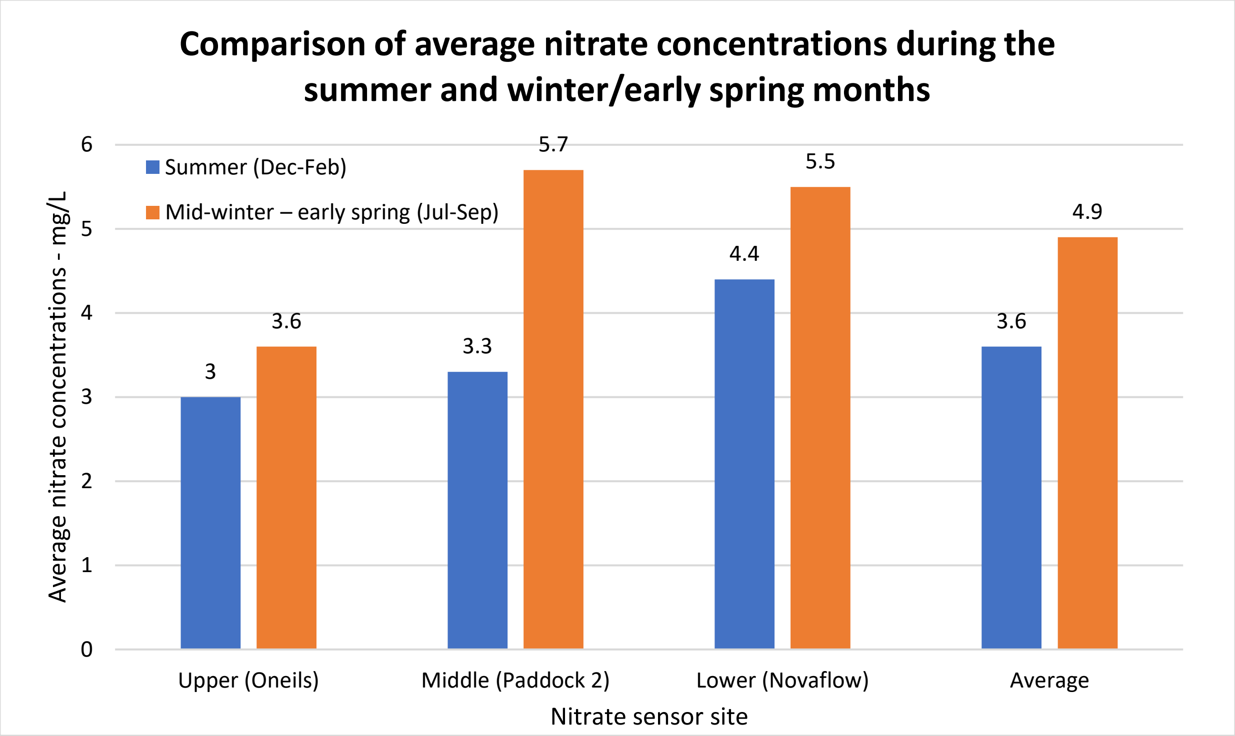

Figure 9: Comparison of average nitrate concentrations during the summer and winter/early spring months.

Post-drainage season, the upper sensor is continued to rise due to a potential regional response above the farm, but by early November 2022 was starting to fall again. The middle site seems to have peaked and is on the decline. The Novaflow is still elevated; it will be interesting to determine if this continues to remain elevated or increases in coming months.

4.2.3 Key drivers of nitrate concentrations

Nitrogen losses from the root zone are driven by mineral nitrogen accumulated within the soil profile (from farm nitrogen inputs) and drainage events. There is limited ability to influence drainage events, excluding irrigation applications.

There was inconclusive evidence to suggest the timing and location of farm management practices, including fertiliser, irrigation and effluent applications, and paddock grazing, influenced nitrate concentrations. The farming practices were managed in accordance with industry Good Management Practices, reducing the risk of adversely impacting water quality. Nitrogen fertiliser inputs were relatively low for a Canterbury dairy farm, in the 2021-22 season an average of 144kgN/ha/yr was applied (**Figure 10**).

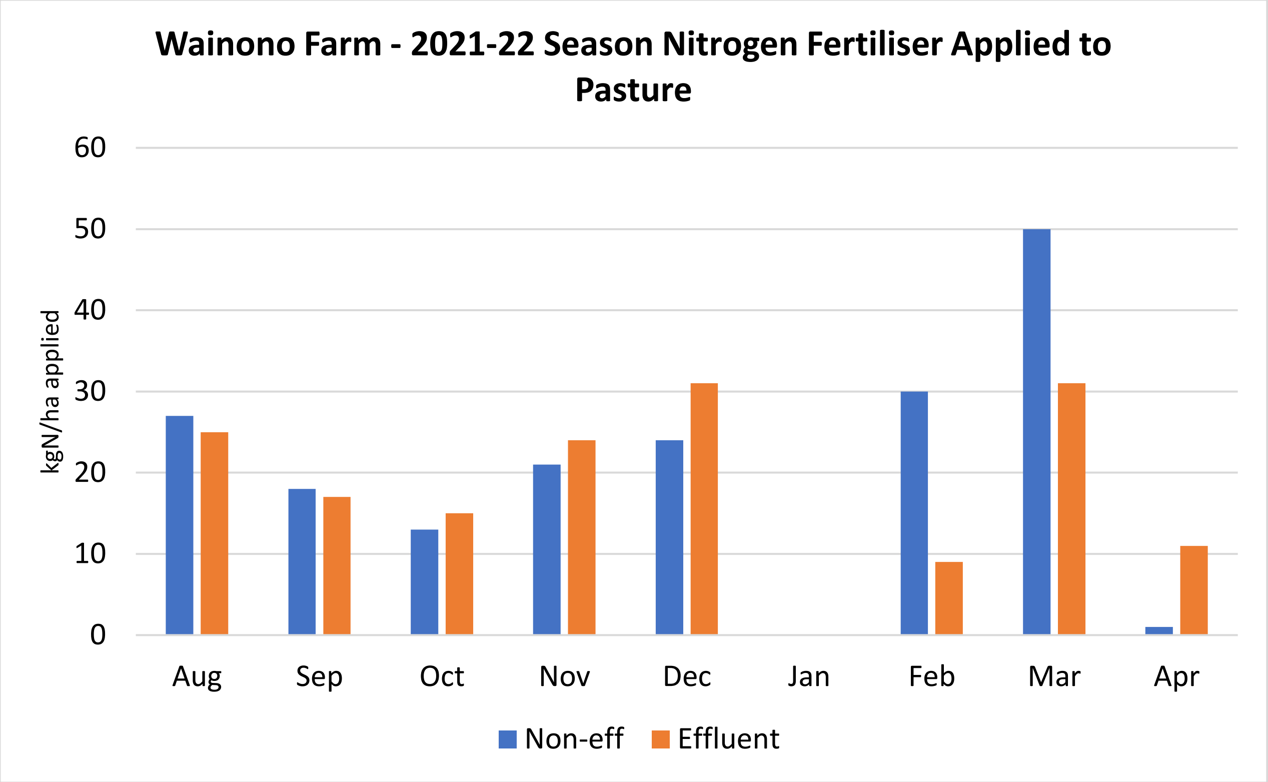

Figure 10: Nitrogen fertiliser applied to pasture on Wainono Farm in 2021-22

Overseer and MitAgator modelling indicated that the kale forage crop block had the highest nitrogen loss risk (**Appendix 4**), contributing to a disproportionately high amount of the total nitrogen losses from the farm. Although the kale crop represented only 6% of the total farm area, it was responsible for 12% of the farm's total nitrogen losses (**Figure 11**). These relatively high losses are attributed to mineralised nitrogen losses from soil cultivation, high stocking rates (from March to June) and the following fallow period that coincide with low plant nutrient uptake and high soil drainage. This crop is located upwards of the middle Paddock 2 site (**Figure 3**) and could have contributed to this site having a different response to the others.

