GEOG309 2024 Project 10

Can small-scale community-developed wetlands be an effective tool for improving water quality?

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Executive summary

- The Montgomery Wetland is located near the Montgomery Highly Modified Water Course (HMWC), adjacent to the Hekeao-Hinds River in Mid Canterbury New Zealand.
- The wetland was designed to reduced nitrate loads in the Montgomery HMWC and was a result of a collaboration between many shareholders, including Wairuna Farms, Dairy NZ, Hekeao-Hinds Water Enhancement Trust, the Mid Canterbury Catchment Collective, and MHV Water.
- The overall research question was 'Can small-scale community-based wetlands be an effective tool for improving water quality'? This was then broken down into two more specific research questions: "has there been any change in the Montgomery Stream water quality over the different phases of the wetland development?' and "what are the shareholder aspirations for the wetland?"
- This research involved both quantitative and qualitative data. Quantitative in the form of nitrate data, supplied from MHV Water, and qualitative in the form of interview transcripts from key shareholders.
- The key findings of this research were:
    - The constructed wetland is successfully removing nitrates from the water.
    - The wetland was successful in keeping within a budget and involving the community in a meaningful project.
    - Community aspirations align and provide direction to enhancement of the wetlands value.
- Future research should focus on developing a plan with mana whenua to ensure their aspirations are included in plans and creating a comprehensive monitoring scheme for the wetland.

Introduction

Just over a year ago, the Hekeao Hinds Water Enhancement Trust (HHWET) and the Mid Canterbury Catchment Collective (MCCC) facilitated the establishment of a constructed wetland on a farm in Hinds, just outside of Ashburton, called the Montgomery Wetland. An experiment based on the recently published 'Constructed Wetland Practitioner Guide' from (Tanner et al., 2022), the wetland was designed with a three-pond system, one with 100% clay lining, one with 10% clay lining and one with no clay lining (see Figure 1). The wetland`s surface water source is the Montgomery HMWC, that flows adjacent to the ponds.

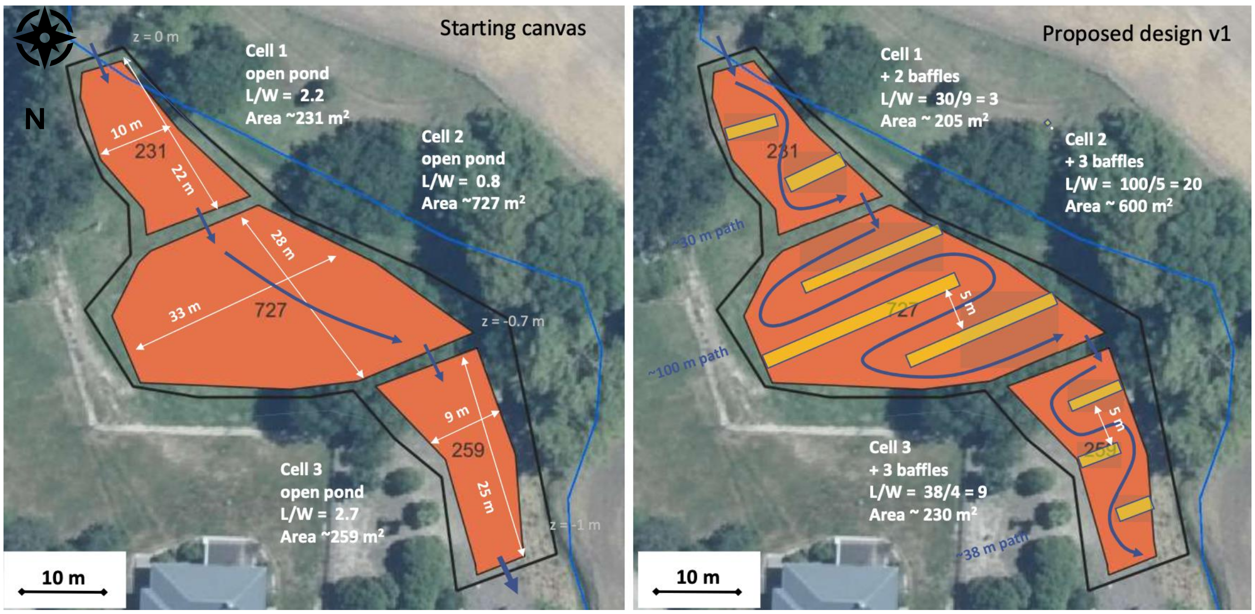

Figure 1. *The constructed wetland`s three-pond system. The northernmost pond is Pond 1 (with 100% clay lining), and the southernmost pond is Pond 3 (with no clay lining). Source: Dairy NZ (n.d). 'Conceptual design for the constructed wetland (that is not a wetland) on Montgomery Drain – stage 1'. {Map}.*

