Lake Midgley

03/05/2024

NRC Lake Number: 257

Habitat size

Connectivity

Buffering

Water quality

Aquatic vegetation diversity

Aquatic vegetation integrity

Endangered species

Presence of key species

LakeSPI score

ECOLOGICAL VALUE SCORE

6 /20

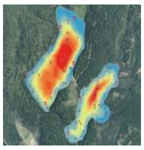
Overall Rank: Moderate

Key impact	Management action
Eutrophication: There are signs of nutrient enrichment from the pasture dominant catchment.	Develop a farm environment plan and use the management tool box for immediate interventions.
Poor riparian margins: Majority of the riparian margin is bare and unfenced.	Exclude stock and densely plant the riparian margins with native species.
Grass carp: Grass carp have eaten all the submerged vegetation.	Remove the remaining grass carp.
Invasive Species: Grass carp are an invasive species and new introductions will cause further damage.	Limit access to the lake and increase biosecurity awareness.

Did you know:
The Nationally Endangered *Centrolepis strigosa* is found here

Northland Regional Council
Te Kaunihera ā rohe o Te Taitokerau

Report card glossary



Habitat size: This score is based on the size and depth of the lake. Large deep lakes are more stable because they have a greater dilution capacity and a larger area to support different habitat types.

Connectivity: This score considers the number of nearby lakes and wetlands. This connectivity is important as several threatened birds travel between waterbodies that form a network of habitats across the landscape.

Buffering: This score is based on the riparian vegetation around the lake and how much native vegetation and wetlands there are in the catchment. This vegetation filters pollutants entering the lake from the surrounding land.

Water quality: This score is based on the nutrient concentrations in the lake. Higher nutrient concentrations typically result in a poor level of ecological health and is often associated with murky water and algal blooms.

Aquatic vegetation diversity: This score is based on how many different species of aquatic plants live in the lake. Lakes with a high diversity of aquatic plants are usually in better ecological condition.

Aquatic vegetation integrity: This score is based on the extent, diversity and condition of native submerged plant. Fully vegetated lakes with a high species diversity are often in the best condition.

Endangered species: This score is based on how many endangered plants and fish live in this lake. Endangered species add value to the ecosystem and are an indicator of good ecological health.

Presence of key species: This score is based on the presence of freshwater mussels (kakahi or torewai). These mussels are important for lake health because they filter the lake and remove algae.

LakeSPI: This score is based on the health, density and extent of native and exotic submerged plants in the lake. This score also integrates the impact of invasive submerged plants.

General description

Lake Midgley was assessed in 2005, 2011 and 2024.

Lake Midgley is a small (3.8 ha), shallow (3 m) dune lake 10 km south of the Kai Iwi Lakes complex (35°53'20"S 173°42'43"E). Grass carp were introduced to the lake in 2007 and a large portion were removed in 2011.

Lake Midgley - Northern view indicating the depauperate riparian margin, pasture dominant land use and exotic forest block

Catchment & sub-catchment description

The lake is in an 815.24-hectare pastoral catchment. High producing exotic grassland makes up 89% of the total catchment area. Forestry exists as shelter belts and small blocks equating to 5% of the catchment area. Five percent native vegetation cover is present across the catchment and of that only 2% are classified as wetlands.

The 82.71-hectare sub-catchment is similarly dominated by exotic pasture (85%) with pockets of exotic forestry along the northern lake margin forming 10% of the total sub-catchment area.

There is an inflow at the eastern end of the lake entering through a wetland area. The outlet on the western side flows to the Moremonui Gully on the west coast approximately 2.5 km south-west of the lake.

All the overland flow entering the lake drains high production pasture and is likely to carry high contaminant loads. These incoming contaminants (nutrients & sediment) contribute to the degradation of water quality and overall lake health. There are sections of established riparian buffer around the lake but is likely insufficient to attenuate the volume of contaminants entering the lake during high rainfall events.

Lake Midgley catchment land cover and overland flow path network

In-lake description

No in-lake assessments were done during the 2024 survey.

Wetland vegetation

Eleocharis sphacelata and *Typha orientalis* both formed small areas of emergent vegetation on the steep sided northern lake margin. Emergent vegetation once formed extensive beds along parts of the lake margin before the introduction of grass carp. These beds have receded and now form small fragments.

