NRM North

Tamar Estuary and Esk Rivers

An investment plan for improving water quality in the Tamar River estuary: Diffuse source management

Technical Report

December 2017

Citation

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This Technical report has been developed for the Tamar Estuary Management Taskforce to aid in the development of a River Action Plan for the Tamar Estuary. The modelling and analysis contained in this report has been undertaken by Dr Rebecca Kelly of isNRM Pty Ltd under the direction of Amanda Locatelli at NRM North. This work has been oversighted and reviewed by the TEMT Catchment Action Working Group whose members consist: Jono Price and Rachel Brown (Dairy Tasmania); Peter Skillern, Brigid Morrison and Nick Steel (TFGA); Martin Read and Glen Napthali (EPA); Martin Gill (Meander Valley Council); Rolph Vos (West Tamar Council) and Rosanna Coombes (NRM North). The report and analysis has also benefited from the contributions and review by the members of the Tamar Estuary and Esk Rivers (TEER) program Scientific and Technical Committee and TEER Strategy and Partnerships Committee.

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Glossary of terms and acronyms

BMP – Best Management Practice.

CAPER DSS – A computer based modelling system that can be used to assess 'what if' type questions related to the impact of management actions on catchment pollutant loads and receiving water quality.

Concentration – the quantity of a substance in a given volume of water.

CSO – Combined system overflow. Discharges of mixed stormwater and raw sewage from Launceston's combined sewer-stormwater system during high flow events.

Diffuse loads – Pollutant loads from land based sources delivered from surface and groundwater systems through the actions of rainfall.

Enterococci - a bacteria used as an indicator of pathogen pollution. Pathogens come from animal or human faeces and when elevated can make people sick if they drink or recreate in water.

Flow – volume of water discharged through a stream over a given period of time.

Green space – land use consisting of conservation and natural environment including national parks, conservation areas, nature reserves and other protected areas.

Load – the total amount of a pollutant.

Point source loads – Pollutant loads discharged from a single identifiable source such as a sewage treatment plant.

RHAP – River Health Action Plan.

Separated stormwater system – the pipes carrying stormwater from urban areas of the catchment to waterways. As opposed to the combined sewer-stormwater system in some parts of Launceston designed to carry sewage and stormwater in the same pipe.

Sewage – water carried waste from households and businesses.

Sewerage – the pipes, channels and other infrastructure used to transport sewage.

STP – Sewage Treatment Plant. Facility where sewage is treated before being discharged either to land through for example, reuse such as irrigation, or into a receiving water body.

Tamar Estuary Zone 1 - the section of the Tamar River estuary between Launceston and Legana.

TEER – Tamar Estuary and Esk River.

TEMT – Tamar Estuary Management Taskforce.

TN – Total nitrogen.

TP – Total phosphorus.

TSS – Total suspended sediments.

WQIP – Water Quality Improvement Plan.

WSUD – Water Sensitive Urban Design. Integrating water cycle management in an urban environment through devices designed to increase the effective perviousness of a catchment or treat stormwater to remove pollutants before it is discharged to a waterway.

Zones – a connected a region of the estuary within which the estuary functions in a similar way, for example in terms of salinity or habitat.

Executive Summary

The Tamar Estuary and Esk Rivers (TEER) drain approximately 15% of Tasmania, consisting of the North Esk, South Esk, Brumbys-Lake, Macquarie, Meander and Tamar foreshore catchments. The Tamar estuary is a drowned river valley, running for approximately 70km from Launceston to Bass Strait. The majority of flows to the estuary come from the North Esk river and the South Esk river, with flows passing from the South Esk river through Trevallyn Dam to the upper estuary.

This Technical Report provides a detailed description of the modelling and analysis undertaken to develop an Investment Plan for managing catchment pollutants in the TEER catchment. The Technical Report has been presented to the Tamar Estuary Management Taskforce for consideration and its recommendations have been incorporated in the River Health Action Plan for the Tamar Estuary. The Investment Plan complements a second Investment Plan that has been developed by the Combined System Overflows Working Group under the TEMT objectives. That plan focuses on reducing pollutants exported from Launceston's combined sewer-stormwater system into the estuary. The Investment Plans have been developed as part of a broader suite of management recommendations prepared by the Tamar Estuary Management Taskforce for the River Health Action Plan.

The recommended actions within the Investment Plans target the upper reaches of the Tamar Estuary from Launceston to Legana (referred to as Tamar Estuary Zone 1). They build on the work previously undertaken in development of a Tamar Estuary and Esk Rivers (TEER) Water Quality Improvement Plan (WQIP) by NRM North for the catchment and are a first step in its implementation.

The TEER catchment is very diverse, with a wide range of landscapes and a significant number of point sources including 26 sewage treatment plants, overflows from Launceston's combined sewer-stormwater system and aquaculture. Modelling of the TEER catchment shows that the majority of Greater TEER catchment loads come from diffuse sources. However, point sources make significant contributions to nutrient and pathogen loads, with 20% to 40% of nutrient loads coming from aquaculture and sewage treatment plants, and approximately 12% of enterococci loads coming from overflows from the combined sewage-stormwater network in Launceston.

This Investment Plan has **improving water quality in Zone 1 of the estuary (Launceston to Legana) through decreased pathogen concentrations** as its primary goal. Additional localised benefits for the freshwater system downstream of investments can be expected and are explored in this report but decisions on where to focus actions in the landscape have focused on maximising the benefits for Tamar Estuary Zone 1 pathogen concentrations. This Investment Plan explores several different options which target different land uses before a recommended 'balanced option' investment pathway is presented.

The analysis found that in order to improve water quality in Tamar Estuary Zone 1, actions in the upper Tamar foreshore catchment area and North Esk river catchments should be prioritised. Some actions above Trevallyn Dam are also recommended as their large impact on pathogen loads means that they still have a considerable impact on Tamar Estuary Zone 1 even after the dampening effect of the Dam has been accounted for.

The range of actions evaluated and recommended in the TEER WQIP were considered. From these, a smaller group of actions have been selected for consideration in the Investment Plan using the following criteria:

- High leverage – actions must have a large relative impact on pollutant loads
- Adoptable – feedback from key stakeholders must indicate that actions can be adopted at sufficient levels with incentives
- Measurable – actions in the Investment Plan need to be able to be accounted for within a planning and investment cycle

Dairy, grazing and urban areas are the three largest contributors to diffuse pathogen loads in the Greater TEER catchment and are major controllable sources of nutrient and sediment loads. Final actions recommended for investment in these land uses are:

- Dairy
    - Improved effluent management
    - Limiting stock access to streams through fencing and provision of off-stream water as well as through addressing issues with stock crossings.
- Grazing
    - Limiting stock access to streams through fencing and provision of off-stream water
    - Incorporation of a 5m wide vegetated riparian buffer within this fencing
- Urban
    - Fixing issues with incomplete separation and sewage intrusion into Launceston's separated stormwater system. This action was not identified in the WQIP but was included in the analysis for this Investment Plan following the success of a recent program run by City of Launceston. This program found sewage intrusion into the separated stormwater system in parts of Launceston is causing elevated pathogen levels in stormwater which is directly discharged into Tamar Estuary Zone 1. City of Launceston have recently undertaken works in the Kings Meadows Rivulet catchment to resolve these issues resulting in significant and measurable improvements in pathogen levels observed. This Investment Plan considers the option of continuing these works to address issues in Trevallyn and Distillery creek stormwater systems.

Based on a detailed analysis of all the potential options in each land use area, a pathway of preferred balanced investment options has been developed, using a mix of investment in the different land uses corresponding to different budgets. These options include a mix of dairy management, grazing management and investments in reducing sewage intrusion into the separated stormwater system. No investment in water sensitive urban design is included given it was found not to be cost effective for reducing pathogen concentrations in Tamar Estuary Zone 1.

The budget for planned investment for activities by land use for the three balanced investment options is given in Table A below.

TABLE A. INVESTMENT IN LAND USES BY MAJOR SUBCATCHMENTS UNDER BALANCED OPTIONS

Land use	$2 million	$5 million	$10 million
Dairy			
Brumbys-Lake, Macquarie, Meander & Tamar	$550,000	$825,000	$1,100,000
Grazing			
North Esk	$1,250,000	$1,330,000	$1,330,000
Upper Tamar	$0	$1,660,000	$1,660,000
Brumbys-Lake, Meander & South Esk	$0	$685,000	$5,410,000
Urban			
Launceston separated stormwater	$200,000	$500,000	$500,000

Figures A and B show the decrease in Greater TEER catchment pollutant loads and Tamar Estuary Zone 1 pollutant concentrations respectively for this balanced investment option versus the cost of investment.

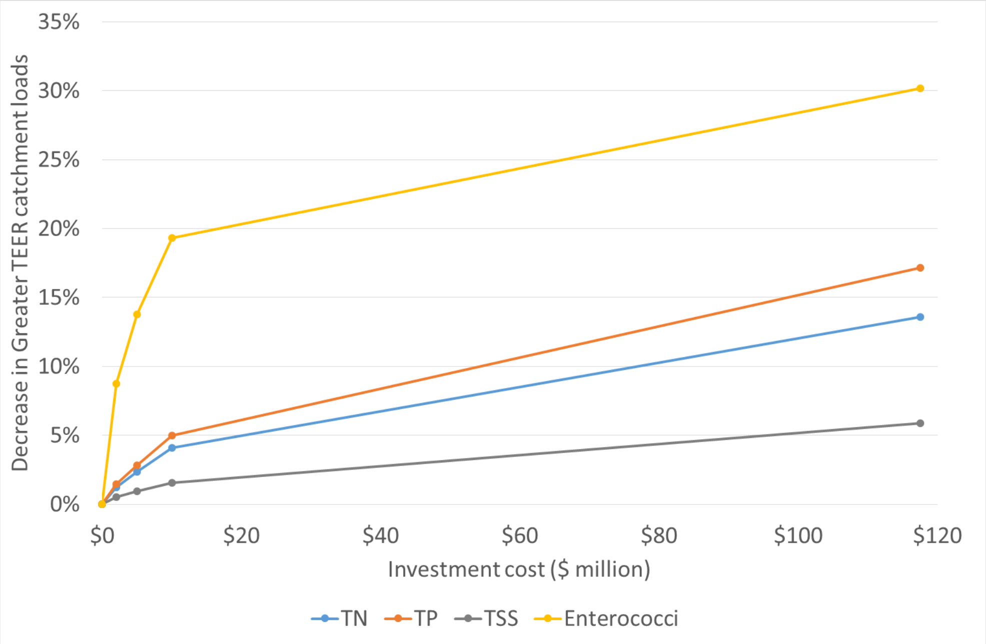

*FIGURE A. DECREASE IN POLLUTANT LOADS IN **GREATER TEER CATCHMENT** FROM BALANCED INVESTMENT OPTION*

This figure shows that the balanced investment options are very cost effective for reducing all pollutant loads, but particularly effective for reducing enterococci loads. The $2 million investment option can be expected to achieve roughly 9% decrease in enterococci loads for the Greater TEER catchment, equivalent to 25% of the potential decrease in enterococci from fully funding these actions for 1.7% of the budget. Relative benefits for other pollutants are smaller but are still represent a greater benefit than relative cost, with roughly 9% of the potential benefit achieved for only 1.7% of the fully funded budget. While the marginal benefit of further investment decreases with subsequent investment, investment of $10 million is still shown to be very cost effective with 25% to 30% of the potential decrease in nutrients and sediment and over 60% of the potential decrease in enterococci loads achieved for only 8.5% of the total cost of fully funding this option. This represents a very good return on investment. It should be noted that benefits in terms of reduced sediment loads are likely to be significantly underestimated as the benefits for increased streambank stability and reduced streambank erosion through exclusion of stock and riparian revegetation are not included in the modelling.

