Date Updated: 11 April 2025

Version: 1

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TUKITUKI LAND CARE

Mangarara Erosion and Sediment Control Strategy

HAWKES BAY

PART ONE: MANGARARA CATCHMENT

1. Summary

The Mangarara catchment community group has actively sought advice to enhance their understanding and devise a comprehensive plan for erosion control and silt retention. Covering an area of just under 4,000 hectares, the Mangarara catchment is the smallest sub-catchment within the Tukituki region. However, silt accumulation poses a significant challenge, with the Mangarara stream bed experiencing a noticeable elevation increase of up to 60 cm in certain areas following cyclone Gabrielle.

This catchment exhibits one of the highest sediment yields across the Tukituki, likely from landslides and sediment delivery to streams. Modelling indicates that it averages nearly 6.5 tonnes of soil lost to water per hectare per year. Notably, past studies have revealed that pasture production on eroded sites takes approximately two decades to reach 70-80% of the productivity observed on uneroded land.

The erosion and sediment control plan proposed herein is structured into two phases. Phase one focuses on immediate priorities identified during desktop investigations and a site visit. Phase 1 includes pest willow management along waterways and afforestation efforts on steep hill country terrain. Specifically, crack willow removal is recommended as a priority in densely infested areas, necessitating collaboration with the Hawkes Bay Regional Council (HBRC) river management staff. Additionally, control measures for other stands of crack willow in the upper catchment are advised to prevent re-infestation. Afforestation options are also explored, with space planting utilising poplars considered suitable for class 6 land. However, due to challenging conditions such as steep slopes, dry sites, and shallow soils, alternative approaches like stock exclusion and native planting with robust species such as kanuka may be necessary for class 7e land. This strategy could involve permanent retirement into native forest or space planting kanuka with grazing underneath once the trees are several years old.

Phase two of the plan outlines potential future actions, emphasising catchment prioritisation and implementation. Recognising erosion as a natural process inherent in rural settings, the inclusion of sediment capture measures is deemed essential for a holistic catchment scale erosion and sediment control strategy. Greater understanding of slope dynamics and flow accumulation patterns will guide the identification and deployment of effective sediment control actions throughout the catchment.

The immediate actions include working with HBRC on catchment scale soil conservation and willow removal. Longer term actions include attaining greater understanding of the flow paths, flow accumulation and hill country erosion sites so that targeted farm scale sediment control actions can be implemented.

2. Introduction

2.1. This Project: Erosion Control and Silt Retention in The Mangarara

The Mangarara catchment community group have sought advice to increase their knowledge and develop a plan around erosion control and silt retention. Silt is a real concern on this side of the Tukituki River with the Mangarara stream bed level lifting by 60 cm in some places since the cyclone. This represents a significant loss of valuable topsoil and potential damage to the stream. As well as affecting stream health, slips and silt buildup are damaging infrastructure, limiting access, and raising health and safety issues due to the unstable and muddy conditions.

2.2. Project Objectives

This report is funded through 'Access to Experts', and the objectives were developed by the catchment group alongside the Access to Experts team at Becca. The objectives for this report are:

- Desktop assessment of catchment land use classification and overall geography to identify erosion prone areas.
- Working with farmers, priority sites and opportunities.
- Summarising the collated data and recommended mitigation measures.
- Present the report back to the catchment group with opportunity for discussion and feedback.

An additional possible objective added by the author of this report is to 'provide a communication tool to the group that supports working with landowners and partners and enables funding to be directed at erosion and sediment control activities'.

2.3. Scope and Limitations

This project was funded by the 'Access to Experts' programme and the project objectives, budgets, timeframes, and outputs were developed by Tukituki Land Care and Becca. This scope limited the project somewhat. For example, the full extent of the catchment could not be covered during the site visit. This meant that specific design of soil conservation planting and sediment reduction practices were not able to be applied at the appropriate scale (farm or paddock scale).

2.4. Report Outputs

This report focusses on supporting the understanding of the catchment from a soil conservation and sediment retention lens. It outlines timeframes, options and recommends priority actions to support planning of catchment scale erosion and sediment control.

3. Mangarara Catchment

3.1. Catchment Location

The Mangarara catchment, located east of Ōtane across the Patangata bridge. It is the smallest sub-catchment in the Tukituki at just under 4,000 ha (figure 1). The community group are keen to do what they can to tackle erosion, particularly identifying the best approach to hill and stream-side management for their catchment. Problem willows in the stream are also a concern for the group[1].

Figure 1 – Location of the Mangarara catchment in the Tukituki.

[1] https://www.tukitukilandcare.org/mangarara-catchment

3.1. Mangarara Sediment Yield

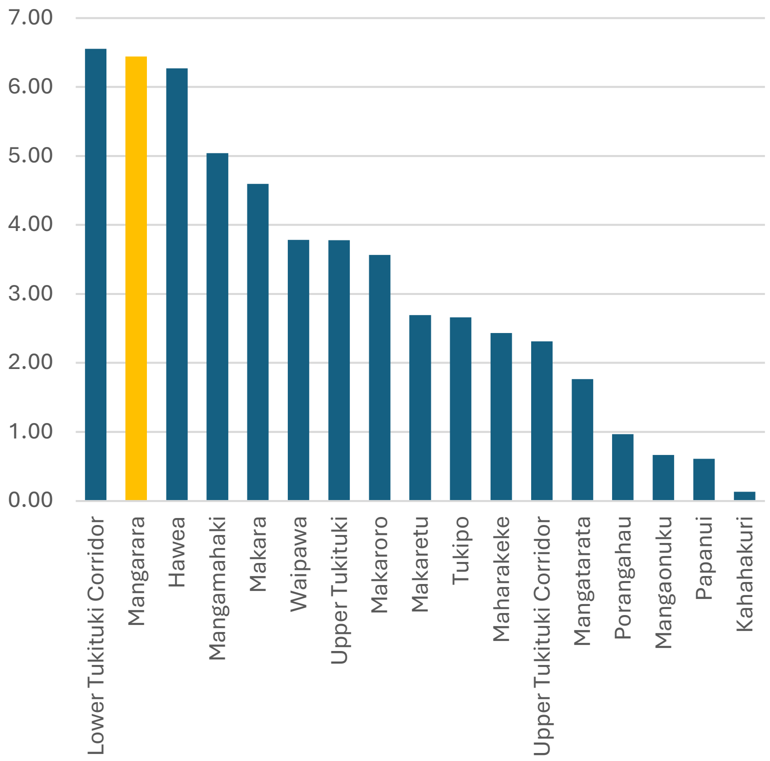

Figure 2 - Sediment load estimates (tonnes/ha/year) per catchment, adapted from SEDNET modelled data from HBRC Report No. RM18-18 – 5002. Note that Mangarara has one of the highest potential sediment loads across the Tukituki.