Fodderbeet crop had a negligible impact, with similar nitrogen loss estimates to pasture (**Figure 11**), as it has lower crude protein concentrations, reducing dietary and urine nitrogen concentrations (Jenkinson et al., 2014).

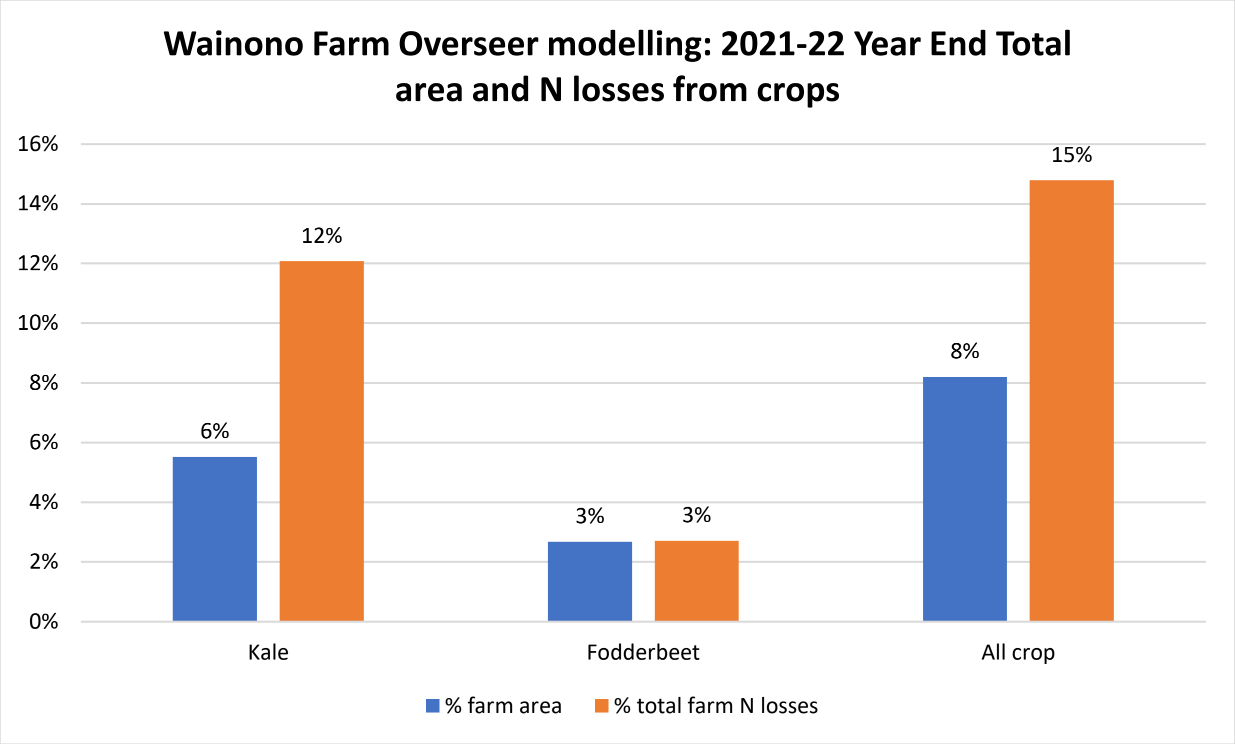

Figure 11: Proportion of total area and nitrogen losses from forage crops on Wainono in the 2021-22 season

Rotorainer travelling irrigators also pose a higher risk of drainage events than pivot irrigators, due to their higher application depths (25 vs 10mm per application, respectively). All sensors were underneath pivot, however the rotorainer irrigation in the surrounding paddocks are likely to have some influence (Figure 12).

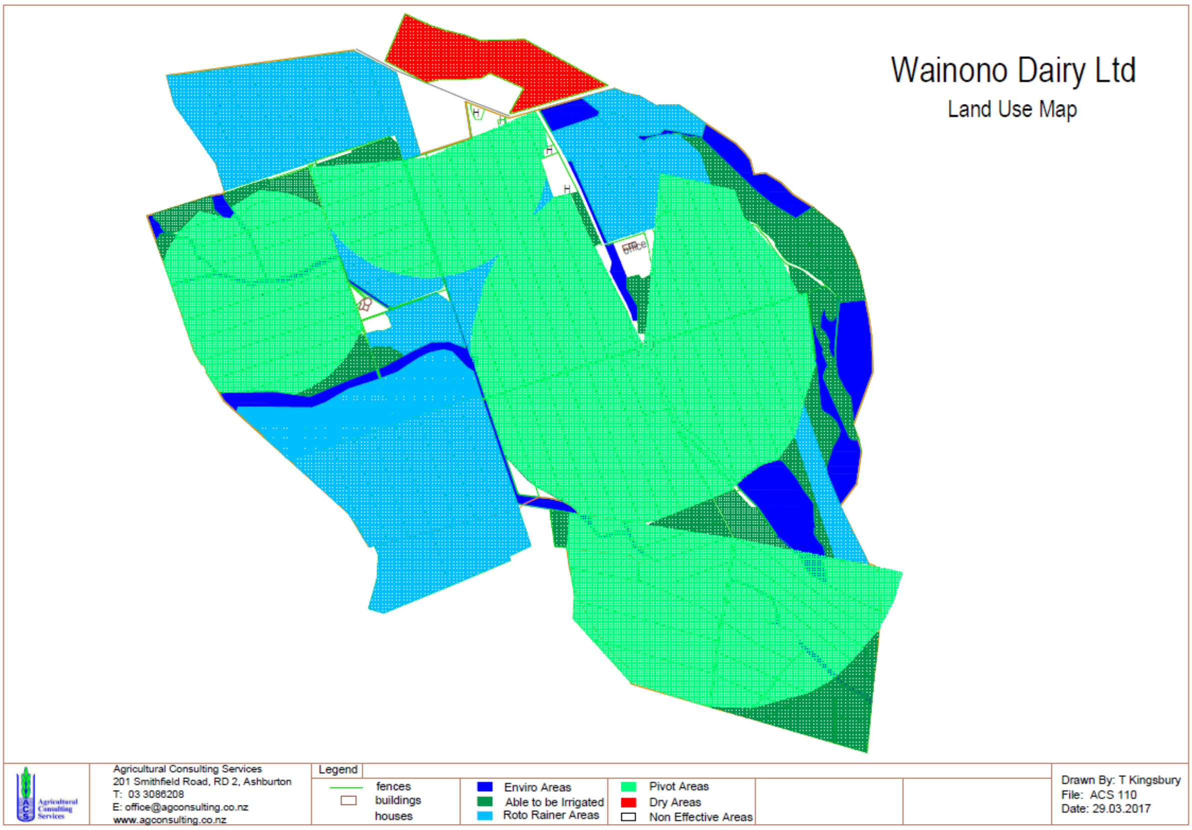

Figure 12: Wainono Irrigation Map

4.3 Stream conductivity and nitrate dynamics

This project aimed to link continuous measurements of electrical conductivity (EC) and individual nitrate-nitrogen (NO_3-N) grab samples collected on Glenfield Stream and Strathconan Creek. Due to a number of confounding factors, this has proved challenging.