Figure B shows the decrease in Tamar Estuary Zone 1 concentrations from investment in the balanced option. This figure demonstrates the cost effectiveness of this option for all budget levels. It also shows the decreasing marginal return to scale of investment with 30% to 55% of the potential decrease in concentration for all pollutants achieved with the first 1.7% of investment ($2 million option). Even with decreasing returns to scale of investment the $10 million investment still represents a very cost effective option for reducing Tamar Estuary Zone 1 concentrations with over 45% of potential sediment reduction, roughly 60% of potential nutrient reduction and over 80% of potential enterococci reductions from diffuse source management achieved with only 8.5% of the fully funded investment cost. As was the case with loads, decreases in sediment concentrations are likely to be significantly underestimated by the modelling.

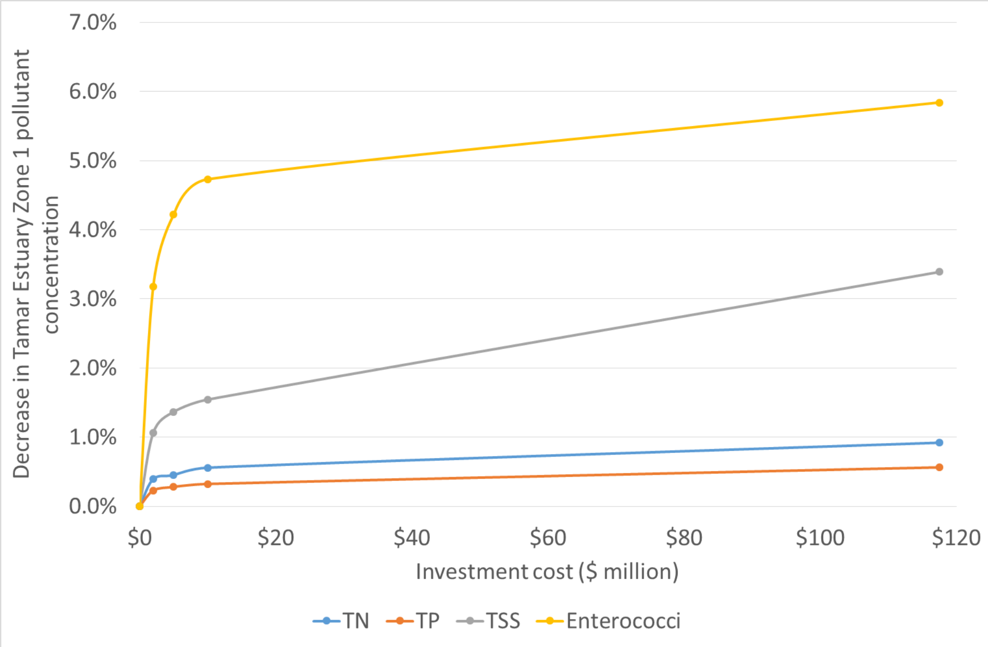

*FIGURE B. DECREASE IN POLLUTANT CONCENTRATIONS IN **TAMAR ESTUARY ZONE 1** FROM BALANCED INVESTMENT OPTION*

These investments would have a range of benefits over time, both in terms of improved water quality in the freshwater system and the estuary as well as improvements to overall stream health. Benefits in the immediate, medium and long term are also explored in this Technical Report.

The actions in this Investment Plan will need to be implemented in partnership with a number of key organisations. It is expected that grazing and dairy action programs would be implemented by NRM North in partnership with Dairy Tasmania and the Tasmanian Farmers and Graziers Association. Past experience in on-ground investments indicates that a planned investment of $1 million per year is appropriate. The balanced options above represent an investment pathway through time to maximise benefits for Tamar Estuary Zone 1 enterococci concentrations.

It could be expected that finding farmers willing to undertake and co-fund investments may become progressively harder over time as the most able and willing are generally early adopters in any program. However this may be off-set to some extent by the momentum created by the relatively large scale of investment, with local landholders seeing the benefit of actions on neighbouring farms and the creation of new behavioural norms amongst local farming communities. The program will need to be flexible in terms of the approaches used to ensure ongoing adoption over time (for example the use of market based mechanisms or higher incentive rates for more difficult works may need to be considered).

Works to address sewage intrusion into Launceston's stormwater system would be led by City of Launceston Council in partnership with TasWater as required. It is expected that these works would be undertaken over a 2 to 5 year period, depending on the scale of investment.

1 Introduction

The Tamar Estuary Management Taskforce was established under the Launceston City Deal with an aim of identifying investments to improve the health of the Tamar Estuary. As part of this work, the Taskforce was charged with delivering a River Health Action Plan by the end of 2017. This Technical Report provides a detailed description of the modelling and analysis undertaken to develop an Investment Plan for managing catchment pollutants that forms part of the River Health Action Plan. This Investment Plan complements a second Investment Plan focused on reducing pollutants exported from Launceston's combined sewer-stormwater system into the estuary. They build on the work previously undertaken in development of a Tamar Estuary and Esk Rivers (TEER) Water Quality Improvement Plan (WQIP) by NRM North for the catchment and are a first step in its implementation.

The WQIP and these Investment Plans consider the impact of investment actions on four major pollutants: Total Nitrogen (TN); Total Phosphorus (TP); Total Suspended Sediments (TSS); and enterococci. TN and TP are nutrients. Elevated nutrient levels can feed the growth of nuisance algae in streams, dams and the estuary. This algae can increase turbidity and can smother and replace native plant and animal species. It can also make water dangerous for recreation and drinking. High levels of TSS make water turbid and dirty looking and can smother and replace native plant and animal species, decreasing the health of waterways. Sediment exports from the freshwater system to the estuary can also contribute to sediment accumulation in the upper estuary. Enterococci is a bacteria used as an indicator of pathogen pollution. Pathogens come from animal or human faeces and when elevated can make people sick if they drink or recreate in water.

Catchment or diffuse pollutants are those that either run off the ground surface or travel through groundwater into the waterway when it rains. Pollutant runoff depends on a number of factors including rainfall, slope, land use and land management. While higher rainfall volumes have the capacity to transport greater amounts of pollutants, greater levels of groundcover and vegetation, such as in natural forest areas, can reduce pollutant runoff. Intense land uses are traditionally associated with higher pollutant loads due to greater inputs of nutrients into the production systems, lower levels of groundcover and the removal of buffers between the stream and the land use. Runoff from urban areas is heavily affected by increased imperviousness which increases runoff, and stormwater infrastructure which bypasses riparian areas meaning pollutants do not get captured by vegetation and are transported very quickly to the stream or water body.

Point source pollutants are those that are considered to come from a single 'point source'. These include discharges from sewage treatment plants (STP), overflows from the combined sewer-stormwater system in Launceston (CSO), exports from fish farms and other industry inputs. Management of these options is not considered in this Investment Plan. Management options for combined system overflows are considered in a second Investment Plan.

The Tamar Estuary and Esk Rivers (TEER) drain approximately 15% of Tasmania, consisting of the North Esk, South Esk, Brumbys-Lake, Macquarie, Meander and Tamar foreshore catchments. The Tamar estuary is a drowned river valley, running for approximately 70km from Launceston to Bass Strait. The majority of flows to the estuary come from the North Esk river and the South Esk river, with flows passing from the South Esk river through Trevallyn Dam to the upper estuary. The Tamar Estuary and its catchment are shown in Figure 1.

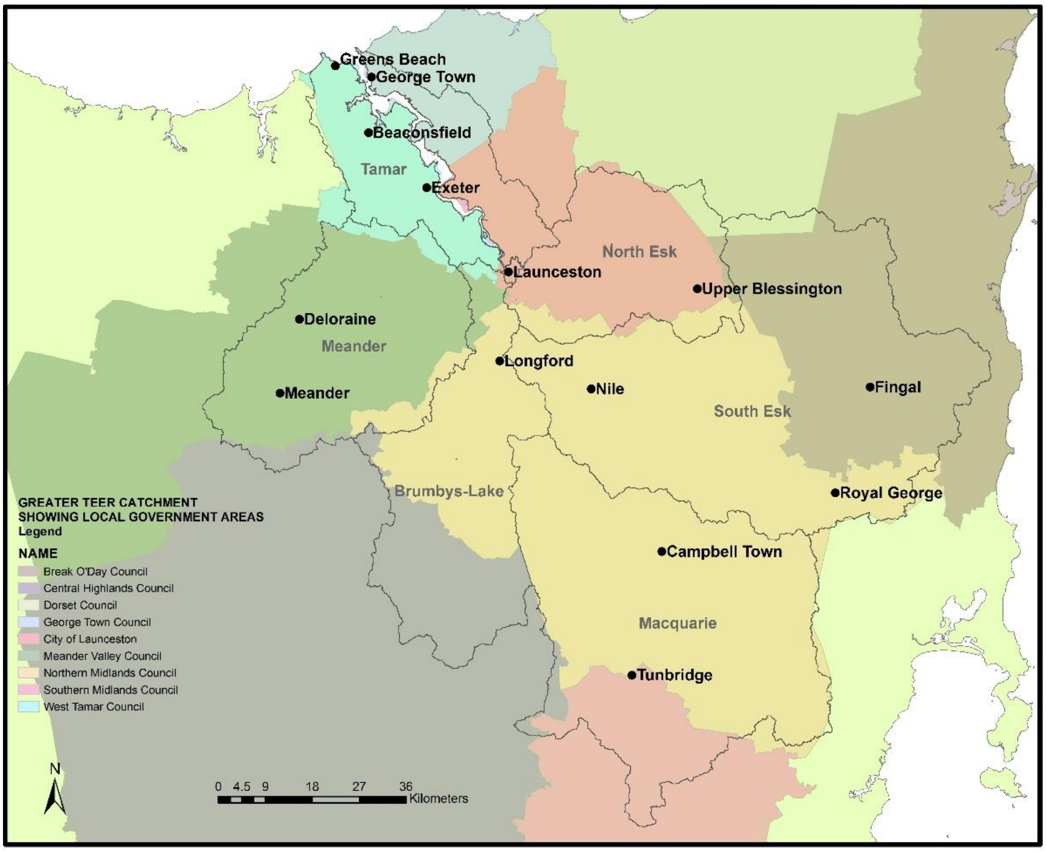

Figure 1. Location of the Tamar estuary and its catchment, including major subcatchments and Local Government Areas

Pollutant loads in the TEER catchment come from a range of diffuse and point sources – directly off the catchment from the various land uses that cover the land surface (diffuse), 26 sewage treatment plants in the catchment and or discharging directly into the estuary, a salmon farm operating in the lower reaches of the estuary, and from combined system overflows. Figure 2 provides an estimate of the proportion of pollutant loads derived from each of these sources. This figure shows that diffuse sources are the major contributor to all Greater TEER catchment pollutants loads but that point sources also make a substantial contribution to nutrients and pathogens. Point source nutrients are largely derived from sewage treatment plants (STPs) and fish farms. Overflows from the combined sewer-stormwater system in Launceston (CSOs) contribute approximately 12% of enterococci but very little nutrient or sediment loads.

