Understanding your landscape's resilience: Beyond Regulation

CASE STUDY 1

Farm Type

Dairy Farm

Location

Brydone (Mid Mataura)

THRIVING SOUTHLAND
Tōnui ana te whenua. Tōnui ana te takata.

LAND & WATER SCIENCE

Understanding your landscape's resilience: BEYOND REGULATION

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Definition of Terminology

Physiographic approach – assesses the dominant processes within the landscape in influencing environmental outcomes by combining existing soil, geological, topography and climate data to understand the landscape factors controlling variation in water quality.

Landscape susceptibility mapping – takes a high-resolution physiographic approach and maps it for a property (the resolution is at paddock scale). This identifies the landscape susceptibility to contaminant loss and soil GHG emissions.

Summary

Many farmers are actively seeking opportunities to reduce their environmental impact in order to meet their own goals, as well as regulations, consumer and community expectations.

Land and Water Science Ltd (LWS) has undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales. Landscape variability has a significant role in governing the type and severity of water quality outcomes, even when land use is the same. Landscape variability also significantly affects soil greenhouse gas (GHG) production.

Linking the landscape susceptibility and farm system allows farmers to target mitigations and contaminant load reductions to reduce their environmental impact.

Method

A multi-disciplinary team met with a case study farmer. The team's expertise included landscape susceptibility mapping, water quality science, and farm systems. Current options/technologies available were considered as mitigations. Options for reducing environmental impact were discussed and perspectives sought on practicality, cost, impact on farm system, and impact on environmental mitigation.

The farm

This case study was conducted on a 172-ha dairy farm owned and operated by a farming family and located near Brydone, South of Gore. The family has good awareness of the changes required of farming and the related pressures (water quality, greenhouse gases, animal welfare, and attracting and keeping good quality people).

The farm consists of two flat to undulating terraces (< four degrees slope), connected by a prominent terrace (steep sidling). Seeps and springs occur along the terrace base, and a drainage channel runs along the bottom of the terrace, which intercepts and conveys nitrate-rich groundwater to the local stream network and, ultimately, the Mataura River. Adjacent to the top terrace is a drainage channel that connects to Ota Creek. The majority of the soils on the property are well drained with a smaller area of poorly drained soils predominately located on the lower terrace.

The farm is at an elevation of 64 to 42 meters above sea level, with a mean annual rainfall of 1,100 mm and an annual temperature of 10.1°C.

The farm operates as a milking platform, peak milking 500 cows, with the majority of cows wintered off and all replacements grazed off. The farm produces above the district average for both pasture and milk solid production.

The Catchment

The farm is located in the mid Mataura Catchment. Land use and various industrial and municipal water discharges are key contributors to the degradation of water quality in the Mataura catchment. Overall, surface water quality in the Mataura Catchment is characterised by elevated *E. coli* (faecal bacteria), nitrogen, phosphorus, and degraded macroinvertebrate community index (MCI).

The upper terrace of the farm is located within the Edendale Groundwater Management Zone (GMZ), and the lower terrace is located within the Lower Mataura Groundwater Management Zone (GMZ). Many parts of the Edendale GMZ show very high nitrate concentrations,

commonly above the World Health Organisation (WHO) nitrate in drinking water standard of 11.3 mg/L NO_3-N.

Currently, the Toetoes Estuary, where the Mataura river discharges at Fortrose, is assessed as being in poor condition.

Landscape susceptibility

Variability in climate, topography, geology, and soils significantly influence the type of contaminant and severity of water quality outcomes even when land use is the same.

The case study farm is predominantly within the oxidising soil and oxidising aquifer environment. Deep drainage to the underlying aquifer is the dominant hydrological pathway with some lateral flow. The oxidising environment has a high capacity to filter and adsorb contaminants and resist erosion (minimal sediment, particulate P and microbial losses) but a limited capacity to remove leached nitrate once it has been lost from the root zone. Over time, leached nitrate can build up in the aquifer, increasing the concentration in groundwater and the baseflow (groundwater contribution to stream flow) contribution these nitrate-rich groundwaters make to surface waters.

The farm has minor areas of the reducing soil oxidising aquifer environment. This environment occurs in lowland areas with finely textured silt or clay-rich, imperfect to poorly drained soils and oxygen-rich (oxidising) underlying aquifers. The soils have diagnostic grey colours and distinctive rust-coloured spots. The ability of the landscape to filter and adsorb particulate contaminants is mainly dependent on how much water can infiltrate the soil. The natural drainage of these soils has typically been modified by artificial drainage to lower the water table and improve soil drainage to reduce the occurrence of overland flow. This allows more particulate contaminants to be filtered by the soil and minimises the occurrence of runoff but creates a pathway for water to transport dissolved (and some particulate) contaminants through. These areas are also likely to have elevated soil nitrous oxide loss.

Environmental mitigation opportunities

Discussions with the farmer about landscape susceptibility risk and farm systems analysis identified opportunities to build a resilient farm system and reduce environmental impact. Changes in environmental impact were estimated using OverseerFM modelling and riparian margin calculations and compared to the 2020/21 season. Estimated change in total greenhouse gas emissions (methane, nitrous oxide and carbon dioxide combined) are reported. In addition, the estimated change nitrous oxide emissions are identified to align with the specific opportunities identified in the landscape susceptibility mapping.

The high-level impact of farm system change on capital investment and farm working expenses was explored through partial budgeting. The cost of green house gases pricing has not been calculated, decisions are yet to be made by Government on an agricultural emissions pricing scheme.

Mitigation options

Mitigating through landscape features and minor farm systems changes provided a reduction in contaminant losses. With the addition of a loafing barn for winter there was an increase in most of the contaminants. The key driver behind this was the increase in stock numbers on the farm over the winter as animals that had previously been grazed off-farm were now assumed to be in the barn. Bringing the cows home to the barn for winter also increased the amount of imported supplement required with the result that managing the increase in nutrients would be key to this system.

Table 1 – Mitigation options

Option	Brief description	Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change	Farm system/financial impact
1	Retire the sidling area from grazing and establish wetlands to capture and treat water emerging from springs from the top terrace	–	–	8% decrease	–	4% decrease	Cost of installing wetlands will require site specific assessment. Rough estimate of $20K
2	Target critical source area on north-western boundary adjacent to the Ota Creek drain	–	–	5% decrease	–	2% decrease	Cost of loss of productive land - buffer zone (0.5 ha). Cost of $3,600/annum. Cost of moving fencing not calculated
3	Reduce grazing intensity on bottom terrace	–	–	–	–	–	Small area of farm, significant farm system impact to minimal reduction in contaminants
4	Farm systems bundle of low-cost mitigations to reduce contaminant loadings. ● Changing all in-shed feeding to lower crude protein feed (eg barley grain) ● Reducing the Olsen P to 35 and fertiliser applied at maintenance o Whey applied at maintenance for P o Phosphate fertiliser in the form of a low solubility phosphate fertiliser ● Instead of applying nitrogen as urea, applied as SustaiN ● Reduce synthetic nitrogen (to 130 kg N/ha) on effluent area to partially take account of nitrogen applied in effluent	3% decrease	5% decrease	5% decrease	7% decrease	7% decrease	Minimal farm system impact, cost of $6,420 per annum

Option	Brief description	Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change	Farm system/financial impact
	• When whey applied reduce synthetic nitrogen to take account of N in whey						
5	20% plantain in pasture sward	<1% decrease	4% decrease	16% decrease	<1% decrease	_	Under sowing a 1/3 of farm each year $8,750/year
6	Decrease stock numbers (by 7%)	2% decrease	5% decrease	8% decrease	6% decrease	1% decrease	Decrease in profitability of $92,600/yr. Increased skill in managing pasture quality at a lower stocking rate. Maintaining current high level of per cow production would be challenging.
7A	Loafing barn for the winter (525 cows)	9% increase	5% increase	2% decrease	10% increase	_	Decrease in profitability of $79,560/yr. May need more plant and machinery, effluent storage (not costed). Provides control over wintering. All cows previously wintered off. Managing barn nutrients key.
7B	Loafing barn for the winter (525 cows), effluent and solids exported	8% increase	4% increase	4% decrease	5% increase	_	Decrease in profitability of $79,560/yr plus cost of moving effluent and solids (dependent on distance exported to). . May need more plant and machinery, effluent storage (not costed). Provides control over wintering. All cows previously wintered off. Managing nutrients by exporting effluent and solids.

Option	Brief description	Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change	Farm system/financial impact
8	Freestall barn for extended lactation and winter	16% increase	3% increase	-	10% increase	_	Overall, a reduction in profitability of $99,683 per annum. May need more plant and machinery, effluent storage (not costed). Provides control over wintering. All cows previously wintered off. Managing barn nutrients key.

Scenario aligned to farmers goals (without significant capital investment)

To meet their goals, the farmers wanted to understand by aligning landscape features and the farm system how much the environmental impact could be reduced within their current farm system without significant capital investment.

A scenario to reduce environmental impact by bundling together a range of mitigation options was identified and the change in environmental and financial impacts were estimated. The result was compared to the year end 2021 nutrient budget. Environmental impact changes were estimated using OverseerFM and financial impacts using partial budgeting.

Table 2 – Combined mitigations without significant capital investment

	Brief description	**Total GHG change**	**Nitrous oxide change**	**N loss change**	**N Surplus change**	**P loss change**	**Farm system/ financial impact**
Scenario A	Mitigations combined: Retire sidling to capture water emerging in springs to treat water flowing from the top terrace Target critical source area on north-western boundary adjacent to drainage channel connected to Ota Drain Farm systems bundle of low-cost mitigations to reduce contaminant loadings 20% plantain in pasture sward	4% decrease	9% decrease	31% decrease	8% decrease	13% decrease	Minimal farm systems impact, cost of $18,770 per annum plus rough estimate of $20,000 for wetland

Scenario aligned to farmer's goals (with significant capital investment)

The farmer also wanted to understand the impact of future-proofing their wintering system (and aligning it with a recently leased adjoining support block). A scenario to reduce environmental impact by bundling together a range of mitigation options was identified and the change in environmental and financial impacts were estimated. This scenario involved significant capital investment. The result was compared to the year end 2021 nutrient budget. Environmental impact changes were estimated using OverseerFM and financial impacts using partial budgeting.

Table 3 - Combined mitigations requiring significant capital investment

	Brief description	**Total GHG change**	**Nitrous oxide change**	**N loss change**	**N Surplus change**	**P loss change**	**Farm system/ financial impact**
Scenario B	Mitigations combined: Install loafing barn for wintering 400 cows Export effluent and manure from loafing barn to lease block Retire sidling to capture water emerging in springs to treat water flowing from the top terrace Target critical source area on north-western boundary adjacent to Ota Drain Farm systems bundle of low-cost mitigations to reduce contaminant loadings 20% plantain in pasture sward	5% decrease	2% decrease	31% decrease	<1% increase	8% decrease	Cost of $79,501 per annum plus rough estimate of $20,000 for wetland May need more plant and machinery, effluent storage (not costed). Provides control over wintering. All cows previously wintered off. Managing barn nutrients key.

In this option there was the increase in stock numbers on the farm over the winter as animals that had previously been grazed off-farm were now assumed to be in the barn. Exporting the effluent and manure from the loafing barn to the adjacent support block is key and should ideally be applied on the areas where supplement has been harvested to replace nutrients.

Conclusion

The main landscape susceptibility issue on the property is nitrate-nitrite-nitrogen (NNN) leaching associated with moderately to well-drained loess soils. These soils overlie a strongly oxidising aquifer that is susceptible to NNN accumulation. Soil nitrous oxide, PP, and *E. coli* susceptibility are of lesser concern and are mainly associated with poorly drained Jacobstown soils and the southeastern corner of the property.

There are many options, both landscape and farm system, which could be implemented to reduce NNN losses from the farm to the underlying aquifer.

Collectively, a terrace wetland system combined with a bundle of low-cost farm systems changes to reduce contaminant loading offer the opportunity to reduce environmental contamination. The installation of a barn for wintering will not achieve environmental mitigation but provide control over cow wintering rather than utilising a third-party grazier.

Further reduction in environmental impact beyond what has been modelled is likely to require:

- Further and new technologies (landscape and farm system)
- Decrease in intensity (e.g., reduction in cow numbers)
- Land use change to a less intensive farm system.

1. The project

Many farmers are actively seeking opportunities to reduce their environmental impact to meet their goals, regulations, consumer, and community expectations.

Farmers have long-term skills and knowledge balancing a range of internal and external factors in their decision-making. Uncertainty in on-farm decision-making has increased in recent years due to:

- Changing consumer and processor expectations
- Supply chain issues and change in cost structures
- Cost of and access to capital
- Concerns about climate change
- Change in regulation
    - Essential Freshwater Package (including National Policy Statement and National Environmental Standard, Freshwater Farm Plans)
    - National Policy Statement for Highly Productive Land
    - Proposed GHG emissions pricing
    - Proposed National Policy Statement on Indigenous Biodiversity
- Price of carbon supporting land use change.

Combining information on the landscape and farm system provides an opportunity to reduce environmental risk and inform farmer decision-making.

2. The farmers and their goals

The 172-ha dairy farm is owned and operated by a farming family and is located near Brydone, south of Gore. The farmers have been working hard over the last 13 years since purchasing the property to:

- Build a robust business in all facets: people, environmental, animal welfare and financials
- Strengthen their financial position by paying off debt
- Plan and build high-quality infrastructure (effluent system, rotary cow shed, housing).

Going forward, this focus on operating a robust farm system, long-term thinking and paying off debt will continue. In addition to this, they also aim to prioritise time with their young family.

They have a good awareness of changes and pressures on farming – water quality, greenhouse gases, animal welfare, attracting and keeping good quality people.

Top of mind for them in the short to medium term is future-proofing their wintering system. Currently the majority of cows are off farm with a grazier during the winter and on fodder crop.

3. Method

Variability in climate, topography, geology, and soils significantly influence the type of contaminant and severity of water quality outcomes even when land use is the same.

A multi-disciplinary team met on-farm with the farmers. Expertise in the team included landscape susceptibility mapping, water quality science and farm systems. Current options/technologies available were considered as mitigations.

During the on-farm visit with the farmer, the following was discussed:

- The farmers goals
- The farmers background on the property and achievements to date
- Catchment issues
- Landscape susceptibility mapping with onsite ground truthing
- Estimated environmental losses from the farm system modelled through OverseerFM from information provided prior to the site visit.

During the visit opportunities to reduce environmental impact were discussed. Perspectives were sought on practicality, cost, impact on the farm system and impact on environmental mitigation. The open discussion with different perspectives allowed opportunities to be identified and refined.

