The CAPTure pilot project:

A spatial tool for prioritising catchment-based actions in the Pūkorokoro catchment, Firth of Thames, New Zealand.

April 2020

Prepared by Reece Hill and Dan Borman

Landsystems

PO Box 4348

Hamilton East

Hamilton 3247

For:

Living Water

Suggested citation:

Hill, R.B., Borman, D.W. (2020) The CAPTure pilot project: A spatial tool for prioritising catchment-based actions in the Pūkorokoro catchment, Firth of Thames, New Zealand. Living Water, Hamilton.

ACKNOWLEDGEMENTS

Thank you to the landowners for previous access to their properties and supplying relevant site management information. Thank you to Living Water, DOC and Fonterra staff for their technical input and guidance, especially Matt Highway, Katie Collins, Dion Patterson, and Rose Graham.

SUMMARY

Living Water has initiated a programme of works in the Pūkorokoro-Miranda catchment to address the high-level objective of "Proven catchment scale freshwater management that demonstrates the protection of lowland threatened ecosystems."

The focus is on catchment management that will lead to enhancement of the Miranda estuarine environment and RAMSAR wetland. Potential benefits of this programme include biodiversity enhancement (and especially benefits to migratory birds), benefits to farmers and benefits to the Firth of Thames (including improved water quality outcomes).

An initial tool developed by Phillips et al. (2019) identified values, threats, and priority locations for the different threats. A potential list of mitigations to address the threats were identified (see Table 2 of the Phillips et al. (2019) report).

Living Water approached Landsystems to further develop the initial Catchment Prioritisation Tool for the Pūkorokoro catchment, focussing on mitigations that farmers could implement, and providing guidance about where these mitigations would be best directed to reduce the impacts on water quality in the lower catchment.

The result has been the development of CAPTure (Catchment Action Prioritisation Tool). CAPTure builds on the concepts of Phillips et al. (2019), incorporating new components including:

a) focussing analyses and outputs on water quality values in the lower Pūkorokoro catchment,
b) developing GIS criteria for incorporating mitigations into the tool, and
c) developing mitigation effectiveness and cost-benefit outputs to guide mitigation efforts in the Pūkorokoro catchment.

A finer scale hydrological framework (based on an available 20 m DEM) was refined with a resulting 441 reach-watersheds delineated across the catchment. Catchment scale datasets included catchment condition survey data and finer scale LUC class delineations. These were incorporated into a geospatial database underpinning the CAPTure tool.

A suite of 12 mitigations were defined and spatial criteria developed for their incorporation into the geospatial database.

Spatial analysis techniques (using Manifold® and SQL) were applied to the geospatial datasets to provide relative comparisons and rankings of water quality value threats, and mitigation derived contaminant reductions and costs. Four prioritisation outputs were presented to provide a range of guidance for the placement of mitigations across the catchment and through time.

The CAPTure outputs indicated that the greatest threats in the catchment were in the lower catchment and driven by nitrogen and microbes. However, with focus on improving lower catchment water quality values, the priority placement of mitigations in the upper catchment was likely to be the most effective and cost efficient.

The initial CAPTure tool developed in this pilot project provides useful guidance for prioritising actions in the Pūkorokoro catchment. Current limitations for the use of the tool and potential improvements have been identified.

All CAPTure outputs are available for use by Living Water and catchment landowners and managers.

Contents

LANDSYSTEMS
KNOW YOUR LAND

INTRODUCTION

Living Water has a programme of work in the Pūkorokoro/Miranda sub-catchment to address the high-level objective of "Proven catchment scale freshwater management that demonstrates the protection of lowland threatened ecosystems."

The focus is on catchment management that will lead to enhancement of the Miranda estuarine environment and RAMSAR wetland. Potential benefits of this programme include biodiversity enhancement (especially benefits to migratory birds), benefits to farmers and benefits to the Firth of Thames (including improved water quality outcomes).

The initial tool developed by Phillips et al. (2019) identified value and threats and priority locations for the different threats. A potential list of mitigations to address the threats was identified - see Table 2 of the Phillips et al. (2019) report.

Living Water approached Landsystems to further develop the initial Catchment Prioritisation Tool for the Pūkorokoro catchment, focussing on mitigations that farmers could implement, and providing guidance about where these mitigations would be best directed to reduce the impacts on the lower catchment water quality.

The result has been the development of CAPTure (Catchment Action Prioritisation Tool). CAPTure builds on the concepts of Phillips et al. (2019), incorporating new components including:

a) focussing analyses and outputs on lower catchment water quality values in Pūkorokoro catchment,
b) developing GIS criteria for incorporating mitigations into the tool, and
c) developing mitigation effectiveness and cost-benefit outputs to guide mitigation efforts in the Pūkorokoro catchment.

The pilot project assesses the added value of refining the tool using improved resolution catchment datasets and incorporating mitigations, and the potential opportunities for using CAPTure in other catchments.

PREVIOUS WORK

WRC Regional prioritisation Project

A 2013 review of Waikato Regional Council's (WRC) sustainable land management programmes highlighted a need to improve prioritisation of Council's catchment works and focus on the ground works in the areas where demonstrable outcomes are most likely to occur.

Over 2013-2014 a prioritisation framework was developed for the Waipā catchment to support the implementation of integrated catchment management in that Zone. The framework was part of a prioritisation process that helped identify priority sub-catchments and sites for soil conservation, water quality (nutrients) and biodiversity in the Waipā. The outputs of the Waipā framework have informed the priority catchment management approach that sits within the Waipā Catchment Plan (Waikato Regional Council, 2014).

Following the Waipā, the Waikato Regional Prioritisation project (WRPP) was initiated, proposing a similar framework for the rest of the Waikato Region. The project had an initial development phase (Phase 1) followed by Phase 2, which incorporated new model data and the use of soil conservation mitigations but only covering the greater Waikato Catchment zones (Waipā, upper Waikato, Central Waikato and Lower Waikato zones).

The spatial framework brought together available spatial model outputs to provide broader (and easier to understand) sets of information about biophysical issues to be used for targeting (prioritising or ranking) catchments and sub-catchments for implementing soil conservation, water quality, biodiversity and riparian management mitigations.

The spatial framework provided a decision support system, intended to be maintained and run by a spatial analyst under direction of land scientists and land management practitioners. The outputs of maps, graphs and data only provide a spatial summary of the main biophysical issues. On the ground expert knowledge of issues as well as any other issues considered important to prioritising implementation were to be part of the prioritisation process and considered alongside framework outputs. For the Waipā prioritisation process several workshops were held to discuss catchment priorities for the zone, with the framework providing the starting point for conversation.

The benefits of using the WRPP framework included having a single decision support tool to provide consistent prioritisation of biophysical issues across the region, catchments within zones and within individual priority catchments. The maps, graphs and data helped identify the relativity across issues and catchments.

Catchment Prioritisation Framework (CPF) Tool

Living Water commissioned Streamlined Environmental Ltd (in conjunction with Landsystems) to develop a method for prioritising actions at the watershed scale, along with a monitoring plan for establishing baseline conditions and assessing progress towards achieving outcomes identified for these actions. The project developed a prioritisation method and associated mapping outputs and tool - the Catchment Prioritisation Framework (CPF) which included a refined hydrological network, catchment values, priorities for threats, a list of potential mitigations for the catchment and a preliminary monitoring plan.

APPROACH

This pilot project draws on methods developed by Phillips et al. (2019), Hill et al. (2015), Hill and Borman (2016), and as part of the Waikato and Waipā River Restoration Strategy, Neilson et al. (2018a and 2018b) and Hill et al. (2017).

In these projects, potential mitigations were identified but only for hillslope and riparian management. In this pilot project, new developments include finer scale catchment data (such as riparian fencing) and an extended suite of water quality related mitigations. GIS criteria are developed for incorporating these mitigations into the spatial analysis. New prioritisation outputs (based on specific water quality related values and mitigation related reductions and cost-benefit estimates) can be used to guide land management actions in the Pūkorokoro catchment. These improvements collectively form the basis for a CAPTure (Catchment Action Prioritisation Tool).

CAPTure is based on a geospatial database and set of analyses which can make use of any available datasets to identify the relative generation of contaminants in a catchment. Additionally, CAPTure estimates relative reductions and costs associated with implementing broad mitigations (e.g. riparian fencing to exclude stock).

Advantages of the approach are that it is not locked into one single model or dataset – so it can use the strengths of multiple models. The selection of models and datasets can be revised easily, with finer resolution datasets or survey information being made use of as it becomes available. The spatial framework allows aggregation of data, and outputs at multiple scales, allowing relative comparison across watersheds, sub-catchments, and broader catchments. The outputs are largely spatial and visual.

The main limitations are the availability of finer scale datasets and the information around the efficacy of mitigations and the ability to place these in the catchment.

CAPTure is not intended to be prescriptive but is intended to provide the initial guidance for strategically implementing mitigations in a catchment, and across catchments. It simplifies the biophysical component of the decision making that a farmer otherwise must collate and consider, allowing them to make quick informed decisions about placing mitigations on their farm.

The Catchment Action Prioritisation Tool (CAPTure) builds on the tool developed by Phillips et al. (2019) and incorporates additional literature to establish preliminary mitigation spatial (GIS) criteria, similar to the approach used in the Waikato and Waipā River Restoration Strategy.

The conceptual approach and components of the three models (WRPP, CPF tool and CAPTure) are shown in Figure 1.

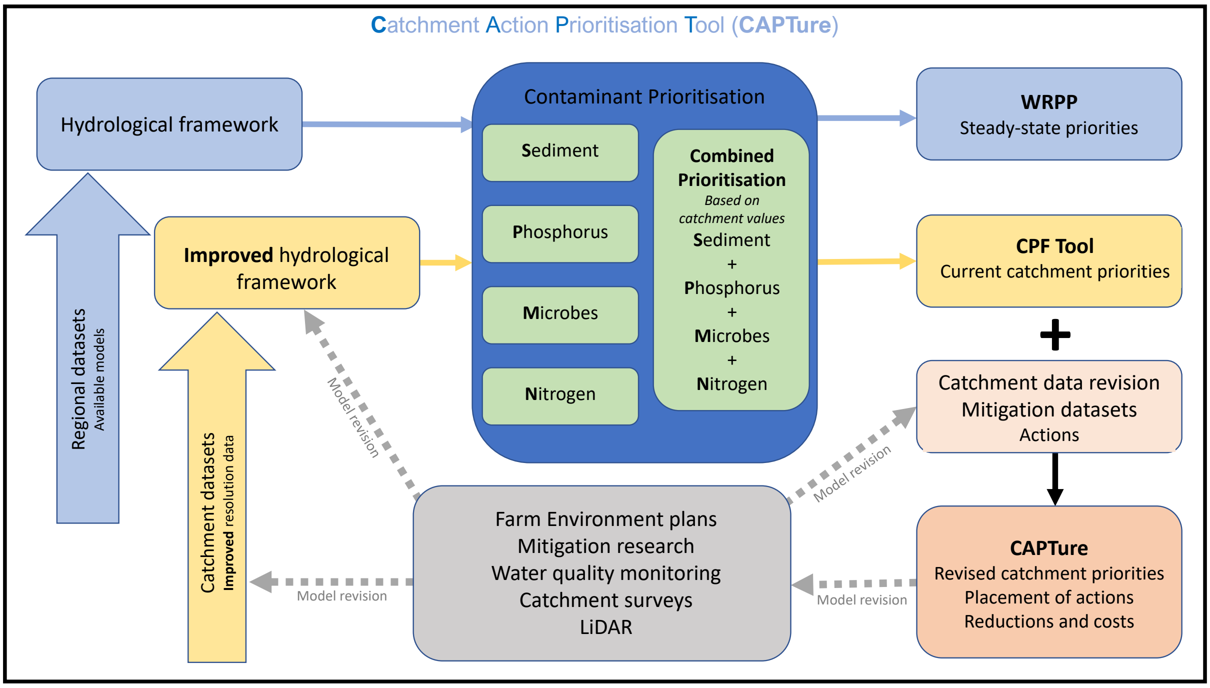

Figure 1: The conceptual approach and components of the three models (WRPP, CPF and CAPTure tools).

The pilot project uses this approach to compare the added value provided by each successive model. The main differences and similarities of the model stages are described in Table 1.

Table 1: The main differences and similarities of the tools/model's components.

Component	**Tool**		
	WRPP (Waikato Regional Prioritisation Project)	CPF (Catchment Prioritisation Framework)	CAPTure (Catchment Action Prioritisation Tool)
Values	Does not identify values or associated them with threats or mitigations.	Identifies values and associates them with threats and mitigations.	Identifies values and associates them with threats and mitigations.
Threats	Identifies soil conservation and nutrient threats.	Identifies a broad range of threats associated with values.	Identifies a broad range of threats associated with values and mitigations.
Framework	Uses watershed reaches derived from REC2.	Uses watershed reaches derived from a DEM.	Uses watershed reaches derived from a DEM.
Datasets	Uses regional datasets only.	Uses regional > catchment scale datasets.	Uses regional, catchment revised regional datasets and catchment datasets.
Mitigations	Soil conservation mitigations only.	Identifies a suite of mitigations but does not apply them in the prioritisation.	Identifies a broader suite of mitigations than the CPF and applies them in the prioritisation.
Priorities	Priorities identified for individual threats for soil conservation and nutrients.	Priorities are not identified.	Priorities identified for individual threats and combined threats for water quality.
Costs	Costs for soil conservation mitigations only.	No mitigation costs are estimated.	Costs are estimated for all mitigations.
Reductions	Reductions are estimated for sediment only.	No reductions are estimated.	Reductions are estimated for N, P, *E. coli* and sediment.

CATCHMENT VALUES AND THREATS

Introduction

Threats can be combined to target the impacts for a specific catchment value. For example, Phillips et al. (2019) identified threat layers for a range of values for the Pūkorokoro catchment (water quality, habitat, taonga, flow regime, land, and biodiversity). For each catchment value there are a set of threats that impact on the values. As part of this pilot project, Living Water were interested in providing a single prioritisation of reach-watersheds that indicate where actions should be focussed for reducing catchment impacts on the lower receiving environment (the overall catchment goal). Catchment actions such as improving fish passage, managing weeds, and improving riparian habitat were considered outside this as they either did not impact on the lower receiving environment, or could be remedied directly by on-farm management.

Threats to water quality in the Pūkorokoro catchment

Phillips et al. (2019) identified values that comprise the water quality value for the Pūkorokoro catchment:

- Sediment
- Nutrients
- Clarity
- Temperature
- Microbes

In turn, a set of threats that impact on the water quality value can be identified:

- Hillslope erosion
- Streambank erosion
- Riparian stock access
- Loss of riparian vegetation
- Elevated nutrients
- Elevated microbes

Combining these threats and calculating a single score can be used to identify reach-watersheds with the greatest overall threat. An additional refinement is to weight the threat scores to place greater emphasis on the threats that have the greater impact on the catchment value.

Combining threats and weighting

The process for combing threats and applying weightings was primarily based on expert opinion; discussions with science staff in this project (from DOC and Fonterra) and knowledge gained from previous work (WRC, 2014; Hill and Borman, 2016; Neilson et. al., 2018 and Phillips 2019).

Water quality monitoring by WRC indicates that sediment is the main water quality issue with lesser issues related to nutrients and biology (Golder, 2015).