Firstly, the EC loggers were not telemetered and were only downloaded when a technician was on site. This meant any equipment failures could not be identified in real-time and addressed rapidly. The EC loggers on loan from Van Walt Ltd of Wanaka had the added advantage of additionally measuring a water level. This was a non-vented device requiring post-correction for barometric pressure changes. To enable barometric correction, a separate baro-logger was installed on the farm. Unfortunately, the data on the baro-logger was corrupted after an insect crawled into its vent and died shortly after sensor deployment. We were unable to find a suitable local barometric pressure record to correct the data, resulting in a gap in the stage data until a Weather Station was installed on site.

Secondly, we were unable to get a continuous record of conductivity or stage at both sites for the whole period of the trial. In the first instance, the Strathconan Creek logger suffered a battery failure shortly after the June 2022 download, with no data post the June download recoverable. In the second instance, the land owner on Glenfield Stream decided around the same time to remove the logger due to several high flow events which he was concerned would sweep it away. This results in both data sets being somewhat shorter than the continuous nitrate monitoring of the galleries and Novaflow.

Thirdly, the original intention was for the farmer (John Wright) to collect NO_3-N grab samples from each of the streams at least monthly and during different stages of the hydrograph after large rain events. While several samples were taken, fewer were collected than originally planned. This was compounded by poor labelling which meant several samples had to be removed from analysis as we could not determine their provenance. Fortunately, we were able to obtain several additional NO_3-N data from when Opuha Water Limited extended their monitoring program to include our EC sites. With these points, we had enough data to attempt a simple regression between EC and NO_3-N.

Finally, it was originally intended for the Lincoln University Analytical Services group to analyse a larger panel of water quality parameters. However, due to staff shortages and several of the planned tests being outside their normal workflows, significant delays developed in receiving the results. Due to the study coming to an end, the decision was made to only process the samples for $N0_3$-N, which is in line with what was being measured at the groundwater sites. The data collected is presented in **Table 1**.

The time-series of water levels and EC for both streams is presented in **Figure 13**. Flow patterns of both streams inferred from the stage data are quite different. As no flow rating exists for the sites, flow calculation is not possible. However, based on the stage record, flow in Strathconan Creek appears far more stable throughout the measurement period, with only short-duration flashy responses to rainfall. The stability of the stage level is somewhat surprising given the slightly smaller catchment area than Glenfield Stream (approximately half the size based on simple topographic map interpretation). The stability of the stage record suggests the flow is strongly supported by groundwater input. We have some evidence for significant groundwater input upstream of our monitoring site as indicated by a sharp rise in $N0_3$-N over a short distance, identified in Opuha Water's monitoring programme on this stream. The greater fluctuations in the water level stage in the Glenfield Stream record are harder to explain. Given

Table 2: Grab samples collected at the Glenfield Stream and Strathconan Creek monitoring sites.

Grab Sample NO_3-N mg/L		
Date	Glenfield Stream	Strathconan Creek
10/11/2021	4.05	1.92
27/11/2021	3.08	2.00
28/11/2021	2.62	1.85
15/12/2021	3.06	1.31
27/01/2022	3.02	
2/02/2022	3.27	1.83
7/02/2022	3.60	1.06
21/02/2022	4.49	1.62
16/03/2022	4.56	2.05
4/04/2022	4.87	1.97
26/05/2022	4.40	1.88
15/06/2022	5.32	1.53

Glenfield Stream's slightly larger catchment area and slightly flatter topography, it would normally suggest more possibility for groundwater baseflow contributions, and consequently a generally smoother stage record. One hypothesis for the roughness of the stage record is inflow from other surface water sources; we note a number of artificial channels and races on Environment Canterbury's hydrology GIS layers that may intermittently provide water to the Glenfield Stream.

Moving into the autumn, Glenfield Stream had a sustained increase in water level following the late summer rainfall. We expect drainage from the upper catchment sustained this flow into the winter, but we then see a major drop off in level into early winter, only to be arrested and then recover with the June rainfall.

It should be noted that neither site had any bed control, so cross-sectional change impacting the level recorded cannot be ruled out and therefore the water level record can only be considered indicative. No attempt to survey cross-sections was undertaken, but visually no significant bed changes were observed.

This more stable stage and assumed flow of Strathconan Creek is also associated with a much narrower range of $N0_3$-N concentrations as measured from the grab samples when compared to Glenfield Stream (**Table 2**). When we fitted a linear regression to predict $N0_3$-N from the associated EC readings an R^2 of 34% was calculated for Strathconan Creek, while an R^2=68% was calculated for Glenfield Stream (**Figure 14**). Neither site had enough data points or a large enough range in $N0_3$-N values to warrant investigating a non-linear solution to the relationship. We considered water level as a predictive variable but decided the worth of such an exercise would be low after initial attempts yielded no improvement. More data points, or potentially a discharge variable may have yielded better results.

Figure 15 presents the estimated $N0_3$-N for both Glenfield and Strathconan Streams. The grab sample readings are overlaid and at Strathconan Creek the absolute differences between the predicted and measured values are small, aided in the most part by the limited range of NO_3-N during the study period. In comparison, the absolute errors associated with predicted and measured are larger for Glenfield, but with the increased range little can be drawn from this.