The surrounding area the wetland is on, and the contemporary surface water pathways can be seen in Figure 2. However, before colonisation, this site was a part of a large wetland area sprawling from the river on to the floodplains (Black Maps, Canterbury Maps, n.d.), high in nitrates, biodiversity and mahika kai localities. These wetlands have largely been drained for food production purposes, producing the lowland agricultural area of Mid-Canterbury seen today. Due to these high historical nitrate levels, fertiliser usage and destructive land management practices, nitrate concentrations (which we are reporting as values of nitrate-nitrogen NO3-N) are a key concern for this area (Legg et al., submitted; Rogers et al., 2023). If in excess concentrations, they can reduce biodiversity and cause drinking water to become toxic to humans (Legg et al., submitted). Land surface recharge (LSR), where water drains through the soil, is a major pathway for nitrates to enter groundwater, which then eventually remerges again as surface water (Bidwell et al., 2009). The extent to which nitrates enter groundwater via LSR depends on soil type, precipitation (including irrigation) and REDOX conditions (Legg et al., submitted). Therefore, nitrates have very complex spatial and temporal patterns (Legg et al., submitted). To manage this, farmers aim to have a variety of tools to mitigate variable nitrate concentrations in water, one example of which is the Montgomery Wetland.

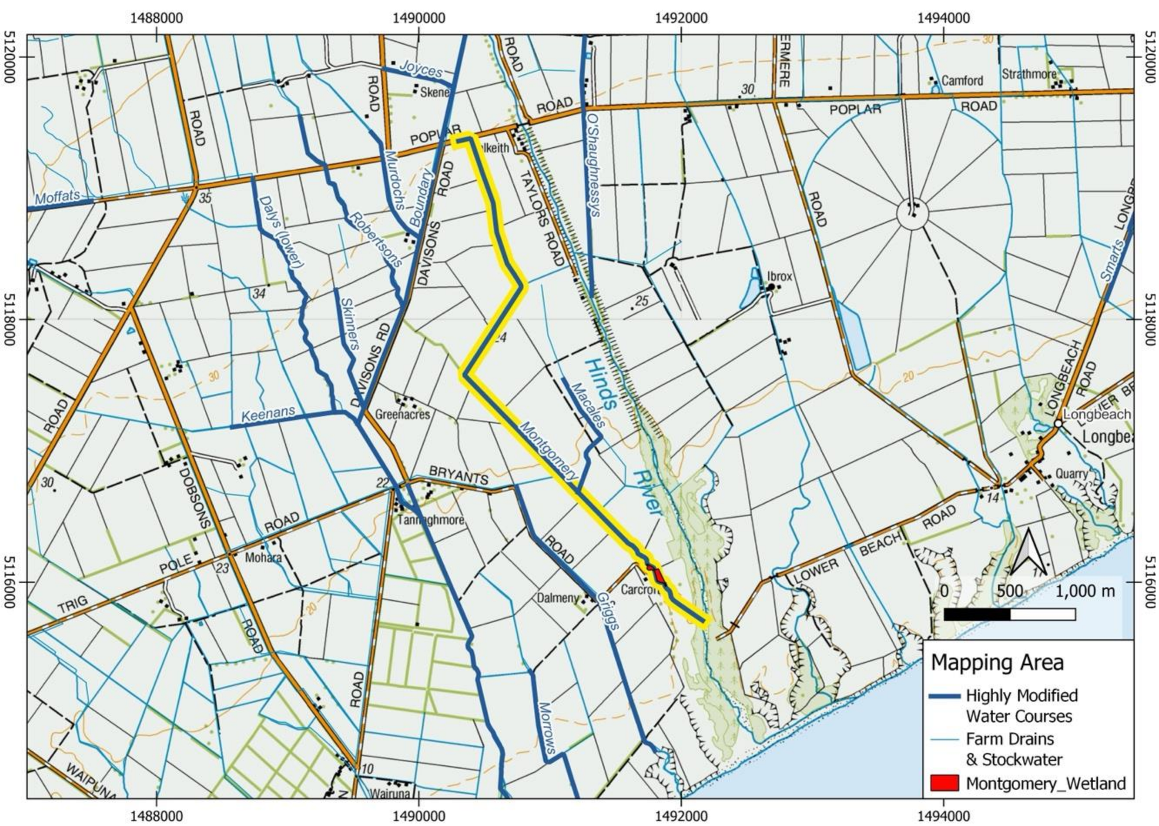

Figure 2. *Map showing the location of the Montgomery Wetland and surface water in the area. Source: MHV Water (n.d). 'Location map of the Montgomery Wetland'. {Map}.*

Constructed wetlands in general can be defined by the following characteristics: presence of water – whether at the surface or within the root zone, unique conditions of the soil and the ability to support vegetation adapted to wet conditions (Setter & Verhoeven, 2009). It has been observed previously that constructed wetlands are effective at reducing nitrate levels in agricultural runoff, particularly on dairy farms. Studies show significant nitrate removal through systems of multiple cells and ponds (Dunne et al., 2005; Gottschall et al., 2007), like what is seen in the Montgomery Wetland design. Research shows that surface flow wetlands can remove up to 82% of nitrogen in water, but their efficiency depends on proper design, hydraulic retention times, and continuous management (Gottschall et al., 2007). Most studies focus on short-term results, raising concerns about long-term viability (Dunne et al., 2005). Although with challenges such as space requirements, constructed wetlands offer a promising solution for improving water quality while supporting sustainable farming (Clarke et al., 2007).