Relative sediment contributions from hillslope and streambank sources are not well documented. Hill and Borman (2016) used 50% hillslope generation and 50% streambank generation for the WRPP. For the Pukorokoro catchment 60% hillslope generation and 40% streambank generation has been used to approximate a likely lower density of incised waterways relative to the catchments of the Waikato Basin.

The final weighting was based on an agreed importance of the threats for impacting on the water quality in the lower catchment, to provide a relative weighting of about 75% sediment/20% nutrients/5% microbes. Sediment is a combination of hillslope and streambank erosion. Riparian protection likely contributes predominantly to sediment, with lesser contributions of direct nutrient and microbe inputs.

The threats and weighting used to address the water quality value for the Pūkorokoro catchment in this project are shown in Table 2. It is worth noting that these weighting can be adjusted in the future if research becomes available.

Table 2. The threats and weightings used to calculate the combined threats score.

Threat	Threat layer(s)	Rationale	Weighting
Elevated sediment	Hillslope sediment	Hillslope sediment generation is the main source of sediment, estimated at ~60% of sediment reaching the lower catchment.	0.35
	Streambank sediment	Stream bank sediment generation is a major source of sediment, estimated at ~40% of sediment reaching the lower catchment.	0.25
Riparian protection	Riparian access	Stock access to waterways provides localised stream bank instability and direct nutrient inputs.	0.075
	Riparian vegetation type	Absence of woody riparian vegetation increases likelihood of stock access to waterways and localised stream bank instability.	0.075
Elevated nutrients	N generation	N loss is a contributing nutrient.	0.10
	P generation	P loss is a contributing nutrient.	0.10
Elevated microbes	*E. coli* generation	*E. coli* loss is a contributing microbe.	0.05

INPUT DATASETS

Introduction

General datasets used in this project are shown in Table 3. It should be noted that the datasets used for the Waikato and Waipā River Restoration Strategy derived layers are the main datasets only. Additional details of the specific methods used can be sourced from the original reports.

Table 3. Specific datasets used to inform the threats for the Pūkorokoro-Miranda catchment analysis.

Item	Dataset/model	Description
Reach-watersheds	New Zealand National Digital Elevation Model (DEM) - North Island (20 metre resolution) [1]	Derived waterway reaches and watersheds (reach-watersheds)
Landcover/Land use	Land Cover Database version 4.1[1]	Vegetation class area (ha)
Threats		
Hillslope sediment generated	Waikato Regional Prioritisation Project (WRPP) outputs used in the Waikato and Waipā River Restoration Strategy[2] (Sediment derived from SedNetNZ outputs for hillslope and streambank erosion processes; nutrients and microbes derived from CLUES outputs; all use updated land use data derived from LCDB v4.1 and AgriBase™ datasets)	Generated yield (t/yr)
		Erosion risk area (ha)
Streambank sediment generated		Generated yield (t/yr)
Total N generated		Generated yield (t/yr)
Total P generated		Generated yield (t/yr)
E. coli generated		Generated yield (count/yr)
Stock access to waterways	Natural Solutions Pūkorokoro Catchment Condition Survey[3]	Riparian margins through pasture that are not fenced
Riparian vegetation type	Natural Solutions Pūkorokoro Catchment Condition Survey[3]	Riparian margins through pasture

[1] Data reproduced with the permission of Landcare Research New Zealand Limited
[2] Waikato Regional Council (2018)
[3] Natural Solutions (2017)

Improved datasets in CAPTure

Where available, CAPTure can include datasets that are at a finer resolution than regional and national scale and are more representative of what is in the catchment. In turn, this improves the CAPTure outputs for decision making. A main limitation to using catchment scale datasets is their availability and completeness. Catchment surveys require greater resources than regional scale surveys and are often completed for part of a catchment or individual farm. Although these partial datasets can be integrated in to CAPTure, whole of catchment datasets are preferable to ensure consistent comparisons across the catchment. The two main dataset improvements used in CAPTure were the Catchment Condition Survey (Natural Solutions, 2017) and a refined (finer scale slope class definition) Land Use Capability slope class classification derived using the DEM.

Catchment Condition Survey (Natural Solutions)

The Pūkorokoro Catchment Condition Survey (Natural Solutions, 2017) provides detailed riparian fencing and vegetation cover information (Figure 4) that replaces regional scale data (estimates) from the Riparian characteristics of pastoral waterways in the Waikato region, 2002-2012 (Jones et al., 2015).

The regional estimates were based on a single percentage value for fencing and vegetation type, for the Hauraki management zone which was applied to all reaches when imposing a riparian mitigation. The catchment condition survey provides vastly improved data (spatially and temporally) for imposing realistic riparian mitigations.

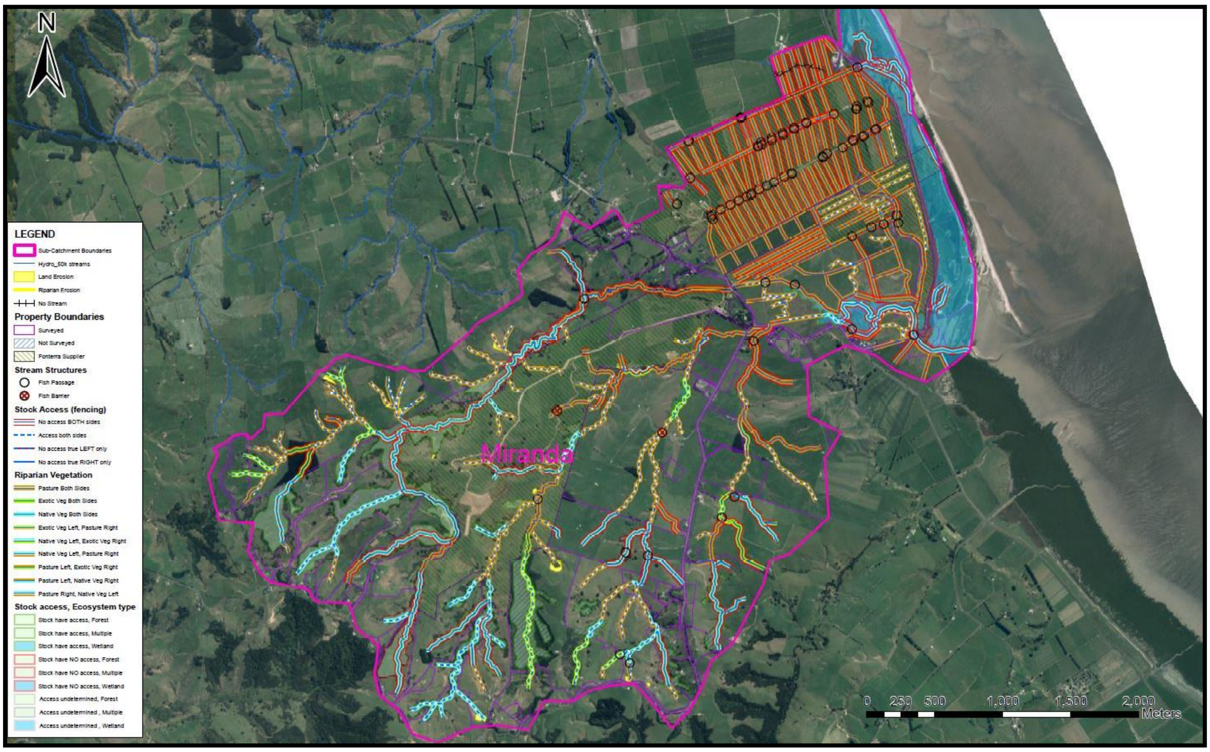

Figure 4. Map of Catchment condition survey spatial data, including stock access (fencing) and riparian vegetation data.

Finer scale LUC

CAPTure uses LUC classes for the spatial placement of some of its soil conservation mitigations. The available LUC dataset (derived from the New Zealand Land Resource Inventory (NZLRI)) is presented at a nominal scale of 1:50,000. At the time, the NZLRI and LUC maps were compiled, topographic data was coarser than the data that is now available. The main impact on the LUC dataset is the result of the lack of topographic differentiation in the LUC dataset relative to what is "on the ground" - LUC classes that are defined by slope class, generally the LUC classes with erosion (e) limitations are coarser than what is on the ground. For the Pūkorokoro catchment, LUC classes 4e, 6e and 7e classes can be refined using finer scale slope class data. In the absence of LIDAR data, the 20 m DEM was used to derive new slope classes and revise the LUC class limitation (sub-class) for each reach-watershed based on the slope class criteria in Lynn et al. (2009). The use of the finer scale LUC improved the spatial definition of these LUC classes and therefore the placement of soil conservation mitigations described in the *Mitigations* section of this report.

HYDROLOGICAL FRAMEWORK

Introduction

The hydrological network of reach-watersheds provides the spatial framework for all analyses. It is the finest spatial base for aggregating all spatial data for analysis. Data outputs for all reach-watersheds can be aggregated or grouped at multiple scales. This framework provides the flexibility to apply any spatially defined boundary to the data for analysis.

The hydrological framework follows the approach outlined in Hill et al. (2015) and Hill and Borman (2016) and used in the Waikato And Waipā River Restoration Strategy (Waikato Regional Council, 2018). The framework was based on the River Environment Classification, v2.5 (REC2), (NIWA, 2019).

The main advantages of using the REC2 hydrological framework is that it provides hydrologically connectivity, models such as CLUES use the REC river segments to perform their calculations, it can be spatially aggregated to interrogate data at various scale, and it provides full national coverage.

The disadvantage for its application in the Pūkorokoro catchment is its coarseness - the limited number of reach-watersheds provides poor spatial delineation.

Due to this coarseness, refinements to the hydrological framework were made for this analysis. A finer scale hydrological network was derived to replace the REC2 based on the hydrological network used in the WRPP.

Finer scale hydrological framework

CAPTure uses a finer scale 20 metre Digital Elevation Model (20 m DEM) based hydrological network.The finer scale framework provides greater spatial delineation of the hydrologically contiguous surface waterway reaches and associated watersheds (reach-watersheds). The main differences in resolution between the REC2 and 20 m DEM derived hydrological networks are presented in Table 4.

Table 4. Differences in resolution between the two hydrological frameworks for the Miranda/Pūkorokoro catchment.

Hydrological framework	Catchment area (ha)	Average reach-watershed area (ha)	Catchment watercourse length (km)	Average reach length (km)	Reach count
REC2 framework	1360	59	23	1.0	23
20 m DEM framework	1362	3	67	0.2	441

A spatial comparison of the difference “grainsize” of the hydrological frameworks is demonstrated in Figure 5. It is important to recognise that although the reach-watersheds are finer, the imposed data may still be from regional (broader scale) datasets.

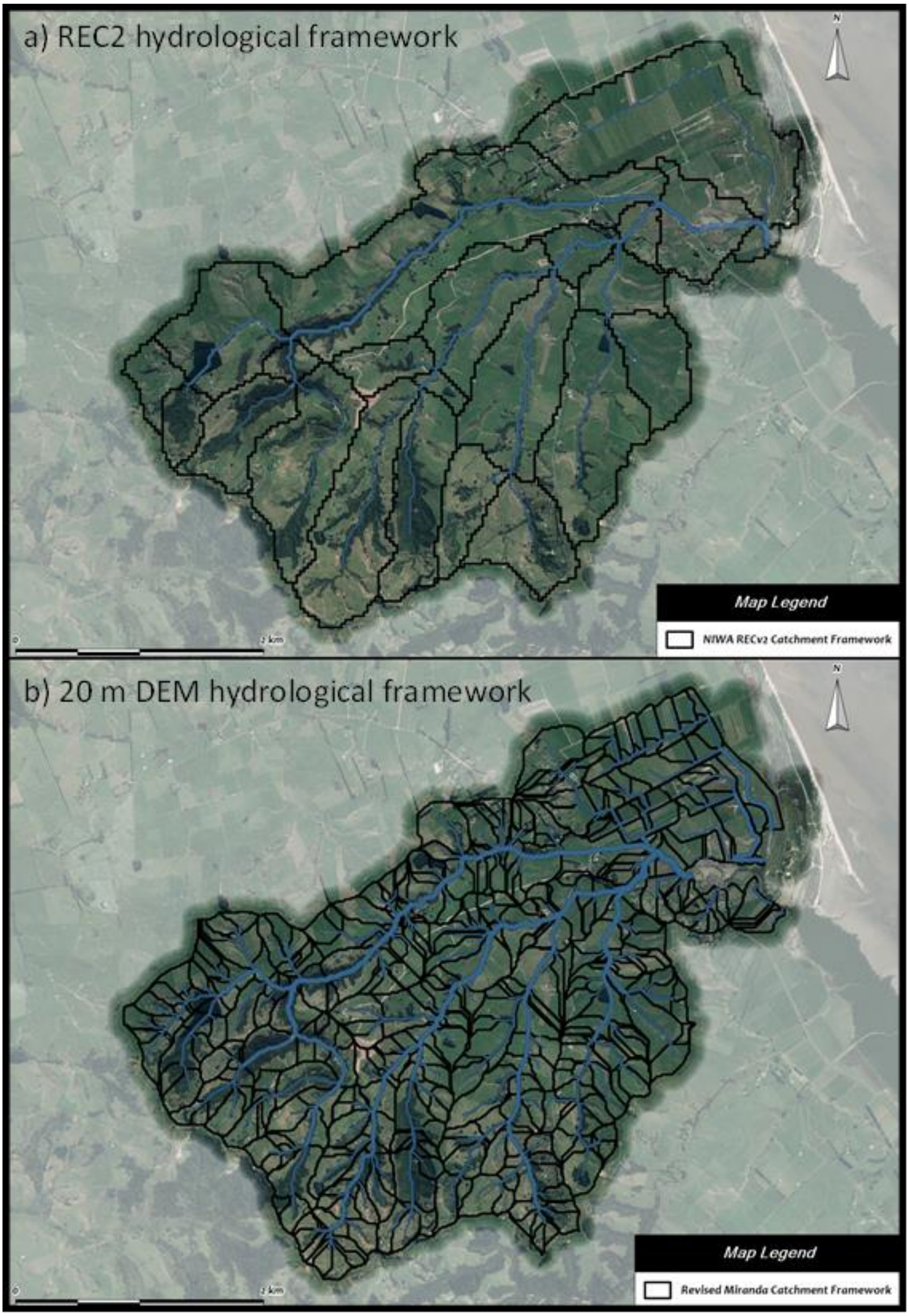

Figure 5. Comparison of a) the REC2 and b) the 20 m DEM hydrological frameworks.

SCORING AND RANKING (PRIORITISATION)

Introduction

CAPTure uses relative normalised scores to prioritise across reach-watersheds in a catchment for threats and mitigations. The approach has both advantages and disadvantages when compared with using absolute data.

The main **advantages** include:

- Data is averaged across model outputs for a threat, this can reduce the influence of extreme outlying data.
- Being able to combine data from multiple output sources (i.e. data from multiple models) to create a single "score" that represents the average of all the model data used – this reduces the reliance on a single model (all models have strengths and weaknesses).
- Being able to combine multiple threats and weight the scores to address a specifically defined catchment value.
- Enabling a relative comparison of the effectiveness of different mitigations.
- Aggregation of reach-watersheds into sub-catchments and catchments to identify threats and the effectiveness at multiple scales.