Much of the lake margin was a narrow band of bare mud, with some indigenous turf species including *Alternanthera nahui*, *Centipeda aotearoana*, *Glossostigma elatinoides* and *Myriophyllum propinquum*. One immature plant of *Centrolepis strigosa* was also noted in this habitat.

Submerged vegetation

No in-lake assessments were done during the 2024 survey. However, rake throws were done at representative locations but failed to collect any submerged vegetation and the lake is assumed to be non-vegetated.

Extensive beds of *Chara australis*, patches of *Potamogeton ochreatus* and small clumps of the Threatened - Nationally Critical *Utricularia australis* were recorded during the 2005 survey. By 2011 all the submerged vegetation aside from a few stunted *Chara australis* plants had been removed by grass carp.

LakeSPI

No in-lake assessments were done so no updated LakeSPI scores were generated. Rake throws were done at representative locations to establish a submerged vegetation assemblage but yielded no macrophytes. This result supports the non-vegetated state recorded in 2011.

Lake Midgley LakeSPI scores as a percentage of the maximum Potential LakeSPI score, Native Condition Index, and Invasive Impact Index

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
2024	Non-vegetated	0	0	0
2011	Non-vegetated	0	0	0
2005	High	66	87	41

Wetland birds

The remaining emergent vegetation provides some habitat for wetland birds but it is likely that majority of the species are common waterfowl including: mallards (*Anas platyrhynchus*) and black swans (*Cygnus atratus*).

The following priority conservation species have been sighted near the lake: banded rail (*Gallirallus philippensis assimilis*), matuku (Australasian bittern) (*Botaurus poiciloptilus*), black shag (*Phalacrocorax carbo novaehollandiae*), mātātā (fernbird) (*Poodytes punctatus*), brown teal (*Anas chlorotis*) and white heron (*Ardea alba*).

Matuku (bittern) and other Threatened and At Risk wetland birds have been consistently observed within a small radius extending east of the lake between 2013 - 2023.

Fish

Divers did not enter the water, so no fish were recorded. In June 2011, 141 grass carp were removed (J. Fulcher, NRC pers. comm.) but it is not known how many remain in the lake.

Aquatic invertebrates

Divers did not enter the water, so no macroinvertebrates were recorded.

There are no records of freshwater mussels in this lake. The water quality impacts from grass carp and lack of host fish make this lake unsuitable for this species.

Endangered species

One immature plant of *Centrolepis strigosa*, ranked as Threatened - Nationally Endangered, was found with recent collections from the nearby Kai Iwi Lakes and on the margin of Maitahi Road.

Lake ecological value

Lake Midgley was assessed as having a "Moderate" ecological value with a score of 6 out of 20. This score reflects the non-vegetated state of the lake however, the overall score is increased by the presence of the Threatened - Nationally Endangered *Centrolepis strigosa*.

Lake Midgley is a small (3.8 ha), shallow (3 m) lake, so it scores a 1 out of 3 for the Habitat Size metric. It is surrounded by small unnamed waterbodies and wetlands so it receives an extra point for connectivity to other waterbodies.

The lake scores a 1 out of 3 for the Buffering Metric because of the depauperate riparian margins and low quantities of native catchment vegetation. The wider catchment consists of 89% pasture and small fragments of non contiguous native bush which reduces the buffering score. As a result, the level of land use impacts on the lake are likely to be high.

No water quality data is available for the lake, so it is automatically assigned a 0 out of 3. This is done to ensure a standardised approach when scoring unmonitored lakes and is representative of the worst-case scenario. From historical information and on-site observations, it is likely that the lake is in a eutrophic state.

The aquatic vegetation diversity at Lake Midgley is poor, there are no submerged species, and the riparian margins are narrow and sparsely vegetated. Eleven emergent plant species were recorded, resulting in a 1 out of 3 for the Aquatic Vegetation Diversity Metric.