4. Case study farm setting

4.1 Physical setting

Hydrology

The majority of the farm sits on top of a loess-mantled alluvial terrace adjacent to the Mataura River and its floodplain within the Mataura River Catchment. Low Burn Creek runs north to south on the lower terrace to the east of the property. A drain leading to Ota Creek is located on the western boundary. The Mataura River runs parallel to Low Burn Creek under two kilometres east of the property.

Seeps and springs can be found along the terrace edge and a drainage channel runs along the bottom of the terrace (Figure 1). In the past, discharge from the terrace springs flowed across the low-lying and poorly drained Jacobstown soils, which likely hosted a red-tussock wetland system. Trenching of the base of the terrace now redirects spring seepage off the property via the drainage network.

The upper terrace of the farm is located within the Edendale GMZ[1] and the lower terrace is located within the Lower Mataura GMZ[2].

[1] https://www.es.govt.nz/environment/water/groundwater/groundwater-management-zones/edendale
[2] https://www.es.govt.nz/environment/water/groundwater/groundwater-management-zones/lower-Mataura

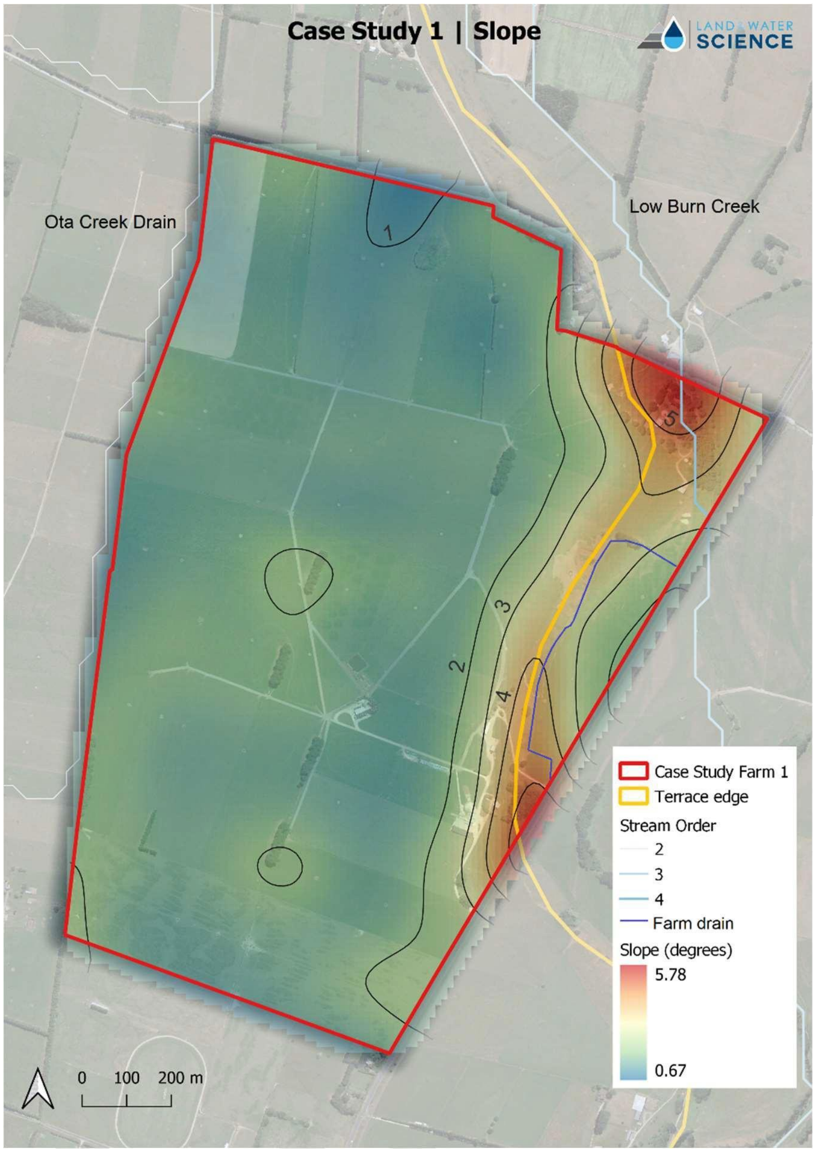


Figure 1. Rivers, streams, and slope. The location of the terrace boundary is shown in orange. Low Burn Creek cuts through the lower terrace to the east. A drain leading to Ota Creek is located on the western boundary. Stream order denotes the relative size of the stream. The nearby Mataura River has a stream order of 7.

Topography and climate

The farm is predominantly flat to undulating (<4 degrees slope) at an elevation of 64 to 42 meters above sea level.

Long-term climate data collected between 1972 to 2016 records an average annual temperature of 10.1 °C and mean annual rainfall of 1100 mm.

Geology

The upper terrace, as identified in Figure 1, is described by New Zealand's geological survey (Q-Map v3; Heron, 2020) as schist-greywacke-quartz sandy gravel in outwash and alluvial terraces. The dominant rock type is gravel with subordinate amounts of sand, silt and clay. The maximum age estimate is 18,000 years old. The lower terrace is described as greywacke sandy gravel overlain by loess (a fine windblown silt) (Heron, 2020). The dominant rock type is also gravel with subordinate amounts of sand and silt. The maximum age estimate of this part of the farm property is 7000 years old.

Overlying the alluvial gravels is a thick mantle of silt (loess) deposited during glacial times. The loess mantle is up to six metres thick in places and is the parent material for the soil developed on the property. The terrace gravels overlie the Gore lignite measures that contain abundant organic carbon, which drives the natural removal of leached nitrate by denitrification. However, where the alluvial gravels overlying the lignite measures are thick, as they are beneath the case study property, the opportunity for denitrification is minimal.

Soils

The TopoClimate South soil survey identifies five main soil series across the property represented by three soil orders - Brown, Gley and Pallic (Figure 2).

The Brown soils are Edendale, with an extent of 85.9 ha (44 percent of the property) through the middle of the property, and Tuturau with an extent of 59.8 ha (30.6 percent of the property) located between the Edendale soil and the terrace edge. Brown soils are the most versatile of the soil orders with few limitations for pastoral farming. The Edendale soil is described as deep, well drained silt loam with slow permeability (<4 mm/hr). The Tuturau soil is a deep, well drained silt loam with moderate permeability (4-72 mm/hr). Both soils have a deep rooting depth and high water holding capacity. The Tuturau soil has a moderate vulnerability for structural compaction due to the light silt loam texture.

The Gley Jacobstown soil has an extent of 21.9 ha (11.2 percent of the property) and is located across the lower terrace and the southwestern corner of the property. Gley soils form in areas where waterlogging is common, resulting in the formation of the indicative grey subsoils and orange mottles (rust spots). The Jacobstown soil is moderately deep to deep poorly drained silt loam with slow permeability. The deep rooting depth may be limited by poor aeration during wet periods. This soil has a severe vulnerability to structural degradation and waterlogging, which has been managed through the installation of artificial drainage.

There are two Pallic soils identified on the property. Generally, Pallic soils have pale coloured subsoils, weak structure and high density in the subsoils. They can be limited by summer dryness and winter wetness. The Otama soil located to the south-east has an extent of 6.6 ha (3.4 percent of the property). The Otama soil is described as a moderately well to imperfectly drained, loamy silt. It is limited by severe structural compaction vulnerability and topsoil erodibility.

The Waikoikoi soil is located along the western boundary, however the resolution of the Topoclimate South survey was insufficient to discriminate the extent of this soil from the subordinate Brown Arthurton soil and the Gley Jacobstown soil. This multi-soil area has an extent of 20.9 ha (10.7 percent of the property). The Waikoikoi soil has a silt texture with variable clay content, resulting in soils that are poorly drained, with very slow permeability in the subsoil and limited aeration during sustained wet periods. Waikoikoi soils have a slightly deep potential rooting depth that is severely restricted by a fragipan at 45–60 cm depth. Fragipans are dense subsurface soil layers that severely restrict water flow and root penetration. These soils have a very severe vulnerability to structural degradation, severe waterlogging and moderate topsoil erodibility.

Figure 2. TopoClimate South soil series mapped at 1:50,000 scale.

4.2 The dairy farm

The 172 ha farm (169 ha effective area) is predominately utilised as a dairy milking platform (165.5 ha) split between two terraces with 12.6 ha of the milking area located on the bottom terrace (Figure 3). There is similar productivity across the top and bottom terraces (Table 4). Connecting the two terraces is a steep sidling (3.5 ha), which is utilised for limited dry stock grazing and has a low pasture productivity.

Figure 3. The dairy farm management blocks, upper terrace, lower terrace, and terrace riser (sidling).

Table 4. Farm management blocks and productivity.

Area	Land use	Productivity (Pasture grown T DM/ha/yr)[1]	Area (hectares)
Top terrace	Milking platform – effluent	18.5	43.3 ha
	Milking platform – non-effluent	18.5	109.6 ha
Bottom terrace	Milking platform – non-effluent	18.5	12.6 ha
Sidling	Limited dry stock grazing	5.6	3.5 ha
Non-productive	Buildings, races, etc	N/A	3.5 ha

In addition to the milking platform, a recently acquired lease block adjoining the southern boundary is being utilised for young stock grazing, silage and some cow wintering (which was previously sourced off-farm through a third party).

[13] Estimated by OverseerFM, based on a default pasture ME

Farm System Description

The farm operates as a milking platform with all cows wintered off the farm (Table 5). All youngstock are grazed off the farm from weaning. Going forward, 200 cows will be wintered on the new neighbouring 19 ha lease block. The majority of cows are wintered with an external grazier on fodder crops. Young stock are grazed off the milking platform. No fodder crops are grown on the property. The stocking rate is slightly above Southland average with milk production per cow and per hectare well above the Southland average. Pasture production is at a high level combined with significant levels of purchased in feed.

Table 5. Farm summary.

		20/21 season Southland Average[4]
Total area (ha)	172	
Effective area (ha)	169	221
Stock and Production		
Cows peak milked	500	615
Cows wintered on farm	0	
Milk solids production per cow	500 kg ms/cow/yr 1.04 kg ms/kg lwt	428 kg ms/cow/yr
Milk solids production per hectare	1490 kg ms/ha/yr	1193 kg ms/ha/yr
Young stock	Grazed off from weaning, return as in calf heifers	
Replacement rate	25%	
Stocking rate	3 cows per hectare 32 revised SU / hectare	
Feed and Fertiliser		
Fodder crop	0 ha	
Purchased supplements	850 kg DM/cow/yr 2510 kg DM/ha/yr	
Synthetic nitrogen applied	176 kg N ha/yr	
Whey (non-effluent area)	20 kg N/ha/yr 36 kg P/ha/yr	
Phosphate fertiliser	0 kg P/ha/yr	
Pasture Grown (estimated by OverseerFM)	18.5 t DM/ha/yr	

The effective usable area of the farm is 169 ha, this includes the sidling and a paddock with accessibility issues which is rarely grazed and used for supplement. The effective area utilized for milking is 156.5 ha with production of 1609 kg ms / ha / yr.

Farm Nutrient and Green House Gas Emissions

Estimates of nutrient and green house gas emissions have been modelled using OverseerFM (Table 6).

"OverseerFM provides a way to estimate how nutrients are cycled within a farm system. This allows the user to better understand annual average nutrient requirements and the likely effects of changing management practices on the farm's overall nutrient inputs and losses."[5]

OverseerFM models nutrient flows to the farm boundary. The farm boundary is to the farm gate and to rooting depth. It does not model what happens to those nutrients beyond this boundary, nor does it model extreme weather or events.

[4] New Zealand Dairy Statistics 2020-21, LIC, DairyNZ

[5] https://www.overseer.org.nz/our-science

OverseerFM greenhouse gas estimates have been calculated using IPCC global warming potentials. Estimated change in total greenhouse gas emissions (methane, nitrous oxide and carbon dioxide combined) are reported. In addition, the estimated change nitrous oxide emissions are identified to align with the specific opportunities identified in the landscape susceptibility mapping.

Modelling biological systems is not exact and there are uncertainties, results are intended to give a 'direction of travel' rather than accuracy.

Table 6. OverseerFM estimates of farm nutrient and greenhouse gas emissions.

	Case Study 1 – 20/21 season OverseerFM v6.4.3
Total farm emissions (eCO_2 t/yr)	2590 21% nitrous oxide 66% methane 13% CO_2
Emissions per hectare (eCO_2 /kg/ha/yr)	15058
Total Farm N Loss (kg/yr)	8168
N Loss/ha (kg N/ha/yr)	47
N Surplus (kg N/ha/yr)	258
Total Farm P Loss (kg)	157
P loss/ha (kgP/ha/yr)	0.9

5. Environmental Contaminants

5.1 Environmental Contaminants

Green House Gases

Rising concentrations of greenhouse gases in the atmosphere increase the earth's temperature. Greenhouse gases comprise of long lived (carbon dioxide and nitrous oxide) and short lived (methane).

The New Zealand Government has the following legislated emissions targets:

- Methane (CH4) emissions to reduce by 10% below 2017 levels by 2030, and by 24 to 47% by 2050
- Nitrous oxide (N_2O) and carbon dioxide (CO_2) to reduce to net zero by 2050

Both methane and nitrous oxide are very potent greenhouse gases. Methane warming potential is circa 30 times more powerful than carbon dioxide. The predominate source of methane in NZ farming systems is from ruminant digestive systems. N2O warming potential is circa 300 times more powerful than CO2. In New Zealand, most nitrous oxide is produced by microorganisms acting on nitrogen introduced to the soil via livestock urine or synthetic fertilisers.

Nitrate

Nitrate is highly soluble and is easily transported through the soil if not used by plants and microorganisms. Nitrates can be transported to ground and surface waters, where it may cause human health and ecological issues. Nitrogen is an essential element for plant growth and is generally added to pastures through biological fixation (in clovers), as fertiliser (in synthetic and organic forms), as effluents or as urine from livestock.

Organic and Ammoniacal Nitrogen (TKN)

Total Kjeldahl Nitrogen (TKN) is a measure of organic, and ammoniacal N. Organic and ammoniacal nitrogen are derived from the breakdown of organic matter (plant roots, leaves), soil organic matter, manure, and animal urine. Organic nitrogen is mineralised to ammoniacal N, and ammoniacal N is oxidised to nitrite and ultimately nitrate. The loss of excessive TKN from land, e.g., from a recently cultivated paddock, is therefore an important factor controlling stream health.

Particulate Phosphorus

Phosphorus is a nutrient for plants and algae. High concentrations in waterways can cause weed growth and algae blooms. Sources of phosphorus are weathering of rocks, erosion of soil and the addition of phosphate fertilisers to pastures and dung from livestock.