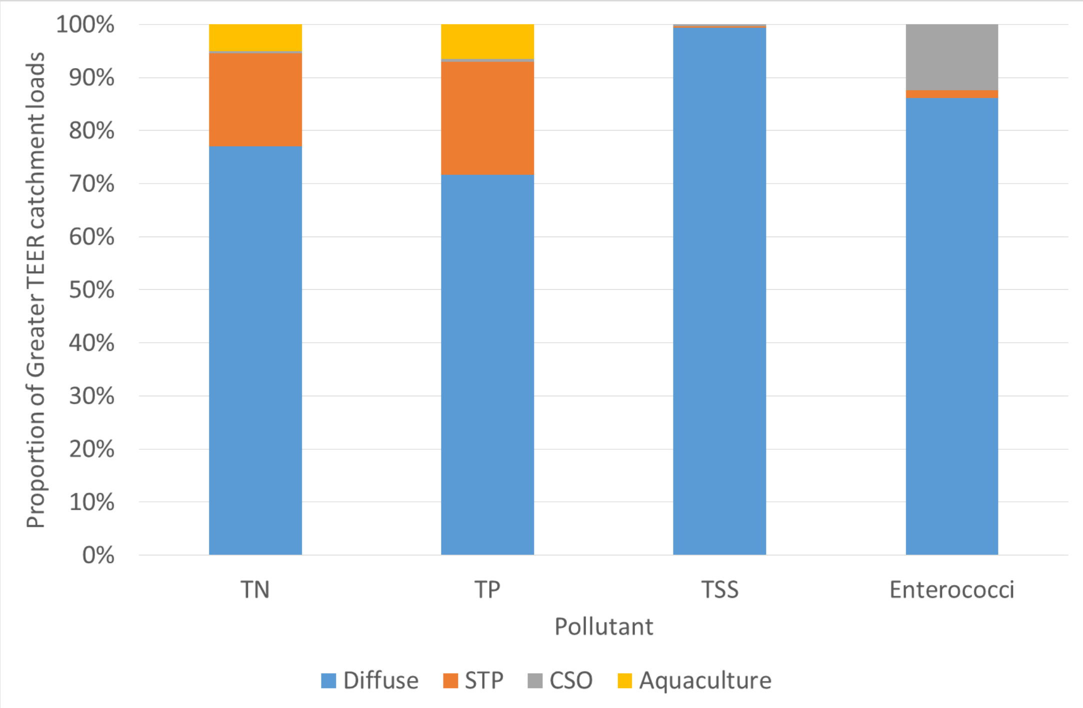

FIGURE 2.PROPORTION OF GREATER TEER CATCHMENT POLLUTANT LOADS FROM VARIOUS SOURCES

In terms of the impact on Tamar Estuary Zone 1 concentrations, the size of pollutant loads of each source is moderated by how directly it enters this portion of the estuary. So sewage treatment plants discharging in the upper estuary, urban areas around Launceston and combined system overflows can be expected to have a significantly greater impacts on Tamar Estuary Zone 1 pollutant concentrations than loads generated higher up in the catchment, particularly those upstream of Trevallyn Dam. Figure 3 shows an estimate of the influence of all these sources on average pollutant concentrations in Tamar Estuary Zone 1. This figure should be read with several caveats. Results shown here presume that each pollutant source is 'switched off'. For example this means that it is assumed that no flow enters the estuary from the catchment when considering the impact of STPs. In reality management changes can impact on loads without reducing flows. A background concentration of nutrients is assumed in the modelling. This accounts for the influence of processes such as nutrient cycling within the estuary and oceanic inputs of nutrients to the estuary. This is treated as a fixed value so doesn't respond to the changes in flow and loads from other sources being modelled here. Background concentrations are not considered to be 'controllable', rather they are naturally occurring and not subject to management. This information is intended to show the relative leverage of actions to reduce loads from these sources on Tamar Estuary Zone 1 concentrations only and should be read in this context.

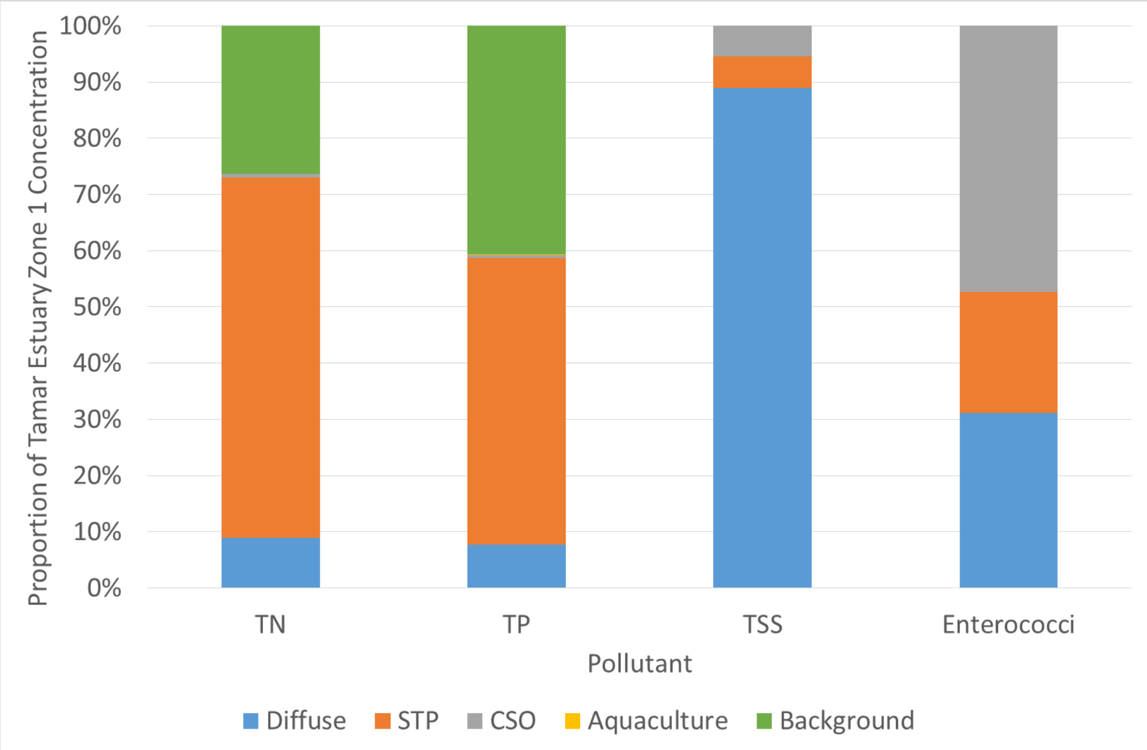

FIGURE 3.ESTIMATED CONTRIBUTION OF VARIOUS SOURCES ON POLLUTANT CONCENTRATIONS IN TAMAR ESTUARY ZONE 1

This figure shows that Tamar Estuary Zone 1 nutrient contributions are driven to a large extent by STP discharge direct to the estuary. Diffuse sources have a significantly smaller impact on Tamar Estuary Zone 1 concentrations than they do to Greater TEER catchment loads. Most of this impact comes from catchment areas that are directly contributing to the estuary, so the upper Tamar foreshore and North Esk River catchments. There is a tidal influence on pollutants entering Zone 1, so pollutant sources further down the estuary can have a small impact on Zone 1. TSS concentrations are largely driven by diffuse rather than point sources, with much of this delivered from urban areas around Launceston and other land use areas in the North Esk catchment. CSOs and STPs do make some contribution to TSS concentrations in Tamar Estuary Zone 1, but this is estimated to be in the order of 5% for each compared to 90% from diffuse sources. CSOs are a very significant drivers of enterococci concentrations in the Tamar Estuary Zone 1, contributing nearly half of the average concentration. The remaining portion come from a mix of diffuse and STP sources, with diffuse inputs estimated to be having slightly more impact than STPs on enterococci concentrations.

As discussed earlier, exports of diffuse pollutants are affected by a range of factors including rainfall, slope, land use and land management. Figure 4 shows the relative contribution of different land uses to Greater TEER catchment diffuse loads (ie excluding loads from point sources). Relative area and flows for each land use are also provided as flow and area are both major drivers of pollutants, all other things being equal.

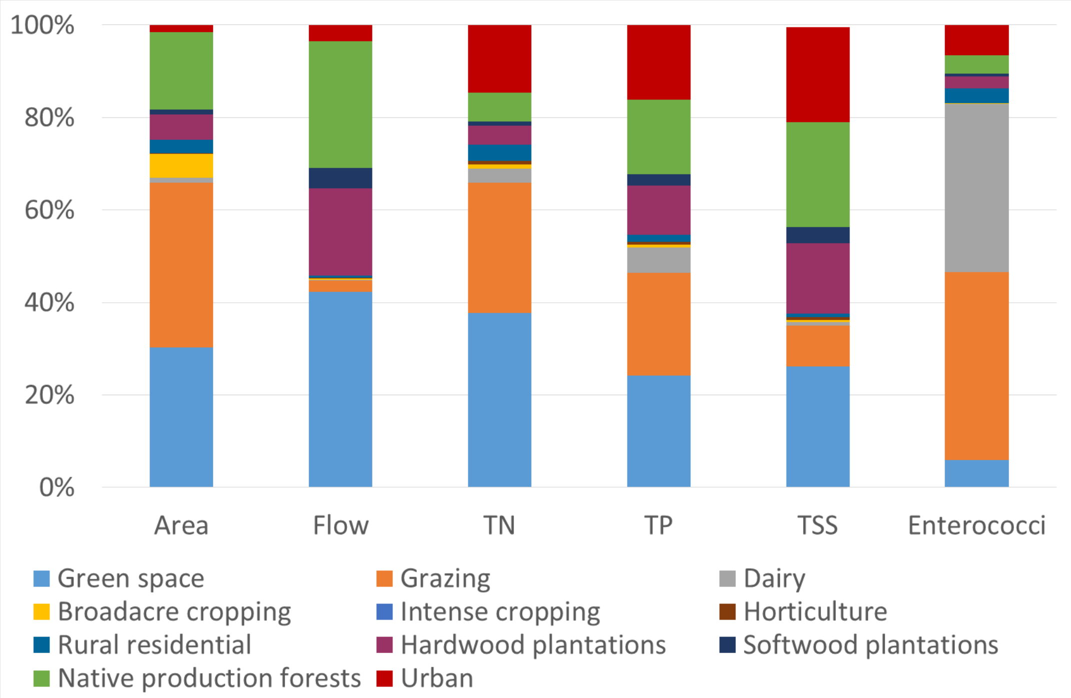

FIGURE 4. RELATIVE CONTRIBUTION OF DIFFERENT LAND USES TO GREATER TEER CATCHMENT LOADS, FLOWS AND AREA

This figure shows that grazing is the dominant land use in the catchment (36% area) but because of its location in lower rainfall areas only produces a relatively small proportion of flows (2%). Grazing areas produce substantially greater relative loads than flows, particularly nutrients and enterococci. Total suspended sediments from grazing areas are also greater than their relative flow contribution but not to the same extent as nutrients. It should be noted that the modelling does not estimate loads from streambank erosion so sediment contributions from grazing areas are likely to be significantly underestimated where stock have access to the stream and/or riparian vegetation has been removed. Grazing areas are the greatest contributor to enterococci loads at a Greater TEER catchment scale, producing slightly more (41%) pathogens than dairy areas (36%). Dairy areas are a very small land use within the catchment (1%) but make a comparatively large contribution to pathogen loads They also contribute substantially more nutrients (3.1% and 5.5% for TN and TP respectively) than their relative flow contribution (0.2%). The other land use that stands out as a significant contributor of pollutants are urban areas. These areas contribute only 2% of the area but over 15% of nutrients and 20% of sediments. They also contribute roughly 7% of the diffuse pathogen loads from the Greater TEER catchment. Note that these results exclude the contribution of urban areas within the combined system as these discharges are included as a point source. Other land uses contribute loads and flows relative to their flow and area contributions.