The main **disadvantages** include:

- Data is averaged across model outputs for a threat, this can lead to loss of the "high and low" extremes within data that may be important - for example most contaminants move through a catchment at high flows.
- Only relative percentage changes can be estimated for threats and mitigations - estimates of absolute yield cannot be calculated.

Calculating scores

The spatial analysis uses MANIFOLD® GIS software and SQL language to write scripts to automate and speed up the analysis. This allows the analysis to be updated regularly if changes are required, or input datasets are modified or added. The analysis requires a score to be computed for each reach-watershed. The final scores are normalised to enable the combination and comparison of threats across the catchment.

Additionally, data are normalised where multiple datasets are used to derive a threat score (e.g. CLUES sediment and SednetNZ can both be used to derive the sediment threat). This approach allows data of different scales to be aggregated to derive a single threat score.

The final score for a reach-watershed has two components: a *reach score* and an *upstream score*.

The *reach score* is derived using the proportion of the threat that occupies the reach-watershed. It represents the threat contribution from the reach-watershed.

For example, using the catchment condition survey data (Natural Solutions, 2017) we can determine the length of stream bank which allow stock access within the reach-watershed by determining the total bank length of the reach that is unfenced. The length contribution of each unfenced section is summed, and the total proportion of unfenced bank length is calculated against the total length of bank within the reach. Higher scores are given to reach-watersheds with a higher proportion of unfenced bank length. Similarly, for area-based threats, higher scores are given to reach-watersheds with a higher proportion of area with the threat. For generation-based threats (such as sediment generation) scores are given to reach-watersheds based on absolute generation values.

The *upstream score* is included to reflect the impact/contribution of the upstream catchment above a reach-watershed. Also, this has the effect on "averaging the scores in closer proximity (in a hydrological context) to simplify the visual pattern later in the prioritisation outputs.

The *upstream score* is derived by averaging all upstream reach-watershed scores for every reach-watershed. The final reach-watershed score is derived by summing the *reach score* and *upstream score* for each reach and scaling the result to yield a normalised score scaled from 0-100:

Reach-watershed threat score =
((Reach score + Upstream score) / Max (Reach score + Upstream score)) * 100

Ranking scores

The ranking of scores for individual and combined threats, mitigations (reductions and cost-benefits) requires that the data are normalised across attributes to provide relativity in the scoring and prioritisation analysis. This has the following advantages:

- Allows the bringing together of multiple datasets,
- provides flexibility to incorporate new data as it becomes available,
- it is hydrologically connected,
- consideration of the upstream catchment condition and inclusion in the score for a reach-watershed, and
- it is scalable to provide information and a framework for whole of catchment and sub-catchment scale assessment.

For individual threats and mitigations, the ranking is simply based on the normalised score for the reach-watershed.

For threats, the highest rank is assigned to the greatest threat. For mitigations, the highest rank is assigned to the greatest reduction, and for cost-benefit the highest rank is assigned to the greatest cost-benefit (the greatest reduction for the least cost).

MITIGATIONS (CATCHMENT ACTIONS)

Introduction

The inclusion of mitigations CAPTure aims to identify actions that can be used by land managers to reduce the water quality related threats in the catchment.

The inclusion of the mitigations in CAPTure provides a way of estimating the "catchment scale" efficacy, in terms of reducing threats, and the cost of doing so.

A key step is defining the spatial extent of each mitigation and developing criteria for imposing the mitigations onto the threats database within the hydrological framework.

This process uses a range of nationally and locally available datasets and current literature on the effectiveness of mitigations and estimates of costs.

CAPTure logically assumes that all mitigations cannot be placed everywhere in the catchment. Mitigation criteria have been developed in a way to place mitigations where they are most likely to be used. Criteria are based on expert knowledge of currently known soil and land management practices. A similar approach has been used to prioritise soil conservation across catchments for the Waikato and Waipā River Restoration Strategy (Nielsen et al., 2018).

The mitigations defined in this project are a first attempt to include mitigations in the spatial framework. The GIS process is structured so that new data or insight can be readily incorporated and the components re-run to update the output database and maps.

The following section of the report provides the criteria used to define mitigations, assumptions and limitations, and opportunities for improvement.

Mitigation selection

Mitigation criteria were defined for each of those mitigations addressed in Table 5 of Phillips et al. (2019). The criteria were based on the best available information from farmers, catchment management staff, in theory targeting the types of mitigations that are either undertaken by farmers or funded through catchment soil conservation work by regional council.

The mitigations selected for use in CAPTure focussed on addressing the threats and values identified for addressing lower catchment water quality (Figure 6) and practical implementation – mitigations that were used by land managers in farm planning.

Potential mitigations

Selected mitigations identified in Phillips et al. (2019) provided the basis for the mitigations used in this CAPTure pilot project. Mitigations were linked with the water quality related threats and values identified specifically for the Pūkorokoro catchment (Figure 6). Additional sources of information were used to increase the suite of mitigations to span the contaminants of interest. Other information sources included:

- McDowell et al. (2013)
- Hill and Blair (2006)
- The menu of practices to improve water quality (Dairy farms and Drystock farms)
- Industry-agreed Good Management Practices relating to water quality (Version 2)

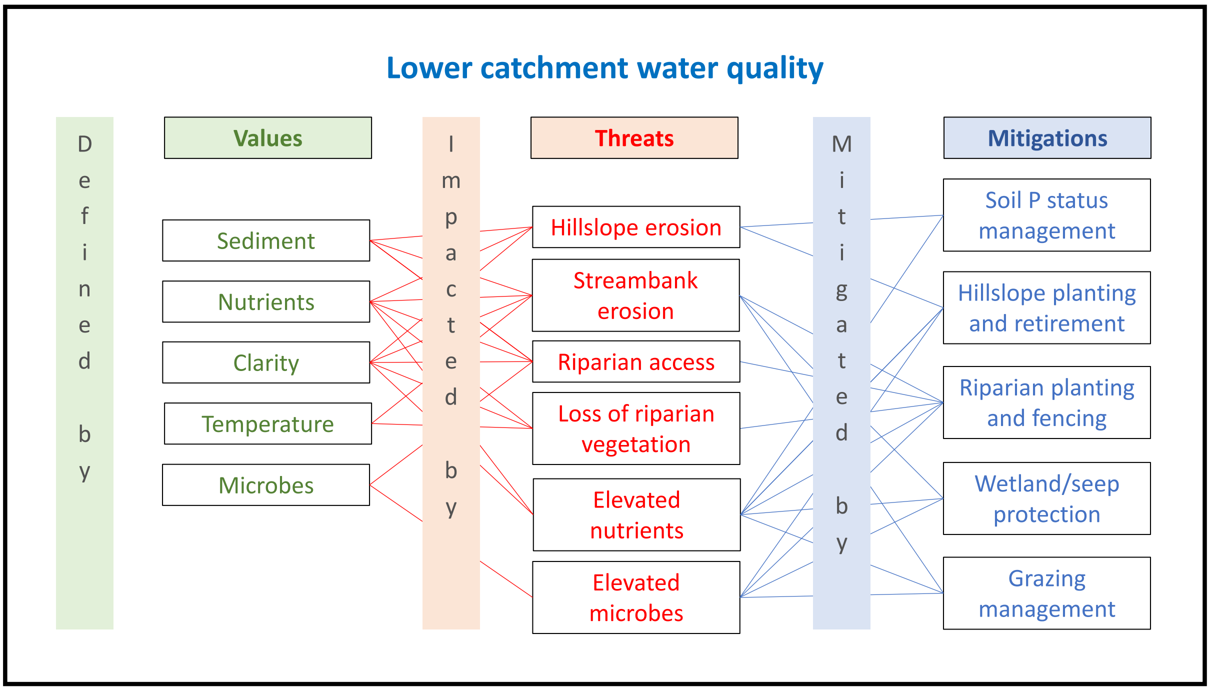

Figure 6: Links between water quality values, threats, and mitigations for the Pūkorokoro catchment.

A suite of twelve (12) mitigations were selected for the CAPTure tool in the Pūkorokoro catchment. These are listed and described in Table 5.

Table 5. The suite of 12 mitigations selected for the CAPTure tool in the Pūkorokoro catchment.

Mitigation	Description
Soil management	
Olsen P (soil P status)	Optimising soil P status for pasture production, minimises soil P loss and maximises vegetation (pasture) cover - for given stock management
RPR (slow release fertiliser)	Optimising soil P availability for pasture production, minimises soil P loss and maximises vegetation (pasture) cover - for given stock management
Hillslope management	
Hillslope pasture stability	Unstable land in broken pasture with slopes >26 to 35 degree slopes, identified using LUC 6e polygons and DEM refined slope class
Hillslope plantations	Land >35 degrees identified using LUC 7e polygons and 20 m DEM refined slope class.
Hillslope retirement	Steep areas not capable of supporting pasture or plantation forestry according to LUC classification) i.e. conservation land only. No 8e areas were classified in the areas in Pūkorokoro catchment.
Hillslope active erosion	Active bare soil erosion areas (e.g. slips) on hillslopes.
Riparian management	
Riparian fencing	Fencing provides stock exclusion. Removes direct input of contaminants to waterways. Rank grass acts as a buffer for sediment, nutrients, microbes as well as stabilising banks.
Riparian woody vegetation	Fencing provides stock exclusion. Removes direct input of contaminants to waterways. Woody vegetation acts as a buffer for sediment, nutrients, microbes as well as deep roots stabilising banks and removing some nutrients.
Wetland management	
Lowland wetland retirement	Retire from stock grazing and fence perimeter of whole area.
Hillslope wetland (seep and ephemeral) protection	Retire from stock grazing and fence perimeter of whole seep area.
Grazing and soil management	
CSA flow path management	These are flow lines and the area surrounding (~5m either side of centre line) connecting with waterway of any size. Avoid placement of gates and troughs, maintain adequate pasture as a filter, and avoid grazing during wet conditions.
Steep soils (>21 degrees)	Avoid grazing heavy stock on steep slopes to minimise soil loss.
Wet soils (Imperfectly, poorly, and very poorly drained soils)	Avoid grazing stock when pugging prone soils are wet.

McDowell et al. (2013) diagrammatically presented the relationship between mitigation cost and effectiveness for reducing sediment, phosphorus, and nitrogen (Figure 7).

The mitigations selected for CAPTure are highlighted green in Figure 7 indicating the range of mitigations covered and the relative cost and effectiveness of the mitigations selected. In general, mitigations closer to the 0-0 intersect are considered most cost efficient.

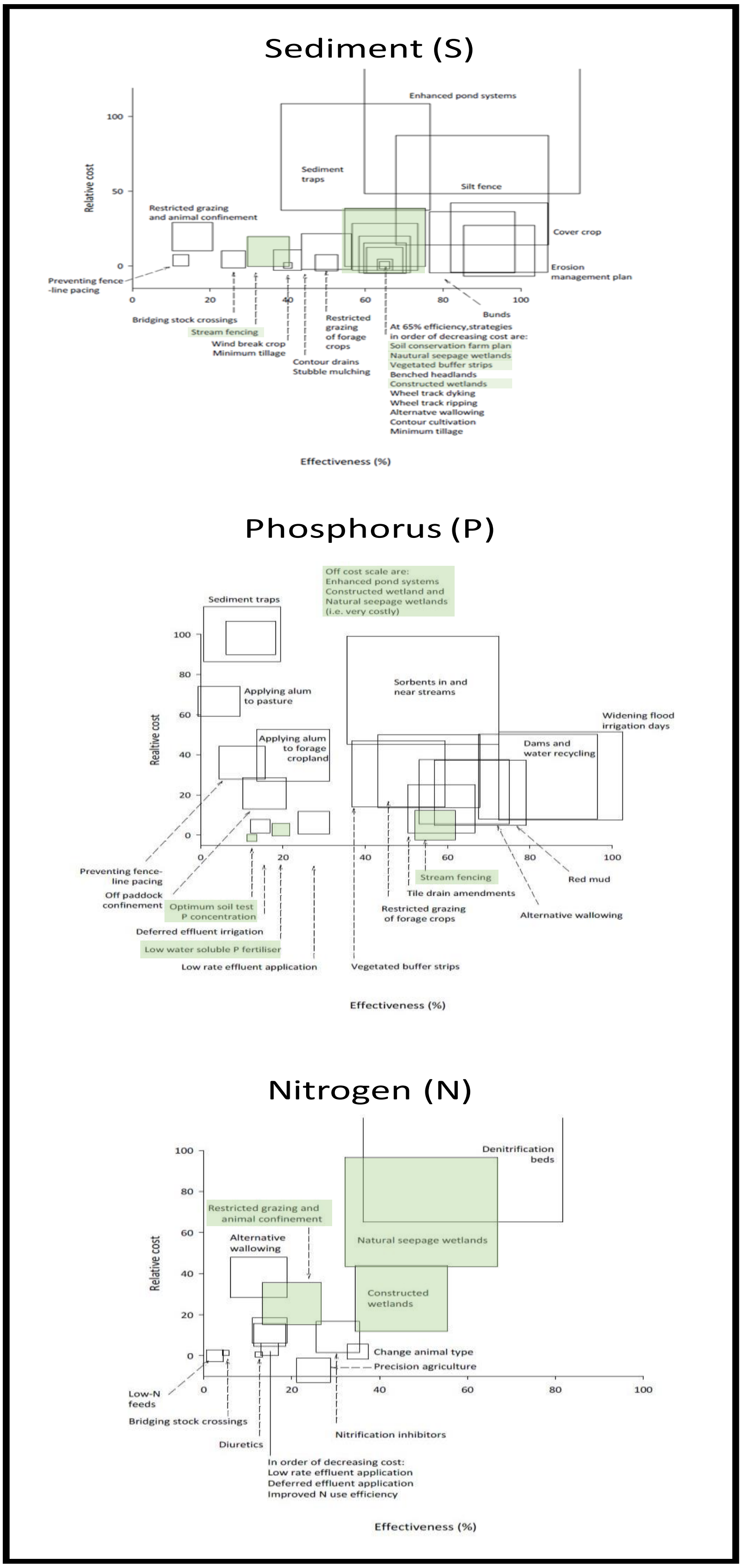

Figure 7. The range and relationship between mitigation cost and effectiveness for reducing sediment, phosphorus, and nitrogen – mitigations used in CAPTure are highlighted green (adapted from McDowell et.al. 2013).

Spatial placement of mitigations

Not all mitigations should be placed everywhere in the catchment. Mitigation placement is limited to the areas which are realistic for placement and targets threats. Estimating where mitigations can be placed and the relative areas, they are effective will assist with prioritising actions in the catchment as well as estimates of reductions and costs.

The specific placement of mitigations to target threats within a catchment, can be identified at a broad scale. For example, when identifying specific areas for mitigating potential soil erosion on pasture, poplar pole planting on pasture, only a portion of the pasture area identified will require pole planting, which cannot be delineated at a catchment scale. The refined placement of most mitigations will require a combination of aerial photo interpretation (a desktop exercise) or farm scale field assessment (e.g. a farm plan or LUC assessment).