Sediment yield in the Mangarara catchment is one of the highest across the Tukituki, with nearly 6.5 t/ Ha/ year modelled through SEDNET (Figure 2).

3.2. Landslides in the Mangarara

Within the wider Tukituki catchment, the sub catchments identified as having the highest percentage area of land with high landslide risk with delivery to streams are the Hawea (5.3%), followed by Mangarara (3.1%), Tukipo (3.0%), and Upper Tukituki (2.9%). Landslides are known to produce high sediment yields, so erosion mitigation activities should focus on those areas. Table 1 summarises highly erodible land in the catchment. Of note is the high incidence of highly erodible land with potential delivery straight to streams. Additionally, the woody vegetation percentage is low, which means there is ample opportunity for afforestation.

Table 1 – Highly erodible land and woody vegetation as a percentage of area (%), in the Mangarara and total Tukituki catchment

Sub catchment	Delivery to stream (%)	Non-delivery to stream (%)	Moderate erosion (%)	Severe erosion (%)	Total erosion (%)	Non-HEL land and water (%)	Woody vegetation (%)
Mangarara	3.1	1.3	1.1	0.0	5.6	87.6	6.7
Tukituki	1.4	0.7	3.5	0.6	6.2	76.7	17.1

3.3. Mangarara Landscape

The Mangarara landscape is dominated by LUC class 6e and 7e. Many parts of the catchment are steep with most of the catchment over 21 degrees and parts of the catchment over 26 degrees (figure 3). These steep areas are highly prone to soil slips.

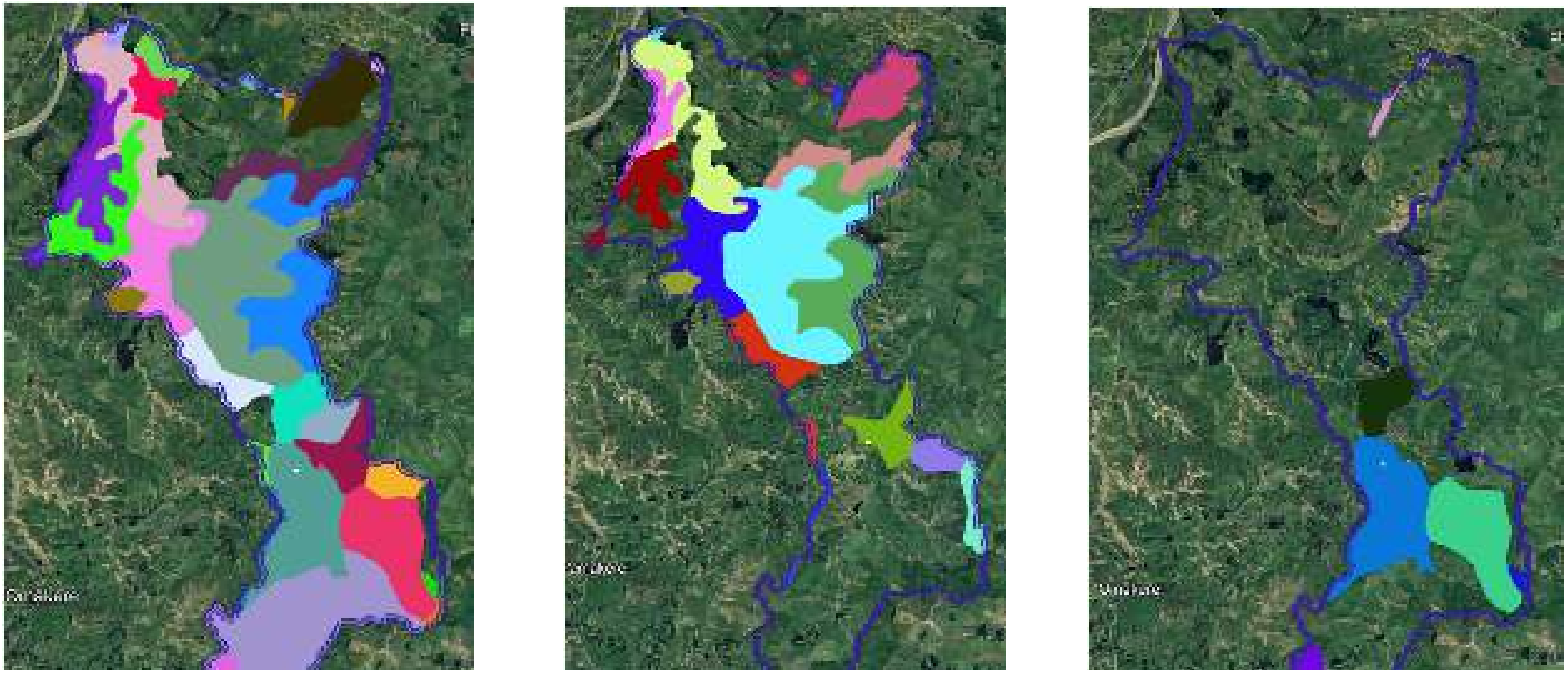

*Figure 3- **LEFT: Land Use Capability:** LUC 6e and 7e (coloured areas) are the predominant class in the Mangarara. **CENTRE: 21-26 degrees slope areas:** The coloured areas represent areas of land that are moderately to steeply sloped. **RIGHT: 26-35 degrees slope areas:** The coloured areas represent areas of land that are very steeply sloped.*

3.4. Land Use Capability

Most of the land in the catchment is classed LUC 6e and 7e (figure 4). Class 6 land is described as not suitable for arable use and has slight to moderate limitations and hazards under a perennial vegetation cover. Erosion is commonly the dominant limitation, but it is readily controlled by appropriate soil conservation such as space planted trees, conservation fencing, water control structures, oversowing and topdressing, and appropriate cattle management. Class 7 land is unsuitable for arable use and has severe limitations or hazards under perennial vegetation. It can be suited to grazing provided intensive soil conservation measures and practices are in place, and in many cases, it is more suitable for forestry[2].

Figure 4 - Land use capability description and limitations.