2 Targeting investments

The best decision of where to target investments in the landscape and what actions to focus on depends on the goals of the investment. Different actions will have different impacts on the various aspects of water quality and, while all actions can be expected to have localised benefits, actions can have very different impacts further down the system. Two questions to be asked before choosing an appropriate catchment investment option are:

1. **What are the environmental outcomes being sought?** Is the focus on sediment accumulation or turbidity? Is there an issue with algal growth that needs to be addressed? Is recreational water quality the issue being targeted? In each of these cases a different

pollutant would be targeted – Total Suspended Solids (TSS) for addressing sediment issues, Total Nitrogen (TN) and Total Phosphorous (TP) to address algal growth, and enterococci (bacteria) if investment is targeting improvements in recreational water quality.

2. **Where are these environmental improvements required?** Is the focus on impacts in the upper estuary? Are we seeking benefits for the entire length of the estuary? Are we concerned for drinking water quality in Trevallyn dam? Are we concerned about other high value local assets in the freshwater system? The best place to target investments will depend on which of these is the focus for investment. For example, investments in the North Esk catchment can be expected to improve water quality in the upper estuary and in local recreational sites on the river but will have no impact of drinking water quality from Trevallyn Dam. Investments above the Dam will benefit both the dam and the estuary but given that the dam acts as a barrier to the passage of some pollutants the benefits to the estuary may be less.

2.1 Goals for this Investment Plan

This Investment Plan has **improving water quality in Zone 1 of the estuary (Launceston to Legana) by reducing pathogen concentrations** as its primary goal. Additional localised benefits for the freshwater system downstream and for other pollutants in Tamar Estuary Zone 1 from investments can be expected but decisions on where to focus actions in the landscape have focused on maximising the benefits for Tamar Estuary Zone 1 pathogen concentrations. Several different options are explored which target different land uses before a set of preferred 'balanced' options is presented.

2.2 Where should actions be focused to improve water quality in Zone 1?

In order to determine where investment is likely to provide the greatest benefit to Zone 1 of the estuary, a set of scenarios were run where the same area affected by the investment was placed in each of the major subcatchments of the TEER catchment (Brumbys-Lake, Meander, Macquarie, North Esk, South Esk, Tamar – split into upper Tamar and lower Tamar). Table 1 summarises these impacts, showing the relative change in Tamar Estuary Zone 1 concentration for a unit change in load for each pollutant. Figure 1 (see Section 1) shows the location of these major subcatchments within the TEER catchment relative to Local Government Areas.

TABLE 1. RELATIVE IMPACT ON TAMAR ESTUARY ZONE 1 CONCENTRATION PER UNIT LOAD REDUCTION FOR INVESTMENT IN MAJOR SUBCATCHMENTS

Pollutant	Brumbys-Lake	Macquarie	Meander	North Esk	South Esk	Lower Tamar	Upper Tamar
Total Nitrogen	0.29	0.26	0.27	4.21	0.2	0.11	3.15
Total Phosphorous	1.1	1.09	1.18	16.69	0.68	0.88	11.6
Total Suspended Solids (sediment)	3.32	3.94	3.96	54.17	3.29	0.8	54.52
Enterococci (bacteria)	0	0	2.88	37.77	0	0	18.81

Given these results it was determined that, all other things being equal, investments should be targeted to subcatchments, where possible, in the following priority order:

1. North Esk
2. Upper Tamar
3. Meander

4. Brumbys-Lake
5. Macquarie and lower sections of the South Esk

The general rule is that investments upstream of and closer to Zone 1 with fewer barriers to pollutant transport between the action and the estuary will have the greatest benefits. Investments should then be targeted within these locations to focus on adoptable actions associated with the greatest reductions in load for a given budget. The magnitude of load reductions from an action are also important, with very high impact actions above Trevallyn Dam potentially having greater benefits than lower leverage actions in the vicinity of Zone 1. These concepts are explored further in the analysis below.

3 Load & Condition Targets in the WQIP

The Water Quality Improvement Plan (WQIP) set forth feasible load reduction targets for the greater TEER catchment. These were determined based on assumed feasible levels of adoption of various potential management actions determined using feedback from key stakeholders. Load reduction targets as a percentage of total point and diffuse loads for the Greater TEER catchment and the contribution made towards these by the different point and diffuse source load reductions are shown in Figure 5. Note that the contribution of diffuse actions to decreasing Greater TEER catchment load and Tamar estuary concentrations shown in Figure 5 and Figure 6 have been updated from those presented in the WQIP to reflect recent updates to the modelling used to develop these Investment Plans.

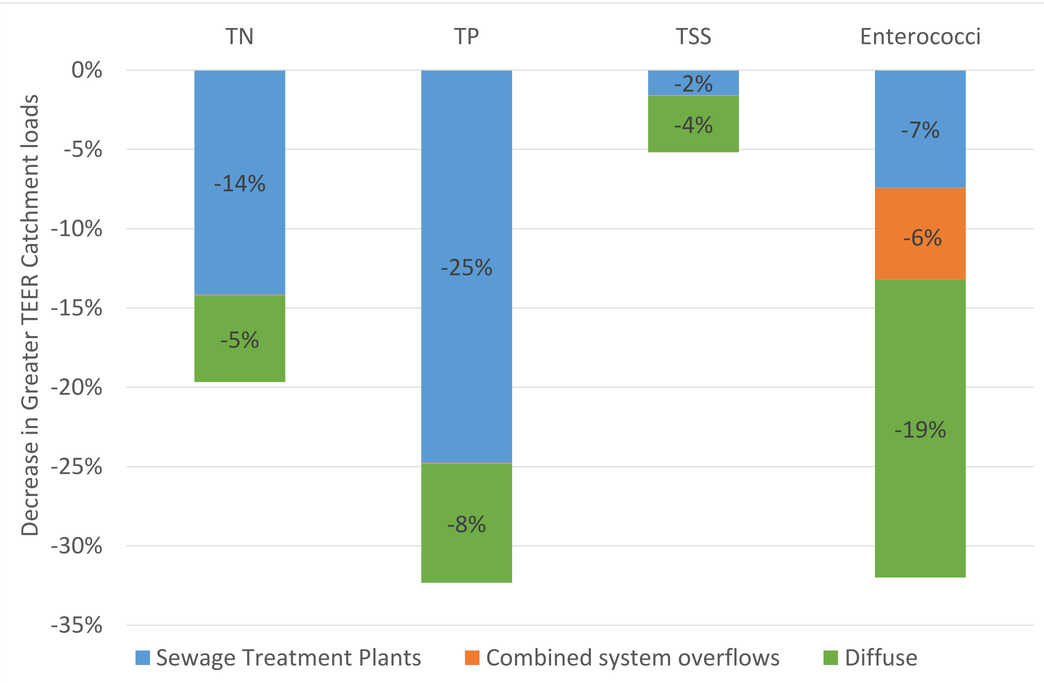

FIGURE 5. TEER WQIP LOAD REDUCTION TARGETS BY POLLUTANT SOURCE FOR THE ***GREATER TEER CATCHMENT***[1]

[1] Note that decreases in Figures 5 and 6 have been changed from the original WQIP to reflect results from more recent modelling which incorporates improved base case data on land use, riparian corridors, CSOs and Launceston's separated stormwater system. Targets for STP and CSOs are based on earlier modelling undertaken for the WQIP given that these related to specific projects at the time of WQIP development. New modelling used to underpin the development of the River Health Action Plan will result in some differences from these estimates. In particular actions proposed in the Combined System Overflows Investment Plan can

This figure shows that diffuse pollutant management is key to reducing loads of sediments and pathogens. It makes a smaller but still important contribution to reducing nutrient loads. Reducing combined system overflows (CSO's) is important for recreational water quality through improved pathogen levels but can be expected to have little to no impacts on nutrients and sediments. Planned upgrades of sewage treatment plants can be expected to have the greatest benefit in terms of reducing nutrient loads, while also having benefits in terms of sediment and pathogen load reductions.

The relative impact of changes in load on estuary water quality depends on where that change occurs in the catchment. Figure 6 shows the relative contribution of load reductions from each pollutant source to targeted Tamar Estuary Zone 1 water quality improvements.

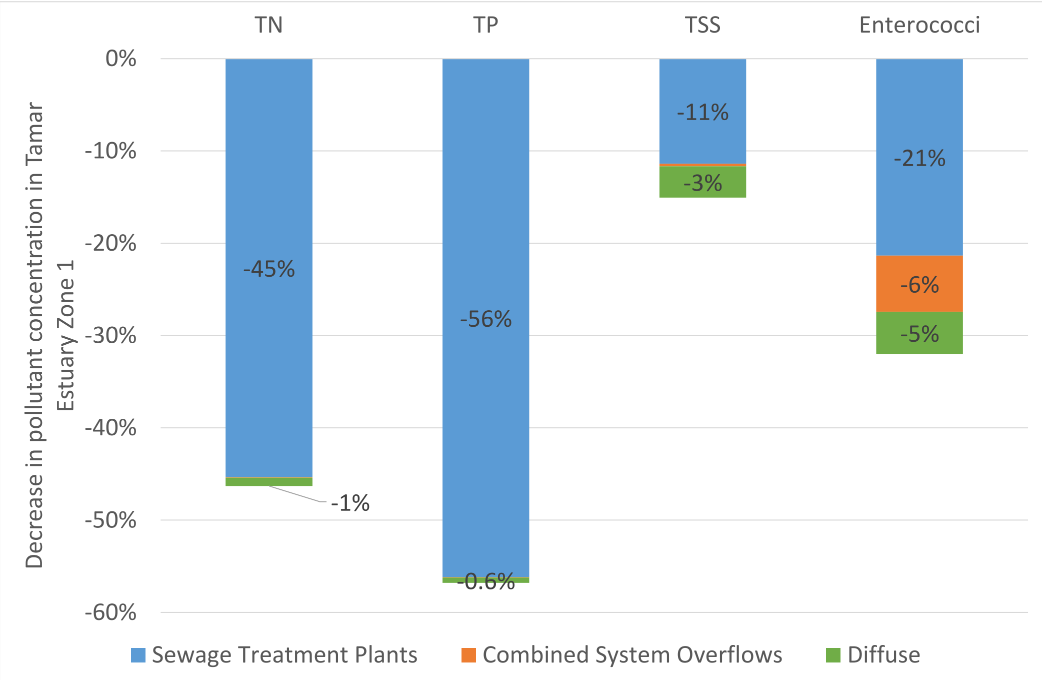

FIGURE 6. CONTRIBUTION OF TARGETED LOAD REDUCTIONS FROM DIFFERENT SOURCES OF POLLUTANTS TO DECREASING CONCENTRATIONS IN ***TAMAR ESTUARY ZONE 1***

This figure shows that:

- upgrades of sewage treatment plants analysed for the WQIP are expected to contribute substantially to improvements in water quality in Tamar Estuary Zone 1 of the estuary across all pollutants, with their greatest benefit in terms of nutrient reductions.
- diffuse (catchment) pollutant load reductions can be expected to have their greatest impact on sediment and pathogen concentrations in Tamar Estuary Zone1. They are also associated with small decreases in nutrient concentrations.