The process of constructing a wetland such as the Montgomery Wetland include challenges such as the precautionary nature of resource consents, like those from the local regional council, Environment Canterbury (ECan). The council enforced rules and regulations for Use of Land, Use of Riverbed, Take, Use and Divert or Dam Water and Discharge (Environment Canterbury, 2022).

While the primary purpose of the wetland is nitrate removal, it has a variety of other benefits. Mana whenua for the land the Montgomery Wetland is on are Kāti Huirapa- represented as Te Rūnanga o Arowhenua (Te Rūnanga O Arowhenua, 2016), and Ngāi Tūāhuriri, represented as Te Ngāi Tūāhuriri Rūnanga. The ability to improve mahika kai is an aspiration for many wetland restoration projects and can be a tool used to improve connection and livelihoods of mana whenua (Robb 2017).

The Montgomery wetland can also enhance wellbeing for the greater Hinds community. Rural communities in Aotearoa face many stressors which can heighten mental health challenges (Jaye et al., 2022), and wetlands as blue spaces offer a multi-sensory nature experience which can reduce stress, depression, and anxiety (Zhang et al., 2021). However, the most valuable wellbeing aspect may be the community interaction it encourages. It provides a unique, relaxing space for social engagement, crucial in isolated rural living (Jaye et al., 2022) and promotes nature connectedness and the positive feeling of making a difference in the community (Zhang et al., 2021).

Using this complex system- the Montgomery Wetland, as an exemplar, the community partners (HHWET and MCCC) wanted to know "Can small scale community-based wetlands be an effective tool for improving water quality?". Our group chose to develop this query further into two specific research questions, with the first one being: “Has there been any change in the Montgomery Stream water quality over the different phases of the wetland development?” and the second one as: “What are the shareholder aspirations for the wetland?”. As the wetland project is in its first year, the research aims to provide a snapshot of the current successes, pitfalls and next steps for the Montgomery Wetland. In addition to this, the research can be viewed an indication of how future wetlands in the catchment could be implemented.

Methods

To look at changes in nitrate over time and space, this required quantitative environmental data collection. Fortunately, MHV Water provided their monitoring data for the site, with the implied standards of data collection from a hydrogeologist working for an irrigation company. Using this dataset made sense given the short time frame of the project, which would not facilitate a sufficient resolution of data if we were to collect our own.

Climate data to compare with nitrate levels was also obtained. This was sourced from CliFlo, the National Climate Database for New Zealand. The weather station chosen was ‘Orari Estate EWS’- Agent Number 35704, because of its relative proximity to the wetland, and similar proximity to the coast. This station was assumed to have similar precipitation levels to the wetland, and therefore this data was deemed appropriate to compare to the Montgomery Wetland nitrate data. The location of the Orari Estate EWS weather station and the wetland can be seen in Figure 3.

Figure 3. *Map showing the location of the Montgomery Wetland and the Orari Estate EWS weather station. Source: Google Earth (accessed 7.10.2024).*

To answer research question two, a selection of interviews was chosen as the best way to gain a good understanding of shareholder perspectives. Snowball sampling was determined to be an appropriate method for our participant selection, such as in Chunga et al. (2023) where shareholders in a Malawi case study were recruited through snowball sampling based upon an inclusion criterion. Snowball sampling also made sense for us as our community partner was the lead hydrogeologist in the wetland development, and through him, we were able to compile a list of key shareholders responsible for the project.

When considering how to conduct the interviews, literature was key to determining methods and scope for this qualitative approach. Research on projects with shareholder engagement in environmental settings tends to keep research objectives broad. For example, in Moore et al. (2022) data is largely collected by way of participatory qualitative practices over an extended period that allows for more ‘tangents’ to be captured. As a result of this, whilst some were kept consistent for comparative analysis, questions were tailored for each participant based on their position and involvement in the project, to understand their perspectives in full.

Therefore, in answering research question two, key shareholders involved in the conception and development of the wetland would be relied upon to gain deep insights, Additional perspectives were sought after too, including other farmers in the catchment who were interested in constructing a wetland of their own. Efforts were also made to seek the perspective of local Mana Whenua, unfortunately, this did not eventuate due to time constraints. Moreira et al. (2024) emphasises the critical role of local knowledge in fostering inclusive water governance, and getting a broad range of local perspectives was key to promoting this in our research.

Research Question Number One

The first research question this project was aiming to answer was ‘has there been any change in the Montgomery Stream water quality over the different phases of the wetland development?’. A complex range of analyses could have been undertaken to answer this question, as there are many temporal and spatial lenses that could be explored for this constructed wetland. The lens that was chosen for our research was: the change in nitrate levels throughout the three-pond system, and the patterns of nitrate levels in the adjacent Montgomery HMWC.

For the comparison of nitrate levels throughout the three-pond system, a time series was produced, as seen in Figure 4. It can be seen from this that nitrate levels drop as the water moves through the first and second pond outlet consistently throughout the 7-month monitoring period.