Calculating mitigation reductions

Reduction (effectiveness) estimates are based on available literature. However, published estimates of reductions for nitrogen, phosphorous, sediment and microbes are variable depending on land use management, landscape, and mitigation implementation. For example, McDowell et al. (2013), provide very high, high, medium, and low effectiveness ratings, the Menu of practices to improve water quality[1] provide percentage ranges with their ratings, which differ depending on the contaminant and land use. The initial mitigation reduction estimates used in this CAPTure pilot project are an initial attempt, and although based on the literature should be considered preliminary.

Where possible CAPTure has approximated nitrogen, phosphorus sediment (excluding hillslope and riparian management) and microbe mitigation reductions to align with the Low, Medium, and High ranges of the Menus – Practices to improve water quality. This is in part to provide some continuity with existing guidance available to landowners. Generally, a midpoint value within the range has been used but, in some situations, a lower or higher value in the range has been applied.

Sediment estimates for hillslope and riparian management, are based Hill and Blair (2005) which reviewed Soil Conservation Research and Catchment Environmental Monitoring information in the Waikato Catchment. Sediment reduction estimates were confirmed and used for the Waikato Regional Prioritisation Project (Hill and Borman, 2016) and the Waikato and Waipā River Restoration Strategy (Neilson et al., 2018a and 2018b). This provides some continuity with existing guidance provided by council for funding soil conservation.

The source of the individual reduction criteria (N, P, sediment and microbes) applied for each mitigation are summarised in Table 6 and mitigation reduction estimates are provided in Tables 8-19.

Table 6: The percentage reduction criteria (N, P, sediment and microbes) for each mitigation.

Mitigation	Basis (source information) for efficacy			
	Nitrogen	Phosphorus	Sediment	Microbes
Soil management				
Olsen P (soil P status)	Menus	Menus	Assumes improving low soil P levels will increase pasture cover and reduce a proportion of sediment runoff.	Menus
RPR (slow release fertiliser)	McDowell et al. (2013)	McDowell (2010)		McDowell et al. (2013)
Riparian management	Same reductions for both - likely be fenced and ungrazed grass or planted and fenced.			
Riparian fence	Menus	Menus	A 60% reduction used in WRPP, based on Whatawhata research data summary in Hill and Blair (2005).	Reduced from High in the Menu to Medium based on Collins & Rutherford 2004.
Riparian woody vegetation	Menus			
Hillslope management				
Hillslope pasture stability	Menus	Menus		Menus
Hillslope plantations	Assumes unstocked and nitrogen decrease to like pine and indigenous.	A 60 % reduction used in WRPP, based on Whatawhata research data summary in Hill and Blair (2005).	A 60% reduction used in WRPP, based on Whatawhata research data summary in Hill and Blair (2005).	Assumes unstocked and microbes decrease to like pine and indigenous.
Hillslope retirement				
Hillslope active erosion	Assume same as Hillslope pasture stability.	Assume same as Hillslope pasture stability.		Assume same as Hillslope pasture stability.
Wetland management				
Lowland wetlands	Menus	Menus	Menus	Reduced from High in the Menu to Medium based on Collins & Rutherford 2004.
Hillslope wetlands (seeps/ephemeral)	Menus	Increased (Medium in the Menu) to High reduction because mitigations would effectively remove stock from these areas.	Increased (Medium in the Menu) to High reduction because mitigations would effectively remove stock from these areas.	
Grazing and soil management				
CSA flow paths	Menus	Increased (Medium in the Menu) to High -mitigations would effectively remove stock from these areas.	Increased (Medium in the Menu) to High -mitigations would effectively remove stock from these areas.	Increased (Medium in the Menu) to High -mitigations would effectively remove stock from these areas.
Steep soils	Menus	Menus	Menus	Menus
Wet soils				

Calculating mitigation costs

Mitigation cost estimates are provided in Tables 8-19. Cost are based on those used for the Waikato and Waipā River Restoration Strategy (Neilson et al., 2018a and 2018b). No costs have been assigned to mitigations where the mitigation is considered cost positive -is likely to save money (soil P status management) or the mitigation is not likely to result in a net cost increase – relates to a change in management (grazing and soil management). Cost estimates for CSA management are difficult to estimate, given the breadth of CSA mitigations (e.g. moving gates and troughs, temporary fencing of flow paths) so a generalised cost for fencing the perimeter of the CSA flow path has been used as an interim cost estimate.

Mitigation limitations and sensitivity

As mention, for all estimates there is a high level of uncertainty around the reductions that can be achieved, or the reductions are highly variable depending on the local conditions, farm management practices, and implementation effectiveness.

The initial suite of mitigations in CAPTure focuses on actions that are more general, such as fencing and planting. Site specific mitigations such as sediment traps, detainment bunds, bridges and constructed wetlands have not been included. This is because of the site specific requirements of these mitigation (for placement, construction, and costs).

The actual percentage reductions used for each mitigation could be challenged, however, for the purpose of their application in this pilot project, the main consideration is that they are within an acceptable range that is likely to prove a relative picture of likely reductions that can be expected across the catchment. CAPTure is flexible to be able to adjust these reduction estimates as new or improved estimates become available.

Factors that are likely to affect the mitigation related outputs are the spatial placement criteria, reduction percentages and cost assumptions applied. For example, applying pole planting to 50% of LUC class 6e pasture requires an assessment of how much of the 6e pasture is likely to require pole planting, is the LUC 6e mapped area correctly identified, the spacing of the poles (for the cost calculation) and what reductions are we likely to get. The affects are also dependent on each mitigation, and where threats are combined and weighted, the lower weighted threat scores are likely to be impacted less.

In general, developing mitigation criteria, placing mitigations, and using mitigations spatially as in CAPTure requires many assumptions at different stages of the process. Throughout the process, a key consideration is to maintain the involvement of catchment landowners and managers to keep the criteria as real as possible.

A specific sensitivity analysis has not been undertaken as part of this pilot project. However, sensitivity could be examined in future work and include assessing the impact of adjusting the spatial placement criteria, reduction percentages and cost assumptions up and down to see what the impact is on the mitigation related outputs (both spatial and non-spatial).

Mitigation criteria

A set of criteria are used to define and describe the mitigations used in this pilot project (Table 7).

Table 7. Criteria used to define individual mitigations.

Mitigation criteria	Details
Description	Describes the type of mitigation and its general placement, benefits and likely relative costs compared with other mitigations.
Datasets	A list of all datasets used.
Spatial placement (GIS criteria)	Criteria for placing the mitigations in the catchment, including factors like along reaches, an area of a land use and land use capability; either a length, an area, or a density per area.
Benefits	These are the estimated changes to farm profit associated with the mitigation. Benefits have been grouped into high, medium, and low classes as per the "*Menu of practices to improve water quality*".
Costs	An estimate of the cost of implementing a mitigation, either a cost per length, or cost per area or per treatment. An estimate of farmer time is included. Costs have been grouped into high, medium, and low classes as per the "*Menu of practices to improve water quality*".
Efficacy (contaminant reductions)	An estimate based on available literature of the contaminants the mitigation will benefit and estimates of the efficacy as a percentage reduction.
Assumptions	Assumptions that were made in defining the mitigation criteria and spatial placement.
Limitations	Limitations associated with the mitigation; datasets, spatial criteria and placement and implementation.

Detailed criteria (based on individual mitigations in Table 7) are provided in Tables 8-19.

Table 8. Olsen P (soil P status) mitigation criteria.

<table>
<tr><td colspan="5"></td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Soil P status management is seen as a cost neutral or potentially cost positive mitigation that can reduce phosphorus loss. Phosphorus attaches to soil particles and soil loss by erosion provides a P source to waterways. Olsen P is a commonly used measure of soil P status. Optimising soil P status for production (avoiding excess and deficient soil P) will reduce P loss.</td></tr>
<tr><td>Datasets</td><td colspan="4">• Phosphorus and sediment threat layers
• Finer scale DEM revised NZLRI LUC
• LCDB derived pasture
• Waikato regional soil quality monitoring Olsen P data</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">The following % reductions be used when above optimum soil Olsen P values are reduced to the appropriate target range (we assume this is the case now when no soil test data is available): assume a 25% reduction is possible on pasture irrespective of land use but better land is higher soil P status - approximates all dairy pasture higher and 50% drystock as some pasture will be below optimum. Use LUC 1-2 pasture 25% reduction, LUC 3-4 15% reduction, and LUC 5-6 5% reduction.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$$</td><td colspan="2">$
No cost was assigned to the Olsen P mitigation because it is assumed to be cost neutral - based on available literature.</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">No catchment scale soil P (Olsen P) data was available. Average Olsen P data for the Waikato region were used to estimate a reduction. The main reduction is likely on dairy farmland. Reductions based on Menu "likely benefit" but aassumes that improving low soil P levels will increase pasture (vegetation) cover and reduce a small proportion of sediment runoff.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>0</td><td>25</td><td>5</td><td>0</td></tr>
<tr><td>Assumptions</td><td colspan="4">Olsen P levels in the catchment are represented by regional data and are constant across farms in the catchment.</td></tr>
<tr><td>Limitations</td><td colspan="4">Olsen P estimates are from regional data so likely fertility intensity has been based on LUC class; better LUC class land assumed to have higher Olsen P levels and greater reductions possible.</td></tr>
</table>

Table 9. Reactive Phosphate Rock (soil P status) mitigation criteria.

<table>
<tr><td colspan="5">Reactive Phosphate Rock (soil P status)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Soil P status management using RPR is seen as a cost neutral or potentially cost positive mitigation that can reduce phosphorus loss. RPR is a slow release P source that allows for vegetation growth to match P released into the soil, without high P status soil being lost by solution and erosion. Optimising soil P status for production (avoiding excess and deficient soil P) will reduce P loss.</td></tr>
<tr><td>Datasets</td><td colspan="4">• Phosphorus and sediment threat layers
• Finer scale DEM revised NZLRI LUC
• LCDB derived pasture
Waikato regional soil quality monitoring Olsen P data</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">The following % reductions be used when above optimum soil Olsen P values are reduced to the appropriate target range (we assume this is the case now when no soil test data is available); assume a 25% reduction is possible on pasture irrespective of land use but better land is higher soil P status - approximates all dairy pasture higher and 50 % drystock as some pasture will be below optimum. Use LUC 1-2 pasture 25% reduction, LUC 3-4 15% reduction, and LUC 5-6 5% reduction.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$</td><td colspan="2">$
No cost was assigned to the RPR mitigation because it is assumed to be cost neutral - based on available literature.</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">No catchment soil P data (Olsen P) was available. Average Olsen P data for the Waikato region were used to estimate a reduction. The main reduction is likely on dairy farmland. Menu "likely benefit" but aassumes that improving low soil P levels will increase pasture (vegetation) cover and reduce a small proportion of sediment runoff.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>0</td><td>10</td><td>5</td><td>0</td></tr>
<tr><td>Assumptions</td><td colspan="4">Soil P levels in the catchment are represented by regional data and are constant across farms in the catchment. RPR is a valid nutrient management option for farmers in the catchment.</td></tr>
<tr><td>Limitations</td><td colspan="4">Soil P estimates are from regional data so likely fertility intensity has been based on LUC class; better LUC class land assumed to have higher Olsen P levels and greater reductions possible. RPR use is dependent on uptake and change of fertiliser practice.</td></tr>
</table>

Table 10. Pasture stability (Soil conservation) mitigation criteria.

<table>
<tr><td colspan="5">Pasture stability (Soil conservation)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Increasing the stability of potentially erodible land/soils (LUC 6e class land) in pasture reduces sediment (and attached P) to the waterways and lower catchment. Pasture stability (on potentially erodible soils) can be managed using soil conservation practices that include pole planting and the establishment of areas of planted trees (including pines and manuka).</td></tr>
<tr><td>Datasets</td><td colspan="4">• Phosphorus and sediment threat layers
• Finer scale DEM revised NZLRI LUC
• LCDB derived pasture</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">• 75% of LUC 6e land area will not require any treatment.
• NB: the whole 6e area in pasture is used to calculate sediment pre and post estimates.
• 25% of LUC 6e land in pasture will require some sort of erosion protection work.
• 12.5% of LUC 6e land in pasture treated with pole planting.
• 12.5% of 6e land in pasture suited for plantation forestry or manuka.
Fencing plantation and manuka combined calculated at 12.5% of total 6e perimeter @ $25/m</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$</td><td colspan="2">$$
• 12.5% of the 6e land in pasture can be treated with pole planting; costed @ $3000/ha
• 12.5% of the 6e land in pasture is likely to be suited for plantation forestry or manuka; both costed @ $3,000 ha
• Fencing plantation and manuka combined calculated at 12.5% of total 6e perimeter @ $25/m</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions In sediment and phosphorus only as stock remain grazing.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>0</td><td>10</td><td>60</td><td>0</td></tr>
<tr><td>Assumptions</td><td colspan="4">The percentage of 6e land to treat, and the proportions of pole planting vs plantation, are broad estimates based on expert opinion. This approximation aligns with that used for soil conservation planning by regional council. The percentage estimates approximate and acknowledge that LUC classes may be different at a farm scale.</td></tr>
<tr><td>Limitations</td><td colspan="4">A simplified mitigation that would benefit from improved spatial delineation of LUC classes.</td></tr>
</table>

Table 11. Plantation forestry (Soil conservation) mitigation criteria.

<table>
<tr><td colspan="5">Plantation forestry (Soil conservation)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Increasing the stability of potentially erodible land/soils (LUC 7e class land) in pasture reduces sediment (and attached P) to the waterways and lower catchment. Changing LUC 7e land use to better match its land capability (woody vegetation) will increase land stability. Soil conservation practices include the establishment of planted trees (including pines and manuka).</td></tr>
<tr><td>Datasets</td><td colspan="4">• Nitrogen, phosphorus, sediment, and microbe threat layers
• Finer scale DEM revised NZLRI LUC
• LCDB derived pasture</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">• 100% of this area is likely to be suited for plantation forestry or manuka.
• Fencing costs for this land have been calculated separately at 50% of perimeter fence required.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$</td><td colspan="2">$$
• plantation forestry or manuka (@ $3,000 ha). Fencing using stock proof fence @ $25/m.</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions In all threats; removal of stock and replacement by woody vegetation results in high percentage reductions.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>70</td><td>80</td><td>60</td><td>80</td></tr>
<tr><td>Assumptions</td><td colspan="4">Assumes all 7e land should not be in pasture. Access to plantations is possible; roading costs are not included in the mitigation costs. Areas may adjoin native or other woody vegetation approximated by 50% fencing of perimeter estimate.</td></tr>
<tr><td>Limitations</td><td colspan="4">A simplified mitigation that would benefit from improved spatial delineation of LUC classes.</td></tr>
</table>

Table 12. Hillslope retirement (Soil conservation) mitigation criteria.

<table>
<tr><td colspan="5">Hillslope retirement (Soil conservation)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Steep areas not capable of supporting pasture or plantation forestry according to LUC classification - i.e. best use is conservation land only. No areas in Pūkorokoro catchment.</td></tr>
<tr><td>Datasets</td><td colspan="4">• Nitrogen, phosphorus, sediment, and microbe threat layers
• Finer scale DEM revised NZLRI LUC
LCDB derived pasture</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">• 100% of this area would be recommended for retirement and reversion
• Assumes no native planting required, just fence and leave
• Retirement requires full stock proof fencing (@ $25m)</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$</td><td colspan="2">$$
• No planting costs
• Retirement requires full stock proof fencing (@ $25m)</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions In all threats; removal of low levels of stock and replacement by woody vegetation results in moderate percentage reductions.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>10</td><td>30</td><td>60</td><td>20</td></tr>
<tr><td>Assumptions</td><td colspan="4">Assumes all LUC class 8e land should be retired.</td></tr>
<tr><td>Limitations</td><td colspan="4">A simplified mitigation that would benefit from improved spatial delineation of LUC classes. No ongoing management costs are included.
Note that no 8e land was identified in the Pūkorokoro catchment.</td></tr>
</table>

Table 13. Hillslope active erosion (Soil conservation) mitigation criteria.