4 Analysis of investment options by land use

This Investment Plan considers the range of actions evaluated and recommended in the TEER WQIP. From these a smaller group of actions have been selected for consideration in the Investment Plan using the following criteria:

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be expected to lead to significantly greater decreases in enterococci concentrations than was estimated as possible in the WQIP.

- High leverage – actions must have a large relative impact on pollutant loads
- Adoptable – feedback from key stakeholders must indicate that actions can be adopted at sufficient levels with incentives
- Measurable – actions in the Investment Plan need to be able to be accounted for within a planning and investment cycle

Actions considered targeted pollutants coming from dairy, grazing and urban areas. These land uses are the three largest contributors to diffuse pathogen loads in the Greater TEER catchment and are major controllable sources of nutrient and sediment loads (ie. loads that are able to be reduced through improved management actions as opposed to loads that are largely driven by uncontrollable factors such as rainfall and high slope). Figure 7 shows the range of actions for each land use considered in the WQIP and the actions selected using the above criteria for assessment in this Investment Plan.

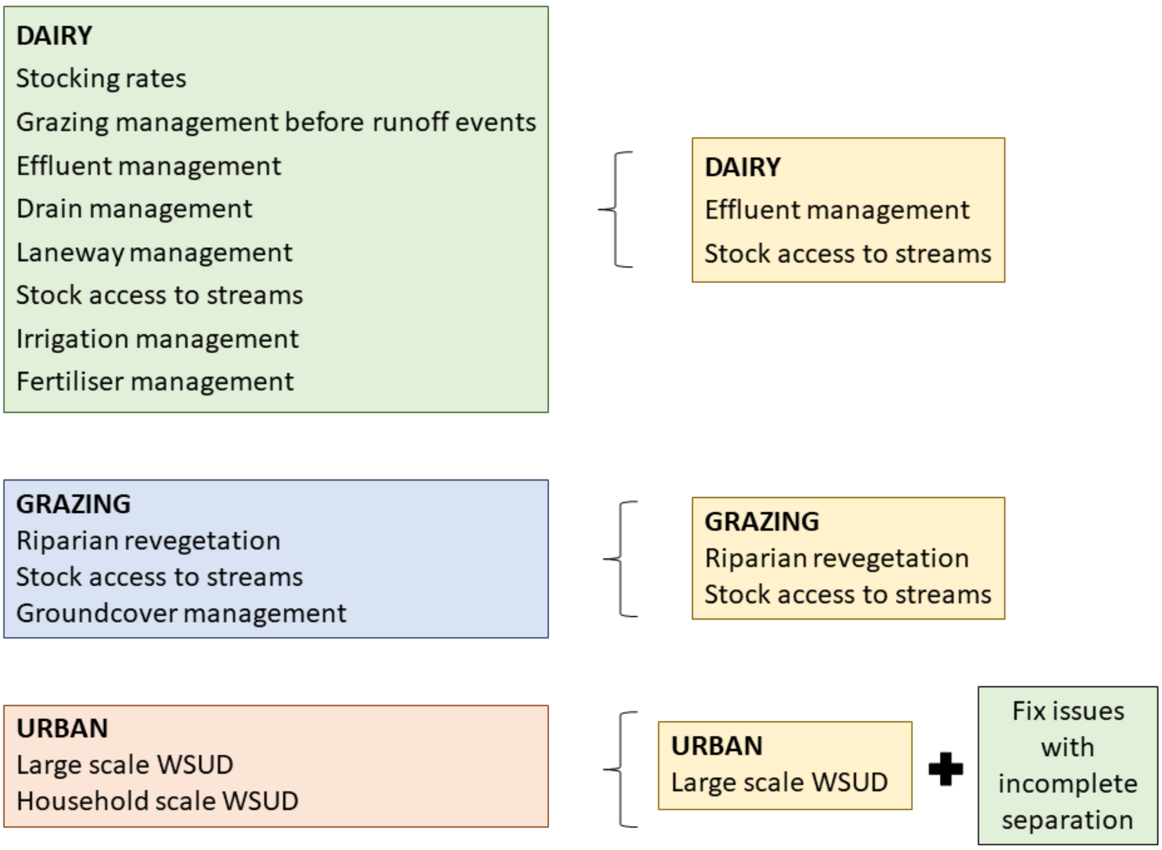

FIGURE 7. MANAGEMENT ACTIONS IN THE WQIP SELECTED FOR INCLUSION IN THE DIFFUSE POLLUTANT INVESTMENT PLAN

Actions considered in developing this Investment Plan are:

- Dairy
  - Improved effluent management
  - Limiting stock access to streams through fencing and provision of off-stream water as well as through addressing issues with stock crossings.
- Grazing
  - Limiting stock access to streams through fencing and provision of off-stream water
  - Incorporation of a 5m wide vegetated riparian buffer within this fencing

- Urban
    - Large scale water sensitive urban design such as wetlands, swales and bioretention systems focused on treating urban runoff to remove pollutants as well as reducing runoff volumes
    - Fixing issues with incomplete separation and sewage intrusion into Launceston's separated stormwater system. This action was not identified in the WQIP but has been in the analysis for this Investment Plan following the success of a recent program run by City of Launceston. This program found sewage intrusion into the separated stormwater system in parts of Launceston is causing elevated pathogen levels in this stormwater which is directly discharged into Tamar Estuary Zone 1. City of Launceston have recently undertaken works in the Kings Meadows Rivulet catchment to resolve these issues there with significant measureable improvements in pathogen levels being observed. This Investment Plan considers the option of continuing these works to address issues in Trevallyn and Distillery creek stormwater systems.

These actions are described in more detail in discussion below. Estimates of feasible levels of adoption for each action were developed as part of the WQIP process using feedback from relevant key stakeholders.

Investment options have been developed for 3 different budget levels - $2 million, $5 million and $10 million. Options have been assessed for the 3 major land uses which are controllable sources of diffuse pollutants from catchments – dairy, grazing and urban. These options have been assessed relative to two goals for the catchment:

- Reducing pollutant concentrations in Tamar Estuary Zone 1.
- Reducing greater TEER catchment diffuse catchment loads.

Results for each land use are presented below before a comparison of the cost effectiveness of investments in all land uses is provided. Note that all catchment load results show the impact on loads from the sum of diffuse and CSO loads. This allows easy comparison with the CSO focused Investment Plan results.

Costs for undertaking actions were determined in consultation with NRM North staff. In some cases, such as for riparian buffers or excluding stock from streams, the cost is based on an incentive payment with an expectation that landholders would co-invest. For other options, such as water sensitive urban design (WSUD) in urban areas, the total upfront cost was included, with an assumption that Councils would cover on-going maintenance costs.

4.1 Dairy

The feasible adoption scenario for dairy areas was analysed and the contribution of improved dairy management to the load reduction target was estimated for each subcatchment. Two dairy management actions are considered in this Investment Plan scenario – improved effluent management and exclusion of stock from streams. These actions were found to be both highly adoptable, measurable and have a high leverage for reducing pollutant exports from dairy areas.

It was found that all targeted actions for dairy management, assuming feasible levels of adoption, could be funded for approximately $1.1 million, well within the $2 million budget scenario. These investments could be expected to decrease Greater TEER catchment diffuse loads by 16% for enterococci, 2% for nutrients TN and TP respectively and 1% for TSS.

The distance of these investments from Zone 1, with most occurring in the Meander and Brumbys-Lake catchments upstream of Trevallyn Dam, means that their relative impact on Tamar Estuary Zone 1 concentrations is significantly less than their impact on Greater TEER catchment loads. This investment can be expected to decrease average Zone 1 estuary concentrations of enterococci by over 1.4%. These water quality improvements are compared to those achieved by grazing management in the next section (see Figure 8 and Figure 9).

4.2 Grazing options

Three actions were identified in the WQIP as priority actions for managing pollutant exports from grazing areas:

- Improving groundcover
- Revegetating riparian buffers of 5m or more
- Excluding stock from streams.

In developing the options for consideration in the Investment Plan it was decided to focus on riparian revegetation and stock exclusion from streams. Options to improve groundcover were not considered as it is difficult to quantify any gains made or to provide a good estimate of the benefits that could be achieved from any investment in improved groundcover (ie. they were not measurable).

Actions in grazing landscapes were prioritised based on their potential impact on water quality in Tamar Estuary Zone 1. In order to determine priority locations for grazing investment, potential actions in each subcatchment were analysed for their impact on estuary water quality.

- The highest priority was given to funding actions in the North Esk catchment
- Second priority was given to high impact actions in the upper Tamar catchment
- Third priority was given to actions closer to Trevallyn Dam, with investments spread between the Meander, Brumbys-Lake and lower South Esk catchments.

Figure 8 and Figure 9 demonstrate the return on investment as the budget for grazing management options increases in terms of two changes – the total decrease in Greater TEER catchment loads, and the decrease in Tamar Estuary Zone 1 pollutant concentration. The maximum value of impact and cost is where all 'feasible'[2] investment in the selected grazing actions is undertaken. The impacts of the single dairy 'full investment' option are also shown on these figures as a single dot for comparison.