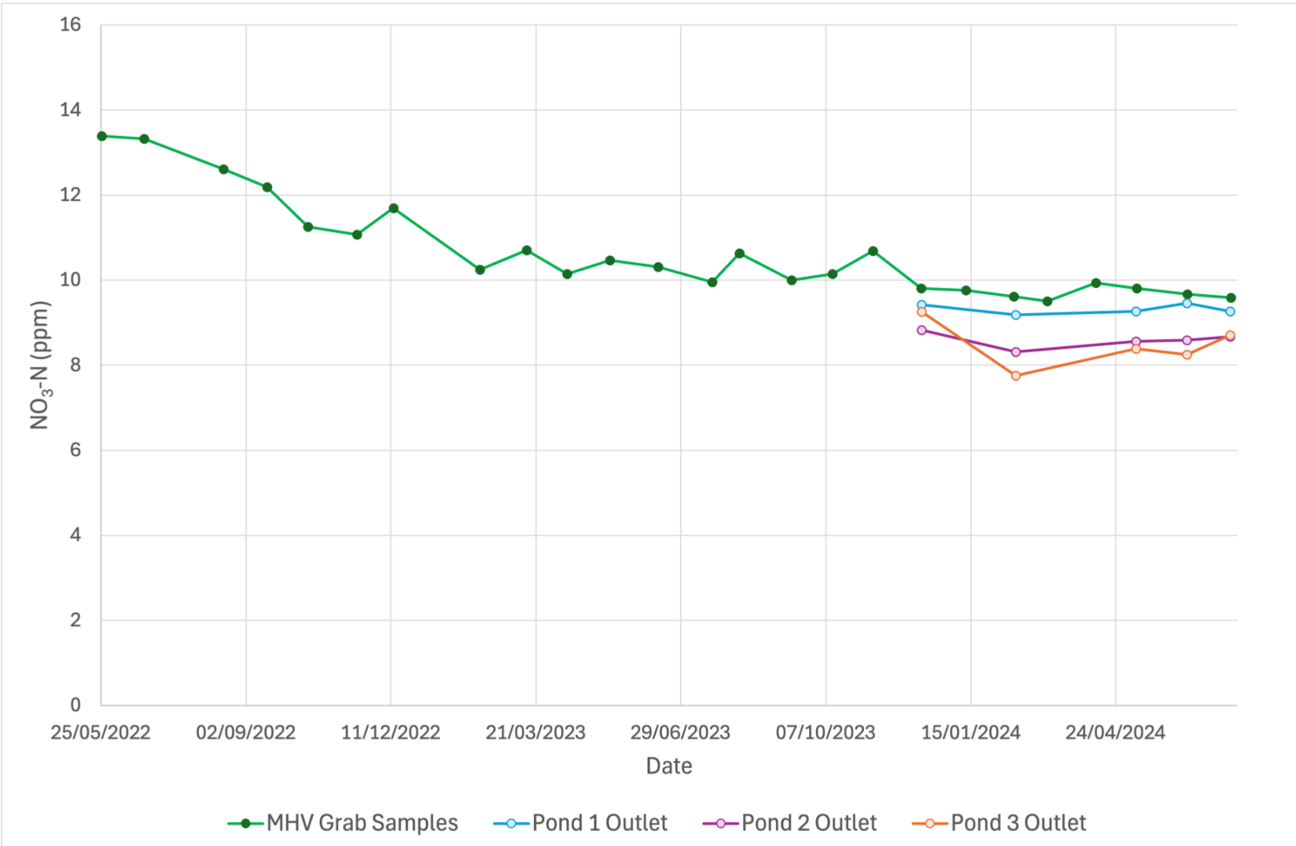

Figure 4. *Nitrate values for Montgomery HMWC and the three wetland ponds.*

The nitrate levels from the third pond outlet are the same or higher than the second pond outlet at the beginning and end of the monitoring period. This is likely due to issues with probe placement and an unexpected characteristic of the wetland. The third pond is predominately dry, and there is an assumption that the lack of clay lining has meant the water is infiltrating through the surface and is connecting back to the Montgomery HMWC underground. This meant the water in the plastic bucket was stagnant (see Figure 5), and the lack of biological activity could have resulted in the high nitrate value at the start of the monitoring period.

Figure 5. *Picture of the third pond outlet, lack of surface flow has allowed the water in the bucket to become stagnant.*

To further explore the effect the ponds are having on nitrate levels, the mean nitrate values of each pond were compared. There is a clear declining trend, as seen in Figure 6. This is supported by a statistically significant result from an ANOVA test to test the difference between each of the means. With an Alpha of 0.05, the P-value for this test was 0.004, meaning that we can be confident there is a valid difference between the three-ponds.