<table>
<tr><td colspan="5">Hillslope active erosion (Soil conservation)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Hillslope pasture areas that have active erosion. Stabilising these areas with soil conservation practices will reduce sediment and phosphorus loss.</td></tr>
<tr><td>Datasets</td><td colspan="4">Nitrogen, phosphorus, sediment, and microbe threat layers
Finer scale DEM revised NZLRI LUC
LCDB derived pasture</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">Additional erosion areas outside LUC 6e, 7 and 8 (LUC 4-6, excluding 6e) in pasture.
Assumes treatment of specific erosion areas such as landslips, earthflows etc. This active slip area is estimated at 1.8% of erosion prone land identified (hectares).</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$</td><td colspan="2">$$
Combined pole planting, stabilisation and dewatering will cost $5000/ha</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions In sediment and phosphorus only as stock remain grazing.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>0</td><td>10</td><td>60</td><td>0</td></tr>
<tr><td>Assumptions</td><td colspan="4">Assumes density of active erosion per unit area. Assumes proportion of soil conservation planting and some structural stabilisation required.</td></tr>
<tr><td>Limitations</td><td colspan="4">A simplified mitigation that could benefit from improved spatial delineation of active erosion areas (potentially via air photo Interpretation). No ongoing management costs are included.</td></tr>
</table>

Table 14. Riparian fencing and planting (Riparian Protection) mitigation criteria.

<table>
<tr><td colspan="5">Riparian fencing and planting (Riparian Protection)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Excluding stock from riparian will Increase streambank stability and reduce the direct addition of dung and urine into waterways. Riparian protection includes fencing without planting (leaving a grass or existing woody vegetation buffer) and fencing with planting. It is unlikely native planting will occur without fencing to provide protection from stock.</td></tr>
<tr><td>Datasets</td><td colspan="4">• Nitrogen, phosphorus, sediment, and microbe threat layers
• Catchment condition survey stock exclusion (fencing) and riparian vegetation
• LCDB derived pasture</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">Pūkorokoro catchment condition survey (stock exclusion and riparian vegetation data) to estimate unfenced and riparian vegetation.
Fencing requirements assumed the following:
• Unless identified by the catchment condition survey all unfenced waterways are grass vegetation (not woody vegetation)
Of unfenced, not all bank length will be feasible to fence:
• 25-50% of unfenced bank length fenced for soil conservation.
• 50% of newly fenced length planted with native species; assume a 5 m riparian buffer: 2km = 1ha of planting.
• 25% of this newly fenced length soil conservation planted.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$</td><td colspan="2">$-$$
• Fencing for exclusion of stock @ $8/m
• 1ha planting/2km; native plants @$37,500 /ha
• Soil conservation planting @$3000 /ha</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions in all contaminants; reduced stock direct inputs and increased stream bed and bank stability.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>10</td><td>30</td><td>60</td><td>20</td></tr>
<tr><td>Assumptions</td><td colspan="4">Not all waterways can be fenced and the proportion that can has been estimated using expert knowledge.
A 5 m riparian buffer is used, native plants planted at a 2 m average spacing and all planted vegetation will be fenced to exclude stock.</td></tr>
<tr><td>Limitations</td><td colspan="4">Improved estimates of the areas where fencing and planting is possible (and not) could be sourced as part of the catchment condition survey or farm plans. Costs for fencing and planting could be improved with farm plan/catchment estimates.</td></tr>
</table>

Table 15. Hillslope wetlands (Wetland protection) mitigation criteria.

<table>
<tr><td colspan="5">Hillslope wetlands (Wetland protection)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Excluding stock from seeps and wetland areas in rolling and steep pasture land can reduce contaminants entering head water streams. Fencing to exclude stock is the simplest way to achieve this outcome.</td></tr>
<tr><td>Datasets</td><td colspan="4">• Nitrogen, phosphorus, sediment, and microbe threat layers
• LCDB derived pasture
• Finer scale DEM revised NZLRI LUC
• 20 m DEM slope class</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">• LUC 4w to 8w (Classes with wetness limitation) in pasture area; and use DEM based flat points/gullies; pasture 20 DEM slope in EFG OR pasture + slope DEM 0-1 degree</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$</td><td colspan="2">$$
An estimate is based on a $2/m fence to exclude stock – as an estimate of a simple permanent fence or a temporary fence. The perimeter of the wetland area is fenced.</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">All contaminants reduced because stock is excluded from area. Less stock trampling will have greatest reduction in sediment and attach phosphorus.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>10</td><td>70</td><td>60</td><td>10</td></tr>
<tr><td>Assumptions</td><td colspan="4">Wetland areas are currently not fenced. Spatial placement criteria are difficult to develop for this mitigation. Does not include management (staff) costs.</td></tr>
<tr><td>Limitations</td><td colspan="4">Catchment scale identification would improve the spatial identification of wetland areas and the placement of mitigations.</td></tr>
</table>

Table 16. Lowland wetlands (Wetland protection) mitigation criteria.

<table>
<tr><td colspan="5">Lowland wetlands (Wetland protection)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Lowland wetlands provide a natural filter for contaminants from the upstream catchment. Excluding stock from lowland wetland areas increases wetland effectiveness. Fencing to exclude stock is the simplest way to achieve this outcome.</td></tr>
<tr><td>Datasets</td><td colspan="4">• Nitrogen, phosphorus, sediment, and microbe threat layers
• LCDB derived pasture
• Finer scale DEM revised NZLRI LUC
• 20 m DEM slope class</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">• On LUC classes with a wetness (w) limitation; wetland in pasture OR 2w and 3w and not in pasture.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$</td><td colspan="2">$
An estimate is based on a $2/m fence to exclude stock – as an estimate of a simple permanent fence or a temporary fence. The perimeter of the wetland area is fenced.</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">All contaminants reduced because stock is excluded from area. Less stock trampling will have greatest reduction in sediment and attach phosphorus.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>10</td><td>35</td><td>35</td><td>10</td></tr>
<tr><td>Assumptions</td><td colspan="4">Wetland areas are currently not fenced. Spatial placement criteria are difficult to develop for this mitigation. Does not include management (staff) costs.</td></tr>
<tr><td>Limitations</td><td colspan="4">Catchment scale identification would improve the spatial identification of wetland areas and the placement of mitigations.</td></tr>
</table>

Table 17. Critical Source Areas (Grazing and soil management) mitigation criteria.

<table>
<tr><td colspan="5">Critical Source Areas (Grazing and soil management)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">CSAs can contribute up to 80% of contaminants from the land and only occupy ~20% of the land area on farms.</td></tr>
<tr><td>Datasets</td><td colspan="4">• N, P, sediment, and microbe threat layers
• Pasture LCDB derived pasture
• 20 m DEM flow path (160 cell)</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">Identify using DEM flow path connecting to REC reaches; 10 m buffer around centre line. DAN: pasture in CSA; start at 160 DEM cells before initiating watercourse 10mx10m.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$</td><td colspan="2">$
Fencing CSA perimeter at a cost of $2/m</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions are based on a general reduction value used by MW-LR for reductions that could be achieved if a farm plan was implemented.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>10</td><td>70</td><td>70</td><td>70</td></tr>
<tr><td>Assumptions</td><td colspan="4">CSAs associated with track management, trough and gate placement are not included; CSA management cost is approximated using a simple fencing parameter to approximate other management options – a token cost to indicate there is a likely cost.</td></tr>
<tr><td>Limitations</td><td colspan="4">CSAs are highly variably in type and nature. CSAs have been “lumped” together to create a generic DCSA mitigation to represent them all.</td></tr>
</table>

Table 18. Steep soils (Grazing and soil management) mitigation criteria.

Steep soils (Grazing and soil management)				
Mitigation criteria	Details			
Description	Heavy stock on steep land increase soil loss, especially where vegetation cover (pasture) is sparse.			
Datasets	• N, P, sediment, and microbe threat layers • Pasture LCDB derived pasture • LUC class - Finer scale LUC • Slope class – 20 m DEM slope class			
Spatial placement (GIS criteria)	Pasture slopes of 21 degrees and greater using 20 m DEM classes E, F, G + LUC 6, 7, 8 with erosion limitation "e"			
Benefit and Cost	Benefit		Cost	
	$$		$ No direct cost; time cost for stock management, temporary fencing; likely to be cost positive with no loss of grass production by preventing soil damage and loss.	
Efficacy (% reductions)	All threats reduced as less stock and lighter stock are grazed. Greatest reductions associated with sediment and phosphorus; slight reductions in nitrogen and microbes due to less or lighter (smaller) stock.			
	Nitrogen	Phosphorus	Sediment	Microbes
	5	35	35	35
Assumptions	Stock management can include less stock and changing stock type. There is no net cost for this mitigation.			
Limitations	Finer DEM data and soil map Information could improve the soils identified at most risk and improve placement of this mitigation. Catchment data on costs associated with this mitigation could be added.			

Table 19. Wet soils (Grazing and soil management) mitigation criteria.

<table>
<tr><td colspan="5">Wet soils (Grazing and soil management)</td></tr>
<tr><td>Mitigation criteria</td><td colspan="4">Details</td></tr>
<tr><td>Description</td><td colspan="4">Wet soils include imperfectly, poor, and very poorly drained soils on low lying areas. Although most soils will be pugged by cattle or damaged by heavy machinery during wet conditions, wet soils are especially prone to impacts given their high water table. Disturbance to the soil surface can reduce infiltration and increase sediment, phosphorus, and microbe (and to a lesser extent nitrogen) runoff.</td></tr>
<tr><td>Datasets</td><td colspan="4">• N, P, sediment, and microbe threat layers
• LCDB derived pasture
• LUC class - Finer scale LUC
• Soil drainage – Fundamental Soil Layer
• Slope class – NZLRI slope
• 20 M DEM slope class</td></tr>
<tr><td>Spatial placement
(GIS criteria)</td><td colspan="4">LCDB Pasture + FSL soil drainage classes very poor, poor and imperfectly drained (FSL soil drainage classes 1, 2 and 3) and slope must be A OR pasture LUC 1w + DEM depressions.</td></tr>
<tr><td rowspan="2">Benefit and Cost</td><td colspan="2">Benefit</td><td colspan="2">Cost</td></tr>
<tr><td colspan="2">$$$</td><td colspan="2">$
No direct cost; time cost for stock management, temporary fencing; likely to be cost positive with no loss of grass production by preventing soil damage and loss.</td></tr>
<tr><td rowspan="3">Efficacy
(% reductions)</td><td colspan="4">Reductions in all contaminants. The main reduction is likely on dairy farmland where stock intensity (and chance of pugging soil damage) is greater.</td></tr>
<tr><td>Nitrogen</td><td>Phosphorus</td><td>Sediment</td><td>Microbes</td></tr>
<tr><td>5</td><td>35</td><td>35</td><td>35</td></tr>
<tr><td>Assumptions</td><td colspan="4">Assumed that the worst impact will be on soils with poorer drainage in lower lying areas.
Mitigation can be implemented by changes to grazing management with no increased capital cost requirements.
Does not include use of heard homes etc.</td></tr>
<tr><td>Limitations</td><td colspan="4">All soils are prone to pugging during wet conditions; limiting the placement to wet soils may not provide an accurate indication of the impacts of pugging (impacts may be closer aligned to farm management practices and stocking rate).</td></tr>
</table>

DECISION SUPPORT OUTPUTS

Introduction

The complete CAPTure spatial database is provided in ESRI file geodatabase (FGDB) format projected to New Zealand Transverse Mercator GD2000 (EPSG: 2193). The geometry has been verified using ESRI tools to an epsilon value of 0.0001m. The database can be interrogated to produce outputs as required, for whole of catchment, sub-catchment, and individual farms. CAPTure output formats presented in this report include graphs and static maps.

CAPTure provides a suite of outputs for determining the catchment priorities and placement of mitigations (on the ground actions) based on the:

1. relative threats to lower catchment water quality
    a. unweighted threats
    b. threats weighted by a catchment specific water quality value,
2. relative reductions the mitigations can provide across the catchment
3. relative cost-benefit of mitigations (incorporating the cost of mitigations and the reductions they provide)

Effectively, the four outputs are steps towards a final output (the cost benefit based output) that incorporates firstly threats, combines the threats to focus on water quality, then applies mitigations where they should go, and finally adds in a cost component to rank reach-watersheds on the basis of reducing the most for the least cost. Individually, each output will suit different land management objectives (see Table 20).

Table 20. Outputs for determining the catchment priorities and placement of mitigations.

Output	CAPTure output	Objective
Threats based (unweighted)	Threat based priority maps and graphs	Provides a simple prioritisation solely on where the greatest relative threats have been estimated across the catchment. This approach does not consider the effects of mitigation placement and the associated reduction efficacy and cost, nor the relative importance of threats on the catchment values.
Threat based Water quality (value weighted)	Water quality value threat-based priority maps and graphs	Provides a simple prioritisation solely on where the greatest relative threats have been estimated across the catchment. This approach does not consider the effects of mitigation placement and the associated reduction efficacy and cost, nor the relative importance of threats on the catchment values.
Reductions based	Reductions based priority maps and graphs	Provides a prioritisation based on where the greatest relative reductions have been estimated across the catchment after mitigation implementation. This approach considers the effects of mitigation placement and the associated reduction efficacy but not cost, nor the relative importance of threats on the catchment values.
Cost-benefit based	Cost-benefit based priority maps and graphs	Provides a prioritisation based on where the greatest relative reductions have been estimated across the catchment after mitigation implementation. This approach considers the effects of mitigation placement and the associated reduction efficacy and cost and can include the relative importance of threats on the catchment values.

For each output in Table 20, ranking is determined by summing the relative scores for each mitigation for individual reach-watersheds, and for sub-catchments. This approach allows priorities to be made by sub-catchment, target areas within a sub-catchment, or target individual water-shed reaches across the whole catchment.

Sub-catchment aggregation

For the purpose of data presentation, the 441 reach-watershed scores have been aggregated into 16 sub-catchments (Figure 8). This has been done to assist with the interpretation of the graph results and provide catchment scale guidance for understanding the broader scale distribution of threats and implementation of mitigations. The individual threat scores for a sub-catchment can be used to prioritise the dominant threat across reach-watersheds in the sub-catchment. All maps are presented by reach-watershed to provide finer spatial detail for threats and mitigations.