3.5. Land Slope

The Mangarara is steeply sloped with most of the catchment over 21 degrees (figure 3). The slope classes represented in figure 3 are based on regional scale datasets (likely 1:63,000), which makes challenging to apply accurately to a small catchment like the Mangarara. What we can assume from this though is that the challenges of hill country erosion are likely to be very common issue throughout the catchment. Land over 25 degrees is where erosion mostly occurs, with more than 50% of the sediment lost from these areas ending up in waterways[3].

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[2] LUC handbook sourced from: https://nzarm.org.nz/resources

[3] https://www.hbrc.govt.nz/assets/Document-Library/Information-Sheets/Land/18569-HBRC-InfoSheet-Erosion-SCREEN-sml.pdf

3.6. Water Quality Indicators of Soil Loss

The Hawkes Bay Regional Council water quality dashboard[4] provides a summary of estimated water quality in the Mangarara. The water quality estimates appear to be largely based on nearby sampling sites, primarily the Makara stream at Lawrence Road. The dashboard notes that increases in turbidity are associated with elevated sediment loading which is linked to erosion. River flow has a strong influence on turbidity and other aspects of water quality. High flows are associated with increased sediment loading and associated contaminants. The relationship between turbidity and rainfall/river flow is a complex one, for example during heavy rain solids are washed into the stream but there is also more dilution. Compared to large powerful rivers like the Tukituki, the fine sediment and organic matter is more likely to settle on the bed of the Mangarara. This sedimentation reduces habitat quality and limits the type of native plants and animals that can live in the stream.

3.7. Riparian Condition

A riparian assessment was undertaken in the Tukituki catchment in 2014. The below graphs are a summary of that work (figure 5). There is little to distinguish he Mangarara from other catchments in the Tukituki as it would be considered an average score for both riparian vegetation and stock disturbance amongst its peer catchments in the Tukituki.

[4] https://www.hbrc.govt.nz/environment/farmers-hub/in-the-tukituki-catchment/tukituki-dashboard/mangarara-dashboard/

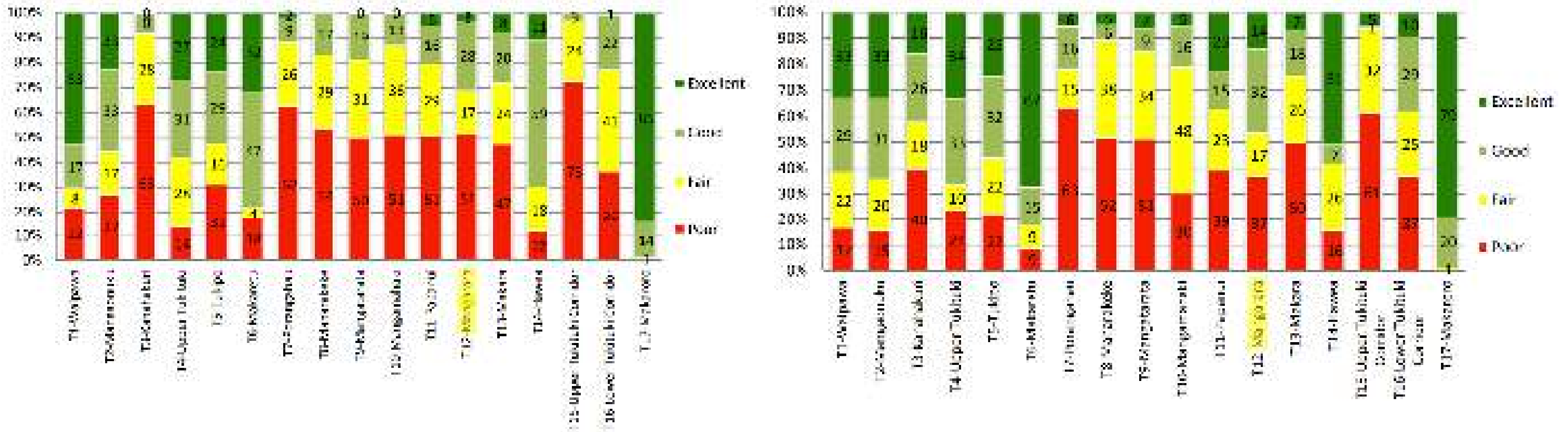

Figure 5 – Riparian Vegetation class (left) and riparian stock disturbance class (right) for catchments in the Tukituki. Note that Mangarara has generally poor vegetation and more balanced stock disturbance score.

The riparian vegetation classification (figure 5) is as follows: **Excellent**: Predominantly indigenous vegetation with dense groundcover which provides sufficient shading along the streambanks, is mainly intact and the riparian vegetation width is larger than 5 m. **Good**: The riparian vegetation is dominated by exotic species. The completeness of the bank or the streamside vegetative buffer is generally reduced, although the lateral extent is still sufficient to provide benefits in terms of shading to the stream. **Fair**: The riparian vegetation is full of gaps and does not provide sufficient shading or other benefits for the stream environment. Vegetation consists predominantly of exotic species and the width of the bankside vegetation is small. **Poor:** The stream/river is nearly void of any trees and suffers from insufficient shading. Predominantly pasture grasses and weeds make up the vegetative cover along the waterway. The Stock disturbance classification is as follows: **Excellent**: Stock has no access to the waterway and no stock damage is visible. **Good**: Stock has access to a small part of the stream/river and stock damage is low. **Fair**: Stock has access to most of the stream/river and stock damage is evident. **Poor**: Stock has access to the entire stream/river and stock damage presents a strong impairment.

4. Opportunity and Impacts of Managing Soil Loss in Mangarara

4.1. The cost of erosion in the farming landscape

The productive and economic cost of erosion can be high. Research undertaken on Wairarapa slip sites observed that pasture production on erosion scars took 20 years to reach a level 70-80% of that on uneroded sites, and subsequently levelled off at 80-85%[5].

Manaaki Whenua Landcare Research reviewed the marginal cost of erosion (negative impact on productivity) and stated that the cost ranges between $0.03 and $5.61 per tonne of soil lost, with a mean value of $1.80 per tonne, depending on land use. The highest marginal cost of aggregated erosion was experienced in vegetables, fruit, and dairy land uses, while the lowest marginal cost of aggregated erosion was experienced in exotic forestry, sheep and beef, and other pastural land uses. The high erosion cost for horticulture is mainly driven by the high annual net revenues ($7–9 k/ha). Sheep and beef, and exotic forestry are often located in marginal land with relatively low annual net revenues, and therefore the marginal impact of erosion was lower[6].