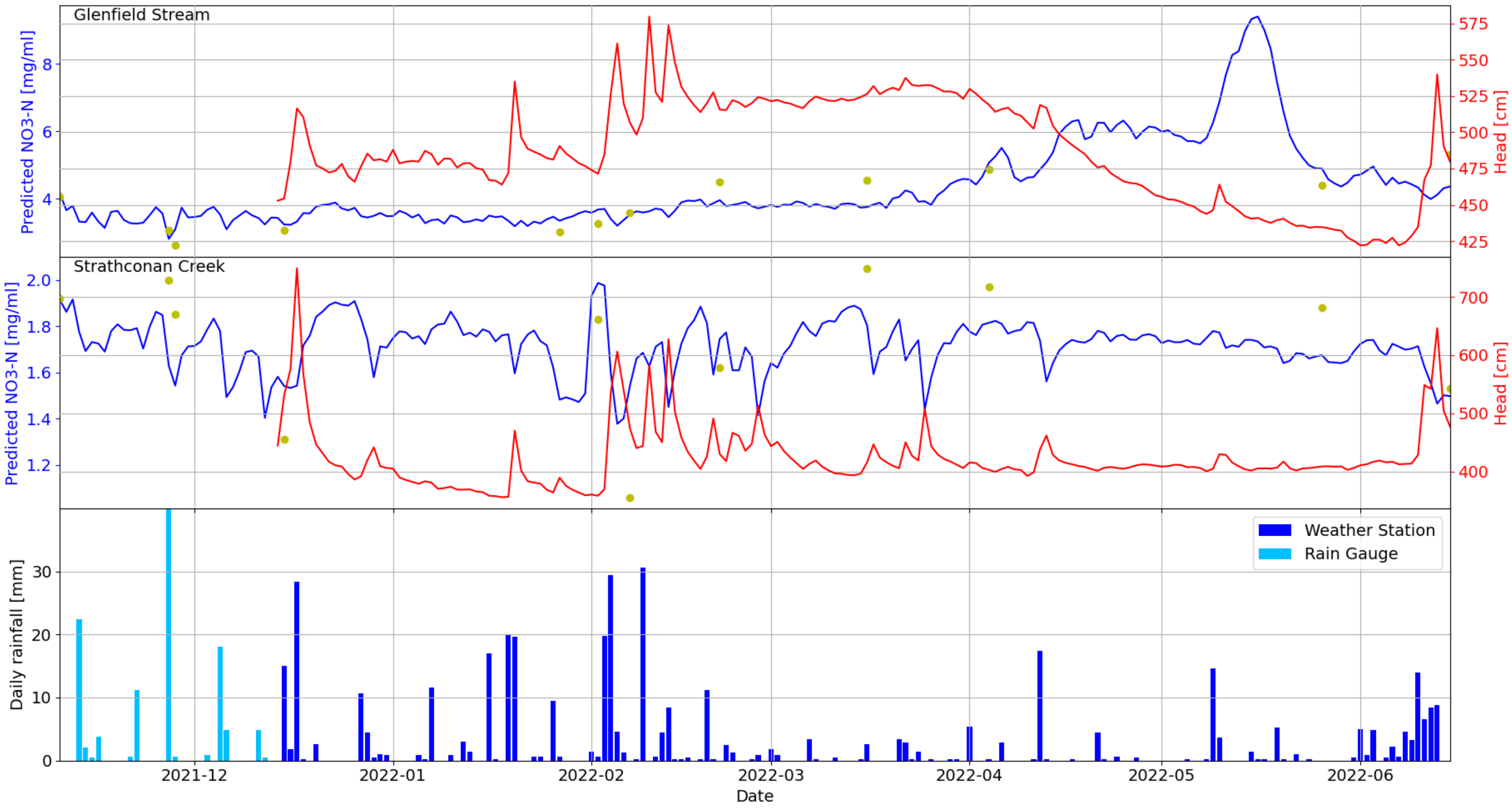

Figure 13: Daily conductivity and water level (head) above the conductivity logger at Glenfield and Strathconan Streams

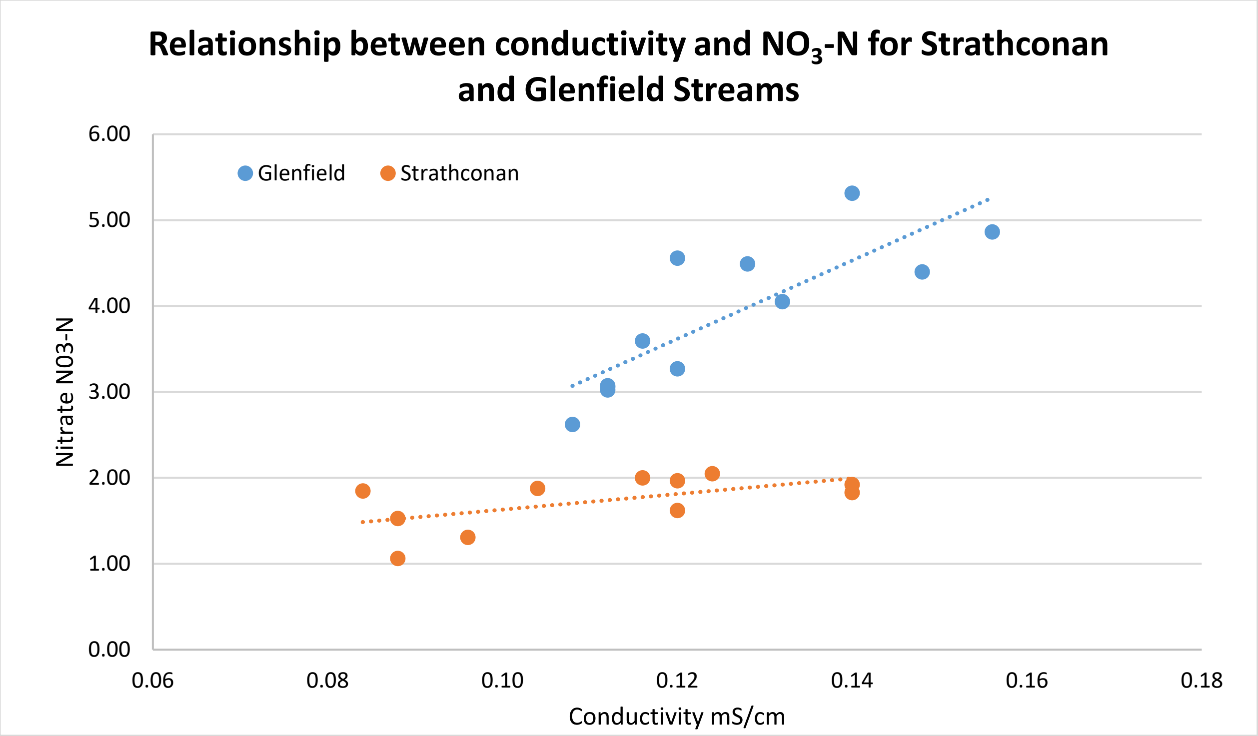

Figure 14: Relationship between conductivity and NO_3-N for Strathconan and Glenfield Streams

Rainfall and the resulting stage rise lead to a decrease in conductivity and, via the estimated relationship to NO_3-N, a drop in nitrate for Strathconan Creek (**Figure 13** and **Figure 15**). This most likely represents dilution from surface run-off and near-surface flow (interflow), i.e., a change in the proportion of groundwater vs interflow and surface runoff. Glenfield Stream does not demonstrate the same responsiveness to rainfall/stage. As noted, the catchment is larger and flatter in general and the proportional contribution of surface run-off and interflow appears to be either less, or at least less flashy.

Of considerable interest is the decline in stage and therefore flow in the May/June period and the associated increase in conductivity when rainfall was low compared to earlier months (**Figure 13**), probably indicating changes in flow apportionment. One possible reason for several of the increases in conductivity in April and May that appear to be related to rainfalls over 15mm is they may be a result of the flushing of NO_3-N sitting in the interflow flow paths. It is also likely that there is a reduction in run-off/interflow proportion in comparison to higher NO_3-N groundwater which may be starting to dominate the base flow of the stream. Both mechanisms would result in increased conductivity.

While the estimated NO_3-N values peak just under 10 mg/L at Glenfield (**Figure 15**), there were no grab samples collected at these higher conductivity values and therefore we have little evidence to support these predictions as they are outside the range of data the regression was built with. We believe much of the increase in conductivity could be related to the changed proportioning of the water sources contributing to the streamflow. Water from the different flow paths is likely to have a different conductivity to nitrate relationship and this could be driving the changes in conductivity more than actual changes in NO_3-N. Without a grab sample during this period to provide a reference point little more can probably be concluded and therefore caution needs to be applied in acceptance of these higher NO_3-N concentrations.