The Aquatic Vegetation Integrity metric is taken from the LakeSPI Native Condition. No updated LakeSPI scores were generated during the 2024 survey and the lake is considered non-vegetated. A LakeSPI score of 0 was generated in 2011 as there was no submerged vegetation greater than 5% cover. The non-vegetated state is attributed to the impacts of the grass carp and degrading water quality.

One immature plant of the Threatened - Nationally Endangered *Centrolepis strigosa* was found. No other endangered species was seen on site. The riparian margins are fragmented and narrow so they do not provide high quality habitat for endangered birds. That being said, there are several sightings of threatened birds in the wider area so these species may use the lake from time to time.

Threats

Grass carp are an ongoing threat to the ecological values of the lake if insufficient numbers have been removed to allow native vegetation recovery.

Access to the lake is restricted so the risk of invasive species introductions is low, but should pest species be introduced, their impacts are likely to be significant as the lake is a non-vegetated state and presents ample habitat for aggressive exotic water weeds.

There are signs of stock access along the riparian margin which limits the establishment of wide riparian buffers and creates erosion issues along the lake edge.

The lake is in a pasture dominated catchment with steep slopes and limited riparian buffers. The high nutrient loads combined with the shallow lake depth and the non-vegetated state puts this system at great risk of rapidly shifting to a turbid algal dominated state.

Management recommendations

The primary threats to Lake Midgley are grass carp, new invasive species incursions, the poor condition of the riparian margins and eutrophication. The following management actions are recommended:

Stock exclusion & riparian enhancement

Stock have damaged the riparian margin and excluding them will prevent erosion, stabilise the lake margin, and allow riparian vegetation to establish. Once fully fenced, additional riparian planting should be done to help stabilise the lake edge and buffer incoming contaminants. The focus should be on planting the areas at the base of the steep exposed slopes.

Grass carp control

The grass carp have created a non-vegetated lakebed and have limited the establishment of emergent vegetation. A survey (eDNA and nets) is recommended to determine the estimated number of carp in the lake. If carp are detected, all efforts should be made to remove them. Consultation with the landowners regarding the impacts of re-stocking carp should be done.

Pathways assessment & biosecurity control plan

The risk of additional invasive species entering Lake Midgley is low, however, if pest species were introduced, their impacts are likely to be significant as the lake is a non-vegetated state and presents ample habitat for aggressive exotic species. Direct communications with the landowners, local hunters/fishermen, and wider engagement with industry bodies (Fish & Game, local hunting and fishing clubs) regarding the spread of these high-risk species is recommended as a first step.

Land/farm management plan

The impacts from the surrounding pasture can be managed through an effective land/farm management plan. An initial assessment should be done to identify intermittent/ephemeral waterways entering the lake, key areas of diffuse overland flow, critical source areas for contaminants, and land use activities that do not follow best practices. Management interventions can then be selected from the Management tool box section to minimise the impacts from the catchment.

Routine monitoring

Lake Midgley is at risk of rapid deterioration due to its non-vegetated state and the impacts of eutrophication. It is recommended that routine monitoring includes monthly water quality sampling as well as 3 – 5 yearly ecological assessments and invasive species surveillance. If further investment is allocated to managing the lake, annual monitoring of macrophyte regeneration is recommended.

Management tool box

The interventions are grouped in tables (tool box) according to the contaminant they manage. Phosphorus, nitrogen, sediment, and *E. coli* were identified as the primary contaminants that drive deteriorating lake health.

The management interventions in the tool boxes are listed in order of efficacy and cost effectiveness e.g., the first option in the table is the most efficient and/or cost-effective way to manage that specific contaminant whereas, the last option is the least efficient and/or most costly intervention. The actual costs and efficiency will differ between farms as it depends on the specific land use activity, scale of the activity/issue, level of existing infrastructure, existing interventions, underlying topography and expected outcomes. For this reason, all interventions should be considered when drafting an environmental management plan.