[2] As defined in the TEER WQIP

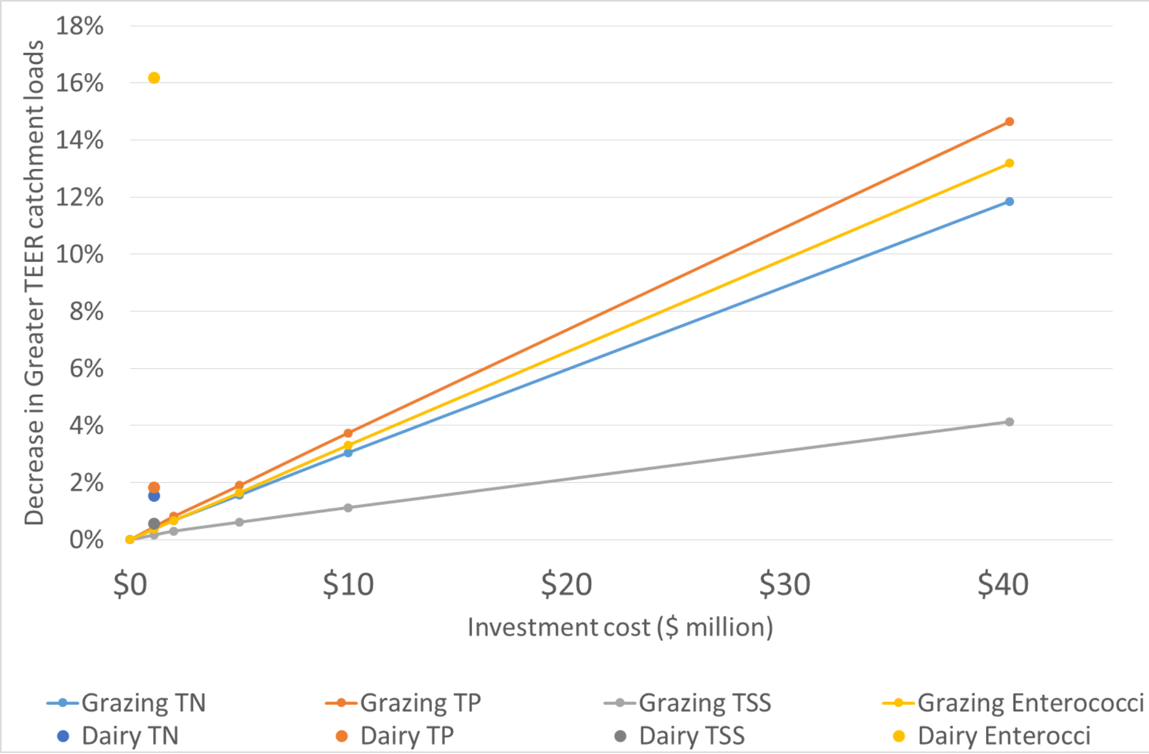

*FIGURE 8. DECREASE IN DIFFUSE POLLUTANT LOADS FROM INVESTMENT IN GRAZING MANAGEMENT FOR THE **GREATER TEER CATCHMENT***

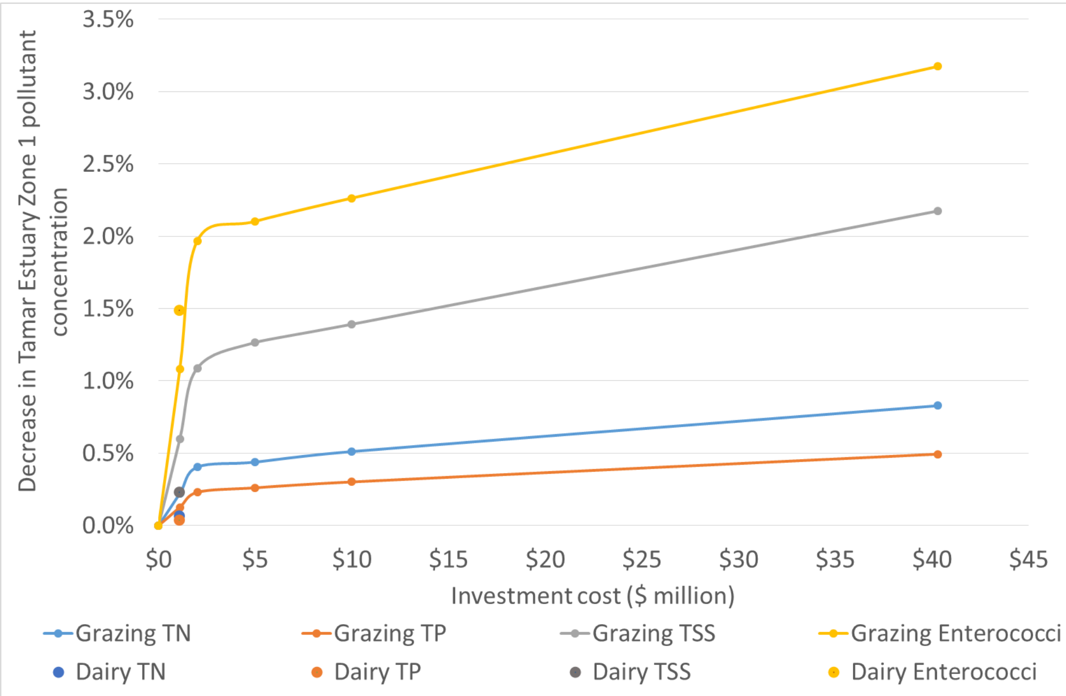

*FIGURE 9. DECREASE IN POLLUTANT CONCENTRATIONS IN **TAMAR ESTUARY ZONE 1** FROM INVESTMENT IN GRAZING MANAGEMENT*

Investments have been targeted for their impact on Tamar Estuary Zone 1 pollutant concentrations. Targeting the highest leverage investments in this way means that the majority of benefits in the estuary are generally achieved with the initial investment of funds (so the relative change in Tamar Estuary Zone 1 concentration for the $2 million investment is greater for each dollar invested than for the $5 million or $10 million options). Further improvements are harder to achieve and so cost more per unit of estuary water quality improvement achieved.

For all pollutants, over 60% to 70% of the potential decrease in concentration from these actions is achieved with a $10 million investment in grazing (at roughly 25% of the total cost of fully funding grazing actions). By comparison, investment in dairy achieves very small benefits in Zone 1 in terms of nutrients or sediment but can also achieve nearly 50% of the potential decrease in enterococci concentration that could be achieved by a full investment (of $40.3 million) in improved grazing management for less than 3% of this budget.

A $2 million investment in improved grazing management can be expected to achieve over 60% of the potential change in enterococci at roughly 5% of the total cost. A $1.1 million investment in improved dairy management could achieve nearly 50% of the potential change in Zone 1 enterococci concentrations from full investment in grazing for less than 3% of the cost.

The shape of the cost versus investment impact curve is different between the Greater TEER pollutant loads and Tamar Estuary Zone 1 concentrations, with the latter displaying a more obvious trend of diminishing marginal returns, while the impact on pollutant loads is more linear. This is because actions are prioritised based on enterococci concentration in Tamar Estuary Zone 1, not on their impacts on Greater TEER catchment loads. It is likely that actions further up the catchment or in the Lower Tamar may have a greater impact on catchment loads without having benefits for the upper estuary.

4.3 Urban options

Pathogens from urban areas outside the combined sewer-stormwater system come primarily from two sources:

- Carried off the land surface in stormwater.
- From areas where sewage enters the stormwater network. This might occur due to illegal sewage connections to the stormwater network or can be where stormwater enters the sewage network causing it to overflow and enter the stormwater system through gutters etc.

Management options to address pathogens and other pollutants in stormwater focus on either reducing stormwater runoff volumes or treating urban runoff to remove pollutants before it enters the stormwater system. These management options are generally referred to as water sensitive urban design (WSUD) and consist of one or more devices in a treatment train. Two different types of water sensitive urban design options were considered in the WQIP: investment in large scale WSUD treatment trains such as wetlands, swales and bioretention systems focused on treating urban runoff to remove pollutants as well as reducing runoff; and household scale systems such as rainwater tanks and raingardens which generally act to reduce the volume of urban runoff.

Intrusion of sewage into the stormwater network is known to be an issue in parts of Launceston. City of Launceston has recently undertaken a monitoring program in its stormwater catchments that shows sewage is entering the system in Trevallyn and Distillery creek. Significant issues were also present in Kings Meadows rivulet when monitoring began. Monitoring data in this stormwater catchment has been used along with other observational methods to identify sources of pathogens in this network. There were a number of illegal connections and other issues which were identified and which have now been addressed. Monitoring data shows this intervention has been very successful in reducing pathogen concentrations in Kings Meadows, particularly during dry weather periods when a base load of pathogens has a larger impact on concentrations. The Investment Plan considers the impact of continuing this work in Trevallyn and Distillery creek stormwater catchments. Monitoring data provided by City of Launceston has been used to estimate the benefits of works with similar benefits expected in these two stormwater catchments as were seen in Kings Meadows.

Three rules of thumb were used to develop urban investment options that maximised impacts on water quality in Tamar Estuary Zone 1:

- Large scale Water Sensitive Urban Design (WSUD) options only (not Household scale WSUD) were considered because of their relatively greater impact on pollutant loads per unit area treated and dollar invested.
- Investment in WSUD was prioritised on areas draining directly to Zone 1 of the estuary so as to have the greatest impact. This investment was assumed to be spread proportional to total investment possible across areas in the Upper Tamar foreshore subcatchment. This assumption was made to reflect both the on-ground difficulties likely to be experienced in siting appropriate treatment trains and devices and the larger benefits for Zone 1 water quality expected from investment in urban areas fringing the estuary.
- Given the relatively low cost of addressing sewage intrusion into the separated stormwater system a single option addressing issues in both Trevallyn and Distillery creek has been considered for comparison with investment in Large scale WSUD.

Figure 10 and Figure 11 demonstrate the return on investment as the budget for urban management options increases in terms of two benefits – the total decrease in Greater TEER Catchment loads, and the decrease in pollutant concentration in Tamar Estuary Zone 1. Note that investment in addressing issues with sewage intrusion into the separated stormwater system are shown as a single point for each pollutant on these figures ("SS"). This investment is shown to be significantly more effective than WSUD for addressing both Greater TEER pathogen loads and Tamar Estuary Zone 1 concentrations. In both cases this investment leads to greater decreases than full investment ($75.6 million) in large scale WSUD for an estimated cost of $500,000. However, unlike large scale WSUD, this action has no impact on sediment or nutrient concentrations.

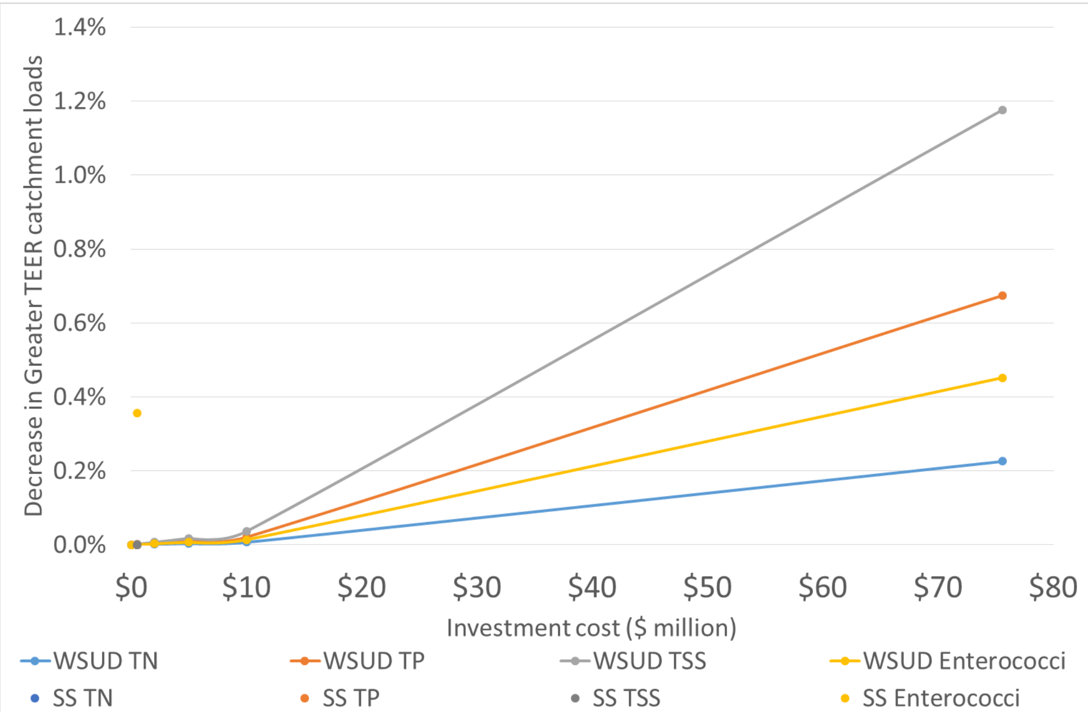

*Figure 10. Decrease in Diffuse pollutant loads from investment in urban management for the **Greater TEER Catchment.** Note WSUD is urban sensitive water design. SS is works to address sewage intrusion to the separated stormwater system in Launceston*

As was the case with grazing, WSUD investments have been targeted for their impact on pollutant concentrations in Tamar Estuary Zone 1. Targeting the highest leverage investments in this way means that the majority of benefits in the estuary are generally achieved with the initial investment of funds (so the relative change in concentration for the $2 million investment is greater for each dollar invested than for the $5 million or $10 million options). Further improvements are harder to achieve and so cost more per unit of estuary water quality improvement achieved.

For all pollutants except total phosphorous (TP), over 20% of the potential Tamar Estuary Zone 1 concentration reduction from feasible investment in large scale WSUD is achieved for $10 million, roughly 13% of the total investment cost. The investments are significantly less effective at achieving total load reduction targets, with only 3% of the potential load reduction achieved for close to 13% of the budget. This is because the most effective options for reducing pollutant concentrations in Tamar Estuary Zone 1 have been targeted rather than the options with the greatest impact on Greater TEER catchment loads.