4.2. The estimated cost of erosion in the Mangarara

Using the above estimates of costs for sheep and beef farming, the modelled 6.5 t/ha/year sediment loss and the catchment size, it is possible to estimate the annual cost of soil loss to the Mangarara community through the following equation:

= (average cost per tonne x tonnes per ha) x total hectares

= ($1.80 x 6.5) x 3,947 = $46,180 loss in income due to erosion per year in the Mangarara catchment.

Note that the above estimate is based on large assumptions, primarily the use of SEDNET modelling and the use of national average figures. This cost figure should not only be used as indicative only but will vary drastically from year to year.

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[5] Lambert, M. G., Trustrum, N. A., Costall, D. A., & Foote, A. G. (1993, January). Revegetation of erosion scars in Wairarapa hill country. In *Proceedings of the New Zealand Grassland Association* (pp. 177-181).

[6] Walsh PJ, Soliman, Wiercinski B 2021. The benefits and costs of erosion control in New Zealand: estimates for policy analysis. Manaaki Whenua Landcare Research Contract Report: LC3924, prepared for MBIE Endeavour Programme “Smarter Targeting of Erosion Control”.

4.3. Effectiveness of options for recovery of highly eroded areas

Fencing and sowing legumes: Rapid establishment of productive pastures on erosion scars in Wairarapa and similar hill country can be achieved by retiring areas from grazing for 2-3 years, and oversowing with white clover and lotus[5].

Over sowing legumes only: Where spelling from grazing is not an option, significant (but reduced) improvements in rate of slip revegetation and subsequent productivity can be made through oversowing white clover seed[5].

Fencing and native afforestation: Significant reduction in erosion, up to 74% less slips occur in native forest compared to pasture[7]. Native species are a great long-term approach but can be very costly and hard to establish in dry exposed hill country. Hardy species like manuka and kanuka have been used in the past as an initial coloniser species to increase canopy cover and reduce costs. This has been used for decades in New Zealand and more recently described as the Tīmata method in an Our Land and Water project.

Space planted poplars: Space planted poplars are one of the most common forms of slope stabilisation in New Zealand and are readily accessible through regional council soil conservation programmes. During cyclone Bola land planted with space planted trees had 22% less erosion than pasture areas without trees[7].

Afforestation with pines: established pine forest had 87% less erosion scars than pasture alone in the Manawatu events in 2004. However pines trees have limited benefit in gully erosion and for stabilising stream bank[7].

Space planted kanuka: A study on a Hawkes Bay farm found 108% more pasture growth under kanuka trees on sloping summer dry hill country pastures compared to open pasture. The study found: 49% more organic matter under the trees, 116% more Olsen-P under the trees, 9% greater porosity under the trees. Perennial ryegrass and cocksfoot dominated the pasture under the trees and browntop dominated the pasture away from the trees. The researchers surmised that these differences are mainly due to livestock preferentially spending more time under the trees grazing, and the trees adding organic matter to the soil[8].

Mānuka only planting: Mānuka planted for erosion control were found to be unlikely to provide effective erosion mitigation on steep land until significant root mass develops below the depth of the shear plane at which most landslides occur. Increasing the planting density, reducing early seedling mortality by better management of weed competition, and/or their replacement (blanking) would probably improve the erosion mitigation effectiveness of low-density manuka

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[7] Phillips, C. (2005, September). Erosion and sediment control using New Zealand native plants—what do we know. In Proc Erosion Control Seminar, Protecting the environment as an asset. NZ Institute of Highway Technology (pp. 11-13).
[8] sourced from https://verdantiaresearch.co.nz/).

plantings. The time (years after planting) to attain canopy closure and root occupancy, if stands of mānuka were to remain fully stocked, varies between landforms and would likely occur between 6.5 and 9 years after planting. However, variable rates in planting density, and of plant mortality, resulting in under-stocking would significantly delay this timing, particularly on landslide-affected slopes.

Grazing under exotic trees: Several studies have found that pasture production can be between 17% and 53% higher under holm oaks in dry areas of Spain and Portugal[9]. The studies suggested that the reasons for this improvement were either increased availability of nutrients under the tree, or microclimate modifications for conserving water (sourced from https://verdantiaresearch.co.nz/).

Another study found that pasture production was 45% higher in southern beech silvopastures compared to open pasture in Argentina[10]. The researchers suggested that the reason for these effects was that there was 80% less wind in areas with the trees compared to areas without trees, resulting in less evapotranspiration under the trees[11] (sourced from https://verdantiaresearch.co.nz/).

Tīmata method: The Tīmata method is the recent popularisation of afforestation using low-cost techniques. This technique significantly reduces challenges associated with affordability, supply of trees and labour, while retaining the ecological end economic benefit of establishing native forest. The principles are: A) 2 m spacing (2,500 stems/ ha), B) 70% manuka or kanuka, C) Small forestry grade trees, D) Careful land preparation including weed and animal pest control[12].

9 Moreno, G. Response of understorey forage to multiple tree effects in Iberian dehesas. Agric. Ecosyst. Environ. 123, 239–244 (2008).
Gea-Izquierdo, G., Montero, G. & Cañellas, I. Changes in limiting resources determine spatio-temporal variability in tree–grass interactions. Agrofor. Syst. 76, 375–387 (2009).
10 Peri, P. L. Patagonia Sur. Sistemas Silvopastoriles en Ñirantales. IDIA XXI For. 5, 245–249 (2005).
11 Bahamonde, H. A., Peri, P. L., Martínez Pastur, G. & Lecinas, M. V. Variaciones microclima´ticas en bosques primarios y bajo uso silvopastoril de Nothofagus antarctica en dos Clases de Sitio en Patagonia Sur. in Proceedings of the 1st National congress of silvopastoral systems 14–16 (INTA Editions, Misiones, 2009).
12 Retiring Farmland into Ngahere Alison Dewes, John Burke, Bronwyn Douglas and Steff Kincheff Funded by Our Land and Water Science Challenge (2022)

4.1. Summary of the Effectiveness of Hill Country Erosion Tactics

There is a wide range of tactics that can be used in hill country landscapes. Table 2 below outlines the typical soil conservation tactics available for deployment in rural landscapes. The table outlines each tactic's application and the probable sediment loss reduction based on relevant literature.

Table 2 – Summary of the effectiveness and application of soil conservation treatments. In general, reduction percentage described below outlines the improvements possible from deploying that tactic compared to undertaking no actions at a site.