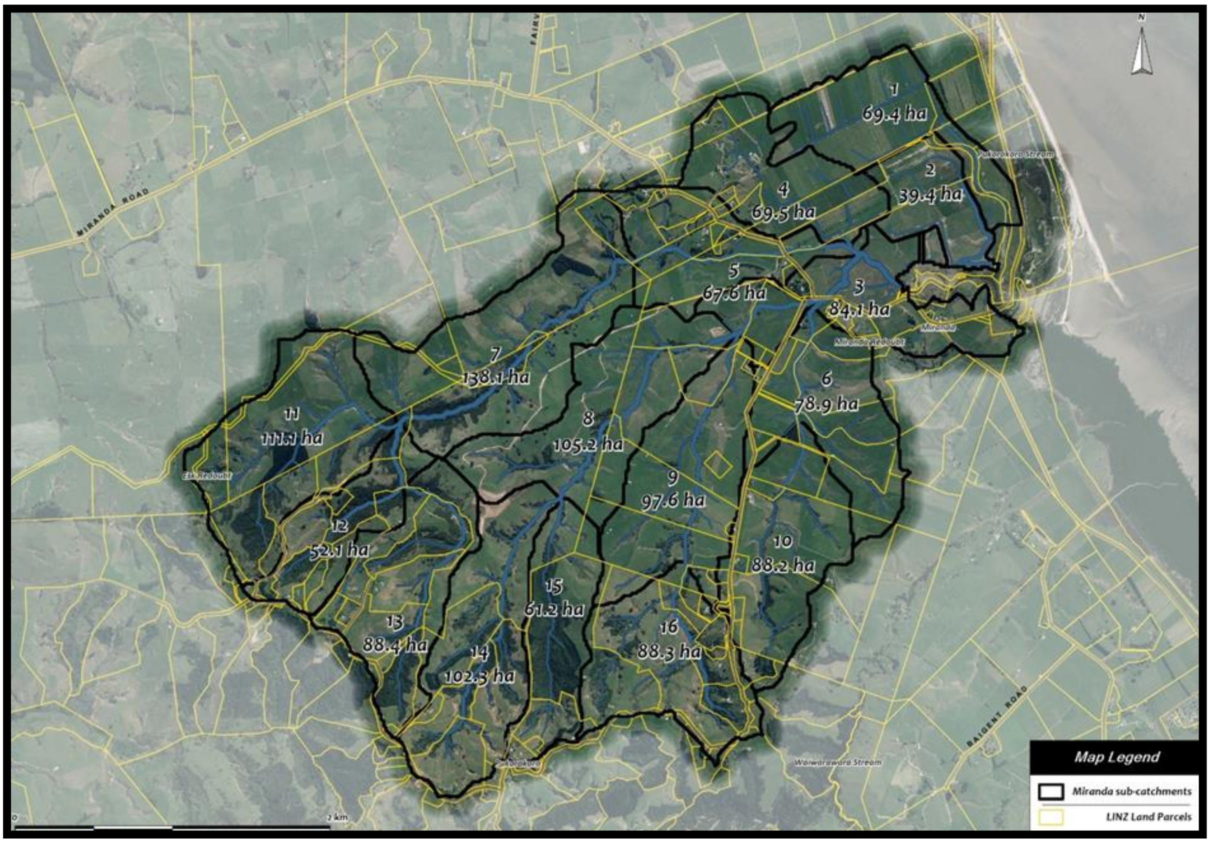

Figure 8. The 16 sub-catchments of the Pūkorokoro catchment used in CAPTure.

The sub-catchment aggregation was calculated by averaging reach-watershed scores on an area weighted basis across the hydrologically contiguous sub-catchments; generally, each main waterway in the catchment was partitioned into an upstream, middle, and lower sub-catchment.

Threat based priorities

Introduction

Threats have been categorised as ranging from low to high risk for the following catchment threats:

1. Hillslope sediment generation
2. Streambank sediment generation
3. Riparian stock access
4. Riparian stabilising vegetation
5. N generation
6. P generation
7. *E. coli* (Microbe) generation

Unweighted threat-based water quality priorities

Outputs for the unweighted water quality threats are simply the normalised scores for each threat. The combined threat scores are used to provide an overall score (and ranking) for the sub-catchments (Figure 9).

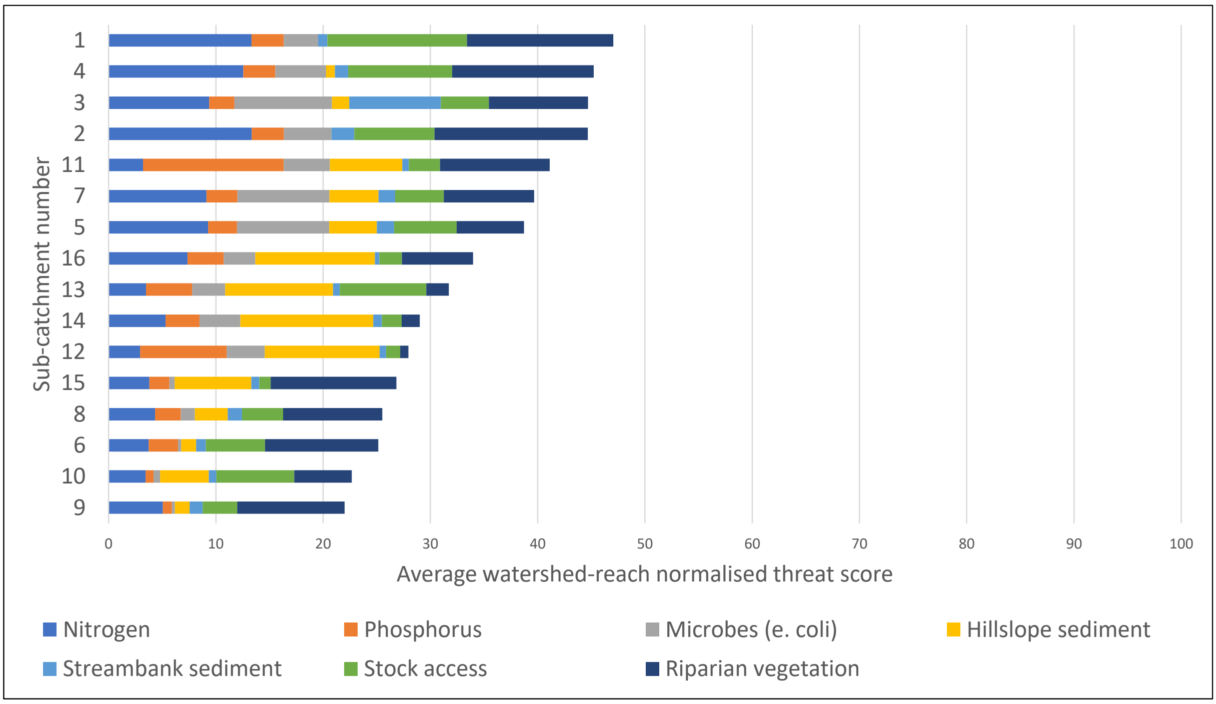

Figure 9. Combined unweighted threat scores (and ranking) for sub-catchments.

Generally, this prioritisation option ranks lower catchment (1, 4 and 3) sub-catchments highest. The full set of unweighted water quality value threat priority maps by reach-watershed are presented in Appendix 1.

Weighted threat-based water quality priorities

The prioritisation option uses the weighted equation based on the water quality values for Pūkorokoro catchment. Applying the equation weightings to the sub-catchment threats scores changes the sub-catchment rankings of threats (Figure 10).

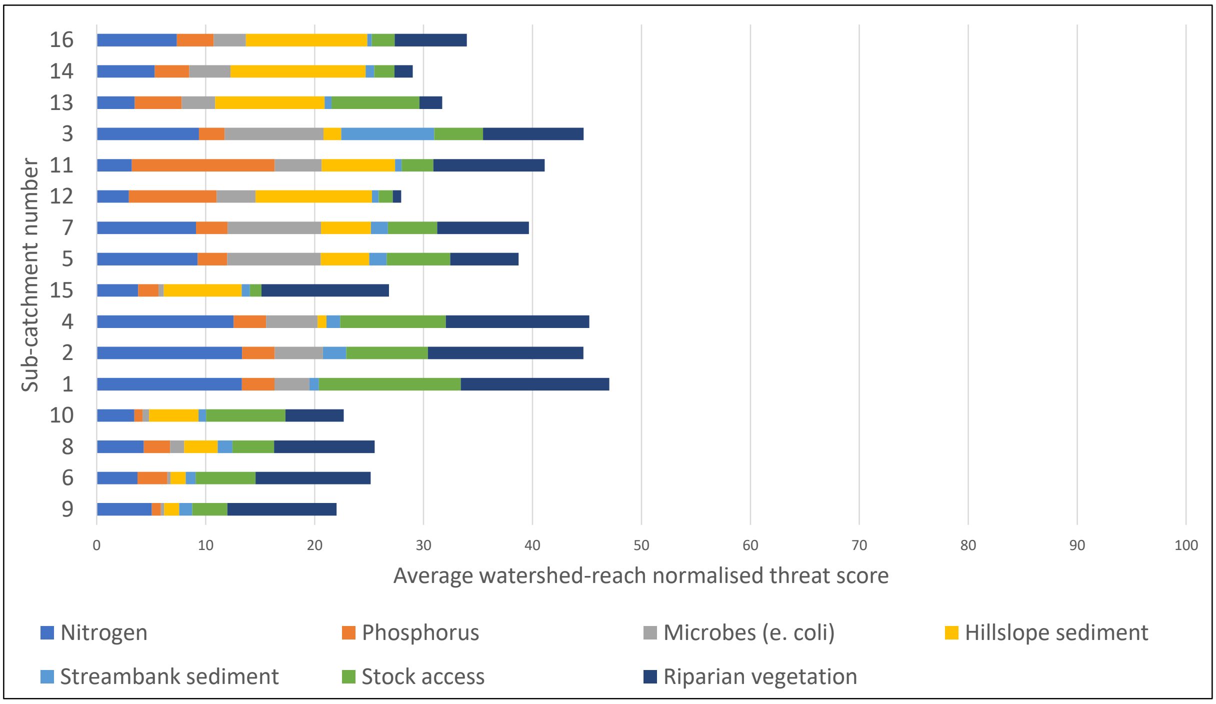

Figure 10. Combined weighted threat scores (and ranking) for sub-catchments.

Generally, this prioritisation output ranks upper catchment (16, 14 and 13) sub-catchments highest. The weighted water quality value threat priority map by reach-watershed is presented in Appendix 1.

Mitigation based priorities

Introduction

Mitigation related prioritisation outputs are based on reductions in threats (N, P, sediment, and microbes) and cost-benefit (the cost of achieving reductions). These outputs attempt to approximate how actions are best placed in the catchment and what these actions are likely to achieve. For general guidance placement maps for all 12 mitigations are provided in Appendix 2.

Reduction based priorities

Using the combined reduction scores for the sub-catchments provides a ranking of sub-catchments as shown in Figure 11.

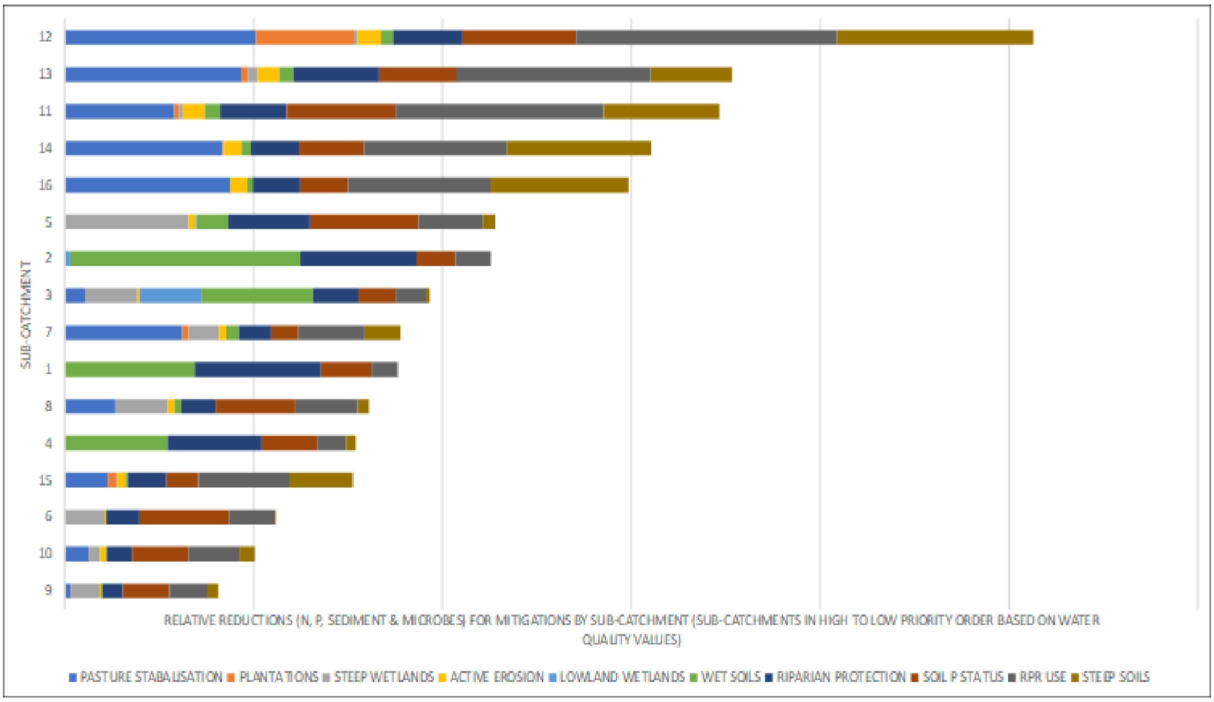

Figure 11. Combined reduction scores (and ranking) for sub-catchments.

Generally, this prioritisation output ranks upper catchment (12, 13 and 11) sub-catchments highest. The full set of mitigation reduction-based priority maps by reach-watershed are presented in Appendix 3.

Cost-benefit based priorities

Using the combined cost-benefit scores for the sub-catchments provides a ranking of sub-catchments as shown in Figure 12.

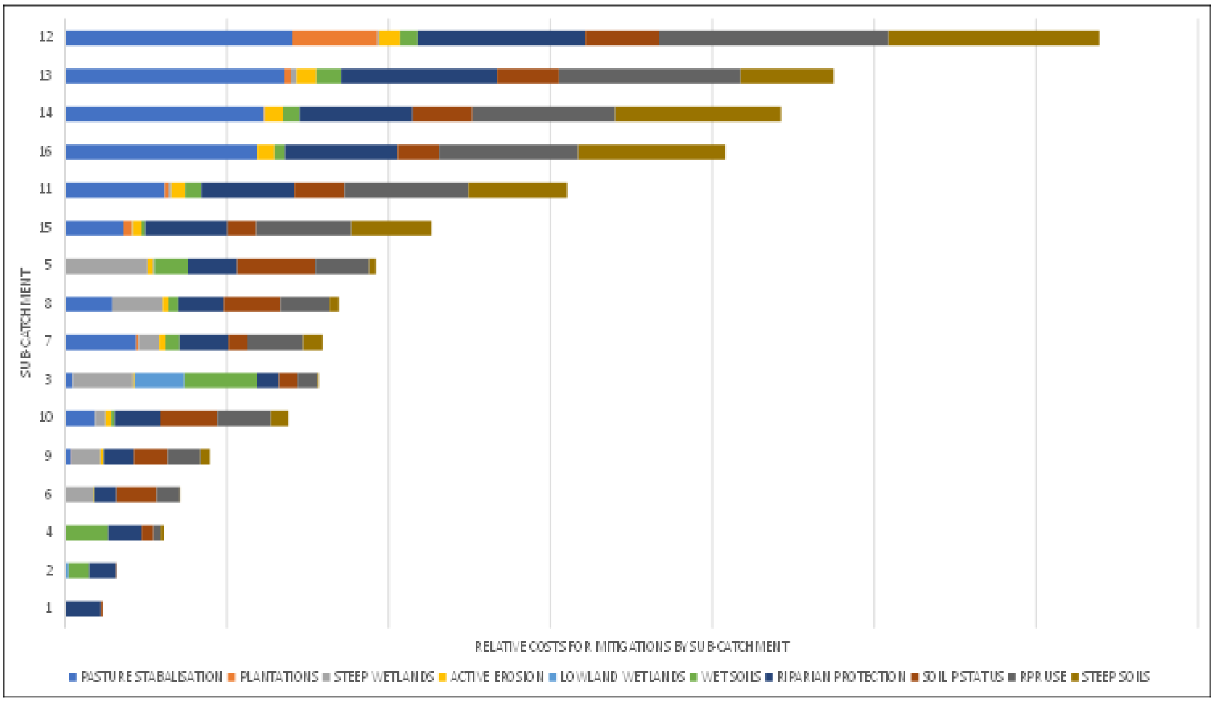

Figure 12. Combined cost-benefit scores (and ranking) for sub-catchments.