Management Interventions for Phosphorus			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to the lake, decreases bank damage, reduces sediment inputs via bank erosion and prevents direct deposition of faces. All of which reduce *E. coli*, N and P loads.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Tile drain amendments	Use of P-sorbing Ca, Al and Fe materials as backfill for artificial	Additional filtration of sediment and faecal bacteria.	This is a potentially costly intervention but is very effective. It should

	drainage systems. This reduces the nutrient load entering the lake.		be considered if there is a lot of overland flow paths draining into the lake.
Controlled release fertiliser	Use low-water-soluble P fertiliser. Less fertiliser-P is lost in runoff due to the low water solubility of products such as reactive phosphate rock resulting in increased P use efficiency.	Increases efficiency and P retention which lowers the overall amount of fertiliser required, resulting in large cost savings.	These types of fertilisers are not appropriate for soil pH < 6.0 or rainfall > 800 mm. Also, cannot be used for capital applications and must gradually replace highly-water soluble P applications at a rate of one-third per year.
Dams and water recycling	Recycling systems that divert irrigation outwash for use in others part of the farm reduces nutrient loads/discharges to the lake.	More efficient use of flood irrigation water and increased nutrient recycling.	Could require a change in irrigation infrastructure so should only be considered if water loss/discharges are a significant impact.
Precision/variable rate application of fertiliser	Precision fertiliser application using remote sensing of the nutrient status of the land to determine where & what nutrients should be targeted. This reduces the overall mobile nutrient load in the catchment and prevents excess nutrient loads entering the lake.	Reduction in the amount of fertiliser required, resulting in large cost saving.	Requires a change to the fertiliser application strategy and can present a higher initial implementation cost. Costs should reduce once the system is in place as less fertiliser will be required.
Precision irrigation	Use sensors to automate irrigation and nutrient inputs and optimises crop utilisation at fine scale.	Reduces the overall water and nutrient requirements, optimised applications result in better yields.	The initial infrastructure can be costly and requires active monitoring to ensure the process is optimised effectively.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas of phosphorus and avoid grazing those areas during wet seasons.	Allows high P areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Refurbish and widen flood irrigation bays	Water exiting flood irrigation bays as outwash represents about 20-50% of that applied. Re-contouring irrigation bays, and/or preventing outwash/wipe-off from accessing the stream network decreases P loads to the lake.	Recycling the water for use elsewhere on the farm reduces overall water consumption and nutrient requirements.	Recontouring can be costly and may result in a minor loss in yield.

Apply aluminium sulphate to pasture, forage cropland or crops in critical source areas	P-sorbing aluminium sulphate (alum) sprayed onto a winter forage crop just after grazing, or sprayed onto pasture a week before grazing, will prevent surface runoff losses of P and reduce nutrient loads to the lake.	Reduces overall catchment phosphorus load.	Presents an additional annual cost.
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce deposition of faeces and surface erosion. This limits the amount of phosphorus entering the lake during the wet season.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.
Cover/ catch crop	Grow cover/catch crops on the same field in the same year, often used after the main crop or grass has been grazed or machinery has exposed the soil. This reduces nutrient and sediment loads to the lake.	Enhances soil health, prevents erosion, reduces nutrient leaching, and improves yield.	This will improve the year-round use of the pasture and can be designed in a way to maximise yields.
In-stream sorbents	Use of P sorbing material textile bags and place them on the stream bed to remove P from baseflow. This reduces the amount of P entering the lake from overland flow paths.	Additional filtration of other contaminants and reduces the catchment contaminant load.	Installation might require in-stream works. The focus should be on streams that flow into the lake and/or drain high impact land use.
Phosphorus matching to crop requirements	Matching soil Olsen P concentrations to pasture and forage crop requirements avoids excessive soil P concentrations and reduces the P load to the lakes and stream network.	An agronomic optimum phosphorus dosing reduces the amount of fertiliser required and the overall annual cost.	Will require targeted soil investigations but the analysis is low cost and can be coupled with other soil health tests.
Vegetated buffers/planting below critical source areas	Vegetated buffer below critical source areas and at the base of steep sloped pastures work to decrease contaminant loss in surface runoff by a combination of filtration, deposition, and improving infiltration.	Stabilises land, provides habitat for fauna and helps create wildlife corridors across the landscape.	Choose vegetation types based on the outcomes and site details. Use different planting mixes for erosion protection than for nutrient attenuation.
Constructed/natural seepage wetlands	Modification of landscape features such as	Enhanced flood attenuation and	These wetland features need to be fenced and