SOIL CONSERVATION TACTICS	*Mass wasting (deep e.g. earth flows)*	*Mass wasting (shallow e.g. soil slips)*	*Sheet and Rill*	*Waterway Erosion*	*Gully*	*Tunnel gully*	*Erosion reduction*
Space planted trees (poplars & eucalypts)	✓	✓	✓	×	✓	✓	14-70%;
Afforestation -Exotics (pines)	✓	✓	✓	×	✓	✓	87% vs pasture 19-66% in gullies 50% catchment wide
Afforestation - Manuka	✓	✓	✓	×	✓	✓	90% fewer landslides vs pasture
Afforestation - Kanuka	✓	✓	✓	×	✓	✓	65% vs pasture
Afforestation -Natives	✓	✓	✓	×	✓	✓	74% less landslides 87% less volumetric

4.2. Summary of the effectiveness of sediment reduction tactics

Sediment reduction and edge of field[13] approaches to reduce the impact of soil loss have been researched less in New Zealand than afforestation and soil conservation. The below list outlines the known major interventions that can be applied in the rural landscape. The interventions exclude good management practices like stock exclusion of waterways, pasture and grazing management.

Table 3 below outlines the typical sediment attenuation tactics available for deployment in rural landscapes. The table outlines each tactic's application and the probable sediment loss reduction based on relevant literature.

Table 3 – Summary of the effectiveness and application of sediment reduction treatments that are typically applied. In general, reduction percentage described below outlines the improvements possible from deploying that tactic compared to undertaking no actions at a site.

SEDIMENT REDUCTION TACTICS	*Mass wasting (deep e.g. earth flows)*	*Mass wasting (shallow e.g. soil slips)*	*Sheet and Rill*	*Waterway*	*Gully*	*Tunnel gully*	*Sediment attenuation*
Grass buffers (see filter strips also) pastoral farming	×	×	✓	×	×	×	20-30% (channelised flow) 40-80% (non channelised)
Critical Source Area management	×	✓	✓	×	×	×	20-30% (pastoral farming - channelised flow)
Grass filter strips (see buffers also)	×	×	✓	✓	×	×	90% (Tss reduced). Grass 90% better than bare soil (AC)

[13] Edge of field tactics are a group of mitigations that operate downstream of a contaminant source, and capture water to treat it. They are normally placed in overland flow path channels before water enters main waterbodies.

Detention bunds	×	✓	✓	×	×	×	70% 23-79% (Decanting earth bund)
Sediment traps (land based)	×	×	✓	×	×	×	50-60%
Wetlands	✓	✓	✓	✓	×	×	60-80%
Sediment trap and wetland	×	✓	✓	✓	×	×	70%
Sediment Traps (Inline waterway)	×	×	×	✓	×	×	50%
Sediment retention pond	×	✓	✓	×	×	×	33%
Debris dams	×	×	×	×	✓	×	80%

PART TWO: EROSION AND SEDIMENT PLANNING

5. Erosion and Sediment Plan Approach

The planning approach outlined in this section is based on information gained from single day in the field and through desktop analysis. Further planning that includes more detailed farm scale approaches will be needed before implementation of a soil conservation or sediment retention plan can occur. This plan helps identify priorities and timing of phased work to help with the next steps of detailed planning.

The approach outlined in this plan is divided into two phases. Phase one prioritises the most important components of erosion and sediment control based on the field work and priorities of the landowners in the catchment. This phase outlines two major workstreams. The first workstream focuses on the management of the invasive willows in the catchment and the second workstream outlines the soil conservation approaches for the steep hill country areas. Phase two focusses on sediment attenuation approaches that may help in the future. These approaches are likely to be less cost effective at reducing sediment into waterways compared to phase one but do provide options worthy of investigating for future catchment planning and reducing the impact of soil loss.

6. Phase One – Waterway Management

6.1. Crack Willow Control

The main riparian areas of the Mangarara, particularly the mid to lower reaches are dominated by crack willow (*Salix fragilis*), (figure 6). Crack willow often blocks streams and exacerbates bank erosion and flooding. They are very invasive, even though it does not produce seed in New Zealand, brittle branches or stems will quickly produce roots, and any bare site downstream of a crack willow tree open to invasion.

In the Mangarara, crack willow are becoming old, breaking, getting washed downstream and choking the river (figure 7). It appears that there are large areas of the catchment where large willows dominate the riparian area, and the author recommends they are removed to reduce the likelihood of further erosion and flooding. It was noted during the field visit that some parts of the catchment have had successful willow removal in the past and streambanks have remained stable in these areas.


Figure 6 - Large crack willow are becoming old and brittle, during storm events they are washing downstream into accumulation areas which may lead to increased erosion.


Figure 7 - Large willows remain on several portions of the main channel. It would be beneficial to remove these and keep these areas willow free through maintenance.

6.1. Crack Willow Control Priorities

It is recommended that the Mangarara catchment group work closely with HBRC river management staff to plan for the removal of blockages and control of existing willows along the main stem. This plan identifies two major areas to undertake this willow control, noting that the catchment group also needs to prevent reinvasion as much as possible by controlling isolated patches of willow upstream. These areas are highlighted in yellow in figure 8, with the pink areas noted in the map showing the areas of successful willow removal in the past.

It is recommended that isolated patches of willow upstream of these areas are removed starting at the top of the catchment. Landowners will also have to ensure that maintenance occurs along stream banks in the future to keep controlling sapling willows as they establish.

Figure 8 – Major willow removal areas (yellow). Willow control 2 area also contains the large debris build up seen in previous photos. Large areas have had successful willow removal in the past (pink), and riparian areas have remained stable.

7. Phase One – Hill Country Erosion

7.1. Soil Slips

The areas investigated in this catchment during the field visit were heavily impacted by slip erosion (figure 9). These shallow soil slips can severely impact waterways by depositing large sediment loads over a short duration. Productivity in these areas can also be drastically reduced, research indicates that this can range between 40-80% less productivity than areas that haven't experienced erosion[14].

Figure 9 – Examples of hill country erosion in the Mangarara. Photos taken in February 2024.

[14] Walsh PJ, Soliman, Wiercinski B 2021. The benefits and costs of erosion control in New Zealand: estimates for policy analysis. Manaaki Whenua Landcare Research Contract Report: LC3924, prepared for MBIE Endeavour Programme "Smarter Targeting of Erosion Control".