Generally, this prioritisation output ranks upper catchment (12, 13 and 14) sub-catchments highest. The full set of mitigation cost-benefit based priority maps by reach-watershed are presented in Appendix 4.

Estimated mitigation effectiveness

The calculated efficacy of mitigations and combined mitigations (based on reductions in N, P, sediment and microbes) is shown in Table 21.

Table 21. The percentages of the estimated reductions as a whole catchment average, and as a sub-catchment contribution.

Estimated efficacy of all mitigations (% mitigated) as a sub-catchment proportion						
Sub-catchment	Nitrogen	Phosphorus	Microbes	Sediment - hillslope	Sediment - streambank	Average
1	13%	79%	49%	19%	50%	42%
2	11%	72%	50%	29%	39%	40%
3	16%	57%	44%	14%	17%	29%
4	11%	70%	42%	15%	45%	37%
5	6%	48%	16%	7%	29%	21%
6	6%	44%	13%	4%	31%	20%
7	50%	55%	53%	37%	6%	40%
8	41%	54%	61%	32%	16%	41%
9	6%	34%	16%	9%	7%	14%
10	29%	50%	34%	23%	11%	29%
11	40%	52%	44%	43%	45%	45%
12	51%	57%	54%	64%	0%	45%
13	63%	68%	67%	71%	16%	57%
14	71%	76%	74%	80%	2%	61%
15	32%	42%	34%	34%	10%	31%
16	67%	70%	70%	79%	13%	60%
Average	32%	58%	45%	35%	21%	38%

The estimates indicate that the reductions of contaminants (relative improvements in water quality in the catchment) could range from 21% (for streambank sediment) to as high as 58% (for phosphorus). The percentage reduction varies across sub-catchments, in line with sub-catchment rankings. These percentage reductions should be treated as indicative, and the percentage assumes all mitigations are fully implemented.

Estimated mitigation costs

Estimated actual costs are summarised by sub-catchment (Table 22). These costs represent the total costs for implementing all mitigations used for a sub-catchment. The estimates provide a guide for determining the likely total cost of fully implementing all mitigations in the catchment and could be used to assist with funding allocation. Of note is the high proportion of the costs being related to the pasture stabilisation mitigation (consisting of mainly pole planting of LUC class 6e pasture). This cost is highly influenced by the large area of LUC 6e land in pasture in the catchment, and the assumption in the mitigation placement that 25% of the total area will require stabilisation to minimise future erosion.

Table 22. Estimated actual costs are summarised by sub-catchment.

Sub-catchment	Soil P management		Soil conservation			Riparian protection	Wetland management		Soil and grazing managment			Total ($)
	Soil Olsen P	RPR	Pasture staballsation	Plantation forestry	Hillslope active erosion	Fencing and planting	Hillslope wetlands	Lowland wetlands	CSA	Wet soils	Steep soils	
1	$0	$0	$0	$0	$657	$193,758	$0	$0	$7,187	$0	$0	$201,602
2	$0	$0	$0	$0	$0	$51,987	$0	$2,326	$10,091	$0	$0	$64,405
3	$0	$0	$92,581	$0	$3,428	$36,430	$6,220	$34,197	$19,734	$0	$0	$192,590
4	$0	$0	$0	$0	$341	$111,839	$0	$0	$10,967	$0	$0	$123,147
5	$0	$0	$0	$0	$4,701	$30,194	$14,443	$1,563	$9,340	$0	$0	$60,241
6	$0	$0	$74,183	$0	$3,855	$45,871	$12,360	$0	$13,493	$0	$0	$149,762
7	$0	$0	$732,015	$5,082	$8,891	$10,290	$7,295	$0	$16,847	$0	$0	$780,420
8	$0	$0	$297,794	$0	$8,057	$25,400	$15,133	$0	$13,710	$0	$0	$360,094
9	$0	$0	$48,923	$2,286	$3,613	$12,375	$10,887	$0	$12,700	$0	$0	$90,783
10	$0	$0	$302,153	$0	$5,623	$21,806	$7,340	$0	$12,285	$0	$0	$349,207
11	$0	$0	$602,582	$7,300	$8,227	$12,632	$760	$0	$11,637	$0	$0	$643,138
12	$0	$0	$374,996	$40,280	$2,916	$0	$280	$0	$4,455	$0	$0	$422,927
13	$0	$0	$698,452	$10,019	$6,076	$8,821	$1,200	$0	$6,545	$0	$0	$731,112
14	$0	$0	$1,034,358	$2,060	$8,118	$2,215	$540	$0	$13,316	$0	$0	$1,060,607
15	$0	$0	$289,048	$15,211	$3,442	$6,359	$420	$0	$4,510	$0	$0	$318,991
16	$0	$0	$812,594	$0	$6,836	$249	$200	$0	$8,498	$0	$0	$828,377
Total ($)	$0	$0	$5,359,679	$82,238	$74,782	$570,226	$77,078	$38,086	$175,314	$0	$0	$6,377,404

Further refinement of mitigation costs for the catchment could vastly improve the cost estimates. For example, subsequent to this analysis, the actual 2019 pole planting costs for Pūkorokoro catchment averaged a cost of $1000/ha at the same spacing of 10m x 10 m used in the CAPTure analysis. Although this would reduce the overall mitigation cost estimates, the change would unlikely change the overall cost-benefit ranking of sub-catchments.

DISCUSSION

Comparison of CAPTure vs previous tool outputs

This pilot project and the development of the initial CAPTure tool provided an initial insight into the practicalities of using available regional and catchment datasets and spatialised mitigations to prioritise actions in a catchment. CAPTure is not intended to be a rigorous scientific research analysis; its purpose is to make the most of available catchment datasets, analysing and presenting the syntheses in a way that increases their “accessibility” for making consistent and informed catchment management decisions and assists the catchment community to implement effective actions to achieve catchment land management goals.

The main improvements provided by CAPTure were the resolution of the outputs - making use of the catchment scale datasets and finer hydrological framework (Figure 13).

The inclusion of mitigations, their spatial placement, and estimates and ranking of associated effectiveness and cost improved the guidance provided to the catchment as well as individual farmers in the catchment. The mitigation outputs should assist with farmer knowledge of the range and effectiveness of mitigations available to them to improve the water quality values of the catchment.

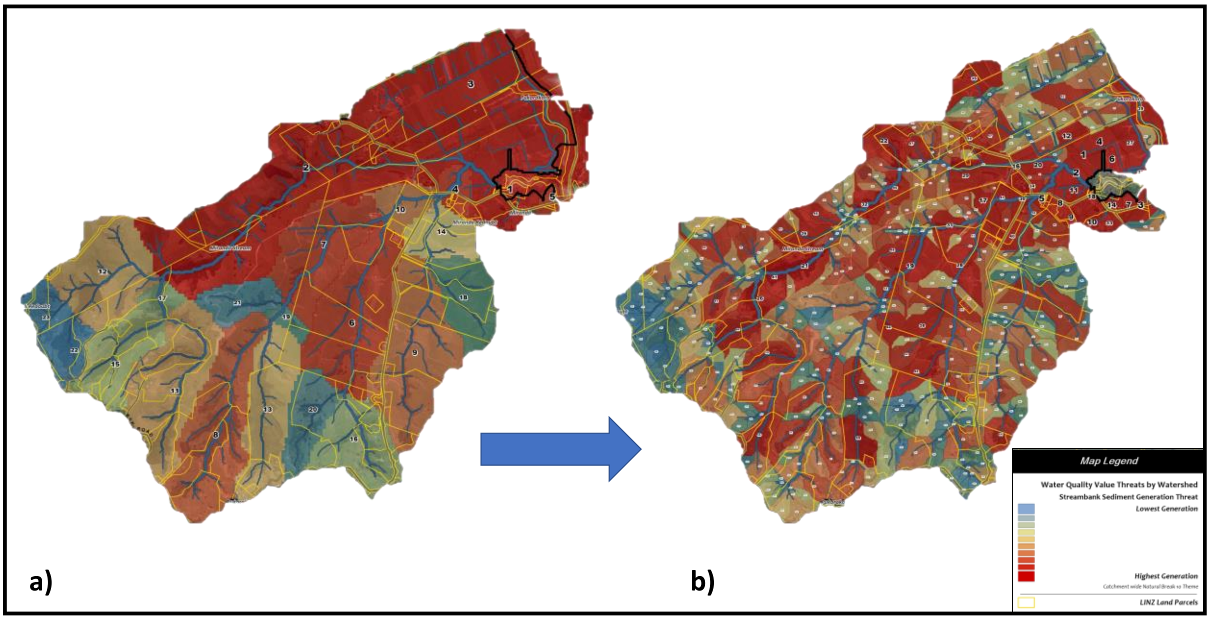

Figure 13. An example of the difference in outputs for streambank sediment generation (a) WRPP output and (b) CAPTure output.

Priorities for land-based water quality mitigation

Priorities for land-based water quality mitigation in the Pūkorokoro catchment using CAPTure (summarised by sub-catchment) are shown in Figure 14.

The unweighted water quality threat prioritisation ranked the lower catchment sub-catchments (1, 4 and 3) highest. This is likely to be because nitrogen and microbe threats are high in the lower catchment. The best use of this output would be to provide a catchment picture of the threats, priori to setting catchment goals and to assist with identifying catchment values.

The weighted water quality value threat output contrastingly ranked the upper catchments (16, 13 and 14) highest. This reflects the greater weighting placed on the sediment and phosphorus threats - deemed more important for the catchment's water quality values. This output provides useful guidance for identifying where the greatest threats are in the catchment once a catchment value has been defined.

The mitigation reduction output ranked the upper catchment sub-catchments (12, 13 and 11) highest. This is likely to be because nitrogen and microbe threats are high in the lower catchment.

The mitigation cost-benefit output showed similarities with the only difference being the replacement of sub-catchment 11 with 14 (12, 13 and 14).

The weighted water quality value threat, mitigation reduction and cost-benefit outputs had common highly ranked sub-catchments (13 was commonly ranked high).

Based on the above outputs, for a whole of catchment approach (i.e. the catchment group works towards the improving the water quality value), targeting sub-catchments ranked high by these three outputs would be a valid approach. If funds (costs) are limited, then prioritising sub-catchment 12 ahead of 13 would be valid. This type of information is useful to show in funding applications for the catchment.

The main use for the mitigation output is at the reach-watershed scale, placing and prioritising mitigations across the catchment, sub-catchments, and farms. These can be used as an initial guide to find problem areas within identified prioritised sub-catchments, especially when commencing a farm environment plan in an unfamiliar area.

Also, work in a catchment should not be limited to the priority catchments alone. Individual mitigations can be targeted using the individual ranking scores, irrespective of the collective subcatchment score and ranking. For Example, referring back to Figure 12, soil P status could be targeted in sub-catchment 5 given its higher cost-benefit score relative to other sub-catchments.

	CAPTure output			
	Threat based		Mitigation based	
	Unweighted	Weighted	Reduction	Cost-benefit
Sub-catchment (ranked highest to lowest priority = top to bottom)	1	16	12	12
	4	14	13	13
	3	13	11	14
	2	3	14	16
	11	11	16	11
	7	12	5	15
	5	7	2	5
	16	5	3	8
	13	15	7	7
	14	4	1	3
	12	2	8	10
	15	1	4	9
	8	10	15	6
	6	8	6	4
	10	6	10	2
	9	9	9	1

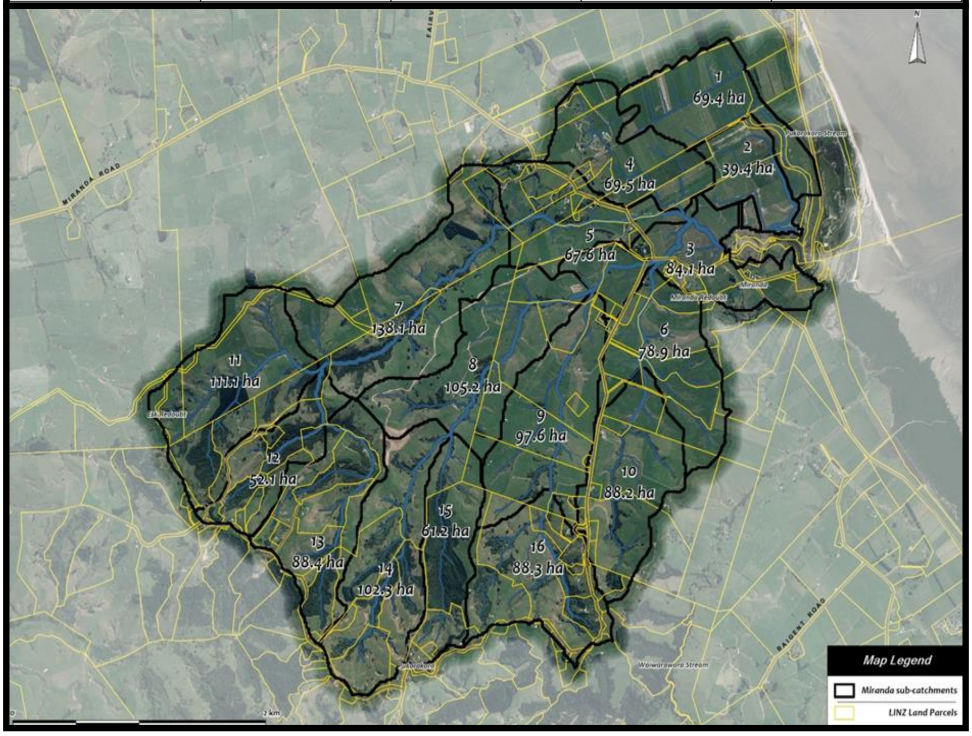

Figure 14. Sub-catchment priorities for land-based water quality mitigation in the Pūkorokoro catchment (map included for easy reference).

CAPTure assessment

Advantages

CAPTure is a tool that provides farmers and land managers quick guidance for seeing the relative threats in a catchment and providing guidance about where to implement mitigations for greatest impact. It is scalable, from reach-watersheds, to sub-catchments and catchments, potentially anywhere datasets are sufficiently available - obviously, the more datasets the better the tool.