This study was undertaken to look at the potential to use lower-cost conductivity probes to help monitor nitrate dynamics. The requirement to take grab samples and have them analysed by a laboratory adds a significant time requirement to the farmers' already busy schedules and could well become a lower priority when other farm activities require attention. The concentration of nitrate in the stream water is not the only substance that affects conductivity. The presence of inorganic dissolved solids such as chloride, sulfate, and phosphate anions, as well as sodium, magnesium, calcium and iron cations, change the conductivity of the water. Therefore, the relationship between conductivity and nitrate will alter if concentrations of these other ions change and this may well have occurred at Glenfield as the contribution of different water sources altered over the study period.

Groundwater applications of EC to NO3-N relationships are often successful, primarily as other ions may not vary as dynamically as they do in surface water situations. That said, Glenfield Stream in particular has helped illuminate the potential for changes in stream flow contribution that may well impact NO_3-N concentrations. Opuha Water, the local catchment group and other stakeholders who are currently discussing the potential for a community lead water quality project in the catchment. They may need to consider continuous monitoring nitrate sensors or more frequent grab samples if they aim to characterise and understand the seasonal and climate-driven variation in these types of streams.

The move to continuous monitoring of nitrates in the surface water is typically more expensive than groundwater if optical sensor technology is used. The use of reduced spectrum UV sensors such as the Hydrometrics GW50 may not perform as well in the surface water environment. Turbidity and dissolved organic carbon are common non-nitrate contaminants in surface water environments and these lower-cost nitrates sensors can suffer calibration issues when they are present. More expensive full spectrometer UV sensors are typically required to compensate for these contaminates, often making replication across several sites difficult.

Figure 15: Predicted NO3-N for Glenfield Streams and Strathconan Creek. Yellow symbols represent grab sample values of NO3-N.

4.4 Community perspectives – field day survey

18 completed evaluation forms were obtained from the field day participants after the results had been presented. These were segmented into the following groups;

- Six farmers
- Six rural professionals
- Six other – including industry, regulators, catchment group co-ordinators

Table 3: Field day survey results

Response number	Farmer average	Rural Prof average	Other average	Average
2. Baseline question - profit. How important is the impact on your farms profit in your decisions to adopt new technologies or practices on your farm?	3.7	3.6	3.36	3.5
3. Baseline question – environment. How important is protection for the environment in your decisions to adopt new technologies or practices on your farm?	3.8	4.1	3.80	3.9
4. Baseline question - risk. How important is the management of risks in your decisions to adopt new technologies or practices on your farm?	3.8	3.8	3.83	3.8
5. What level of impact will the adoption of this technology have on your farm?	2.9	3.5	3.35	3.2
6. How complex do you think the use of the technology will be to inform landowners of the impact of farm management and biophysical factors on water quality?	2.9	3.2	3.28	3.1
7. Will you need new skills & knowledge to adopt the technology?	2.2	3.3	2.62	2.7
8. What is your assessment of the relative upfront costs for the adoption of the technology?	2.0	2.5	2.10	2.2
9. What impact on your farms profit do you see arising from the adopting of the technology?	2.8	3.1	2.63	2.9
10. How long do you think it will be before profits are obtained from adopting the technology?	2.3	3.4	2.52	2.7
11. Do you think this technology will improve your current knowledge of the state and trends of water quality on your farm/catchment.	4.7	4.2	4.10	4.3
12. What do you think the environmental impacts on your farm will be from adopting the technology?	3.5	3.8	3.87	3.7
13. How long will it take for these environmental impacts to occur?	2.8	3.1	2.84	2.9
14. Will the adoption of the technology have any impact on the management of risks on your farm?	3.3	3.8	3.64	3.6
15. Will the use of the technology make things easier or more convenient on for your farm management?	2.9	3.3	3.23	3.1
16. How satisfied are you with today's field day?	4.5	4.8	4.37	4.6

For most of the questions there was not a large difference between the respondent groups apart from questions.

- Q3 Rural professional respondents rated protection of the environment as more important in their decisions in relation to the adoption of new technology.
- Q5 Farmers saw less potential impact from the adoption of the technology on their farm.
- Q7 Farmers rated the need for new skills and knowledge to adopt the technology higher than the other two groups.
- Q10 Farmers were more pessimistic in relation to the amount of time before profits were attained from adopting the technology.

The ADOPT model provides a prediction of the adoption level as the time to near peak adoption level for the technology. The aggregated results from the three groups provided a prediction that the time to near peak adoption would be 13 years with 75% of participants adopting the technology. It also predicted that 29% of participants will adopt the technology in five years, while 68% of participants would adopt it in ten years, with 5.8 years to 50% adoption (**Figure 16**).

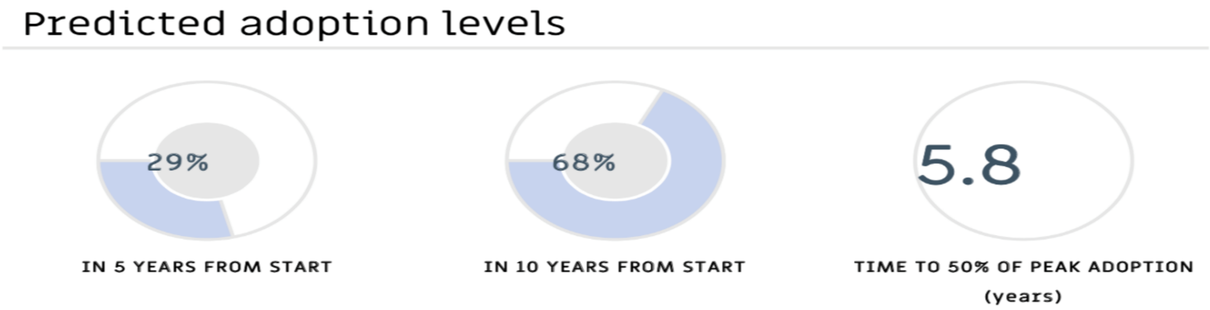

Figure 16: Predicted adoption level real-time water quality monitoring technology

The ADOPT tool also identifies the most sensitive questions that have an impact on the peak adoption level. Factors that have a high sensitivity could become a focus for extension activities to support a change in the peak adoption level. In relation to this project, it identified environmental costs and benefits as the most significance influence on peak adoption '*To what extent would the use of the innovation have net environmental benefits or costs?'* The aggregated result for this survey to this question was a **moderate** environmental advantage and resulted in a peak adoption level of 75%. The impact of changes to the peak adoption level resulting in changes to the results of this measure are illustrated in **Figure 17**. This illustrates that if potential users identified the technology as having a **large** environmental advantage, then a peak adoption level of 88% is predicted (13% higher than the predicted peak adoption level of 75%). Conversely if the survey respondents only identified a **small** environmental advantage the predicted peak adoption level would be only 52% (23% lower than predicted peak adoption level).