Particulate phosphorus (PP) refers to phosphorus that is associated with particles such as suspended sediments. Phosphorus binds to soil particles. When soil is lost by runoff it takes the phosphorus with it.

Particulate phosphorus loss requires water to erode and carry sediment that is enriched in phosphorus to a waterway. The risk of runoff is elevated with increasing slope of land. Soils with elevated P-retention can sequester a large amount of P from fertiliser or animal wastes. Erosion of such soil can transport large amounts of P to waterways where it drives eutrophication. Soils that are imperfectly to poorly drained tend to be more susceptible to P loss via runoff or mole-pipe drainage. Well drained soils tend to have a low susceptibility to PP loss as they are less likely to runoff. However, well drained soils with elevated Olsen P values can release higher concentrations of dissolved P into soil solution. Ensuring Olsen P values do not exceed optimal values is a good way of limiting dissolved P leaching.

Dissolved Reactive Phosphorus

Dissolved reactive phosphorus (DRP) refers to the soluble phosphorus compounds in water and is the dissolved P fraction that is not attached to sediment. The redox environment determines the mobility of DRP in the soil and groundwater systems, and the abundance of P. Soils and groundwater systems that are low in oxygen (anoxic) tend to leach dissolved reactive phosphorus. Poorly drained soils lose more DRP than well-drained soils due to lesser P-retention. Under low oxygen conditions (anoxic), the minerals that hold onto P (P-retention) dissolve, and P is released, or P introduced to such an environment is not retained by the soil or aquifer materials.

Sediment

Sediment is the loose sand, silt, clay, and other organic particles suspended in a waterway or settled on the bottom. Sediment can come from soil erosion or the decay (decomposition) of biological material and is transported by water, wind, and ice to waterways. Although sediment is a natural part of a waterway, the type and amount potentially available to transport is influenced strongly by the geology and topography of the surrounding area and land use practices. Weaker or fine textured rock types, such as mudstone, naturally have a higher sediment load and more turbid water due to these rock types being more easily erodible. This natural sediment load is elevated by land use practices that cause structural damage to soils or leave soil bare and exposed. Under agriculture, sediment can also be enriched with nutrients. Nutrient-rich sediment has a much larger detrimental effect in waterways than sediment from natural state or areas with a low land use intensity.

E. coli

Microbial contaminants are disease-causing organisms. *E. coli* (Escherichia coli) is just one type of bacteria commonly found in the gut of warm-blooded animals and people. High concentrations of *E. coli* indicate contamination, which can degrade drinking water supplies and the safety of waterways. Microbes and bacteria often 'stick' to particles (sediment) and are then transported to waterways in runoff, particularly after heavy weather.

For more information on environmental contaminants, see landscapedna.org/science/water-quality-contaminants/.

5.2 State of the Mataura Catchment

Land use and various industrial and municipal water discharges are key contributors to the degradation of water quality in the Mataura Catchment[6].

Currently, the Toetoes Estuary, where the Mataura river discharges at Fortrose, is considered to be in poor condition. Toetoes Estuary has areas that are currently assessed as D band (poor) for macroalgae, Gross Eutrophic Zone (GEZ), mud content and sediment oxygen levels. A reduction in nutrient and sediment inputs is needed to improve the estuary classification above 'D' band (poor). Faecal bacteria also needs to be reduced to at least C band (fair) or better at the estuary monitoring sites.

Overall, surface water quality in the Mataura Catchment is characterised by elevated *E. coli* (faecal bacteria), nitrogen, phosphorus, and degraded macroinvertebrate community index (MCI). Many parts of the Edendale GMZ show very high nitrate concentrations.

For further information on water quality in Mataura Catchment refer to appendix 1.

6. Landscape susceptibility

Variability in climate, topography, geology, and soils significantly influence the type of contaminant and severity of water quality outcomes even when land use is the same. We refer to the variability in climate, topography, geology and soil as 'landscape factors'. These are the physical, chemical, and biological (organic matter) components of the earth that control the susceptibility ('risk') of the landscape to contaminant loss (Figure 4). Landscape factors, especially soil texture and drainage also have a significant effect on governing soil greenhouse gas (GHG) production. For geologically diverse landscapes, such as New Zealand, the type and severity of contaminant loss vary significantly. Even in relatively simple landscape settings, variation in landscape factors may account for the majority of spatial variation in water quality relative to land use on its own.

[6] Norton, N., Wilson, K., Rodway, E., Hodson, R., Roberts, K. L., Ward, N., ... & Greer, M. (2019). Current environmental state and the "gap" to draft freshwater objectives for Southland. *Environment Southland Technical Report*, *12*.Moran, E., Pearson, L., Couldrey, M., & Eyre, K. (2017). The Southland economic project: agriculture and forestry. *Environment Southland Technical Report Publication*, (2017-02).

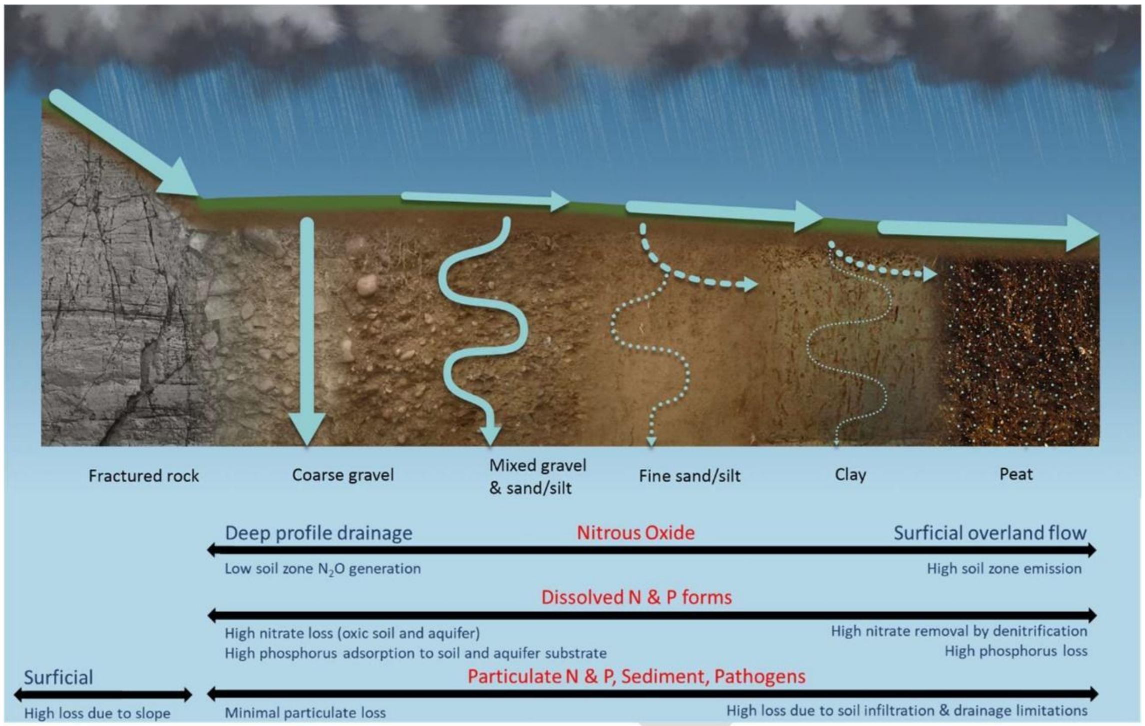


Figure 4. Conceptual diagram of susceptibility for contaminant loss under various landscape properties. Susceptibility for contaminant loss is strongly controlled by the pathway water takes to leave the land and the chemical processes of reduction-oxidation 'redox' that takes place within the soil and geological materials.

LWS has generated a classification that maps the landscape factors controlling variation in the type and severity of water quality issues. The classification, Physiographic Environments of New Zealand (www.LandscapeDNA.org) is designed to support land users in understanding how and why water quality variation occurs across the landscape and identify the most important susceptibility on their property. In doing so, LandscapeDNA seeks to support targeting actions specific to their location and the issues they face. This mapping is undertaken by combining existing soil, geological, topography and climate data to understand the landscape factors controlling variation in water quality. The map has a resolution of 1:50,000. At this scale, it is appropriate for providing catchment context and describing the general farm environment but is not at the resolution suitable for paddock scale management decision- making.

Mataura River Catchment's physiographic setting is provided in Figure 5. Alpine and bedrock environments comprise 53 percent of the catchment with the lowlands dominated by the reducing soil oxidising aquifer (18.2 percent of the catchment) and oxidising soil and aquifer environment (16.1 percent of the catchment). For specific details on each physiographic environment and its landscape susceptibility, see landscapedna.org/science/physiographic-environments/.

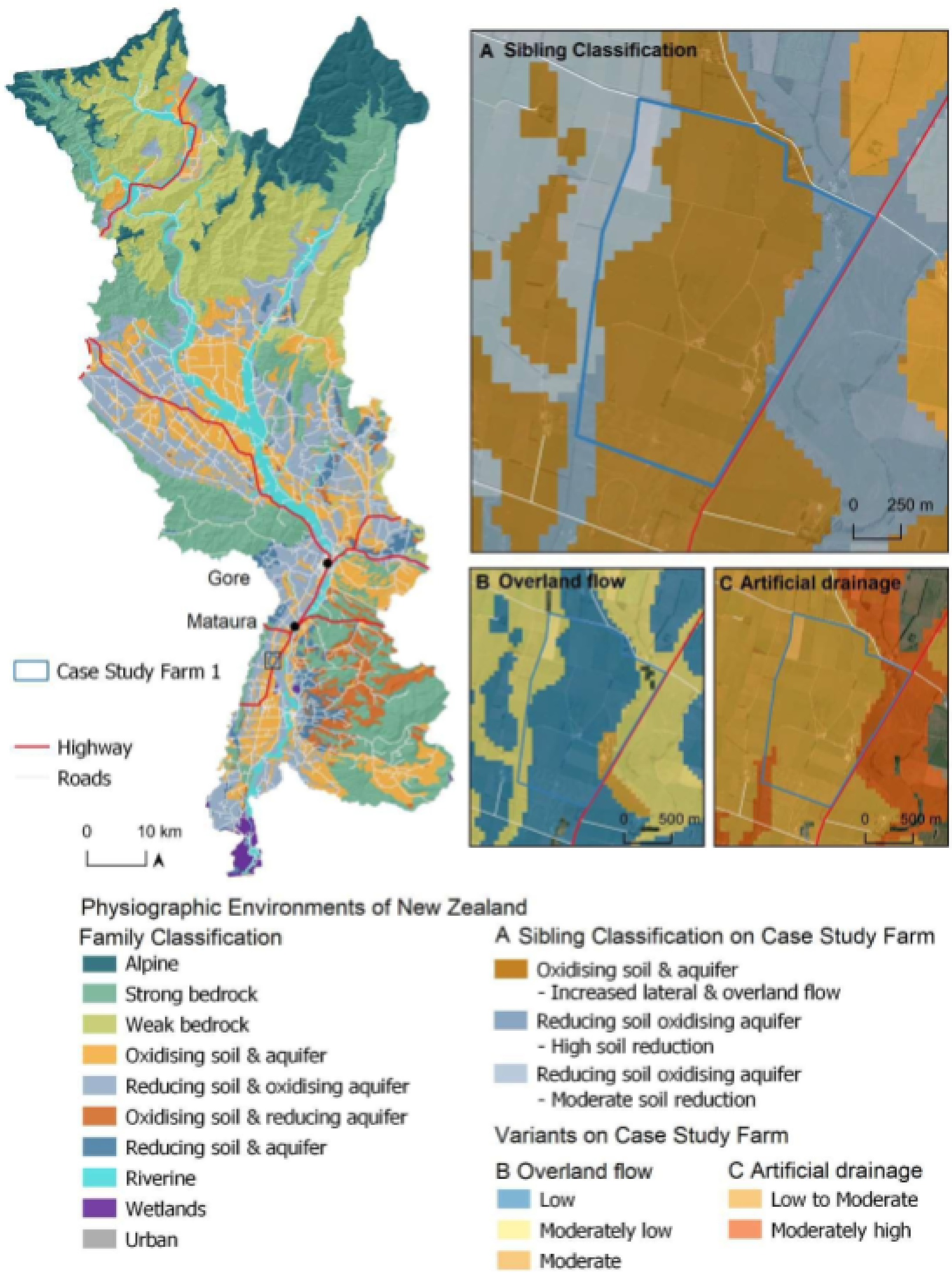


Figure 5. Physiographic environments of the Mataura Catchment and case study farm.

The case study farm is located predominantly within the oxidising soil and aquifer environment (153 ha, 78 percent of the property; Figure 5A). Deep drainage to the underlying aquifer is the dominant hydrological pathway with some lateral flow as indicated by the sibling class of increased lateral and overland flow. This environment has a high ability to filter and adsorb contaminants and resist erosion (minimal sediment, particulate P and microbial losses). As the landscape has little to no ability to remove nitrogen once it has been lost from the root zone, there is a high risk of nitrate nitrogen leaching into the shallow aquifer. Over time, nitrate can build up in the aquifer, increasing the concentration in groundwater and in-stream. Elevated nitrate concentration is evident in wells drawing from the Edendale aquifer, commonly exceeding the World Health Organisation (WHO) drinking water standards of 11.3 mg/L NO_3-N. Three of the largest springs (seeps) discharging at the base of the terrace were sampled in December 2022 as part of this project, revealing elevated nitrate concentrations that range between 7.6 to 9.1 mg/L nitrate and nitrogen (NO_3-N).

The farm has minor areas of the reducing soil oxidising aquifer environment (42 ha, 22 percent of the property; Figure 5A). This environment occurs in lowland areas with finely textured silt or clay-rich, imperfect to poorly drained soils and oxygen-rich (oxidising) underlying aquifers. The soils have diagnostic grey colours and distinctive rust-coloured spots. The ability of the landscape to filter and adsorb particulate contaminants is largely dependent on how much water can infiltrate the soil. The natural drainage of these soils has typically been modified by artificial drainage to lower the water table and improve soil drainage, reducing the occurrence of overland flow (Figure 5B and C). This allows more particulate contaminants to be filtered by the soil and minimises the occurrence of runoff but creates a pathway for water to transport dissolved (and some particulate) contaminants through. These areas are also likely to have elevated soil nitrous oxide loss.

6.1 Susceptibility of case study farm

LWS has undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales. The resolution of the mapping is 50 x 50 m providing a much more resolved understanding of contaminant susceptibility than physiographic environments on their own. The maps are of sufficient resolution to show paddock scale variation in susceptibility.