	depressions and gullies to form wetlands creates additional catchment buffering. Restoring natural seepage wetlands at the heads and sides of streams will reduce the contaminant load entering the stream/lake network.	increased habitat and biodiversity values.	restored to a good ecological condition for them to provide a high level of ecosystem services.
Sediment traps/retention ponds/bunds	In-stream sediment traps and retention ponds will allow coarse sized sediment and associated N and P to settle out. Bunds constructed along paddock edges creates ponds of water at the bottom of fields where sediment settles out which prevent excess contaminants from entering the lake.	Potential to buffer storm events and downstream flooding.	Typically, only effective on cropping land with slope greater than 3 degrees.

Management Interventions for Nitrogen			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to the lake, decreases bank damage, reduces sediment inputs via bank erosion and prevents direct deposition of faces. All of which reduce *E. coli*, N and P loads.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Change animal type	Animal type influences nitrogen leaching due to differences in the spread of urinary nitrogen. Nitrogen leaching from sheep and deer is approximately half that from beef cows at the same level of feed intake.	Also leads to decreased N2O emissions.	Careful consideration of the animal type is required as some species exacerbate other contaminant issues e.g., a change to deer may lead to greater sediment and P loss.
Constructed/natural seepage wetlands	Modification of landscape features such as depressions and gullies to form wetlands creates additional catchment buffering. Restoring natural seepage	Enhanced flood attenuation and increased habitat and biodiversity values.	These wetland features need to be fenced and restored to a good ecological condition for them to provide a high level of ecosystem services.

	wetlands at the heads and sides of streams will reduce the contaminant load entering the stream/lake network.		
Cover/ catch crop	Grow cover/catch crops on the same field in the same year, often used after the main crop or grass has been grazed or machinery has exposed the soil. This reduces nutrient and sediment loads to the lake.	Enhances soil health, prevents erosion, reduces nutrient leaching, and improves yield.	This will improve the year-round use of the pasture and can be designed in a way to maximise yields.
Reduce nitrogen in critical source areas	Reduced use of nitrogen fertiliser on winter forage crops coming out of long-term pasture and avoid excessive nitrogen inputs to effluent blocks. This reduces the nitrogen load entering the lakes during high rainfall events.	Decrease emissions of greenhouse gases, reduce overall fertiliser requirements and an improvement in energy use.	Will require targeted soil investigations to ensure an accurate soil nitrogen profile.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas of nitrogen and avoid grazing those areas during wet seasons.	Allows high nitrogen areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Precision/variable rate application of fertiliser	Precision fertiliser application using remote sensing of the nutrient status of the land to determine where & what nutrients should be targeted. This reduces the overall mobile nutrient load in the catchment and prevents excess nutrient loads entering the lake.	Reduction in the amount of fertiliser required, resulting in large cost saving.	Requires a change to the fertiliser application strategy and can present a higher initial implementation cost. Costs should reduce once the system is in place as less fertiliser will be required.
Precision irrigation	Use sensors to automate irrigation and nutrient inputs and optimises crop utilisation at fine scale.	Reduces the overall water and nutrient requirements, optimised applications result in better yields.	The initial infrastructure can be costly and requires active monitoring to ensure the process is optimised effectively.
Controlled release fertiliser	Use slow-release nitrogen fertiliser. Less mobile nitrogen is lost in runoff due to the low water solubility and slow release resulting in	Increases efficiency and nitrogen retention which lowers the overall amount of fertiliser required, resulting in large cost savings.	These types of fertilisers may result in a lower initial yield and might not be as effective in cold dry soil.

	increased nitrogen use efficiency.		
Denitrification beds	Large containers filled with woodchips that intercept drain flow and denitrify nitrate in water to nitrogen gas which is released to the atmosphere. These reduce the concentrations of bioavailable nitrogen entering the lake.	Provides additional filtration of other contaminants.	Suitable for tile/sub-surface drains or small surface drains. Can create hydrological blockages in larger channels.
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce deposition of faeces and surface erosion. This limits the amount of phosphorus entering the lake during the wet season.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.