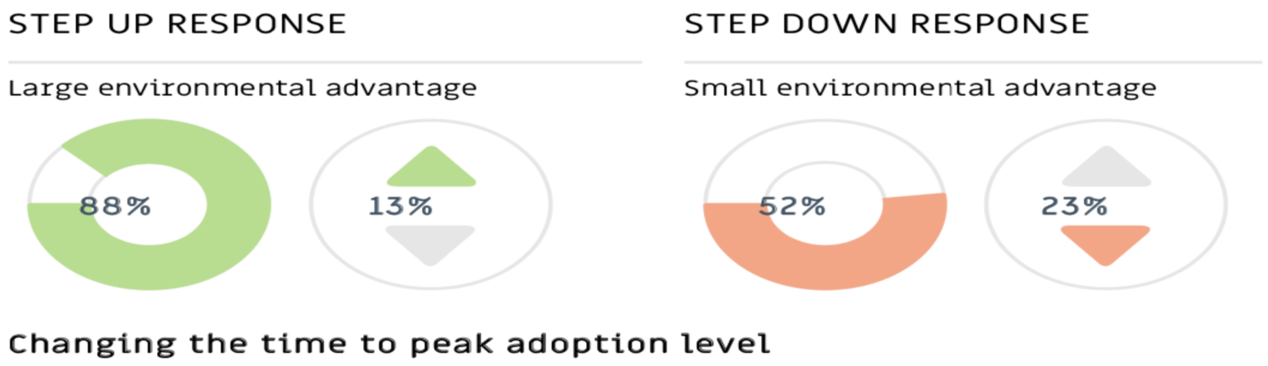

Figure 17: Most sensitive question impact on peak adoption level.

The ADOPT tool can also identify the most sensitive questions that have an impact on the amount of time to peak adoption level. In relation to this project, it identified 'Trailable' as the most sensitive question - *How easily can the innovation (or significant components of it) be trialled on a limited basis before a decision is made to adopt it on a larger scale?* The survey response identified the trialability of the technology as difficult to trial. The impact of changes to the time to peak adoption level resulting in changes to the results of this measure are illustrated in Figure 18.

Figure 18: Most sensitive question impact on time to peak adoption level.

There was a high average score in relation to participants satisfaction with the field day – average score of 4.6 out of a maximum 5.

Though the results provide a positive predication into the adoption of the real-time water quality monitoring technology they should be treated with caution and take into account the following:

- ADOPT predicts adoption rates within the target population – i.e., those that attended the field day and who answered the survey. It does not predict adoption of an individual. The inputs to ADOPT recognise that a population is diverse so the focus is on the proportion of a population with particular characteristics.
- It should be noted that the people who attended the workshop are probably not representative of all farmers/stakeholders in the district. They were interested enough in the topic to attend the workshop. It would be anticipated that there would be a lower level of predicted adoption over the district population.

In the workshop discussions it was apparent that most of those who participated in the workshop saw merit in the use of the technology however they saw its application as having most potential for the monitoring of water quality at a catchment level rather than for an individual farm.

5 Conclusion and Recommendations

The project team felt the programme was highly successful as it has generated significant community engagement around continuing the journey to learn more about the drivers of nitrate issues in the catchment and may well be the genesis of a much larger community-led monitoring programme. The power of having an informed community cannot be underestimated, paving the way for robust, informed discussions.

The farmer, John Wright, was an ideal advocate for the programme as he was willing to share the data openly with all interested stakeholders and has encouraged the community to get involved. Too often farmers are nervous about sharing information due the perception they will be persecuted for it, but John has shown by positive example how much can be learnt by engaging in the process.

While the length of the programme was relatively short, there has been enough variation in nitrate readings to foster interest from John and a broader range of stakeholders to understand why. While definitive linkages to the exact drivers could never be determined in a short duration project such as this, the people are interested to continue to develop understanding to support their own efforts is a significant outcome. It is clear that the nitrate issue is a catchment problem and best addressed by the community, rather than relying on individuals to address. A subtlety revealed was that water grab sampling can become a lower priority for farmers during their peak busy periods, suggesting continuous monitoring will be more reliable and successful due to lower time burdens.

Overall, this project demonstrated that this sensor technology is reliable and effective, and has significant potential for wider application, specifically:

- **A medium-term catchment monitoring and management programme** - successfully developed in collaboration with scientists, project managers, and local landowners to:
    - Help support better understanding of the dynamic and often elevated nitrate concentration in the local groundwater and groundwater feed streams. What is the impact of hydrological environments, soil drainage types and farm systems on nitrate concentrations?
    - Identify hotspots and mitigation areas
    - Inform environmental investments.
- **An alternative adaptive management regulatory approach –** to reduce the reliance on nutrient models as a standalone measure and support a flexible, outcome-based approach. Careful consideration would need to be given to the significant influence that climate has on nitrate concentrations, which is beyond control of the landowner.
- **Mitigating nitrogen loads from artificial drainage** – to target reductions in the high nitrate concentrations from the Novaflow outlet. Mitigations could include avoiding high nitrogen risk activities such as winter forage cropping or trialling woodchip bioreactors or denitrification walls to reduce nitrogen loads from drainage (following recent trials by organisation such as ESR, NIWA and Lincoln Agritech).
- **Wetland science** – to address the current lack of wetland data. Sensor technology would need to be suitable for monitoring wetland water, as dissolved organic carbon can be high.


All elements of nature are related in space and time and therefore what happens upstream will effect what happens downstream

Whakapapa - genealogies and generations

The Opihi River

6 References

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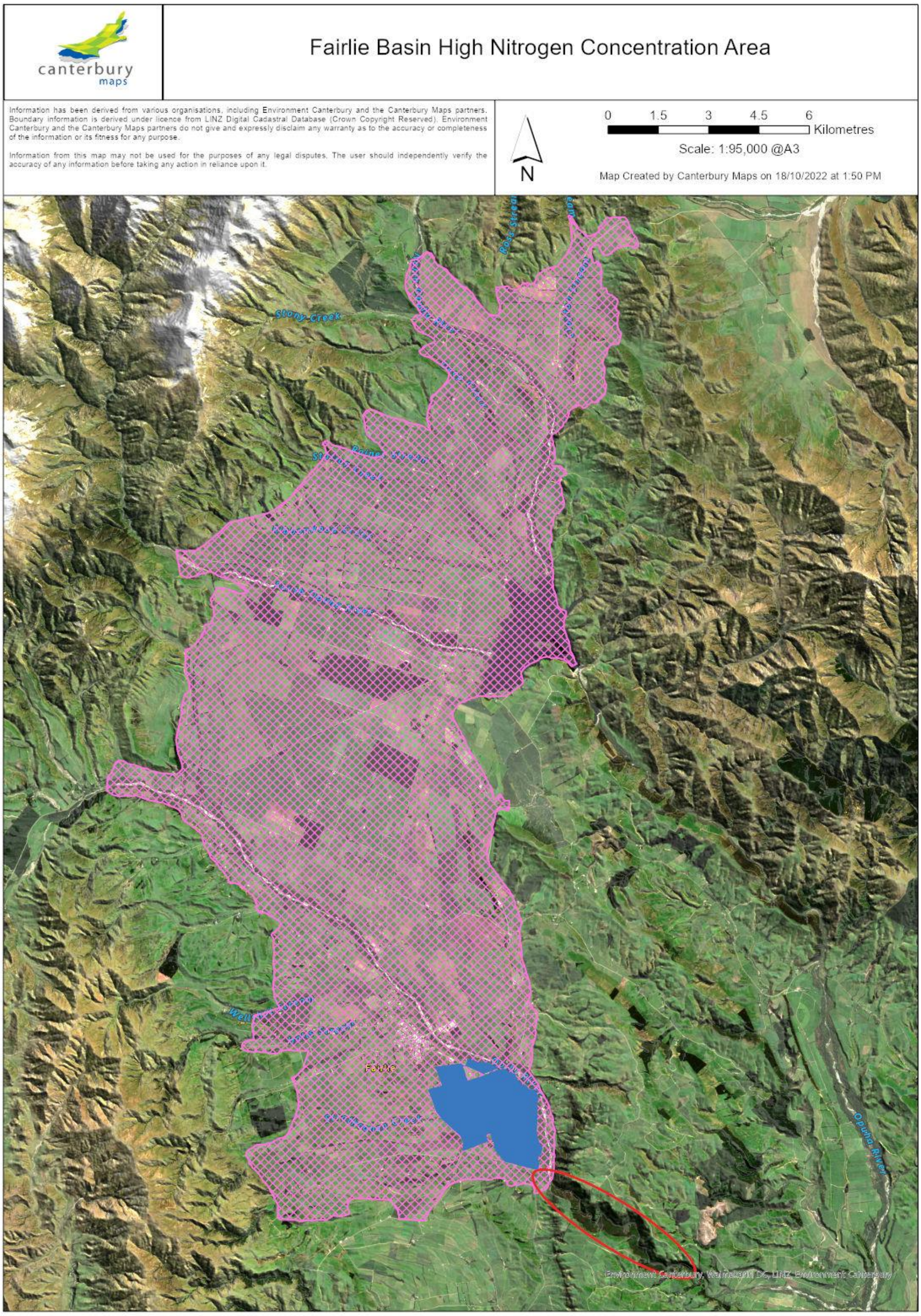
7 Appendices