7.2. Hill Country Erosion – Afforestation as a Priority Action

Stabilisation of soil in the rural environment is primarily undertaken by planting trees. All types of forest will provide some benefit to the reduction of erosion, with the most common approaches being reversion to or planting of native plants, planting production forestry and space planting exotics like poplars and eucalyptus. As described above, native planting, particularly kānuka on the challenging 7e land may be the most viable way to establish forest as poplars have proven challenging to establish in these very shallow mudstone (papa) hill country areas.

Farmers in the catchment expressed their desire to control erosion, continue grazing and provide shade and shelter. In many cases the most beneficial and cost-effective option to achieve these goals would be through space planted trees. Poplar species on class 6e land will be an excellent option. Several varieties are available through HBRC (table 4). Appropriately spaced trees can also meet the Emissions Trading Scheme (ETS) requirements[15] (i.e.: 30% canopy cover) and can increase the overall profitability of hill country land. Generally, poplars are planted as poles which are cut to 3 m lengths and cost around $20/ pole. Research indicates that planting poplars less than 10 m apart for soil slips, 5-6 m apart for earthflows and 4-6 m apart in gullies achieves the best results.

Table 4 – Poplar varieties typically available through HBRC.

Crows Nest (Populus x euramericana)	Moderately fast growth with light branching and narrow crown, good tolerance for drier sites and wind exposure on mid-to upper slopes. Suitable for erosion control and recommended variety for shelter belts.
Fraser (Populus x euramericana)	Moderate growth rate and open, narrow crown. Similar tolerance for drier sites and wind exposure on mid- to upper slopes as Crowsnest. Mainly suitable for erosion control. New variety, limited availability.
Kawa (Populus deltoides x yunnanensis)	Fast growth rate, semi rough bark and moderate crown with strongly central leader. Prefers summer moist sites with limited exposure. Suitable for erosion control and recommended variety for poplar timber (good stem form and relatively high basic wood density). Late bud break and leaf fall compared with other poplars.
Veronese (Populus x euramericana)	Fast growth rate and moderately narrow crown, suitable for a range of sites and some tolerance for drier sites, mature trees can be susceptible to a degree of wind damage on exposed sites. Suitable for erosion control, shelterbelts, agroforestry and amenity planting.

[15] How forest land is defined in the ETS | NZ Government (mpi.govt.nz)

Afforestation with pines can also be an option, and this has occurred in the Mangarara in the recent past. Pines can be a useful tool to reduce soil slips, and careful consideration should be made around the long-term approaches to harvesting and the economic returns. There are useful guides to be found in the New Zealand Farm Forestry Association including Tree Farmer which is a bespoke tool that supports tree growing at any site in New Zealand https://treefarmer.fgr.nz/.

7.3. Soil Conservation – HBRC support through advice and funding

A recommended immediate action is to partner with HBRC to create a soil conservation plan. Working with HBRC will help access their expertise and funding. In summary this approach includes:

- Experts from HBRC will help landowners to design and erosion control plan with landowners.
- Successful projects have a grant rate for erosion control plants between 50%-75% cost share with the landowner.
- Typical approaches include afforestation, primarily space planted poplars and willows (e.g., figure 10). These are delivered as poles or cuttings.
- Indicative budget per property is up to $50,000 per property per year.
- There is an opportunity to fund sediment capture actions, like sediment traps, detention bunds and wetlands.

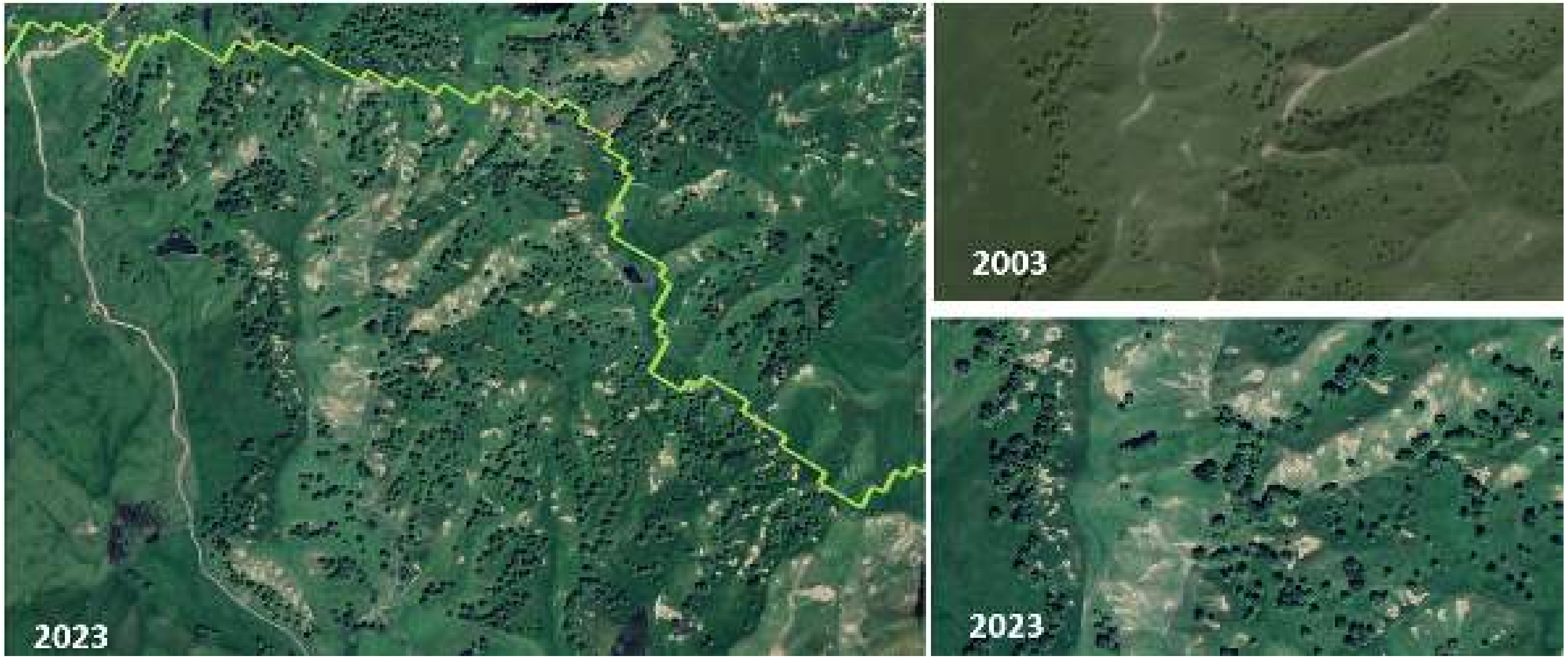

Figure 10 – Nearby areas have had extensive erosion control space planting completed. These trees were likely planting in the early to mid- 1990s based on the arial photography.