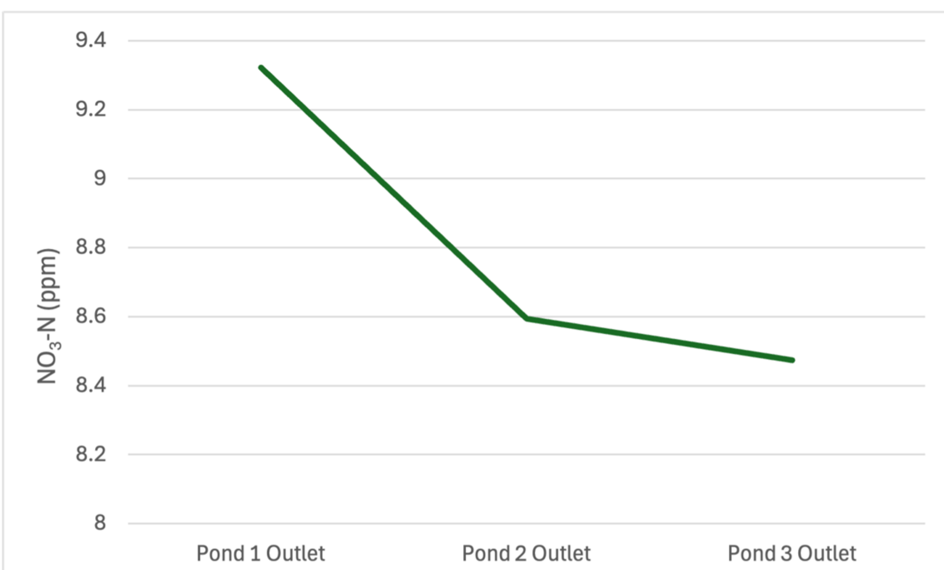

Figure 6. *Comparison of mean nitrate values in the wetland.*

For this to be more relevant to farmers who wanted to implement a similar program, we wanted to explain the pattern of nitrate levels throughout the system and throughout the year. This would further illustrate the behaviour of nitrates in this HMWC and describe trends that could influence the future effectiveness of the wetland.

We looked at the nitrate levels in the adjacent Montgomery HMWC compared to local precipitation data. There were two nitrate datasets used, MHV grab samples from the drain taken once a month, and values from a permanent probe in the HMWC, recording values daily. Unfortunately, the upstream permanent probe was struck by lightning in Autumn of 2023, and the replacement probe was moved to a downstream position. Therefore, the data has a gap in Autumn/Winter of 2023, and we cannot use the permanent probe data to do an upstream/downstream analysis of nitrate levels as the monitoring period does not overlap.

As mentioned in the introduction, nitrates have a complex seasonality, and this can be seen in Figure 7, as there are many peaks and troughs throughout the two years. There are corresponding peaks and troughs for the nitrate and precipitation data, especially around December 2022, March 2023, November 2023 and March 2024. An ANOVA test was conducted on the seasonal averages for nitrates from the MHV grab samples, and with a significant P-value of 0.009, we can tell there is a seasonal difference in nitrate levels.

However, because of their complex nature, we did not expect to find a strong linear relationship between the nitrate and precipitation data. The results of a regression between the two datasets can be seen in Figure 8, and with a correlation coefficient of -0.15 for rainfall and the MHV samples, and 0.45 for the permanent probe values, there was no strong relationship found.

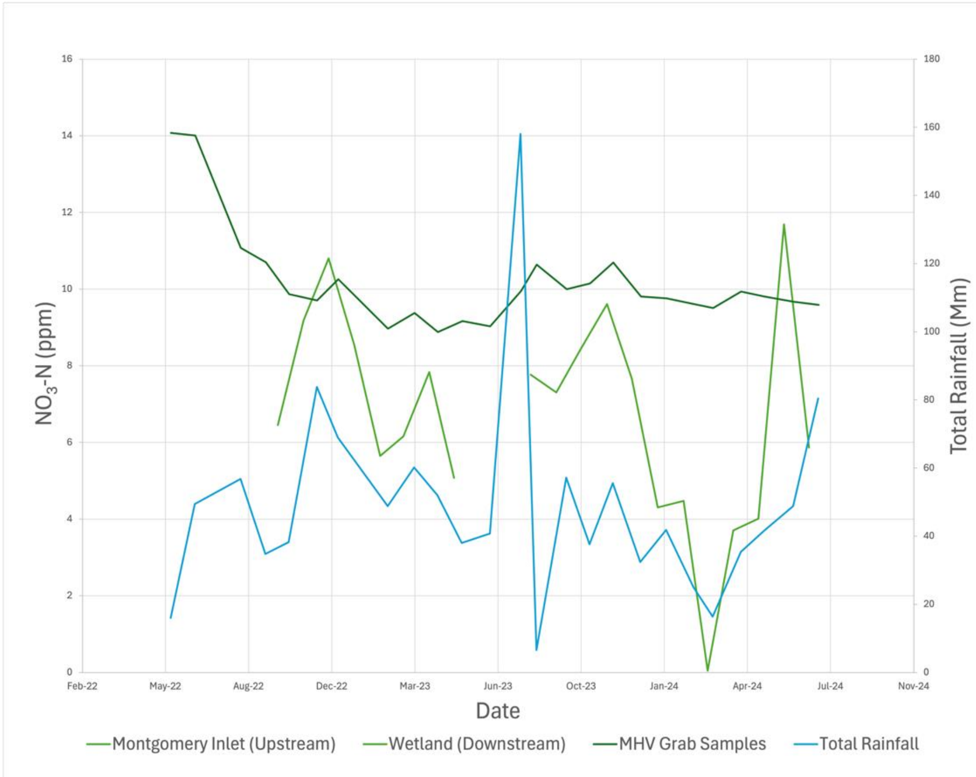

Figure 7. *Time series comparing Montgomery HMWC nitrate and precipitation values.*