The maps of landscape susceptibility highlight the various contaminants and their forms using a scale of 0 – 100 (0 being low and 100 being high susceptibility). The landscape's dominant influence on contaminant production and transport means that much more attention needs to be paid to these spatially driven factors.

It is important to emphasise the following for the susceptibility models presented below. They:

A. Are entirely independent of land use and only identify the natural susceptibility of the landscape to contaminant loss that is associated within soil, geology, and topographic factors (e.g., slope, elevation),

B. Do not consider any existing environmental management practices or physical mitigations that are already in place (e.g., sediment traps, wetlands),

C. Do not represent actual losses or contaminant loads.

The susceptibility maps are coloured from red, reflecting elevated susceptibility to the contaminant or emission in question, to blue, reflecting low susceptibility.

Nitrous Oxide and NNN

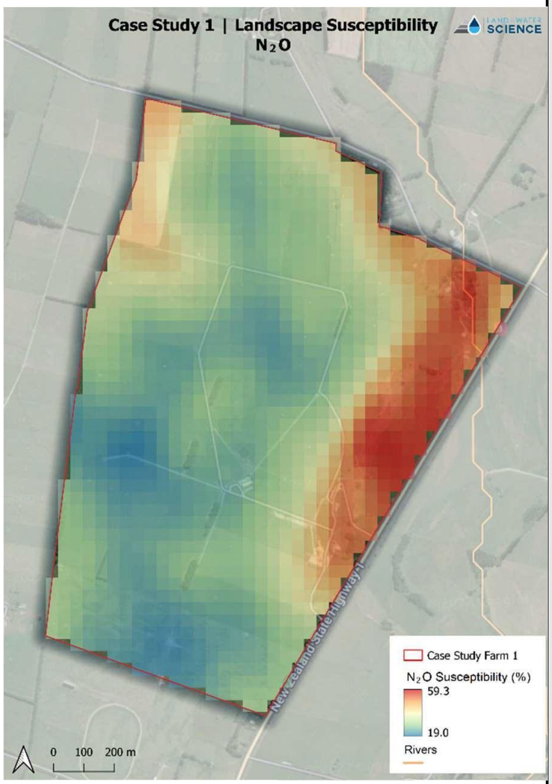
<table>
<tr><th>Landscape susceptibility – N_2O (soil nitrous oxide)</th><th>Landscape susceptibility – NNN (nitrate – nitrite nitrogen)</th></tr>
<tr><td>

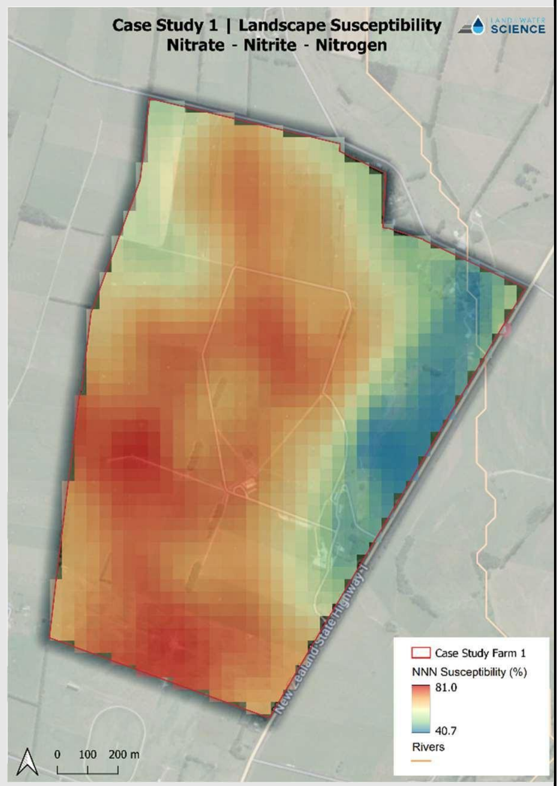
Figure 6. Landscape susceptibility to nitrous oxide.</td><td>

Figure 7. Landscape susceptibility to NNN (Nitrate- Nitrite-Nitrogen).</td></tr>
<tr><td>N_2O susceptibility ranges from 19 to 59.3 percent on the case study farm. A soil that is slowly permeable and imperfectly to poorly drained is more susceptible to nitrous oxide generation. Across the case study farm areas of elevated soil nitrous oxide susceptibility are associated with poorly drained Jacobstown soils. A minor area of moderate susceptibility occurs towards the northwest. Nitrous oxide generation is favoured where soil saturates in response to high intensity rainfall events, or due to low evapotranspiration during the cooler winter months.</td><td>NNN susceptibility ranges from 40.7 to 81 percent on the case study farm. Across the subject property the areas of elevated susceptibility to NNN leaching are associated with well drained and moderately permeable Edendale and Tuturau soils on the top terrace. These soils overlie a strongly oxidising aquifer that is susceptible to NNN accumulation.</td></tr>
</table>

The susceptibility of the landscape to nitrous oxide loss is the opposite of that of NNN leaching (Figures 6 and 7). This reflects the role of redox processes (e.g., oxidation and reduction reactions) in controlling whether or not NNN is removed or able to accumulate in the shallow water table aquifer beneath the property.

Sources of nitrogen in Case Study 1 include those purchased in supplements, synthetic nitrogen, applied whey, and biological fixation from clover.

- The nitrogen surplus in the effluent area is estimated at 251 kg N/ha with an approximate estimate of 11 ppm nitrate as nitrogen leaving the root zone as leachate.
- The nitrogen surplus in the non-effluent area ranges from 204 to 217 kg N/ha, with an approximate estimate of 9 to 10 ppm leaving the root zone as leachate.

Particulate phosphorus and dissolved reactive phosphorus

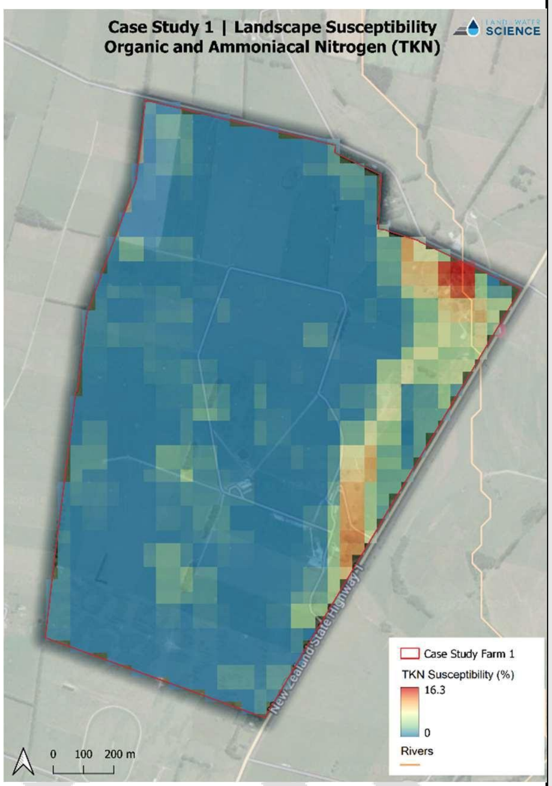
<table>
<tr><th>Landscape susceptibility – PP (particulate phosphorus)</th><th>Landscape susceptibility – DRP (dissolved reactive phosphorus)</th></tr>
<tr><td>


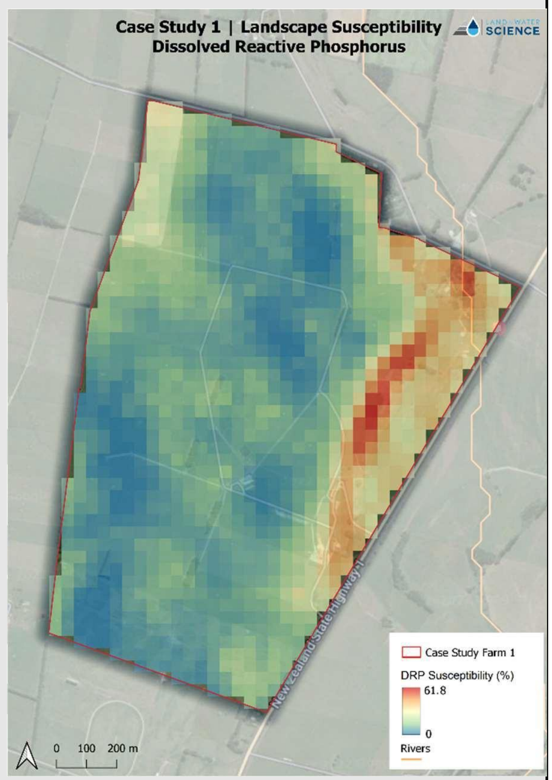
Figure 8. Landscape susceptibility to PP (particulate phosphorus).
</td><td>


Figure 9. Landscape susceptibility to DRP (dissolved reactive phosphorus).
</td></tr>
<tr><td>PP susceptibility ranges from 0 to 16.3 percent on the case study farm. The above map reflects an overall low susceptibility for particulate phosphorus for the subject property. The steep sidling (terrace edge) has the highest level of susceptibility within the property boundary.</td><td>DRP ranges from 0 to 61.8 percent on the case study farm. The areas of elevated dissolved reactive phosphorus susceptibility are associated with the steep sidling and the bottom terrace Jacobstown soils.</td></tr>
</table>

The topsoil P-retention ranges from low (23 percent on the Waikoikoi soils) to medium on the Edendale, Tuturau, and Jacobstown soils (38-43 percent).[7]

The average Olsen from soil test results[8] is 40 mg/l with variation between blocks (average of 29 to 43 mg/l) and significant range within blocks (22 to 76 mg/l) (Table 7).

For sedimentary soils with milk solids production in the top 25 percent for the area the target Olsen P is 30 to 40[9]. Phosphate retention ranges from low to medium across the property.

[7] Manaaki Whenua Landcare Research S-Map soil reports
[8] Hill Laboratories Report - all paddock soil testing completed July 2021 by Balance Agri-nutrients
[9] Fertiliser Use on New Zealand Dairy Farms, Fert Research

Table 7. Olsen P (mg/l) on the property.

	Olsen P Average	Olsen P Range
Top terrace (Waikoikoi soils)	29	22 to 38
Top terrace (Edendale soils)	41	24 to 65
Top terrace (Tuturau soils)	43	32 to 76
Bottom terrace (Jacobstown soils)	40	38 to 41

In the 2020/21 season, the only form of phosphate applied was as whey to the non-effluent areas on the top and bottom terraces. Lower Olsen P paddocks are targeted for whey application (utilising all paddock soil testing information); at the rates of whey applied, the application would provide above maintenance phosphate applications at 36 kg P/ha/yr (maintenance estimated at 26 to 33 kg P/ha/yr). In addition to the whey applications, OverseerFM estimates that an additional 10 kg P/ha/yr is applied from the addition of supplements.

Turbidity and organic & ammoniacal nitrogen

Landscape susceptibility – Sediment (turbidity)

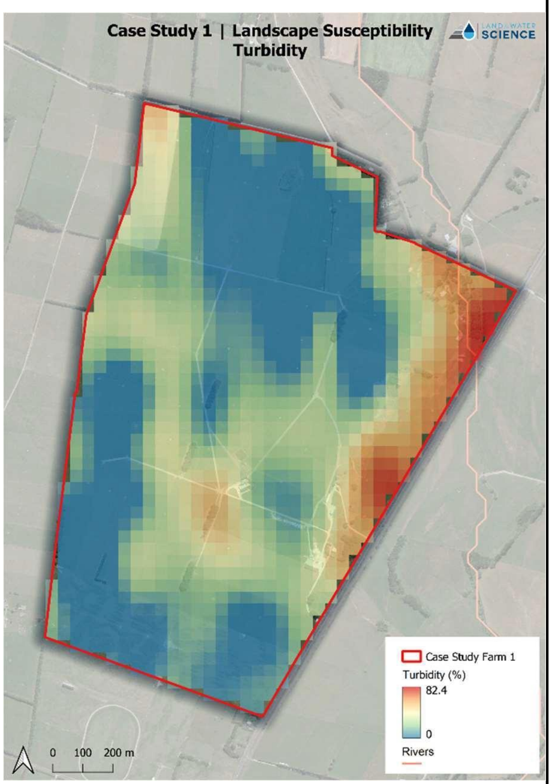


Figure 10. Landscape susceptibility for sediment as indicated by turbidity.

Turbidity susceptibility ranges from 0 to 82.4 percent on the case study farm. Areas of elevated sediment susceptibility are associated with poorly drained Jacobstown soils, with a minor area of moderate susceptibility occurring towards the northwest and near buildings.

Landscape susceptibility – TKN (organic and ammoniacal nitrogen)

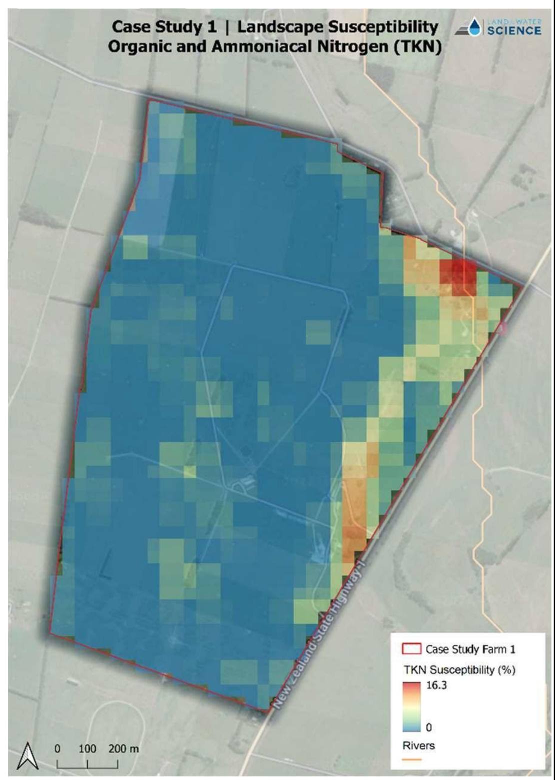


Figure 11. Landscape susceptibility to organic and ammoniacal nitrogen.

TKN susceptibility ranges from 0 to 16.3 percent on the case study farm. This map reflects an overall low susceptibility for TKN for the subject property. There is a small area with some minor elevation of TKN susceptibility noting a max in the northeast and terrace edge area.