CAPTure can use model datasets as well as catchment datasets this bases the guidance not only on what threats are active (e.g. active slips) but on the potential risk of future threats (e.g. potentially unstable land).

CAPTure is flexible, it can be revised by adding new datasets and mitigations to improve the guidance it provides without having to rebuild a complex model over a long period – revisions can be achieved in weeks, not months or years.

CAPTure requires expert input on a catchment by catchment basis. This is a limitation but also an opportunity for engaging the catchment community. Input from catchment groups and land managers is an important part of CAPTure including testing that priorities are meaningful and developing realistic mitigations.

Limitations

The effectiveness of CAPTure is like any spatial land use tools out there (e.g. LUCI, OVERSEER, MitAgator), it is limited by the availability of fit for purpose datasets. Often, the datasets we have available are at a regional scale and finer scale datasets are few and far between. CAPTure is no different, but it can make use of all datasets at any scale, to provide the best guidance. Also, it is flexible so as new datasets become available it can be updated quickly.

CAPTure will not work out how much nutrient to use on your farm, or where to apply it (that's a job for tools like OVERSEER®) and it won't work out your paddock scale risk areas (that's a job for tools like MitAgator). However, it does use a few of the same datasets that underpin these tools.

CAPTure doesn't try and estimate absolute loads, nor does it try and estimate attenuation through the catchment, or the catchment absolute load (that's a job for tools like CLUES). However, the generations layers we create do use the yield values from models like CLUES, SedNetNZ and NZEEM.

CAPTure makes use of scientifically robust models and less objective mitigations and costs that require simplified spatial criteria for their inclusion in the analyses. Although the general CAPTure framework and processes remain consistent, the other variables are catchment specific and require refining on a catchment basis.

Aside from limitations governed by data availability, CAPTure includes many necessary generalisations and assumptions throughout. This necessary combine all the different data used and simplify the complexity of the spatial analyses. This does compromise the "scientific robustness" of the approach but does allow for (relatively quick) delivery of meaningful outputs for catchment groups.

CAPTure is not intended to provide the "silver bullet" for prescribing priorities and the exact placement of mitigations. Instead its value is in providing a synthesis of multiple catchment data and an initial meaningful and approachable picture of relative water quality related priorities within a catchment.

Who can use CAPTure?

CAPTure is essentially a complex assortment of GIS spatial analysis queries, so to run it you do need to be a GIS expert. However, the outputs are visual and aim to be farmer friendly. These can be packaged and made available to uses in any media – for example on a web platform, even Google earth.

We are currently looking at ways to make the outputs from CAPTure more accessible and interactive for farmers and land managers.

Potential for national and regional application

CAPTure is structured such that a national coverage could be achieved, based on any available datasets at national, regional or catchment scale. However, the Currently, there is a high reliance on CLUES model generation outputs for nitrogen, phosphorus, and microbes. Use of CLUES requires agreement for its use by the owners (NIWA). The reliance on CLUES is a result of other model datasets being either unavailable or non-existent. This is similar for sediment generation estimates, where SedNetNZ (being developed for regions by Manaaki Whenua Landcare Research) is only available for some regions and is only available on region by region agreement. CAPTure has its main value when catchment data are available, and a finer scale hydrological framework can be constructed (using a LIDAR based DEM or other DEMs).

Essentially, CAPTure could be developed nationally, albeit at a likely regional scale applicability where only national and regional datasets were available but at catchment scale for individual catchments where datasets are available (e.g. catchment condition surveys or similar).

Extension of CAPTure to the wider Western Firth Catchment would be a possible initial step, provided there is catchment data (i.e. catchment condition survey data) covering the area. The cost of extending CAPTure is likely to be similar to the cost of CAPTure for Pūkorokoro catchment, mainly associated with collating catchment data, revising mitigations, running the spatial analysis to generate the outputs. Working with the catchment group throughout the process is also essential.

Industry application

CAPTure provides outputs that can be used by individual farmers but also provides industry with outputs to guide whole of catchment approaches to mitigation implementation, and the likely impacts mitigations will have in a catchment and relative to other catchments.

The aim is to have the same threats and mitigations in CAPTure and in farm environment plans, so farmers and land managers in a catchment can communicate actions from a catchment top a farm scale. CAPTure provides the initial guidance.

Farmer application

CAPTure is not a replacement for farm environment plans, instead it provides the initial guidance for focussing effort to deliver farm plans – where they are likely to have the greatest impact in a catchment, or for larger farms, guidance on where to focus action within the farm. CaPTure also provides the connection between farm environment plans and regional water quality objectives and policy.

The intention of CAPTure is to make use of all the complex model datasets out there, combine them quickly in a meaningful and easy to interpret way, allowing farmers to get action on the ground, to protect catchment values. CAPTure outputs have not yet been compared (tested) against the recommendations of actual farm plans to test if there is useful alignment. However, in the Pūkorokoro catchment common threats and mitigations in CAPTure have been used to develop and guide farm plan priorities (Table 23).

Table 23. Pūkorokoro catchment common threats and mitigations in CAPTure and used in farm plans (common threats in red and common mitigations in blue).

Threat to Values	Level of Threat	Risk Area	Mitigation options
Hillslope sediment generated	Low - Medium	Steeper gullies on the property	Retirement and planting already in place or to be completed
Streambank sediment generated	Low - Medium	On flats of the property	Stock exclusion, with riparian and bank stabilisation planting
Total N generated	Low - High	On flats of the property, lighter soils with increased leaching properties	Appropriate stocking rates, cutting supplement off flats, timing of N fertiliser (chook manure)
Total P generated	Low - Medium	Run off from area with larger catchment areas, high Olsen P levels	Ensure optimum phosphate fertility through soil testing programme. Overland flow management in larger catchment areas
E. coli generated	Low	Run off from effective area	Appropriate setbacks and stock exclusion
Stock access to waterways	Low - High	Steeper gullies	Permanent or temporary fencing
Fish passage impedance	Low - High	Tributaries entering the main water course	Appropriate culverts and fish passage mechanisms installed
Weed infestation	Low - High	Around centre of farm in wetter area	Retirement and planting
Riparian habitat	Low - Medium	Centre of farm plus headwaters of tributaries	Planting of riparian areas
Lowland soil degradation	High	Pugging in wet periods	Strategic grazing, retirement of wet areas
Upland soil degradation	Low - High	Run-off from hillsides surrounding flats	Retirement of risk areas

Further testing of the alignment of CAPTure against actual farm plan recommendations would help improve this connection.

Improving the accessibility of CAPTure to farmers and catchment groups would likely increase encourage involvement. Currently, CAPTure is available as electronic maps and graph outputs. The maps are not dynamic in the sense that an individual can focus in on their property and easily see multiple outputs. Google MyMaps was briefly trialled as an option for displaying the output layers. However, this was found to be limited in functionality.

Alignment with council policy

CAPTure uses the concepts developed for regional prioritisation of soil conservation in the Waikato region for the Waipā Catchment Plan (Waikato Regional Council, 2014), the Waikato Regional Prioritisation Project (Hill et al., 2015; Hill and Borman, 2016) and the Waikato Restoration Strategy (Neilson et al., 2018a; Neilson et al., 2018b; Hill et al., 2017). What we have done is rescaled the framework for catchment use, added in catchment datasets and built a suite of mitigations which include those that regional Council land managers use and fund as well as those that the farmers in the catchment use. The end result is a tool that is more fit for purpose at a catchment scale , includes a suite of mitigations that can be used by the farmers in the catchment, many of the mitigations will be supported (and potentially funded) by regional council existing programmes, they will align with water quality policy, and on a catchment basis should demonstrate what reductions can be achieved.

In addition, the outputs are likely to be familiar to farmers in other parts of the Waikato region, where the regional prioritisation outputs have been used for Healthy Rivers Wai Ora catchment stories, catchment planning and the Waikato and Waipā River Restoration Strategy.

Because CAPTure is based on a similar prioritisation approach supported by the Waikato River Authority, Waikato Regional Council and DairyNZ, there are potential benefits for individual catchment groups to align their catchment works to secure funding and work towards common goals.

Potential improvements

This pilot project and the initial development of the CAPTure tool are a first insight into the potential value of using a combination of regional and catchment datasets to provide a spatial framework for guiding catchment land management decisions and actions.

Potential improvements have been identified as the tool has been developed, however, further use of CAPTure with be invaluable to confirm the value of using it, and to identify where it can be improved.

As with any models and spatial tools, the availability of datasets remains a challenge and a limitation to the accuracy of the guidance provided. Catchment condition survey data and other catchment scale datasets vastly improve the spatial (and in some situations, the temporal) accuracy of the placement and outputs of the tool. Developing the scope of the catchment condition survey as well as exploring the use of farm environment plan data could prove useful for CAPTure.

Mitigations are highly variable and often locally specific. Improving the criteria for mitigations, cost information, spatial placement, and effectiveness of mitigations in CAPTure would improve the reduction and cost estimate outputs. Currently, the mitigation outputs are untested against Farm Environment Plans, this could be tested to provide more confidence in the CAPTure mitigation related estimates and outputs, and to adjust specific mitigation criteria in CAPTure.

A sensitivity analysis including the spatial placement criteria, reduction percentages and cost assumptions on the mitigation related outputs (both spatial and non-spatial) would provide useful insights for refining the mitigations.

The initial CAPTure outputs are limited to summary graphs and static maps. These outputs could be developed, possibly automating summary graphs, and developing reporting templates useful to catchment landowners and managers. Potentially, an interactive web environment with the ability to provide outputs at various scales (for example, by farm boundary) would increase the usefulness and accessibility of CAPTure to individual land owners and managers within a catchment.

CONCLUSIONS

Initial indications are that the CAPTure tool provides improved guidance for catchment scale mitigation placement compared with previous spatial tools. This is primarily due to the finer hydrological network, finer scale LUC spatial definition, catchment condition survey data, and the addition of mitigations and their placement to guide priorities in the catchment.

The flexibility of CAPTure allows datasets that define threats and mitigation criteria to be updated as new datasets become available.

Although CAPTure has the potential for national application, the reliance on catchment datasets remains a limitation to full national application. The best interim approach is to develop CAPTure on a catchment by catchment basis after an initial assessment of available catchment datasets is completed.

All four of the CAPTure outputs trialled in the Pūkorokoro catchment provided useful and slightly different guidance for catchment, sub-catchment and (to a lesser extent) farm scale mitigation decision making.

CAPTure provides a mechanism for aligning catchment work with regional policy and funding objectives, this has the potential to assist catchment groups collectively work towards these objectives in a more efficient and cost-effective way.

One of the strengths of CAPTure is in providing a whole of catchment multi-scale picture of the issues and the most effective way to mitigate the threats to work towards catchment values.

Initial indications are that CAPTure provides useful guidance for implementing farm plans, although further research is required to confirm this.

Further improvements could include:

- refining the mitigation placement and costs, with the assistance of catchment specific information,
- expanding the scope of the catchment condition survey to include wetland areas and CSAs,
- improving the scale of LUC and soil map information to refine the placement of mitigations, and
- expanding and refining the suite of mitigations available in CAPTure.

REFERENCES

Collins R, Rutherford K. (2004) Modelling bacterial water quality in streams draining pastoral land. Water Research 38. p770-712.

Golder Associates (2015) Miranda/Pukorokoro Hydrological and water quality review. Prepared for Department of Conservation, June 2015. 49 pp.

Hill, R., Borman, D., Desmond, T. (2017) Prioritising soil conservation and water quality issues for the Waikato River and Waipā River Restoration Strategy, New Zealand. http://riversymposium.com/wp-content/uploads/2017/08/Day-2_1330_Reece-Hill-.pptx.

Hill, R., Borman, D. (2016) Waikato Regional Prioritisation Project: Phase 2 Overview. Waikato Regional Council Internal Series 2016/22, Waikato Regional Council, Hamilton, NZ. 32 pp.

Hill, R., Borman, D., Neilson, K., Leathwick, J. (2015) Waikato Regional Prioritisation Project: A Spatial Framework for Prioritising Soil Conservation, Water Quality and Biodiversity (Phase 1). Waikato Regional Council Internal Series 2015/19, Waikato Regional Council, Hamilton, NZ. 264 pp.

Hill, R., Blair, I. (2005) Middle Waikato Pilot Project: A Review of Soil Conservation Research and Catchment Environmental Monitoring Environment Waikato Technical Report 2005/16. Environment Waikato, Hamilton.

Industry-agreed Good Management Practices relating to water quality (Version 2).

Jones H., Kimberley, M., Hill, R., Borman, D. (2015) Riparian characteristics of pastoral waterways in the Waikato region, 2002-2012. Technical Report 2015/49. Waikato Regional Council, Hamilton.

Lynn IH, Manderson AK, Page MJ, Harmsworth GR, Eyles GO, Douglas GB, Mackay AD, Newsome PJF (2009). Land Use Capability Survey Handbook – a New Zealand handbook for the classification of land 3rd ed. Hamilton, AgResearch; Lincoln, Landcare Research; Lower Hutt, GNS Science. 163p.

McDowell, R.W. (2010) The efficacy of strategies to mitigate the loss of phosphorus from pastoral land use in the catchment of Lake Rotorua, Report for Environment Bay of Plenty.

McDowell, R.W., Wilcock, B., Hamilton, D.P., 2013. Assessment of strategies to mitigate the impact or loss of contaminants from agricultural land to fresh waters. Report for Ministry for the Environment RE500/2013/066. https://www.mfe.govt.nz/sites/default/files/assessment-strategies-mitigate-impact-loss-contaminants-agriculturalland-freshwater_0.pdf.

Menu of practices to improve water quality (Dairy farms and Drystock farms).

Natural Solutions (2017) Pukorokoro Catchment Condition Survey, Sep 2017. Natural Solutions Contract Report 17/156 – update. Prepared for Living Water Programme. 28pp.

Neilson, K., Hodges, M., Williams, J., Bradly, N. (2018a) Waikato and Waipā River restoration strategy - Volume 1. Waikato Regional Council Technical Report 2018/08 Volume 1, Waikato Regional Council, Hamilton, NZ.

Neilson, K., Hodges, M., Williams, J., Bradly, N. (2018b) Waikato and Waipā River restoration strategy - Volume 2. Waikato Regional Council Technical Report 2018/08 Volume 2, Waikato Regional Council, Hamilton, NZ.

Phillips, N.; Borman, D., Eivers, R and Hill, R. (2019) Pūkorokoro/Miranda Catchment Prioritisation Tool and Monitoring Plan. Report DOC1801–1, Streamlined Environmental, Hamilton.

Waikato Regional Council (2014). Waipā Catchment Plan, Technical Report TR 2014/33. Waikato Regional Council, Hamilton.

APPENDIX 1: THREAT MAPS FOR THE PŪKOROKORO CATCHMENT

APPENDIX 2: MITIGATION PLACEMENT MAPS FOR THE PŪKOROKORO CATCHMENT

APPENDIX 3: MITIGATION REDUCTION MAPS FOR THE PŪKOROKORO CATCHMENT

APPENDIX 4: MITIGATION COST-BENEFIT MAPS FOR THE PŪKOROKORO CATCHMENT