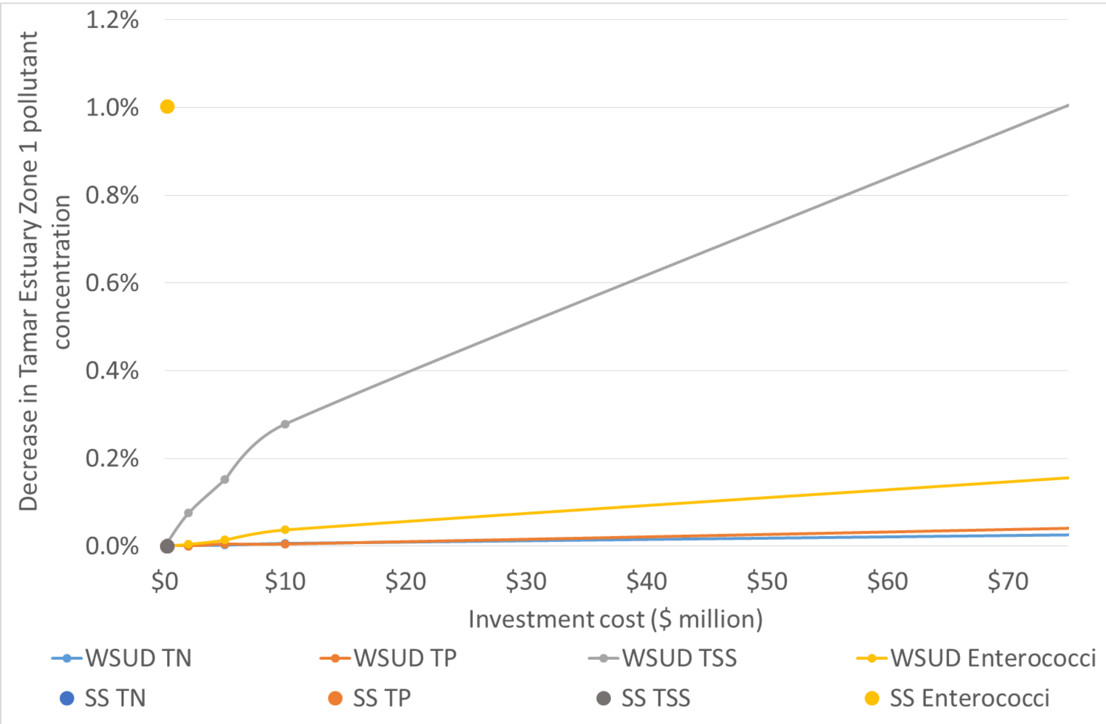

*FIGURE 11. DECREASE IN POLLUTANT CONCENTRATIONS IN **TAMAR ESTUARY ZONE 1** FROM INVESTMENT IN URBAN MANAGEMENT. NOTE WSUD IS URBAN SENSITIVE WATER DESIGN. SS IS WORKS TO ADDRESS SEWAGE INTRUSION TO THE SEPARATED STORMWATER SYSTEM IN LAUNCESTON*

These results clearly demonstrate that WSUD is most appropriately focused on sediment reduction, with much smaller benefits being seen in terms of nutrient or pathogen concentrations in Tamar Estuary Zone 1. **Water quality benefits for Zone 1 from water sensitive urban design in the areas fringing the upper estuary can be expected to be significantly smaller for Zone 1 water quality, particularly for enterococci, the targeted pollutant, than dairy or grazing management**. Actions to address sewage intrusion to the separated stormwater system in Launceston are very effective at reducing pathogen concentrations in Tamar Estuary Zone 1. These actions provide comparable improvement in Tamar Estuary Zone 1 concentrations as $1 million in grazing management or roughly 2/3 the benefit of a similar investment in improved dairy management, for less than half this cost. **Investment in addressing sewage intrusion into the separated stormwater system is an effective, relatively low cost option to reduce pathogen concentrations in Tamar Estuary Zone 1.**

5 Comparison between management of different land uses

Investment in each of these options has very different outcomes, both in terms of Greater TEER catchment loads and changes in concentration in Tamar Estuary Zone 1. Figure 12 and Figure 13 show the proportion of Greater TEER catchment diffuse load and Tamar Estuary Zone 1 concentration reductions relative to that achieved with fully funded actions for all land uses respectively. The relative cost as a proportion of the cost of fully funding these actions is also included in these figures.

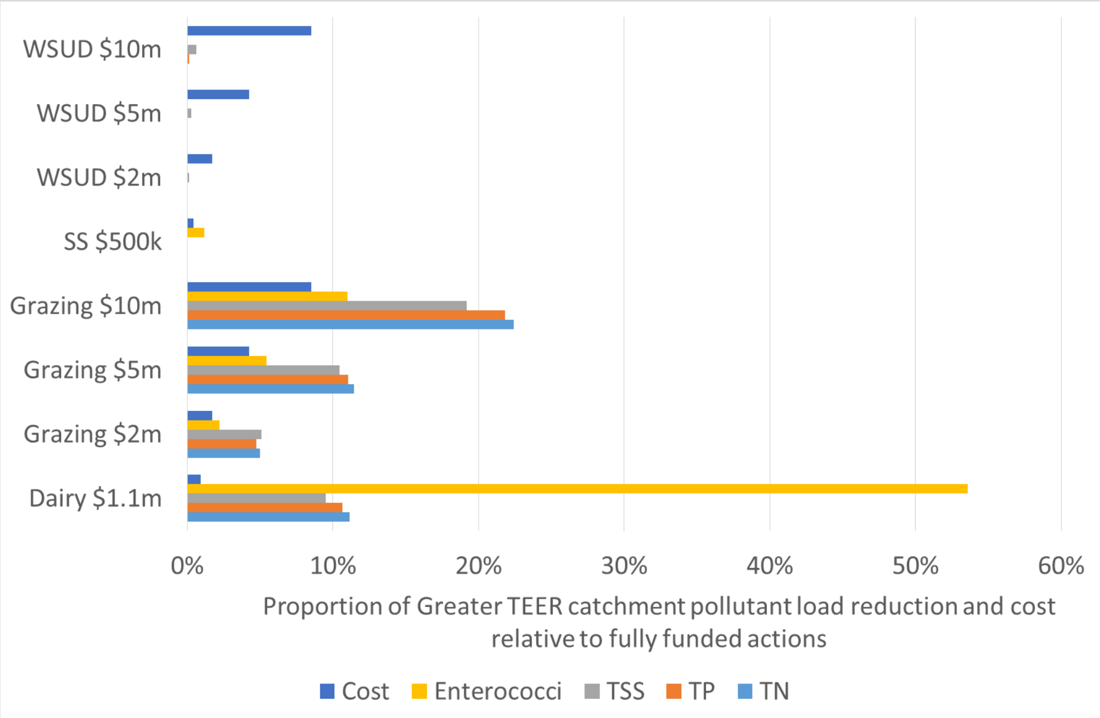

*FIGURE 12. PROPORTION OF **GREATER TEER CATCHMENT** DIFFUSE LOAD REDUCTIONS AND COSTS RELATIVE TO FULLY FUNDED ACTIONS MET WITH INVESTMENT OPTIONS*

This figure shows that investing in dairy has the greatest benefit in terms of load reductions at a significantly smaller cost ($1.1 million) compared to any grazing or WSUD option. Dairy management is also most cost effective for reducing nutrient and pathogen loads, achieving nearly 16% of the potential pathogen load decrease from fully funded actions. Investment in grazing is more effective at reducing loads for all pollutants at all budgets than investment in WSUD. The proportion of Greater TEER catchment load reductions from WSUD investment options is less than 0.6% of the fully funded decrease for all pollutants for all budget options. Actions to reduce sewage intrusion to the separated stormwater system achieve over 1% of the potential decrease in pathogen loads with fully funded actions at 0.4% of the cost. This action has no impact on sediment or nutrient loads.

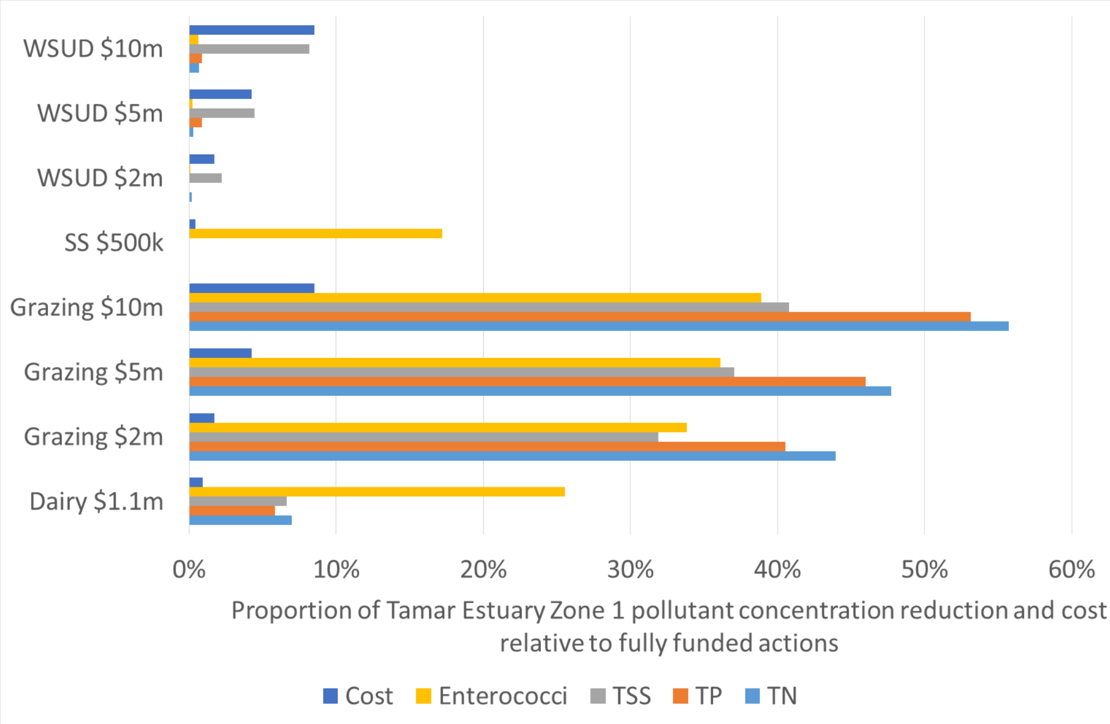

*FIGURE 13. PROPORTION OF **TAMAR ESTUARY ZONE 1** CONCENTRATION REDUCTIONS AND COSTS RELATIVE TO FULLY FUNDED ACTIONS MET WITH INVESTMENT OPTIONS*

Figure 13 shows that relative benefits from investment in grazing are greater for Tamar Estuary Zone 1 concentrations than they were for the Greater TEER catchment loads. This is because activities have been focused in areas with the greatest impact on concentrations in Tamar Estuary Zone 1 rather than the greatest impact on Greater TEER catchment loads. Dairy management is still an important option for improving Tamar Estuary Zone 1 water quality, particularly enterococci, but the differences between dairy and grazing are less stark than was the case for Greater TEER catchment loads. The figure shows that the greatest impacts on all pollutant concentrations in Tamar Estuary Zone 1 come from management of grazing areas, however these come at a greater cost than either dairy actions or those in the separated stormwater system. Impacts on Tamar Estuary Zone 1 concentrations from dairy management are significantly greater for enterococci than for nutrients or sediments, with roughly 25% of the potential pathogen concentration reduction achieved for less than 1% of the cost. This emphasises the importance of identifying the goal of investment (eg. load versus concentration, specific pollutants versus a balance of water quality outcomes) in prioritising investments. Actions to reduce sewage entering the separated stormwater systems are very effective at reducing pathogen concentrations in Tamar Estuary Zone 1, with 17% of the potential concentration reduction achieved for 0.4% of the cost.