E. coli

Landscape susceptibility – *E. coli*

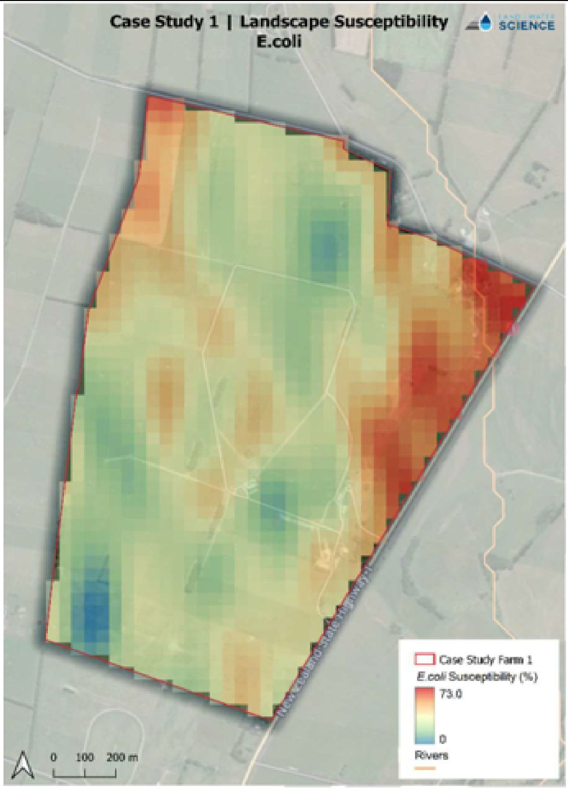


Figure 12. Landscape susceptibility to E. coli (Escherichia coli).

E. coli susceptibility ranges from 0 to 16.3 percent on the case study farm. Elevated susceptibility is in the areas associated with the steep sidling and bottom terrace Jacobstown soils. There is also an area of increased susceptibility on the northwest portion of the property which is adjacent to Ota Creek drain.

7. Environmental mitigation opportunities

During the site visit it was identified through landscape susceptibility, farm systems analysis, and discussions with the farmer that there were opportunities to reduce environmental impact (Figure 13).

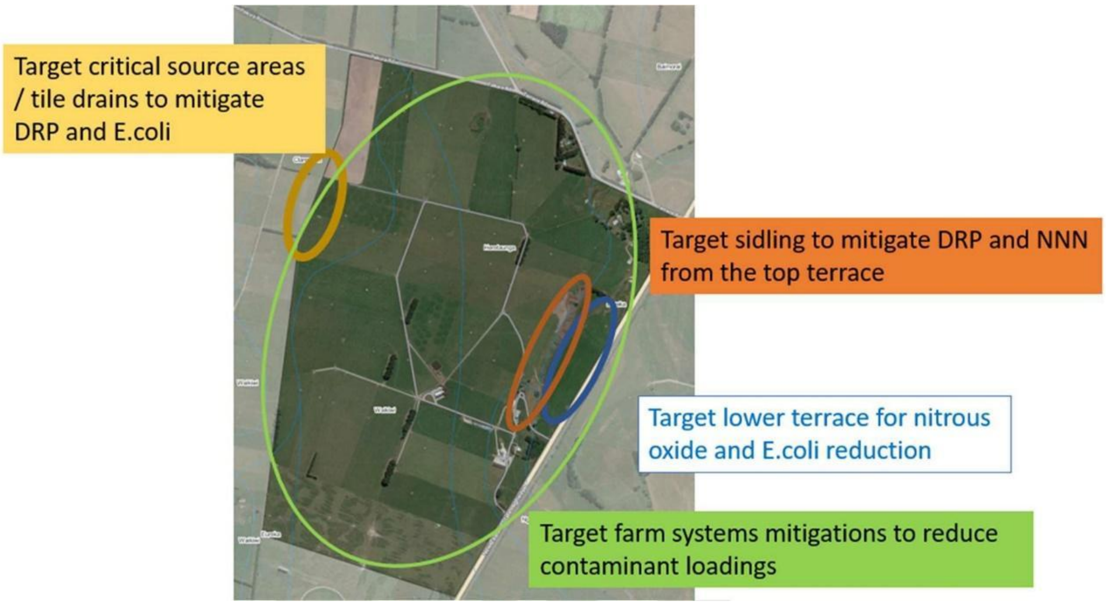


Figure 13. Opportunities to reduce environmental impact.

Opportunities to reduce environmental impact were investigated with the change in environmental impact were modelled through OverseerFM and compared against the 2020/21 season.

Considering actions that are high farm system change/cost requires extensive analysis, as these changes impact:

- Income
- Costs
- Capital requirements
- Profitability
- Stock and pasture/feed management
- Skills required to operate changed farm system.

Partial budgeting was utilised to explore the high-level impact of farm system change on capital investment and farm working expenses. This method has been chosen so farmers can follow the approach and relate it to their own situation. Further analysis should be undertaken before finalising any decisions, using a model such as Farmax to analyse farm system feasibility and detailed budget/cashflow implications completed.

7.1 Mitigation scenarios modelled

Each option below has been modelled separately and compared against the 2020/21 season.

Option 1: Retire sidling to capture water emerging in springs to treat water flowing from the top terrace

Description

The highest susceptibility for phosphorus loss (DRP and PP) on the property is on the three ha steep sidling.

There is the opportunity to repurpose the sidling by retiring the area from grazing and develop a wetland area along the base to capture nutrient runoff / seepage. This would regenerate the terrace spring and wetland system that once occupied this area so as to provide a treatment area. This treatment area could be designed to intercept contaminant pathways from the terrace by drawing water seepages from the top terrace and discharging from the terrace riser (sidling) into a wetland treatment area (Figure 14). Figure 15 to 17 show photos of the current seep and terrace area.

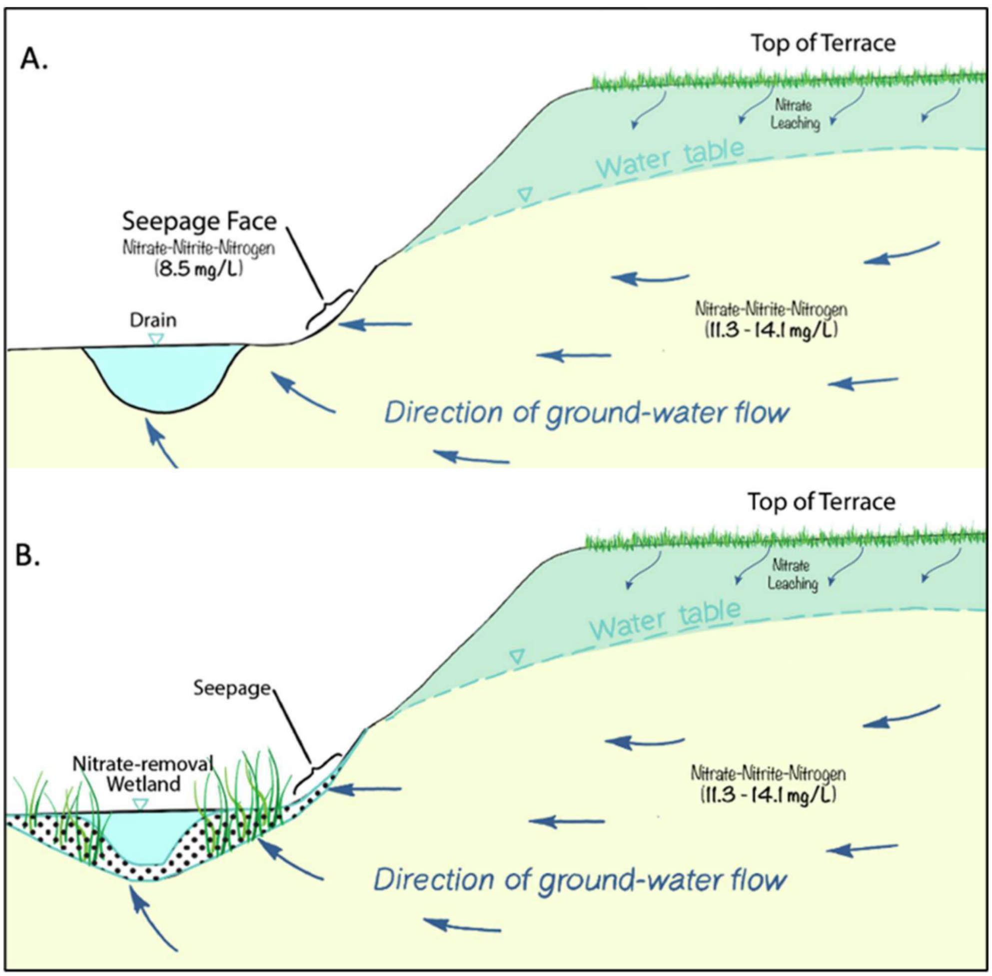


Figure 14. A. Current landscape setting: high nitrate springs/seeps and groundwater flow are intercepted by an artificial drain and conducted to the surface water network. B. Proposed restoration of terrace wetland system to facilitate nitrate removal, enhance carbon storage, and biodiversity. The wetland system will be designed to intercept and mitigate the discharge of high nitrate waters from the upper terrace aquifer.

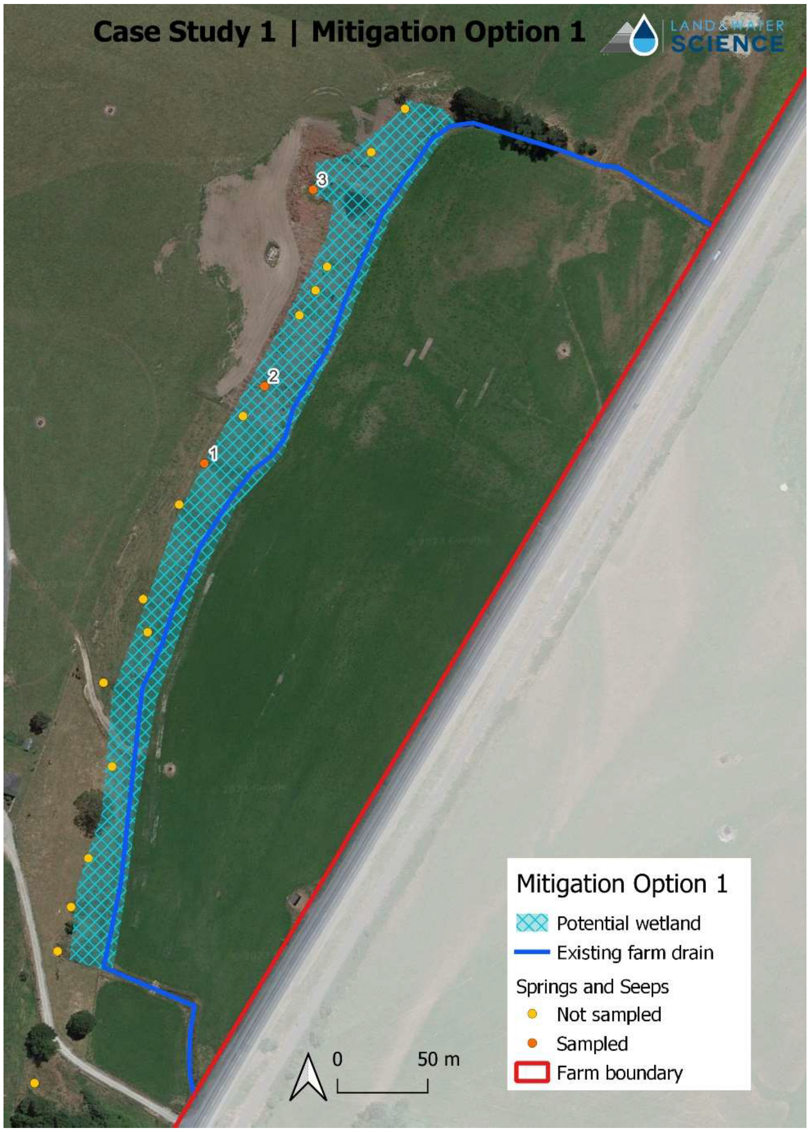


Figure 18. Potential wetland area (1.5 ha) on the sidling. Modification to the existing farm drain would be required to develop the seepage wetland system. The springs sampled are identified with sample numbers.

Impact on environmental contaminants

OverseerFM modelling has estimated the environmental impact of retiring three ha of sidling and installing a 1.5 ha wetland with a 60 ha catchment area (Table 8).

Table 8. OverseerFM estimated impact of mitigation for Option 1.

Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change
-	-	8% decrease	-	4% decrease

Compared with the Year End 2020/21

Farm system

The sidling has low pasture productivity therefore retiring it will have little impact on the farm system/feed supply.

Financial impact

The cost of wetland establishment has not been calculated and will require a site-specific assessment, there is rough estimated cost of $20,000.

Other impacts

The site specific assessment for wetland establishment should also include a risk assessment for Health and Safety, in this case the farmer is concerned about the proximity of the house and the risk to children).

This case study shows the potential for an integrated catchment approach to reducing contaminant losses from the Edendale terrace. The terrace extends alongside the Mataura River for 45 km with springs and seeps along the edge (Figure 19).

Although the proposed wetland will sequester carbon, the impact of this has not been calculated.

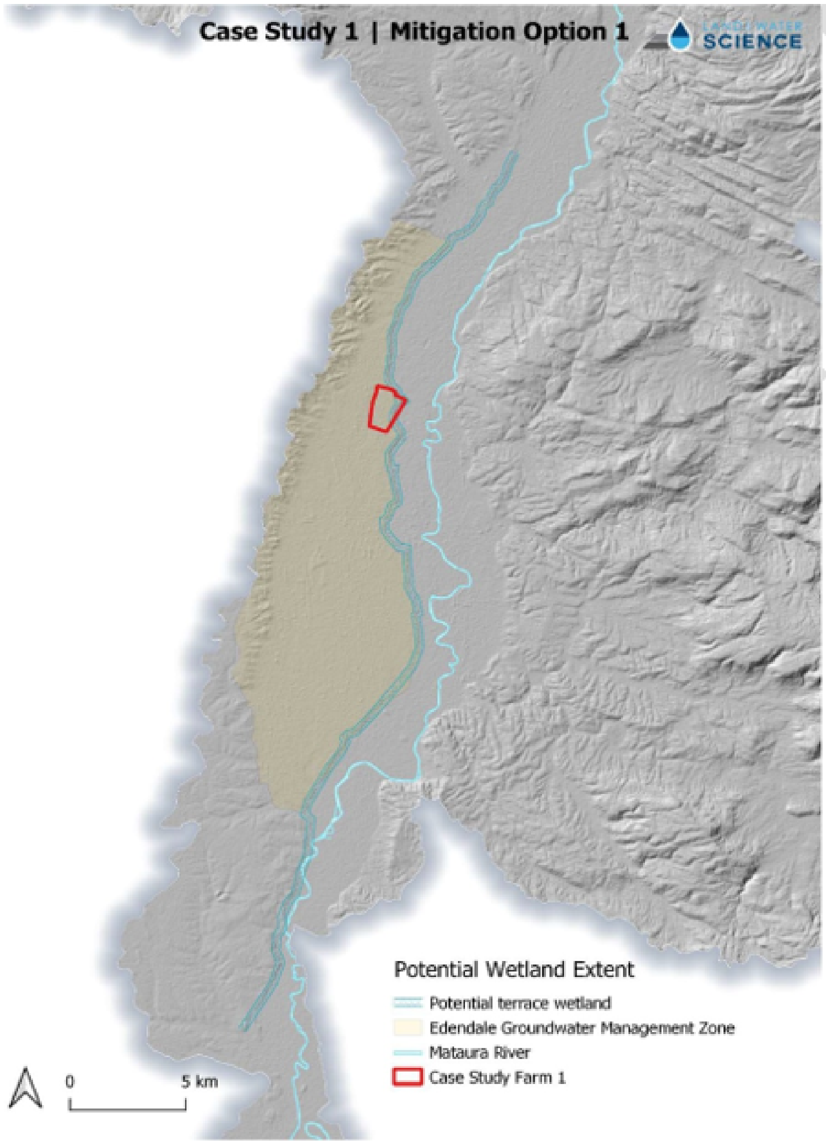


Figure 19. Location for potential terrace wetland in the Mataura catchment.