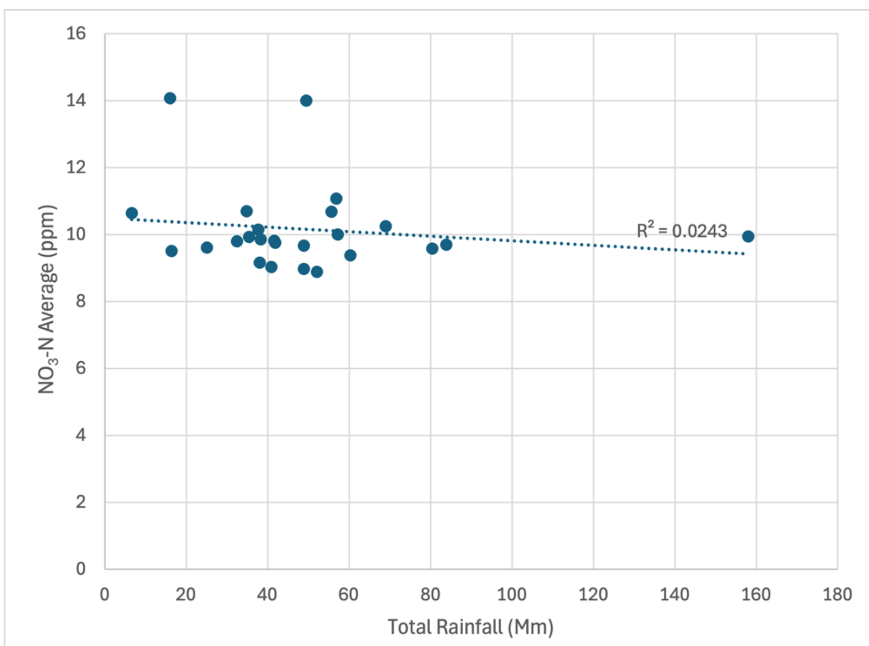

Figure 8. *Montgomery HMWC nitrate vs rainfall linear regression.*

Overall, the constructed wetland system is removing nitrates as the water moves through the three ponds. A longer dataset would result in a more comprehensive pattern of nitrate removal throughout the ponds, and throughout the year. A weak linear relationship between nitrate and precipitation data means we cannot use rainfall to predict the nitrate levels of the Montgomery HMWC. However, we did find a complex seasonality, as was predicted, and further analysis of more data would provide a more detailed picture of nitrate behavior throughout the seasons. This information could then be used to predict the effectiveness of the wetland throughout the year.

Research Question Number Two

From our interview process, commonly mentioned words were collated. Figure 9 shows the word cloud that sums the themes that arose from stakeholder's answers, an apt representation of key aspects of the wetland.

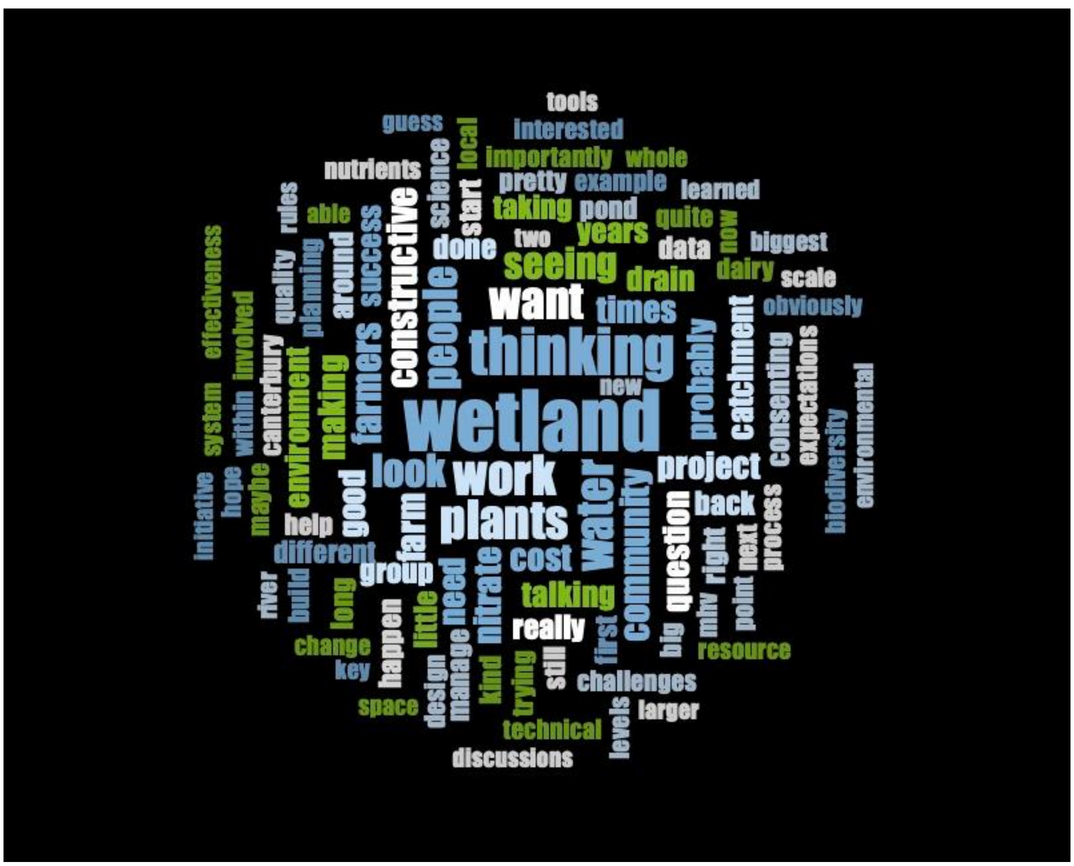

Figure 9. *Word cloud showing the most common words mentioned in the interview transcripts.*