Management Interventions for Sediment			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to the lake, decreases bank damage, reduces sediment inputs via bank erosion, and stabilises the stream network.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input. Prevents direct deposition of faces and reduces *E. coli*, N and P loads.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Cover/ catch crop	Grow cover/catch crops on the same field in the same year, often used after the main crop or grass has been grazed or machinery has exposed the soil. This reduces nutrient and sediment loads to the lake.	Enhances soil health, prevents erosion, reduces nutrient leaching, and improves yield.	This will improve the year-round use of the pasture and can be designed in a way to maximise yields.
Contour cultivation	Cultivation along contours of cropping land with slopes greater than 3 degrees reduces the speed and eroding power of runoff water.	Stabilises slopes and prevents slips. Increases yield by farming steep areas. Reduces nutrient loads from highly mobile soils during high rainfall events.	Requires new techniques and earthworks. This practice should be combined with detention ponds/bunds at the base of the slopes to further enhance contaminant attenuation.

Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce surface erosion. This limits the amount of sediment entering the lake during the wet season.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.
Sediment traps/retention ponds/bunds	In-stream sediment traps and retention ponds will allow coarse sized sediment to settle out. Bunds constructed along paddock edges creates ponds of water at the bottom of fields where sediment settles out which prevent excess contaminants from entering the lake.	Potential to buffer storm events and downstream flooding.	Typically, only effective on cropping land with slope greater than 3 degrees.
Constructed/natural seepage wetlands	Modification of landscape features such as depressions and gullies to form wetlands creates additional catchment sediment buffering. Restoring natural seepage wetlands at the heads and sides of streams will reduce the sediment load entering the stream/lake network.	Enhanced flood attenuation and increased habitat and biodiversity values.	These wetland features need to be fenced and restored to a good ecological condition for them to provide a high level of ecosystem services.
Vegetated buffers/planting below critical source areas	Vegetated buffer below critical source areas and at the base of steep sloped pastures work to decrease sediment loss in surface runoff by a combination of filtration, deposition, and improving infiltration.	Stabilises land, provides habitat for fauna and helps create wildlife corridors across the landscape.	Choose vegetation types based on the outcomes and site details. Use different planting mixes for erosion protection than for nutrient attenuation.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas of sediment and avoid grazing those areas during wet seasons.	Allows high sediment areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Minimum tillage/ direct drilling of seed	Direct drilling of seed into stubble or pasture reduces the proportion of time that land is bare and erodible during the growing cycle. This greatly reduces the sediment loads entering the lakes/streams.	Enhanced soil condition and stability. Less erosional issues and increased productivity.	May not be suitable for all crop types.

Increasing forested area/ windbreaks	Combination of retirement and pole planting on highly erodible land. Introduction of tree roots to soil regolith protects soil on steep slopes from mass movement erosion.	Stabilises slopes and prevents slips. Increases yield by farming steep areas. Reduces nutrient loads from highly mobile soils during high rainfall events.	This intervention should be planed with other re-vegetation interventions to create blue-green networks and wildlife corridors across the landscape.

Management Interventions for *E. coli*			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to stream and lake banks reduce stream bank damage and stops the direct deposition of excreta (*E. coli*) into the waterways.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input. Prevents direct deposition of faces and reduces *E. coli*, N and P loads.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas near waterways and avoid grazing those areas during wet seasons.	Allows these areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce the amount of deposited excreta during the wet season. This limits the amount of *E. coli* entering the lake during high rainfall events.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.
Sediment traps/retention ponds/bunds	In-stream sediment traps and retention ponds will allow faeces settle out. Bunds constructed along paddock edges creates ponds of water at the bottom of fields where excreta accumulate. This prevents excess *E. coli* from entering the lake.	Potential to buffer storm events and downstream flooding.	Typically, only effective on cropping land with slope greater than 3 degrees.
Vegetated buffers/planting below critical source areas	Vegetated buffer below critical source areas and at the base of steep sloped pastures work to decrease excreta (*E. coli*) loss in surface runoff by a combination of filtration, deposition, and improving infiltration.	Stabilises land, provides habitat for fauna and helps create wildlife corridors across the landscape.	Choose vegetation types based on the outcomes and site details. Use different planting mixes for erosion protection than for nutrient attenuation.