7.4. Priority Sites for Hill Country Erosion Planting

While space planted trees, retirement of areas to natives and the creation of new exotic forest areas will all have a substantial benefit to soil conservation, the initial recommended action is to work with HBRC to plan planting in erosion control areas. While deeper investigation and planning will likely be required while working with HBRC to access funding, figure 11 below outlines the priority areas in the catchment that will likely provide the greatest benefit to reducing loss in the Mangarara. These areas have been prioritised as they are the steepest and have the highest current level of slips, which aligns to priority drivers of soil erosion in the Mangarara.

Figure 11 – Catchment scale sites likely a priority for afforestation and soil conservation. These areas have the highest incidence of slips, the major driver of sedimentation in the Mangarara.

8. Phase Two – Sediment Capture and Catchment Scale Analysis

8.1. Catchment Scale Prioritisation and Placement of interventions

One of the most useful ways to understand and manage a catchment for sediment control is to understand slopes, overland flow paths, and areas of water accumulation using LiDAR. This LiDAR simply provides heights of thousands of points of land across a catchment, usually at 1 m spacing which enables the examination of slopes and contours in the landscape. LiDAR can map flow paths, areas where flow will accumulate during rainfall and areas with the highest erosion risk. The below images (figure 12) demonstrate how this approach can be used to prioritise sediment capture areas (blue) or stabilise high risk erosion areas (yellow and red areas) at farm or catchment scale. This type of approach could be highly beneficial to the Mangarara catchment group, and will help prioritise soil conservation, sediment management actions and good management practices like riparian planting and stock exclusion from sensitive areas.

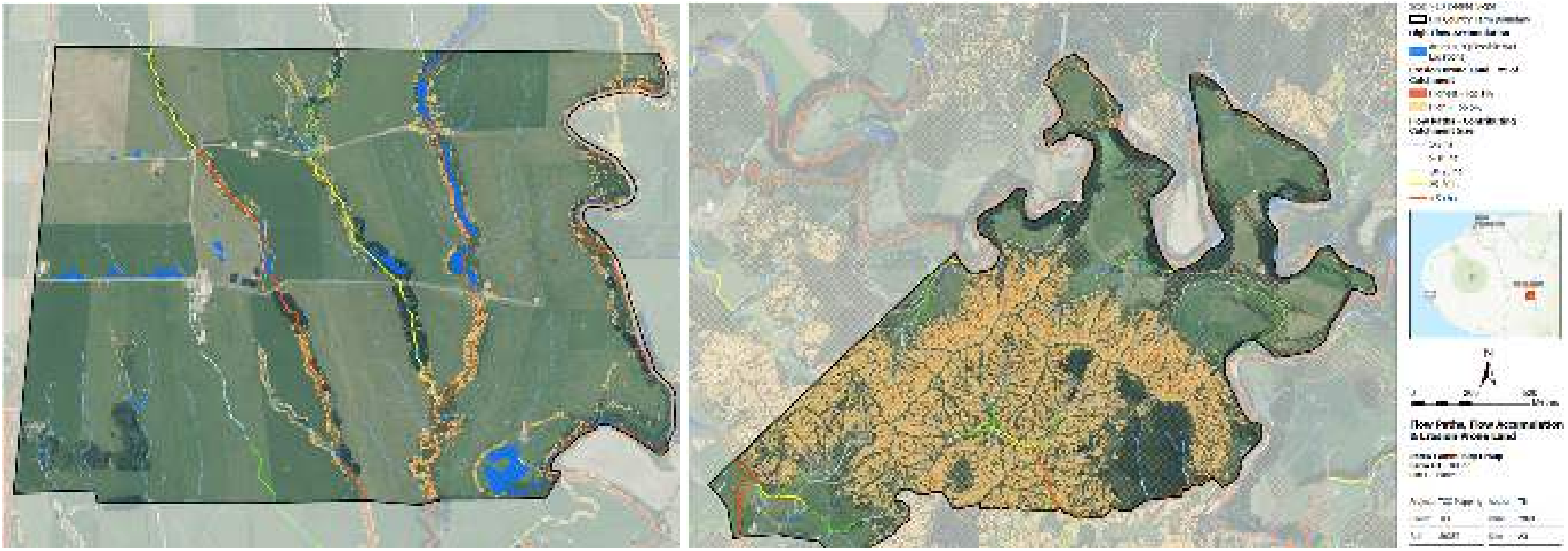

Figure 12 – Examples of how LiDAR can be used to identify erosion, flow paths and erosion areas. Both images are presented at farm scale to aid in farm planning (sourced from an Element Environmental project with Taranaki Catchment Communities).

8.1. Sediment Capture Actions

Soil conservation measures like those described above in phase 1 and section 3 are likely the most cost-effective actions to take to reduce the amount of sediment to waterways in the Mangarara. Erosion however is an inevitable process and soil will be lost to waterways irrespective of land use, meaning that sediment capture is also an important component in improving water quality.

In general, soil conservation techniques can address erosion issues at their source, leading to long-term benefits in terms of sediment reduction and overall watershed health. Sediment capture devices, such as constructed wetlands and vegetated filter strips, are effective at trapping sediment and pollutants before they reach water bodies. These devices can provide immediate improvements in water quality by capturing sediments that would otherwise impact aquatic ecosystems. Studies have shown that constructed wetlands can remove a significant amount of sediment and nutrients from runoff. For example, research has demonstrated that a constructed wetland in a rural catchment reduced sediment loads by 50% and nutrient concentrations by 40%[16].

Sediment capture devices typically involve upfront costs for installation, maintenance, and periodic cleaning. However, these devices can provide immediate water quality improvements and help prevent sedimentation issues downstream. The cost-effectiveness of sediment capture devices in rural environments depends on factors such as the type of device used, maintenance requirements, and the specific sediment load in the catchment[17].

In general sediment capture devices, including sediment ponds or settling basins, work by slowing down water flow, allowing sediments to settle due to gravity. These devices often utilise sedimentation basins, wetland plants or specialised filter media to trap sediment particles. Generally, sediment capture devices operate by intercepting and slowing down water flow, facilitating the separation and capture of sediment from water, thereby improving water quality and reducing sediment transport downstream.