Analysis of transcripts answered the second research question: “What are the shareholder aspirations for the wetland?”. We quickly found that the interviews answered this, and more. Four key themes emerged from the transcripts- what is the purpose of the wetland, what are the current successes of the wetland, what are some key things to get right, and finally what are the shareholder aspirations.

Purpose of the Constructed Wetland

The constructed wetland in Hinds was designed as a small-scale trial to reduce nitrate levels in surface water and demonstrate its effectiveness to local farmers. The goal of the wetland was to create a replicable model for nitrate management that could be adopted widely, proving that wetlands could be a solution. Participant 1 mentioned it was about “trailing something, not letting it get too big and being able to monitor it from a science point of view, because there was no work available when we did it to say how effective wetlands were”. Results show that the wetland is working as intended but has not reached optimal performance yet. Participant 2 stated, “If you can make it sound easy to do and repeatable that’s the win.” As the wetland improves in the future in performance, as it matures and becomes more established this could drive wider adoption of the wetland.

Another aspect of ‘proving it could be done’ was successfully building the wetland despite bureaucratic hurdles. In the past this has discouraged farmers from attempting projects of a similar nature. Participant 2 explains that “time barriers… are generally to do with the consenting process. It's just a lot of paperwork… because it’s quite complex, it erodes the enthusiasm for the group to go forward and do it”. This, accompanied by high costs, has prevented the participation of a broader group of farmers. Participant 3 added to this with, “Resource consenting, the rules in the plan are too prohibitive…. It’s the farmer that ends up paying for the bill”.

Successes of the Constructed Wetland

Given the dairy industry can be a divisive topic in New Zealand’s public domain, it is important that the successes of the project are promoted. Although expectations were higher, data shows a clear reduction in nitrate levels within the Hekeao-Hinds River subsequently achieving the intended purpose of the constructed wetland. Participant 2 who was a significant part of the wetlands formulation and technical aspect notes this win:

> "They had no financial incentive to do this… there was no carrot… There was no legal requirement for something. They did it because they wanted to do it….that's a win. People actually doing stuff."

Another widely viewed success of the project is that it is a co-developed initiative between a multitude of NGOs, absent of government involvement. Grass roots action in the dairy producing powerhouse of Mid-Canterbury is a significant step forwards in reducing nitrates. This bottom-up approach involves a range of different collaborators, and the incorporation of community science is the first of its kind in the region. Participant 5 explains the various community groups and members working together for a common goal.

> "HHWET cover the whole catchment mountains to the sea, Ashburton to the Rangitata River. The Mid-Canterbury Catchment Collective also covers that area, and they actually go wider out to the Rakaia River. The groups work together…with social connections…down to the individual farmer level…We have collectively created the structure, where we can {have} my perspective {for} the technical oversight of projects… and we have the people who work with the local community"

As the wetland is intended as a proof of concept, the project being completed on budget is another significant success. Efforts were made to ensure the project was kept as low of a price as possible. This involved developing the wetland in a way, so it did not require resource consent, otherwise making the process far more expensive and even potentially bringing it to a halt. Further efforts were made to source cost-effective plants. Participant 1 describes this process:

> We paid a discounted rate for the construction…and then the local supply company, Royal Co, gave us discounted price of pipe … we've actually done everything we possibly could on the cheap.

This reduced the wetlands cost to approximately $22,000, demonstrating that a low-budget trial wetland can be effective.

Key Things to Get Right

We found a consensus that the ponds need at least 10% clay for water to sufficiently flow through the system. A quote in our interview with Participant 3 supports this idea. “The one technical thing I’ve learned for sure is that you do need clay in the soil, 10% clay or more in the soil, if you want it to hold water.” As mentioned in the results for Research Question Number One, the two ponds lined with clay allowed the water to flow through the system, while the third pond (not lined with clay) produced an insufficient amount of water flow.

It was clear that an understanding that the wetland is not the ‘silver bullet’ for nitrate pollution was crucial. It is apparent from the initial results that the wetland cannot remove most of the nitrogen in the water. Participant 3 stated this was never the intention: “we’re not under any expectation to be suggesting this is the silver bullet or the solution to nitrate pollution …”. The wetland being a “tool in the toolbox” was a common mindset however, and scientists and farmers alike considered this to be an appropriate expectation of the wetland, to avoid a disappointing nitrate-removal result.

As an additional mindset requirement, the wetland was found to have a holistic range of successes, where not one aspect is more important than any other. A quote from the interview with Participant 2, shows the different ways success can be measured: “How do you measure [success] if it’s working, if it is still in place and doing its thing? … is it still doing what it’s designed to do? Is it still filtering water and is it still acting with water? … does it have increased biodiversity or wairuatanga or mauri elements that has increased with it?” There are multiple ways of viewing the success of the wetland. This holistic approach of viewing the wetland allows for a positive outlook towards what wetlands can do for us and the environment.