Option 2: Target critical source area on north-western boundary adjacent to a drain leading to Ota Creek

Description

There is a small area of increased susceptibility for a range of contaminants on the northwest boundary of the property which is adjacent a drainage channel that connects to Ota Creek.

Options to reduce/mitigate contaminate loss include:

- Manage any critical source areas by increasing the buffer zone to the drainage channel in this area
- Ensure the tile/drain system is operating to reduce wet periods on these soils
- Investigating tile drainage treatment options prior to discharge into the drainage channel, including wetland/sediment traps
- Minimising grazing on these soils when it is wet and avoid pugging
- Ensuring no significant periods of bare soil, especially during winter cropping.

Impact on Environmental Contaminants

If the riparian area adjacent to the drainage channel is increased by 10m for 500m with a 25 ha catchment area. Using riparian buffer performance estimates [10] (Table 9).

Table 9. Estimated impact of mitigation for Option 2.

Total GHG change	Nitrous oxide change	N loss change	N Surplus change	P loss change
-	-	5% decrease	-	2% decrease

Compared with the Year End 2020/21

Planting the riparian area with deeper rooting plants to remove nitrate from the subsurface flow would provide further mitigation.

Farm system

Increasing the buffer zone would result in the loss of 0.5 ha of productive land and extra purchased in supplement .

Financial impact

The net financial cost of this option is $3,600 per annum (in additional purchased in supplement).

Other impacts

The cost of moving the existing fencing infrastructure has not been calculated.

[10] McKergow, L., Matheson, F., Goeller, B., Woodward, B. (2022) Riparian buffer design guide, Water quality design and performance estimates. Design and performance estimates. NIWA, Hamilton, New Zealand.

Option 3: Target bottom terrace

The lower terrace has a soil that is slowly permeable and imperfectly to poorly drained and thus is more susceptible to nitrous oxide generation and phosphorus/*E. coli* loss. Options to reduce/mitigate these contaminants include:

- Ensuring the tile/drain system is operating to reduce wet periods on these soils
- Minimising grazing on these soils when it is wet to avoid pugging
- Reducing nitrogen applied as synthetic N or whey
- Ensuring there are no significant periods of bare soil, especially during winter cropping.

Targeting the bottom terrace and reducing grazing frequency was not considered because:

- This would involve some farm systems change and as the bottom terrace is a small part of this farm (less than 7 percent) the impact is not warranted
- There is a potential for perverse outcomes – e.g., reducing the grazing frequency on the bottom terrace would increase intensity on the top terrace (unless stock numbers are decreased).

Option 4: Farm systems bundle of low cost mitigations to reduce contaminant loadings

Following discussions during the site visit a bundle of farm system changes to reduce contaminant loadings was considered as a 'package'.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM (Table 10):

- Changing all in-shed feeding to a lower crude protein feed (eg barley grain)
- Reducing the Olsen P to 35 and fertiliser applied at maintenance
    - o Whey applied at maintenance for P
    - o Phosphate fertiliser in the form of a low solubility phosphate fertiliser
- Applying SustaiN for nitrogen instead of urea
- Reducing synthetic nitrogen (to 130 kg N/ha) on effluent area to partially take account of nitrogen applied in effluent
- Reducing synthetic nitrogen when applying whey to partially allow for the N in whey.

Table 10. OverseerFM estimated impact of mitigation for Option 4.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
3% decrease	5% decrease	5% decrease	7% decrease	7% decrease

Compared with the Year End 2020/21

Farm system

Currently the in-shed feeding comprises of PKE, DDG and barley grain. Replacing all in-shed feed with barley grain (which is a lower crude protein) would reduce flexibility in supplement purchase decisions (which can vary from season to season based on availability / price). Barley grain is estimated to fed at around 2 kg/cow/day this should not be an issue for animal health.

Reducing phosphate fertiliser applications and applying phosphate fertiliser in a low solubility phosphate form would have minimal impact in terms of system / cost as little phosphate fertiliser is applied. Most of the phosphate applied is in the form of whey (which has no cost to the farmer for product or application). An Olsen P of 35 is within the range to sustain current pasture production.

The lower synthetic nitrogen application on the effluent and whey areas is likely to have minimal impact on pasture production due to the N surplus estimated on these areas.

Financial impact

At current prices the cost of removing DDG and PKE and replacing with all barley gain (compared with the Year End 20/21) would be $13,200.

Applying SustaiN instead of urea, and reducing synthetic nitrogen applied on the areas where effluent / whey is applied will reduce the synthetic nitrogen cost by $6,780 (compared with the Year End 20/21).

The net cost of this option is $6,420.

Other impacts

The impact on future agricultural emissions pricing has not been calculated.

Option 5: Farm systems mitigation – use plantain in pasture sward

Description

Research on plantain has shown that a reduction in nitrate leaching of 20 to 60 percent is possible in pastures containing 30 to 50 percent plantain.[11] More work is underway to gain a greater understanding of the potential for plantain to reduce nitrous oxide emissions. One experiment has shown that in pastures with 30 percent plantain nitrous oxide emissions in urine patches is reduced by 53 percent. OverseerFM modelling reflects some of the mitigation properties of plantain and when more data becomes available it is likely there will be even more reduction. On some farms persistence and palatability[12] has been found to be an issue.

[11] https://www.dairynz.co.nz/feed/crops/plantain/environmental-benefits-of-plantain/

[12] https://www.dairynz.co.nz/media/5794666/plantain-dairy-grazing-management_a4-web-booklet.pdf

Impact on Environmental Contaminants

Estimated by modelling 20 percent plantain in the pasture sward in OverseerFM (Table 11).

Table 11. OverseerFM estimated impact of mitigation for Option 5.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
<1% decrease	4% decrease	16% decrease	<1% decrease	No change

Compared with the Year End 2020/21

Farm system

The practicality of using plantain in pastures in Southland is in the early stages. It is likely a third of the farm would have to be resown each year to maintain an average of 20% plantain in the sward.

Managing weeds in pastures that contain plantain can be challenging as plantain is susceptible to some of the common weed sprays.

Financial impact

If plantain is broadcast to a third of the farm each year, cost for seed would be approximately $8,750 per annum. It is assumed the seed would be broadcast with fertilizer, so no additional cost for broadcasting.
The net cost of this option is $8,750 per annum.

Other impacts

The impact on future agricultural emissions pricing has not been calculated.

Option 6: Decrease stock numbers (by 7 percent)

Description

Decreasing the number of cows peak milked to 465 cows (a reduction of 35 cows) will require increased skill/focus on pasture management to maintain pasture quality and per cow production. Maintaining the current high level of per cow production (500 kg ms / cow / yr) would be challenging.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM, reduced by 35 cows and less imported supplement (Table 12).

Table 12. OverseerFM estimated impact of mitigation for Option 6.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
2% decrease	5% decrease	8% decrease	6% decrease	1% decrease

Compared with the Year End 2020/21

Farm system

A crucial aspect for this option is that lower stocking rates require increased skill/focus on pasture management in order to maintain pasture quality and per cow production. If pasture quality is lost, it can have a significant impact on production.

Considering actions that are significant farm system change/cost require extensive analysis, as these impact:

- Income
- Costs
- Capital requirements
- Profitability
- Stock and pasture/feed management
- Skills required to operate the changed farm system

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses, see appendix 2 for further detail.

The net cost of this option is $92,600 per annum.

Other impacts

The impact on future agricultural emissions pricing has not been calculated.

Option 7A: Off paddock facilities for winter (loafing barn)

Description

It is assumed that a loafing style barn is built for 525 cows and all cows will be wintered at home rather than the current practice of grazing off-farm for June and July. It is also assumed that the barn is used as a calving pad for August and September at the same amount and with the same feed as the current calving pad. No cows are milked into the winter. More plant and machinery and additional effluent storage may also be required. An extra 315 t DM in silage is purchased. Synthetic nitrogen applications are reduced in recognition of the increase in nitrogen purchased in feed being applied as effluent and solids.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM, all cows wintered at home in a loafing barn (Table 13). Note – the cows were previously wintered off, so stock units are effectively increasing.

Table 13. OverseerFM estimated impact of mitigation for Option 7A.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
9% increase	5% increase	2% decrease	10% increase	_

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system. The barn system may also provide flexibility during adverse weather at other times in the season.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses, see appendix 3 for further detail.
The net cost of this option is $79,560 per annum.

Other impacts

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether any additional effluent storage is required and its cost.

It is also recognised that bringing a significant amount of nutrients onto a farm can mean additional challenges in managing nutrients for environmental and animal health risk.

Option 7B: Off paddock facilities for winter (with effluent and solids exported)

Description

In addition to option 7A (a loafing style barn is built for 525 cows and all cows will be wintered at home and the barn is used as a calving pad for August and September), it is assumed that all effluent and solids from the barn are exported. Ideally effluents / solids would be applied to where the supplement was harvested for the barn to return nutrients harvested. In this option it is assumed that effluent and solids are exported to the adjacent lease block (and that this is harvested for supplement). Imported feed has been priced taking into account the value of the nutrients returned.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM, all cows wintered at home in a loafing barn with effluent and solids exported (Table 14). Note – the cows were previously wintered off, so stock units are effectively increasing.

Table 14. OverseerFM estimated impact of mitigation for Option 7B.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
8% increase	4% increase	4% decrease	5% increase	–

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system aligned with integrating it within the adjacent lease block. The barn system may also provide flexibility during adverse weather at other times in the season.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses, see appendix 4 for further detail.

The net cost of this option is $79,560 per annum plus cost of moving effluent and solids (dependent on distance exported to).

Other impacts

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether any additional effluent storage is required and its cost.
- The cost of exporting effluent and solids (will depend on the distance the product needs to be transported)

Option 8: Freestall barn with extended lactation

Description

It is assumed that a freestall style barn is built for 525 cows (410 mature cows and 115 R2 heifers) and all cows will be wintered at home rather than grazed off-farm for June and July, which is the current practice. It is also assumed that the barn is used as a calving pad for August and September (at the same amount and with the same feed) as the current calving pad. Lactation is extended and 410 cows are milked until 20 June while effluent is not applied in June. More plant and machinery and effluent storage may be required and an extra 392 t DM in silage is purchased. Synthetic nitrogen applications are reduced to take account of increased nitrogen being applied as effluent and solids as purchased in feed.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM based on all cows wintered at home in a freestall barn with lactation extended until 20 June (Table 15). Note – the cows were previously wintered off-farm so, effectively, stock units are increasing.

Table 15. OverseerFM estimated impact of mitigation for Option 8.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
16% increase	3% increase	_	10% increase	_

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system. The barn system may also provide flexibility during adverse weather at other times in the season.

Financial impact

Partial budgeting has been utilised to explore the high level impact of farm system change on capital investment and farm working expenses, see appendix 5 for detail.

The net cost of this option is $99,683 per annum.

Other impacts

These include:

- Extending the effluent area (above 150 kg N/ha/yr).

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether extra effluent storage is required
- Whether a discharge consent for winter milking is required and its cost.

It is also recognised that bringing a significant amount of nutrients onto a farm can mean additional challenges in managing nutrients for environmental and animal health risk.

7.2 Scenarios Aligned to Farmer Goals

Farmers tend not to make one decision in isolation, they align multiple factors with their goals. This can result in multiple changes as they work towards achieving their goals.

Scenario A - Reducing environmental impact without significant capital investment

Description

The farmer wants to understand, by aligning landscape features and the farm system how much they could reduce their environmental impact within their current farm system. The "bundle "of options selected to achieve this are:

- Option 1 – Retiring sidling to capture water emerging in springs to treat water flowing from the top terrace
- Option 2 – Targeting the critical source area on north-western boundary adjacent to the drainage channel that connects to Ota Creek
- Option 3 – Implementing a farm systems bundle of low-cost mitigations to reduce contaminant loadings
    - Changing all in-shed feeding to a lower crude protein feed (eg barley grain)
    - Reducing the Olsen P to 35 and fertiliser applied at maintenance
        - Whey applied at maintenance for P
        - Phosphate fertiliser in the form of a low solubility phosphate fertiliser
    - Applying nitrogen as SustaiN, instead of urea
    - Reducing synthetic nitrogen (to 130 kg N/ha) on effluent area to partially take account of nitrogen applied in effluent
    - Reducing the application of synthetic nitrogen recognising the N in whey
- Option 4 – Farm systems mitigation – use 20 percent plantain in the pasture sward.

Impact on Environmental Contaminants

Table 16. OverseerFM estimated impact of mitigation for Scenario A.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
4% decrease	9% decrease	31% decrease	8% decrease	13% decrease

Compared with the Year End 2020/21

Farm system

The sidling has low pasture productivity therefore retiring it will have little impact on the farm system/feed supply.

Increasing the buffer zone would result in the loss of 0.5 ha of productive land and extra purchased in supplement.
Currently the in-shed feeding comprises of PKE, DDG and barley grain. Replacing all in-shed feed with barley grain (which is a lower crude protein) would reduce flexibility in supplement purchase decisions (which can vary from season to season based on availability / price). Barley grain is fed at around 2 kg / cow / day this should not be an issue.