In summary catchment management for sediment management should include both soil conservation and sediment capture. Afforestation and other soil conservation methods address the problem at its source by preventing soil from becoming dislodged and entering waterways. Additionally, afforestation provides other ecological benefits, such as carbon sequestration and wildlife habitat. However, despite best efforts at source control, some sediment will still make its way into waterways, especially during extreme weather events. Sediment capture devices provide a second line of defence, trapping sediment before it impacts water bodies. While afforestation provides long-term benefits, sediment capture devices can offer immediate improvements in water quality.

[16] Smith, R., Brown, K., & Davis, S. (2019). Effectiveness of a constructed wetland for sediment and nutrient removal in a rural catchment. Water Research, 55(2), 123-137.
[17] Johnson, M., White, A., & Green, D. (2017). Cost-effectiveness of sediment capture devices in rural environments: A case study. Journal of Water Resources Planning and Management, 25(1), 78-91.

8.2. Sediment Capture Examples

The below images are examples of sediment capture actions that have been implemented in rural catchments (figures 13 and 14). There are many different ways to capture sediment, and while they operate in different catchment sizes, operate using the same principles of slowing flow to enable sediment to drop out.

Figure 13 – Clockwise from top left: Detention bund build into a natural valley system. A retention dam, that holds water year-round. A large wetland. An in-stream sediment trap. A small-scale detention bund (under construction).

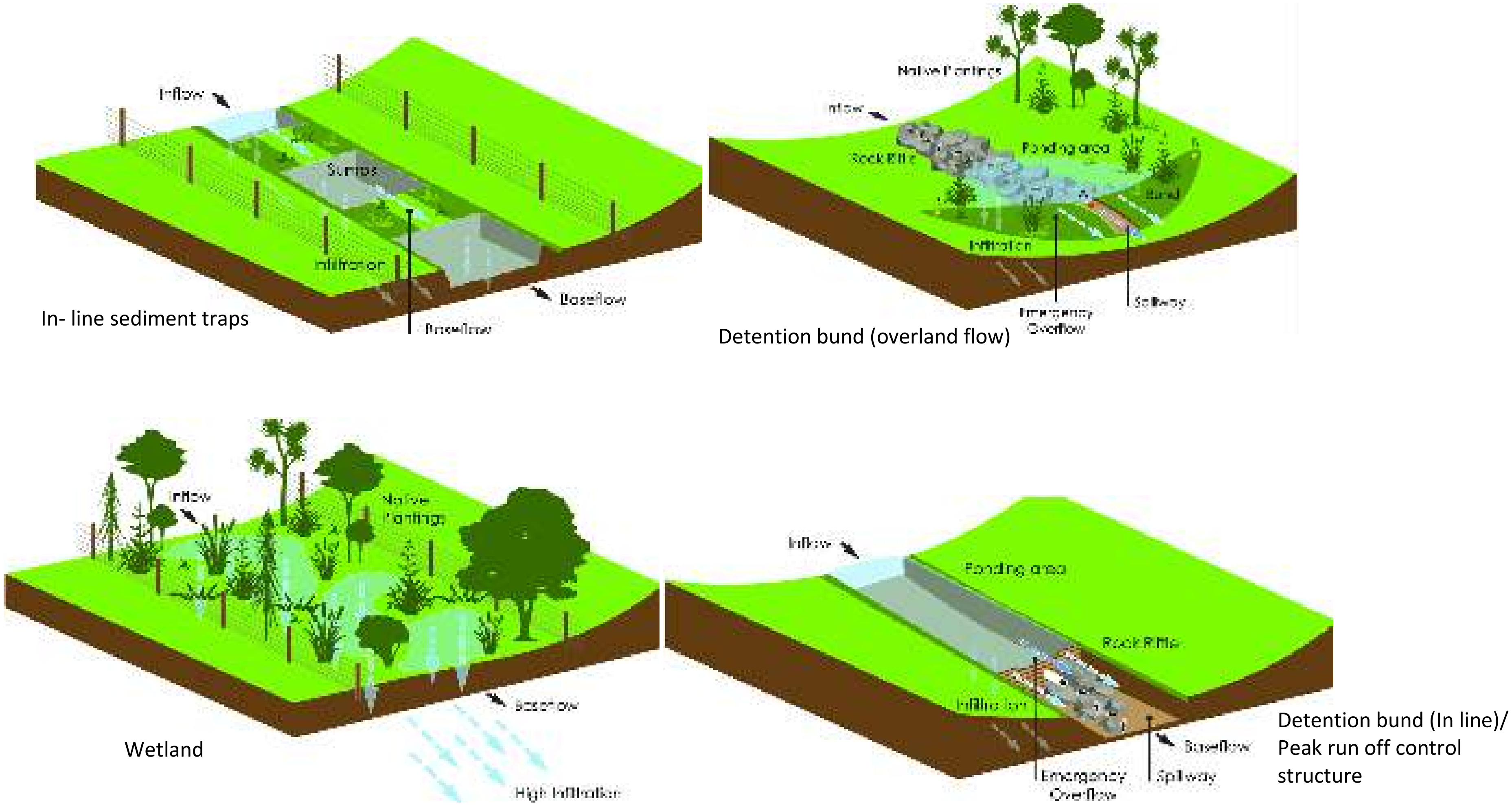

Figure 14 – Schematic examples of sediment capture actions in rural landscapes (design by Matt Couldrey - Geoid).

9. Conclusions and Recommendations

Mangarara catchment has significant soil loss issues, including large areas of soil slips and stream bed sedimentation accumulation. This soil loss impacts the catchment's economy and water quality. The impact of soil loss has been exacerbated recently by cyclone Gabrielle.

The Mangarara catchment exhibits one of the highest sediment yields across the Tukituki, averaging nearly 6.5 tons per hectare per year. Moreover, concerning landslide risks and sediment delivery to streams, the Mangarara ranks as one of the top sub-catchments within the broader Tukituki catchment. Notably, past studies have revealed that pasture production on eroded sites takes approximately two decades to reach 70-80% of the productivity observed on uneroded land.

It is recommended that the Mangarara catchment group focusses on the high priority work to reduce soil slips and stream bank erosion. This includes undertaking crack willow removal in the lower catchment and stabilisation of soil in high priority areas using afforestation appropriate for each site. Both of these high priority focus areas will benefit greatly from the involvement of HBRC.

At the same time, while the high priority work is underway, it is recommended that the Mangarara catchment group undertakes further analysis of the state of the catchment using GIS approaches such as LiDAR. This should enable additional understanding of priority sites and the location and type of sediment control actions that should be installed.