Maintenance and continuous monitoring of the wetland are essential to success. Weeds and poor planting density have been challenges seen in the wetland participant 2 notes that “I would like to see ongoing discussions about how we are going to manage it, so it doesn’t become a proverbial white elephant”, with participant 3 agreeing, “constructed wetlands require a lot of maintenance… they’re not a system of plug and play”. By addressing these problems, the wetland will be able to continue to function properly.

Lastly, to avoid large losses to the farmers, utilising “hard to manage” land contributed further to the success. A quote from the interview with Participant 1 emphasised this: “Choosing a less productive piece of land for the wetland ensures minimal impact on farming while maximising the environmental benefits”.

Aspirations

Aspirations among stakeholders were relatively consistent amongst the research pool, an interesting discovery as we were expecting divergent aspirations to be a focus issue. Seven key themes were identified, the first being maintaining community involvement and citizen science. Concerns were raised that engagement in the wetland is decreasing, affecting management processes. To quote Participant 2, “A wetland is successful as long as people still recognize and care for it”. In conjunction with this, an aspiration was to establish continuous maintenance, especially as no defined ‘champion’ currently exists to head organization. Shareholders wish to use the wetland as a tool to raise awareness of the positive change farmers are making, to change negative opinions on the industry, and to influence further change. To quote Participant 4, "even if it's a costly investment that doesn't actually have any return if it's doing good for the environment most farmers will probably invest in that”. Additionally, it is hoped that the wetland will influence the building of other community-built wetlands, using the Montgomery of wetland as effective proof of the concept. Finally, to reach their goal of restoring a piece of the farm to its pre-anthropogenic state, they wish to increase biodiversity, and maintain the health of the Montgomery Stream. This especially refers to increasing aquatic biodiversity, bird life, and native pollinators, decreasing nitrate concentrations and promoting the overall health of the stream, and supporting the growth of native plantings into a “riparian jungle with habitat value”, to quote Participant 3.

We consider all these aspirations to be achievable with proper planning of maintenance and engagement surrounding the wetland. To work towards achieving these, suggestions for improving the wetland have been determined as below.

Next steps	Strategies
Establishing key tasks	• Prioritising goals • Community engagement • Defining community roles and tasks • Defining a clear 'manager' of the wetland • Nitrate monitoring • Maintenance and growth • Increasing biodiversity
Maintaining community engagement	• Regular surveys of successes and areas that require more attention • Working bees e.g. planting, weeding, general maintenance • Biodiversity surveys
Increasing community engagement and introducing new contributors	• Hosting community days • Engaging with local schools, community groups, and businesses • Running interactive workshops e.g. biodiversity monitoring • Engaging with other catchment groups to encourage new wetlands

Figure 10. Table displaying next steps and enactment strategies to improve the Montgomery Wetland.

We expect that the establishment of key tasks and organization and definition of different roles will encourage further maintenance and monitoring of the wetland. Organized events, such as monitoring and biodiversity surveys and working bees may encourage community engagement by creating purposeful interaction with the wetland. Finally, community engagement may be increased by introducing local groups and individuals through activities such as community days, interactive workshops, and engaging with other catchment collectives. Specifically, we suggest that an event should be held to showcase the Montgomery wetland to community members and Aotearoa catchment collectives, demonstrating the successes and benefits of the wetland and encouraging the development of other community-built wetlands.

Limitations with lack of mana whenua

We failed to access a vital perspective for our research, as we did not manage to get representation from mana whenua in our interviews and data collection. The restoration of the natural environment is deeply connected to Mana Whenua, and local iwi and communities. Without their input, we are unable to provide insight and speak on behalf of their perspective on how they would like restoration projects to be conducted or collaborated with Mana Whenua. Future actions involving constructed wetlands should be run past Mana Whenua for inclusiveness and cultural purposes.

Limitations of interviews

For our interviewing method, a flaw arose when we did a dyadic interview for two participants instead of an individual interview as we did for the rest of the shareholders. This complicated the transcribing process and could have reduced the validity of our data due to two people being influenced by one another.

Conclusion

Our research found that the Montgomery Wetland has been successful in its first year. Not only are the three ponds removing nitrates from the water, but there are many other social benefits that have already become evident in its first year. These include the following:
Given the wetland is intended as a proof of concept, the project being completed on budget, without the added bureaucracy of a resource consent is a significant milestone. Ultimately proving that there are grassroots tools available in efforts to reduce agricultural nitrates. There needs to be simplified barriers to demonstrate results to win broader support for constructed wetlands, as results show the wetland is effective, and is expected to increase in performance with time as the constructed wetland matures. The value it offers to the Hinds community, providing a space to make a positive contribution to the environment, enriched by social engagement. Viewing wetlands holistically allows for a more positive outlook for wetlands, providing more opportunities for future wetlands.

We look forward to the future development of the wetland and hope to see it continue to be a prime example of an effective tool for improving water quality in Mid Canterbury.

Acknowledgements

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