Reducing phosphate fertilizer applications and applying phosphate fertilizer in a low solubility phosphate form would have minimal impact in terms of system / cost as little phosphate fertilizer is applied. Most of the phosphate applied is in the form of whey (which has no cost to the farmer for product or application). An Olsen P of 35 is within the range to sustain current pasture production.

The lower synthetic nitrogen application on the effluent and whey areas is likely to have minimal impact on pasture production due to the N surplus estimated on these areas.

The practicality of using plantain in pastures in Southland is in the early stages. It is likely a third of the farm would have to be resown each year to maintain an average of 20% plantain in the sward.

Managing weeds in pastures that contain plantain can be challenging as plantain is susceptible to some of the common weed sprays.

Financial impact

The cost of wetland establishment has not been calculated and will require a site-specific assessment, there is rough estimated cost of $20,000.

The net financial cost of this option is $3,600 per annum (in additional purchased in supplement). At current prices the cost of removing DDG and PKE and replacing with all barley gain (compared with the Year End 20/21) would be $13,200.

Applying SustaiN instead of urea, and reducing synthetic nitrogen applied on the areas where effluent / whey is applied will reduce the synthetic nitrogen cost by $6,780 (compared with the Year End 20/21).

If plantain is broadcast to a third of the farm each year, cost for seed would be approximately $8,750 per annum. It is assumed the seed would be broadcast with fertilizer, so no additional cost for broadcasting.

The net cost of this option is $18,770 per annum, plus capital investment of $20,000.

Other impacts

The cost of moving the existing fencing infrastructure has not been calculated.
The impact on future agricultural emissions pricing has not been calculated.

Scenario B - Reduce environmental impact, capital investment and future proof wintering

Description

Wintering is currently off-farm with a third-party grazier; however, the farmer has been working towards future proofing their wintering system and has leased 19 ha next door since the 2020/21 season. The lease block is consented as dairy support and can winter up to 200 cows on grass. The balance of the block can be used for young stock and growing supplement crops.

A scenario has been run with the following assumptions:

- Installation a loafing style barn for 400 cows for wintering only - this gives flexibility should cow numbers decrease in the future
- Wintering off the balance of the cows on the neighbouring lease block
- Importing some silage from the neighbouring lease block
- Exporting effluent and manure from the barn to the lease block
- Plus, all options to reduce environmental impact without significant capital investment:
  - Option 1 – Retiring sidling to capture water emerging in springs to treat water flowing from the top terrace
  - Option 2 – Targeting the critical source area on north-western boundary adjacent to the drainage channel that connects to Ota Creek
  - Option 3 – Implementing a farm systems bundle of low-cost mitigations to reduce contaminant loadings
    - Changing all in-shed feeding to barley grain
    - Reducing the Olsen P to 35 and fertiliser applied at maintenance
      - Whey applied at maintenance for P
      - Phosphate fertiliser in the form of a low solubility phosphate fertiliser
    - Applying nitrogen as SustaiN instead of urea
    - Reduce synthetic nitrogen (to 130 kg N/ha) on the effluent area to partially take into account the nitrogen applied in effluent
    - Reducing synthetic nitrogen to take account of N in whey
  - Option 4 – Farm systems mitigation – use 20 percent plantain in pasture sward.

At this stage reducing cow numbers was not considered as an option because the negative financial impact of reducing cow numbers would prohibit investment in a wintering barn and the repayment of debt.

Note – to take an apples-with-apples approach the lease block has been treated as a separate enterprise environmentally and financially in the partial budget. Land use consent conditions on the lease block require that it does not incur a higher nutrient loss.

Impact on Environmental Contaminants

Table 17. OverseerFM estimated impact of mitigation for Scenario B.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
5% increase	2% decrease	31% decrease	<1% increase	8% decrease

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system aligned with integrating it within the adjacent lease block. The barn system may also provide flexibility during adverse weather at other times in the season.

The sidling has low pasture productivity therefore retiring it will have little impact on the farm system/feed supply.

Increasing the buffer zone would result in the loss of 0.5 ha of productive land and extra purchased in supplement.

Currently the in-shed feeding comprises of PKE, DDG and barley grain. Replacing all in-shed feed with barley grain (which is a lower crude protein) would reduce flexibility in supplement purchase decisions (which can vary from season to season based on availability / price). barley grain is fed at around 2 kg / cow / day this should not be an issue.

Reducing phosphate fertiliser applications and applying phosphate fertiliser in a low solubility phosphate form would have minimal impact in terms of system / cost as little phosphate fertiliser is applied. Most of the phosphate applied is in the form of whey (which has no cost to the farmer for product or application). An Olsen P of 35 is within the range to sustain current pasture production.

The lower synthetic nitrogen application on the effluent and whey areas is likely to have minimal impact on pasture production due to the N surplus estimated on these areas.

The practicality of using plantain in pastures in Southland is in the early stages. It is likely a third of the farm would have to be resown each year to maintain an average of 20% plantain in the sward.

Managing weeds in pastures that contain plantain can be challenging as plantain is susceptible to some of the common weed sprays.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses (Table 22), see appendix 6.

The net cost of this option is $79,501 per annum, plus a rough estimated capital cost of $20,000 to install the wetland.

Other impacts

These include:

- Providing flexibility to decrease cow numbers in the future

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether extra effluent storage is required

8. Conclusion

The main landscape susceptibility issue across the case study property is nitrate-nitrite- nitrogen (NNN) leaching associated with moderately to well drained loess soils. These soils overlie a strongly oxidising aquifer that is susceptible to NNN accumulation. Many wells from across the entire Edendale aquifer system, have elevated NNN concentrations that approach or exceed the current WHO guideline of 11.3 mg/L nitrogen as nitrate.

Soil nitrous oxide, PP, and *E. coli* susceptibility are of a lesser concern and mainly associated with poorly drained Jacobstown soils and the south-eastern corner of the property.

There are many options, both landscape and farm system, which could be implemented to reduce NNN losses from the farm to the underlying aquifer. Consideration needs to be given to both future and legacy losses. Specifically, NNN in the existing groundwater system immediately beneath the farm will take some time to decrease. Treatment of legacy NNN exiting the Edendale GMZ may be achieved through regeneration of the terrace spring and wetland system that once occupied the area of low-lying Jacobstown soils that form the south- eastern sector of the property.

Specific options considered for this property were:

Table 18. Mitigation options

		Net cost	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
Option 1	Retire the sidling area and establish wetlands	Approx. $20,000	-	–	8% decrease	–	4% decrease
Option 2	Target Ota Creek drainage channel critical source area	$3,600/yr	–	–	5% decrease	–	2% decrease
Option 3	Reduce grazing intensity on bottom terrace		–	–	–	–	–

		Net cost	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
Option 4	Farm systems mitigations bundle	$6,420/yr	3% decrease	5% decrease	5% decrease	7% decrease	7% decrease
Option 5	20% plantain	$8,750/yr	<1% decrease	4% decrease	16% decrease	<1% decrease	–
Option 6	Decrease stock numbers by 7%	$92,600/yr	2% decrease	5% decrease	8% decrease	6% decrease	1% decrease
Option 7a	Loafing barn	$79,560/yr	9% increase	5% increase	2% decrease	10% increase	–
Option 7b	Loafing barn (effluent exported)	$79,560/yr plus costs of exporting effluent	8% increase	4% increase	4% decrease	5% increase	–
Option 8	Freestall barn for extended lactation and winter	$99,683/yr	16% increase	3% increase	–	10% increase	–

Taking into account the farmers goals (without significant capital investment), the following scenario of landscape and farm systems mitigations was developed:

Table 19 – Combined mitigations without significant capital investment

		Net cost	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
Scenario A	Retire sidling Target critical source area Farm systems mitigations bundle 20% plantain	$18,770 per annum plus Approx. $20,000 for wetland	4% decrease	9% decrease	31% decrease	8% decrease	13% decrease

Taking into account the farmers goals (with significant capital investment), the following scenario of landscape and farm systems mitigations was developed:

Table 20 – Combined mitigations with significant capital investment

		Net cost	Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
Scenario B	Wintering barn Effluent exported to lease block Retire sidling Target critical source area Farm systems mitigations	$79,501 per annum plus Approx. $20,000 for wetland	5% decrease	2% decrease	31% decrease	<1% increase	8% decrease

	bundle 20% plantain						

Reducing current and future NNN losses requires consideration of the farm system and the timing of losses of NNN from the soil to the aquifer. Any activities that reduce NNN build up in the soil, prior to the winter months when water moves from the soil to the aquifer will have a positive net effect on water quality.

Collectively, a terrace wetland system combined with efforts to reduce excess NNN in the soil prior to the winter months when NNN is lost from the farm system offers the greatest resilience. It combines both landscape and land use decision-making to design a mitigation strategy that is directly targeting the environmental and regulatory risks to the property. The regeneration of the terrace-wetland system would also address issues of phosphorus, *E. coli*, and soil nitrous oxide losses over the long-term with the potential to sequester carbon as part of an offset.

Further reduction in environmental impact beyond what has been modelled is likely to require:

- Further and new technologies (landscape and farm system)
- Decrease in intensity (e.g., reduction in cow numbers)
- Land use change to a less intensive farm system.

Appendices

Appendix 1 - State of the Mataura Catchment

Surface Water

There are 18 sites in the Mataura River Catchment that water quality is measured at with very good to good water quality in the upper catchment which declines down catchment as the cumulative effects of land use activities take effect. Overall, surface water quality in the Mataura Catchment is characterised by elevated nitrogen, phosphorus, sediment, *E. coli*, and degraded macroinvertebrate community index (MCI). A recent report by LWP estimated the nutrient load reductions required to meet catchment objectives are 79 percent for total nitrogen, and 58 percent for total phosphorus[13]. The Mataura Freshwater Management Unit was the worst for suspended sediment with 61 percent of sites in D band (poor) in 2019 and only 35 percent of sites meeting visual clarity objectives[14].

Groundwater

Across the Edendale GMZ many areas show moderate to very high nitrate concentrations. The main pathway for contamination to reach groundwater is through deep drainage and artificial drainage. Nitrate can accumulate in the aquifer due to limited dilution from low nutrient surface waters, the relatively slow rate of groundwater throughflow and the oxidising conditions present in the unconfined aquifer meaning natural removal rates are low. Microbial contamination is also elevated in some areas. Typically, the Edendale GMZ has a naturally high ability to remove microbial contaminants due to the presence of slowly permeable loess deposits underlying the soil profile and the relatively deep water table. However, the use of soak holes to augment surface drainage has the potential to allow contaminants to bypass the soil zone and rapidly infiltrate to groundwater. Phosphorus concentrations are low in the Edendale GMZ and are unlikely to be an issue due to the ability of the overlying soil to retain P.

In the Lower Mataura GMZ localised areas of elevated nitrate, phosphorus and microbial contamination impact groundwater quality. Generally, nitrate is less of a risk across this zone as the redox state of the groundwater is mixed to reducing, reflecting the reducing conditions in the soil zone and the shallow depth of organic-rich lignite measure sediments. These factors increase the potential for denitrification to naturally remove nitrate in shallow groundwater. However, reducing conditions also increase phosphorus mobility and although concentrations are generally low across the Lower Mataura GMZ there are elevated phosphorus levels where reducing conditions are found. Where there are localised areas of oxic groundwater, nitrate concentrations are elevated and phosphorus concentrations are low. Groundwater quality in this zone may also be compromised by elevated iron and manganese concentrations that occur naturally in reducing aquifers.

[13] Snelder, T. (2020). Assessment of Nutrient Load Reductions to Achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties: To inform the Southland Regional Forum process. Prepared for Environment Southland by Land and Water People.

[14] Norton, N., Wilson, K., Rodway, E., Hodson, R., Roberts, K. L., Ward, N., O'Connell-Milne, S., DeSilva, N., & Greer, M. (2019). Current environmental state and the "gap" to draft freshwater objectives for Southland. *Environment Southland Technical Report*, *12*.

Toetoes Estuary

Currently the Toetoes Estuary where Mataura River discharges at Fortrose is considered to be in poor condition. Toetoes Estuary has areas that are currently assessed as D band (poor) for macroalgae, Gross Eutrophic Zone (GEZ), mud content and sediment oxygen levels. recent NIWA report stated that most (~95 percent) of the nutrient load to the estuary comes from the Mataura River[15]. The nutrients from the Mataura River dominate the Mataura arm and lower estuary, but also supply ~ 38 percent of total nitrogen (TN) and total phosphorus (TP) in the Titiroa arm of the estuary. Overall, a reduction in nutrient and sediment inputs is needed to improve the estuary classification above D band (poor). Faecal bacteria also needs to be reduced to at least C band (fair) or better at the estuary monitoring sites.

[15] Plew, D., Dudley, B., Shankar, U. (2020) Eutrophication susceptibility assessment of Toetoes (Fortrose) Estuary. NIWA Client Report, 2020070CH: 58.

Appendix 2 -

Option 6: Decrease stock numbers (by 7 percent)

Description

Decreasing the number of cows peak milked to 465 cows (a reduction of 35 cows) will require increased skill/focus on pasture management to maintain pasture quality and per cow production. Maintaining the current high level of per cow production (500 kg ms / cow / yr) would be challenging.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM, reduced by 35 cows and less imported supplement (Table 21).

Table 21.. OverseerFM estimated impact of mitigation for Option 6.

Total GHG change	**Nitrous oxide change**	**N loss change**	**N surplus change**	**P loss change**
2% decrease	5% decrease	8% decrease	6% decrease	1% decrease

Compared with the Year End 2020/21

Farm system

A crucial aspect for this option is that lower stocking rates require increased skill/focus on pasture management in order to maintain pasture quality and per cow production. If pasture quality is lost, it can have a significant impact on production.

Considering actions that are significant farm system change/cost require extensive analysis, as these impact:

- Income
- Costs
- Capital requirements
- Profitability
- Stock and pasture/feed management
- Skills required to operate the changed farm system

Financial impact

Partial budgeting has been utilised to explore the high level impact of farm system change on capital investment and farm working expenses (Table 22).

This method has been chosen so farmers can follow the approach and relate it to their own situation. Before finalising decisions further analysis should be undertaken using a model such as Farmax. This will ensure analysis of farm system feasibility and provide detailed budget/cashflow implications.

Table 22. Partial budget (decreasing by 35 cows).

Increased Income • None	Reduced income Milk 35 cows x 500 kg ms/cow x $8 = $140,000 Stock sales 8 cull cows @ $700/cow = $5,600
Reduced costs Variable per cow costs $816 x 35 = $28,560 Decreased purchased in supplement 170 T DM @45c/kg DM = $76,500 Decreased interest cost (on cows sold) 35 cows x $1800 x 8% = $5,040	Increased costs Supplement making at home 170 t DM @ 17 c/kg DM = $28,900 Replacing supplement nutrients with fertiliser 170 t DM x 166 = $28,220
$110,100	**$202,720**

The net cost of this option is $92,620 per annum.