Appendix 1: Wainono Farm System Information (2021-22 season)

Effective area (ha)	639 ha; two milking platforms
Stock & production	Peak cows: 1,816 FxJ cows (2.84 cows/ha) Annual milk production per cow: 446 kg MS (3-yr average) All replacements grazed off-farm and the milking herd is wintered off-farm
Fertiliser	Annual N fertiliser applied to pasture: 161 kgN/ha/yr (effluent); 182 kgN/ha (non-eff). SustaiN was applied from August to April, following the cows. P & S (Superten) applied in late spring. Whole farm soil testing was completed in 2022, soil fertility has been increasing. Average Olsen P (33) and pH were optimal (6), with several paddocks above optimal. Feed demand, soil temperate and soil moisture guides decision making.
Imported supplements	430 tDM imported & fed in-shed = 240 kgDM/peak cow/yr
Crops	Used for autumn transitioning: • 38ha kale • 18ha fodderbeet
Irrigation	85% effective area irrigated • 381 ha pivot (10mm every three days) • 165 ha roto-rainer (25mm every ten days) Efficient irrigation practices – VRI, soil EMS mapping, soil moisture monitoring Water takes from several bores, infiltration galleries, and irrigation pond (200,000m^3)
Effluent	Two storage holding ponds Liquid effluent applied via a travelling irrigator or injected pivot Application area – 11% of pastoral area.

Appendix 2: High Nitrogen Concentration Zones identified in Proposed Plan Change 7 of the Canterbury Land and Water Regional Plan. Wainono Dairy, the case study farm, is shown as the shaded blue area at the southern end of the Fairlie Basin High Nitrogen Concentration Zone (pink hatched area). The Opihi Gorge (red circled area) drains the Upper Opihi groundwater zone.



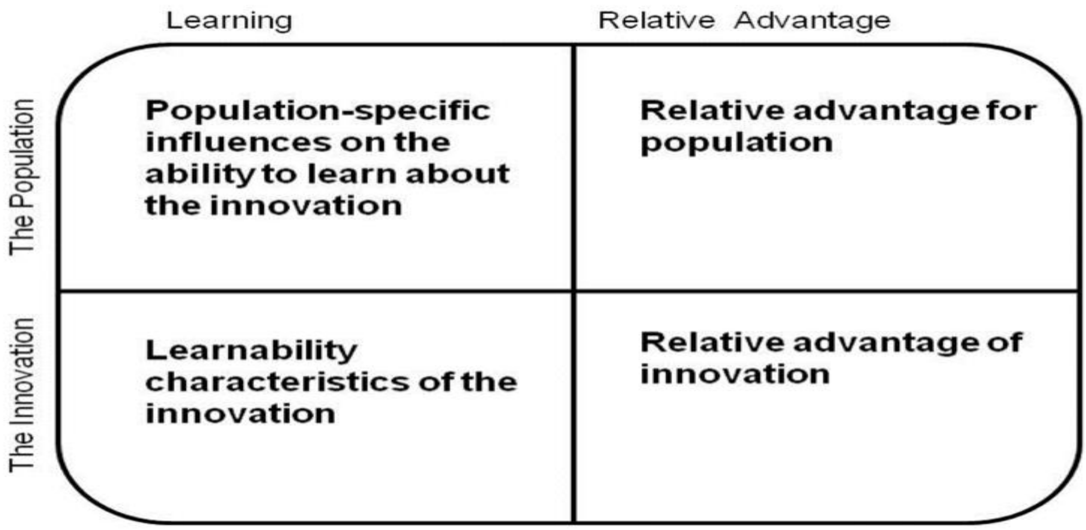
Appendix 3: Stakeholder Survey Methodology

As part of the evaluation the project undertook an analysis with stakeholders to clarify their perceptions on the relative value and potential for the adoption of real time water quality monitoring and associated technology as demonstrated by the project.

The evaluation used the ADOPT Tool (Kuehne et al., 2017) developed by the Australian CSIRO to help determine the potential level of adoption and impact from the use of this technology. ADOPT incorporates sets of factors that studies have shown to commonly influence the rate and peak level of adoption within a population. ADOPT is structured around four aspects of adoption:

- Characteristics of the innovation
- Characteristics of the population
- Actual advantage of using the innovation
- Learning of the actual advantage of the innovation

Responses to questions related to these 4 main topics or quadrants allow a number of relevant factors to be calculated, which in turn allows for a Peak Adoption Level and the Time to Near Peak Adoption to be predicted.



The four quadrants of the ADOPT model

For the evaluation of this project a modified ADOPT questionnaire was developed and incorporated into the workshop evaluation form for the final field day held at Wainono Farm on Wednesday 3 October 2022. Modifications to the survey from the ADOPT model included the following:

- The ADOPT tool has 22 questions – this was reduced to 14 for this project as some of the ADOPT questions were seen as less relevant in this situation.
- The survey used a slider score based on a range of 1 (low) to 5 (High) which reflected the question style used in the ADOPT online version.
- The survey also included additional questions to support the evaluation of the field day:
    - *16. How satisfied are you with today's field day?*
    - *17. What was the key point you took away from today's workshop and any other comments*

The questionnaire was initially developed using the *Survey Monkey* online survey tool to facilitate feedback from the project leaders as well as to ensure that the survey design was efficient. *Survey Monkey* rated the final survey as `Perfect' with a predicted 4min time to complete.

The survey was then transferred to a paper-based format to make it easier for the field day participants to complete it. The workshop evaluation form was provided to all field day participants at the end of the workshop after they had been provided with information on the technology, results from the project as well as presentations and discussions on the wider potential application of the technology. Background information on the purpose of the survey was provided before it was circulated with participants urged to complete it.