Other impacts

The impact on future agricultural emissions pricing has not been calculated.

Notes to partial budget calculations

Variable per cow costs (per cow/yr) – winter grazing $369, young stock (25 percent RR) $241, animal health $90, breeding $60, shed expenses $21, electricity $35. Non

variable costs – staff, vehicle, R & M, admin, standing charges.

Nutrients previously brought to the property in purchased in supplement, fertiliser prices at November 2022. Assumes nutrients are required and therefore have a value.

27 kg K/t DM x $2.90 = $78.30
3 kg P/t DM x $5.46 = $16.38
23 kg K/t DM x $3.10 = $71.30
$166/t DM

Appendix 3 -

Option 7A: Off paddock facilities for winter

Description

It is assumed that a loafing style barn is built for 525 cows and all cows will be wintered at home rather than the current practice of grazing off-farm for June and July. It is also assumed that the barn is used as a calving pad for August and September at the same amount and with the same feed as the current calving pad. No cows are milked into the winter. More plant and machinery and additional effluent storage may also be required. An extra 315 t DM in silage is purchased. Synthetic nitrogen applications are reduced in recognition of the increase in nitrogen purchased in feed being applied as effluent and solids.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM, all cows wintered at home in a loafing barn (Table 23). Note – the cows were previously wintered off, so stock units are effectively increasing.

Table 23. OverseerFM estimated impact of mitigation for Option 7A.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
9% increase	5% increase	2% decrease	10% increase	–

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system. The barn system may also provide flexibility during adverse weather at other times in the season.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses (Table 24). This method has been chosen so farmers can follow the approach and relate it to their own situation. Before finalising decisions, further analysis should be undertaken using a model such as Farmax. This will ensure analysis of farm system feasibility and provide detailed budget/cashflow implications.

Table 24. Partial budget (wintering all cows at home in loafing barn).

Increased Income ● None	Reduced income ● None
Reduced costs Winter grazing off – 525 cows x 60 days x $43/week = $193,500 Wintering cartage – 525 cows x $60 return = $31,500 Fertiliser savings (from extra purchased in feed into barn), 315 t DM x $166/t DM = $52,290	Increased costs Loafing barn $M1.2 at 8% = $96,000 Depreciation on loafing barn (25 yrs straight line) $48,000 Feed – 525 cows x 10 kgDM/cow/day x 45c/kgDM x 60 days = $141,750 Running cost and R&M (machinery, barn) = $37,500 Bedding material ($64/cow) = $33,600
$277,290	**$356,850**

Overall, a reduction in profitability of **$79,560/year.**

Other impacts

These include:

- Control over wintering
- An increase of overall stock units (RSU) of eight percent as cows were previously wintered off-farm.

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether any additional effluent storage is required and its cost.

It is also recognised that bringing a significant amount of nutrients onto a farm can mean additional challenges in managing nutrients for environmental and animal health risk.

Notes to partial budget

Fertiliser – extra 315 T DM feed purchased.

Fertiliser saving[16] – nutrients in the extra 315 t DM silage purchased, fertiliser prices at November 2022 used. Assumes nutrients are required and therefore have a value.

27 kg N/t DM x $2.90 = $78.30
3 kg P/t DM x $5.46 = $16.38
23 kg K/t DM x $3.10 = $71.30
$166/t DM

[16] https://www.dairynz.co.nz/media/5795018/facts_and_figures_dnz30- 001_updated_dec_2021_v6.pdf

Appendix 4 -

Option 7B: Off paddock facilities for winter (with effluent and solids exported)

Description

In addition to option 7A (a loafing style barn is built for 525 cows and all cows will be wintered at home and the barn is used as a calving pad for August and September), it is assumed that all effluent and solids from the barn are exported. Ideally effluents / solids would be applied to where the supplement was harvested for the barn to return nutrients harvested. In this option it is assumed that effluent and solids are exported to the adjacent lease block (and that this is harvested for supplement).

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM, all cows wintered at home in a loafing barn with effluent and solids exported (Table 25). Note – the cows were previously wintered off, so stock units are effectively increasing.

Table 25. OverseerFM estimated impact of mitigation for Option 7B.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
8% increase	4% increase	4% decrease	5% increase	–

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system aligned with integrating it within the adjacent lease block. The barn system may also provide flexibility during adverse weather at other times in the season.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses (Table 26), This method has been chosen so farmers can follow the approach and relate it to their own situation. Before finalising decisions further analysis should be undertaken using a model such as Farmax. This will ensure analysis of farm system feasibility and provide detailed budget/cashflow implications.

Table 26. Partial budget (wintering all cows at home in loafing barn with effluent and solids exported).

Increased Income • None	Reduced income • None
Reduced costs Winter grazing off – 525 cows x 60 days x $43/week = $193,500 Wintering cartage – 525 cows x $60 return = $31,500	Increased costs Loafing barn $M1.2 at 8% = $96,000 Depreciation on loafing barn (25 yrs straight line) $48,000 Feed (priced net of fertilizer cost)– 525 cows x 10 kgDM/cow/day x 28.4c/kgDM x 60 days = $89,460 Running cost and R&M (machinery, barn) = $37,500 Bedding material ($64/cow) = $33,600
$225,000	**$304,560**

The net cost of this option is $79,560 per annum.

Other impacts

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether any additional effluent storage is required and its cost.
- The cost of exporting effluent and solids (will depend on the distance the product needs to be transported)

Notes to partial budget

Feed priced net of fertilizer – 45c kg DM – 16.6c/kg DM in fertilizer returned = 28.4c/kg DM

Appendix 5 -

Option 8: Freestall barn with extended lactation

Description

It is assumed that a freestall style barn is built for 525 cows (410 mature cows and 115 R2 heifers) and all cows will be wintered at home rather than grazed off-farm for June and July, which is the current practice. It is also assumed that the barn is used as a calving pad for August and September (at the same amount and with the same feed) as the current calving pad. Lactation is extended and 410 cows are milked until 20 June while effluent is not applied in June. More plant and machinery and effluent storage may be required and an extra 392 t DM in silage is purchased. Synthetic nitrogen applications are reduced to take account of increased nitrogen being applied as effluent and solids as purchased in feed.

Impact on Environmental Contaminants

Estimated by modelling in OverseerFM based on all cows wintered at home in a freestall barn with lactation extended until 20 June (Table 27). Note – the cows were previously wintered off-farm so, effectively, stock units are increasing.

Table 27. OverseerFM estimated impact of mitigation for Option 8.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
16% increase	3% increase	_	10% increase	_

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system. The barn system may also provide flexibility during adverse weather at other times in the season.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses (Table 28). This method has been chosen so farmers can follow the approach and relate it to their own situation. Before finalising decisions further analysis should be undertaken using a model such as Farmax. This will ensure analysis of farm system feasibility and provide detailed budget/cashflow implications.

Table 28. Partial budget (wintering all cows at home in loafing barn).

Increased Income 10920 kg ms x $8 = $87,360	Reduced income • None
Reduced costs Winter grazing off - 525 cows x 60 days x $43/week = $193,500 Wintering cartage – 525 cows x $60 return = $31,500 Fertiliser savings (from extra purchased in feed into barn) 392 t DM x $166/t DM = $65,072	Increased costs Freestall barn $M2.2 at 8% = $176,000 Depreciation on barn (25 yrs straight line) $88,000 Feed – 525 cows x 10 kgDM/cow/day x 45c/kgDM x 60 days = $141,750 410 cows lactating x 8.5 kg DM above maintenance x 20 days x 45c/kg DM = $31,365
	Running cost and R&M (machinery, barn) = $40,000
$377,432	**$477,115**

The net cost of this option is $99,683 per annum.

Other impacts

These include:

- Control over wintering
- An increase of overall stock units (RSU) of 11 percent as cows were previously wintered off-farm and lactation is extended
- Extending the effluent area (above 150 kg N/ha/yr).

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether extra effluent storage is required
- Whether a discharge consent for winter milking is required and its cost.

It is also recognised that bringing a significant amount of nutrients onto a farm can mean additional challenges in managing nutrients for environmental and animal health risk.

Notes to partial budget

Fertiliser – extra 392 T DM feed purchased

Fertiliser saving[17] – nutrients in the extra 392 t DM silage purchased, fertiliser prices at November 2022 used. Assumes nutrients are required and therefore have a value

27 kg N/t DM x $2.90 = $78.30
3 kg P/t DM x $5.46 = $16.38
23 kg K/t DM x $3.10 = $71.30
$166/t DM

[17] https://www.dairynz.co.nz/media/5795018/facts_and_figures_dnz30- 001_updated_dec_2021_v6.pdf

Appendix 6 -

Scenario B - Reduce environmental impact, capital investment and future proof wintering

Description

Wintering is currently off-farm with a third-party grazier, however, the farmer has been working towards future proofing their wintering system and has leased 19 ha next door since the 2020/21 season. The lease block is consented as dairy support and can winter up to 200 cows on grass. The balance of the block can be used for young stock and growing supplement crops.

A scenario has been run with the following assumptions:

- Installation a loafing style barn for 400 cows for wintering only - this gives flexibility should cow numbers decrease in the future
- Wintering off the balance of the cows on the neighbouring lease block
- Importing some silage from the neighbouring lease block
- Exporting effluent and manure from the barn to the lease block
- Plus, all options to reduce environmental impact without significant capital investment:
    - Option 1 – Retiring sidling to capture water emerging in springs to treat water flowing from the top terrace
    - Option 2 – Targeting the critical source area on north-western boundary adjacent to the drainage channel connecting to Ota Creek
    - Option 3 – Implementing a farm systems bundle of low-cost mitigations to reduce contaminant loadings
        - Changing all in-shed feeding to barley grain
        - Reducing the Olsen P to 35 and fertiliser applied at maintenance
            - Whey applied at maintenance for P
            - Phosphate fertiliser in the form of a low solubility phosphate fertiliser
        - Applying nitrogen as SustaiN instead of urea
        - Reduce synthetic nitrogen (to 130 kg N/ha) on the effluent area to partially take into account the nitrogen applied in effluent
        - Reducing synthetic nitrogen to take account of N in whey
    - Option 4 – Farm systems mitigation – use 20 percent plantain in pasture sward.

At this stage reducing cow numbers was not considered as an option because the negative financial impact of reducing cow numbers would prohibit investment in a wintering barn and the repayment of debt.

Note – to take an apples-with-apples approach the lease block has been treated as a separate enterprise environmentally and financially in the partial budget. Land use consent conditions on the lease block require that it does not incur a higher nutrient loss.

Impact on Environmental Contaminants

Table 29. OverseerFM estimated impact of mitigation for Scenario B.

Total GHG change	Nitrous oxide change	N loss change	N surplus change	P loss change
5% increase	2% decrease	31% decrease	<1% increase	8% decrease

Compared with the Year End 2020/21

Farm system

This option would provide control over wintering, however there is an increased day to day workload over the winter period (compared with the current grazing off). New skills may be required to manage a barn system and the nutrients generated within this system aligned with integrating it within the adjacent lease block. The barn system may also provide flexibility during adverse weather at other times in the season.

The sidling has low pasture productivity therefore retiring it will have little impact on the farm system/feed supply.

Increasing the buffer zone would result in the loss of 0.5 ha of productive land and extra purchased in supplement.

Currently the in-shed feeding comprises of PKE, DDG and barley grain. Replacing all in-shed feed with barley grain (which is a lower crude protein) would reduce flexibility in supplement purchase decisions (which can vary from season to season based on availability / price). Barley grain is fed at around 2 kg / cow / day this should not be an issue.

Reducing phosphate fertilizer applications and applying phosphate fertilizer in a low solubility phosphate form would have minimal impact in terms of system / cost as little phosphate fertilizer is applied. Most of the phosphate applied is in the form of whey (which has no cost to the farmer for product or application). An Olsen P of 35 is within the range to sustain current pasture production.

The lower synthetic nitrogen application on the effluent and whey areas is likely to have minimal impact on pasture production due to the N surplus estimated on these areas.

The practicality of using plantain in pastures in Southland is in the early stages. It is likely a third of the farm would have to be resown each year to maintain an average of 20% plantain in the sward.

Managing weeds in pastures that contain plantain can be challenging as plantain is susceptible to some of the common weed sprays.

Financial impact

Partial budgeting has been utilised to explore the high-level impact of farm system change on capital investment and farm working expenses (Table 30). This method has been chosen so farmers can follow the approach and relate it to their own situation. Before finalising decisions further analysis should be undertaken using a model such as Farmax. This will ensure analysis of farm system feasibility and provide detailed budget/cashflow implications.

Table 30. Partial budget (wintering 400 cows at home in loafing barn).

Increased Income • None	Reduced income • None
Reduced costs Winter grazing off - 400 - cows x 60 days x $43/ week = $147,429 Wintering cartage – 400 cows x $60 return = $24,000 Fertiliser savings (from extra purchased in feed into barn) 240 t DM x $166/ tDM = $39,840 Reducing nitrogen applied and applying SustaiN = $6,780	Increased costs Barn $915K at 8% = $73,200 Depreciation (25 yrs straight line) = $36,600 Feed purchased – 240 t DM @ 45c/kg DM = $108,000 Running cost and R&M (machinery, barn) = $28,600 Bedding material ($64/cow) = $25,600 Extra feed (reduced area of 0.5 ha in increased buffer zone – Ota Creek drain) = $3600 All barley grain = $13200 Under sowing plantain into 1/3 of farm every year = $8,750
$218,049	**$297550**

The net cost of this option is $79,501 per annum, plus a rough estimated capital cost of $20,000 to install the wetland.

Other impacts

These include:

- Providing flexibility to decrease cow numbers in the future

The following have not been calculated:

- The impact on future agricultural emissions pricing
- The potential for extra staff costs over the winter
- Whether additional machinery is required and its cost
- Whether extra effluent storage is required

Notes to calculations

Fertiliser – extra 240 T DM feed purchased.

Fertiliser saving[18] – nutrients in the extra 240 t DM silage purchased, fertiliser prices at November 2022 used. Assumes nutrients are required and therefore have a value.

27 kg N/t DM x $2.90 = $78.30
3 kg P/t DM x $5.46 = $16.38
23 kg K/t DM x $3.10 = $71.30
$166/t DM

[18] https://www.dairynz.co.nz/media/5795018/facts_and_figures_dnz30-001_updated_dec_2021_v6.pdf

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