Survey

1. Please tick the box that best reflects your relevant background/representation.

☐ Farmer ☐ Rural Professional ☐ Rural industry ☐ Community/catchment group. ☐ Other ________________

2. Baseline question - profit. How important is the **impact on your farms profit** in your decisions to adopt new technologies or practices on your farm?

1 Maximising profit is not a strong motivation for adoption.	5 Maximising profit is a strong motivation for adoption

1--|--**5**

3. Baseline question – environment. How important is **protection for the environment** in your decisions to adopt new technologies or practices on your farm?

1 Environmental protection is not a strong motivation for adoption	5 Environmental protection is a strong motivation for adoption

1--|--**5**

4. Baseline question - risk. How important is the **management of risks** in your decisions to adopt new technologies or practices on your farm?

1 Minimisation of risk is not a strong motivation to adoption	5 Minimisation of risk is a strong motivation for adoption

1--|--**5**

5. What level of **impact** will the adoption of this technology have on your farm?

1 Almost none of the farm's enterprises will benefit from the adoption of this innovation.	5 Almost all of the farm's enterprises will benefit from the adoption of this technology.

1--|--**5**

6. How **complex** do you think the use of the technology will be to inform landowners of the impact of farm management and biophysical factors on water quality?

1 Very difficult to evaluate the effects of use due to complexity	5 Very easy to evaluate the impact

1--|--**5**

7. Will you need **new skills & knowledge** to adopt the technology?

1 I will need new skills and knowledge to adopt	5 I will not need any skills of knowledge to adopt

1--|--**5**

8. What is your assessment of the **relative upfront costs** for the adoption of the technology?

1 Requires a very large initial investment	5 No initial investment required

1--|--**5**

9. What **impact on your farms profit** do you see arising from the adopting of the technology?

1 Large profit disadvantage from adoption	5 Very large profit advantage from adoption

1--|--**5**

10. How long do you think it will be before profits are obtained from adopting the technology?

1 More than 10 years	5 Immediately

1--|--**5**

11. Do you think this **technology will improve your current knowledge of the state and trends of water quality** on your farm/catchment.

1 No increase in knowledge if the state and trends in water quality.	5 Significant increase in the knowledge of the state and trends in water quality

1--|--**5**

12. What do you think the **environmental impacts** on your farm will be from adopting the technology?

1 Large environmental disadvantage from adoption	5 Very large environmental advantage from adoption

1--|--**5**

13. **How long will it take for these environmental impacts to occur?**

1 More than 10 years	5 Immediately
1--|	--**5**

14. Will the adoption of the technology have any impact on the **management of risks** on your farm?

1 Large increase in risk if adopted	5 Large decrease in risk if adopted
1--|	--**5**

15. Will the use of the technology make things **easier or more convenient** on for your farm management?

1 Large decrease in ease and convenience	5 Large decrease in ease and convivence
1--|	--**5**

16. How satisfied are you with today's field day?

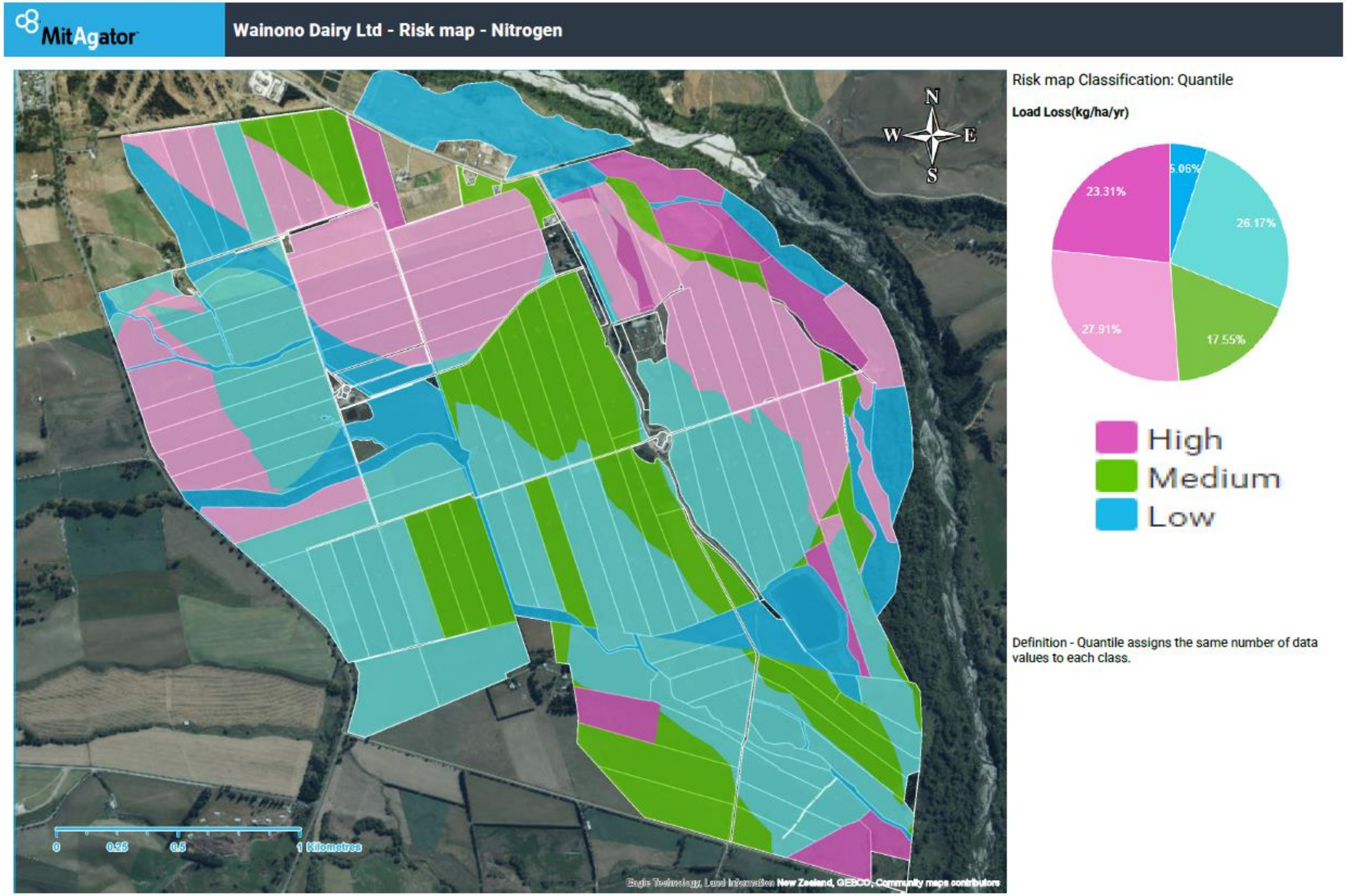
1 Very dissatisfied	5 Very satisfied
1--|	--**5**

17. What was the key point you took away from today's workshop and any other comments

Thank you for participating in this survey

Jon Manhire, Managing Director, The AgriBusiness Group NZ jon@agribusinessgroup.com

Appendix 4: Wainono Nitrogen Risk Map: 2021-22 Year End. Source MitAgator, Ballance-Agri Nutrients



Definition - Quantile assigns the same number of data values to each class.