Tables 2 and 3 provide a comparison of the unit costs of achieving load and concentration improvements respectively. Costs are shown per unit load (nutrients=kg, sediments=tonnes, pathogens=billions of cfu). Relative unit costs for concentration improvements in Tamar Estuary Zone 1 are provided per 1% decrease in the concentration of the pollutant in Zone 1.

*TABLE 2. RELATIVE COST OF EACH UNIT OF LOAD REDUCTION FOR THE **GREATER TEER CATCHMENT** FOR LAND USE BASED INVESTMENT OPTIONS*

Investment Option	TN ($/kg)	TP ($/kg)	TSS ($/tonne)	Enterococci ($/billion cfu)
Dairy $1.1m	$40	$2,400	$1,950	$1
Grazing $2m	$150	$9,900	$6,580	$36
Grazing $5m	$170	$10,600	$8,040	$37
Grazing $10m	$170	$10,700	$8,780	$37
SS $500k	NA	NA	NA	$17
WSUD $2m	$74,100	$181,800	$285,700	$8,725
WSUD $5m	$74,600	$192,300	$277,800	$8,723
WSUD $10m	$74,600	$192,300	$270,300	$8,723

This table shows the cost effectiveness of improved dairy management for reducing Greater TEER catchment loads, with the cost per unit load reduction for all pollutants significantly cheaper from dairy management. In general there is an increasing cost per unit load as investment in grazing increases, reflecting the benefits of investing in 'low hanging fruit' first. Investments in reducing sewage intrusion to the separated stormwater system are more effective for pathogen load decreases than grazing or WSUD options but have no benefit for nutrient or sediments. Relative cost changes for increasing investment in WSUD vary more between pollutants than other actions, with nutrient costs increasing with increased investment and sediment and pathogen costs decreasing or remaining constant depending on the investment amount. Both grazing and dairy management are substantially cheaper ways of achieving load reductions than WSUD for all pollutants.

*TABLE 3. RELATIVE COST OF EACH 1% OF CONCENTRATION REDUCTION IN **TAMAR ESTUARY ZONE 1** FOR LAND USE BASED INVESTMENT OPTIONS*

Investment Option	TN	TP	TSS	Enterococci
Dairy $1.1m	$1,700	$3,300	$480	$70
Grazing $2m	$500	$900	$180	$100
Grazing $5m	$1,100	$1,900	$390	$240
Grazing $10m	$2,000	$3,300	$720	$440
SS $500k	NA	NA	NA	$50
WSUD $2m	$132,600	NA	$2,600	NA
WSUD $5m	$204,300	$100,700	$3,300	$36,200
WSUD $10m	$160,400	$201,500	$3,600	$26,900

Investment in reducing sewage intrusion into the separated stormwater system is the most cost effective action for reducing pathogen concentrations in Tamar Estuary Zone 1 but has no benefit for sediment or nutrient concentrations. Differences between the cost effectiveness of grazing and dairy for improving pollutant concentrations in Tamar Estuary Zone 1 are less obvious. Lower levels of investment in grazing management are more cost effective than dairy investment at reducing nutrient and sediment concentrations in Tamar Estuary Zone 1. Reductions in pathogen concentrations are more cost effectively addressed with dairy management than grazing management. Increasing the investment in grazing management increases the average unit cost substantially. At $10 million invested in grazing, dairy management is more cost effective per unit concentration than grazing for all pollutants except TP where the cost is the same. Urban management is in all cases significantly less cost effective than investment in either grazing or dairy management or in fixing issues with sewage intrusion to the separated stormwater system.

6 Considerations for feasibility of investment

The actions evaluated in this Technical Report have been taken from the recommendations in the TEER WQIP. While all the options and levels of adoption in the WQIP were based on feedback from key stakeholders about what is 'feasible' some options are more easily implemented:

- The dairy industry is well organised and has a track record of oversubscription to funding rounds. Improving effluent storage and handling and excluding stock from streams are highly adoptable actions. Fencing off streams and provision of quality off-stream water supplies also has production benefits for dairy farmers, through improved cow health, reduced incidence of mastitis, reduced milk cell counts and higher quality and production of milk. It is expected that there would be very good uptake of funding opportunities and significant changes in management on the ground as a result of funding.
- The grazing industry is less well organised and will be harder than dairy to engage in large scale investment programs. Regardless there are industry leaders and Landcare groups that could help facilitate extension of funding to these landholders. The dairy industry is currently developing partnerships with other livestock industries to encourage improved management practice. This is another vehicle through which implementation may be enabled. The proposed action for grazing in this Investment Plan focuses on narrow 5m buffers which are considered to be significantly more adoptable than wider buffers due to reduced issues with weeds and pests. Provision of off-stream water can also be expected to improve uptake. In addition there has been a recent update to Australia's market assurance scheme for red meat integrity. The **Livestock Production Assurance** (LPA) program is very influential in commercial red meat production which covers beef, dairy and sheep animals being sold for meat. Since 1 October 2017 there have been some significant updates to the scheme, particularly focused on animal welfare and biosecurity[3]. Support of on-farm activities such as fencing off waterways and providing clean drinking water for stock, as well as revegetating riparian buffers will help livestock producers meet LPA requirements with regards to drinking water, biosecurity and shade/shelter for livestock. This means that, as is the case for dairy farmers, there is a strong market driver for beef and sheep producers to undertake these activities.
- Retrofitting water sensitive urban design to existing urban areas is more difficult than the proposed actions in either dairy or grazing. Councils are often reluctant to engage with WSUD due to a lack of in-house expertise in design and maintenance of these systems. Many Councils express concerns about the long term maintenance costs of these systems. In addition there are often significant physical constraints that must be taken into account in designing and locating systems, particularly around Launceston and Riverside where high slopes and a lack of available land are issues. Given these difficulties and the relatively low cost effectiveness of this action it was decided that large scale WSUD should not be included in this Investment Plan.
- Actions to address sewage intrusion into the separated stormwater system in Launceston are very cost effective for addressing pathogen concentrations in Tamar Estuary Zone 1.

[3] https://www.mla.com.au/meat-safety-and-traceability/red-meat-integrity-system/lpa-changes/

They are also relatively straightforward to implement with City of Launceston having in-house expertise capable of carrying out such a project.

7 Balanced investment approach

Based on this analysis a set of balanced investment options has been developed, using a mix of investment in the different land uses with different levels of investment. These options include a mix of dairy management, grazing management and investments in reducing sewage intrusion into the separated stormwater system.

Table 4 shows the budget for planned investment for activities by land use.

Table 4. Investment in Land uses by major subcatchments under balanced options

Land use	$2 million	$5 million	$10 million
Dairy			
Brumbys-Lake, Macquarie, Meander & Tamar	$550,000	$825,000	$1,100,000
Grazing			
North Esk	$1,250,000	$1,330,000	$1,330,000
Upper Tamar	$0	$1,660,000	$1,660,000
Brumbys-Lake, Meander & South Esk	$0	$685,000	$5,410,000
Urban			
Launceston separated stormwater	$200,000	$500,000	$500,000

Figure 14 and Figure 15 show the decrease in Greater TEER catchment pollutant loads and Tamar Estuary Zone 1 pollutant concentrations respectively for this balanced investment option versus the cost of investment.

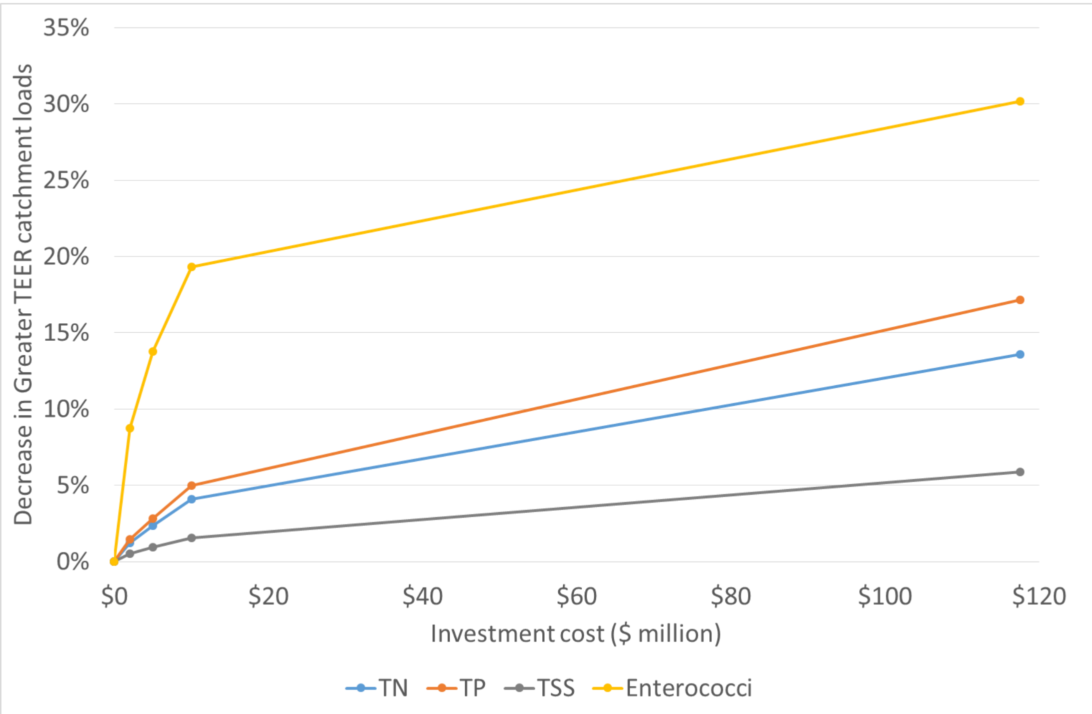

*Figure 14. Decrease in pollutant loads in **Greater TEER catchment** from balanced investment option*

This figure shows that the balanced investment options are very cost effective for reducing all pollutant loads, but particularly effective for reducing enterococci loads. The $2 million investment option can be expected to achieve roughly 9% decrease in enterococci loads for the Greater TEER catchment, equivalent to 25% of the potential decrease in enterococci from fully funding these actions for 1.7% of the budget. Relative benefits for other pollutants are smaller but are still represent a greater benefit than relative cost, with roughly 9% of the potential benefit achieved for only 1.7% of the fully funded budget. While the marginal benefit of further investment decreases with subsequent investment, investment of $10 million is still shown to be very cost effective with 25% to 30% of the potential decrease in nutrients and sediment and over 60% of the potential decrease in enterococci loads achieved for only 8.5% of the total cost of fully funding these options. This represents a very good return on investment. It should be noted that benefits in terms of reduced sediment loads are likely to be significantly underestimated as the benefits for increased streambank stability and reduced streambank erosion through exclusion of stock and riparian revegetation are not included in the modelling. Using very conservative estimates of the benefits of these actions for streambank erosion the reduction in tonnes of sediment is likely to be at least three times what is estimated using the CAPER DSS model[4].

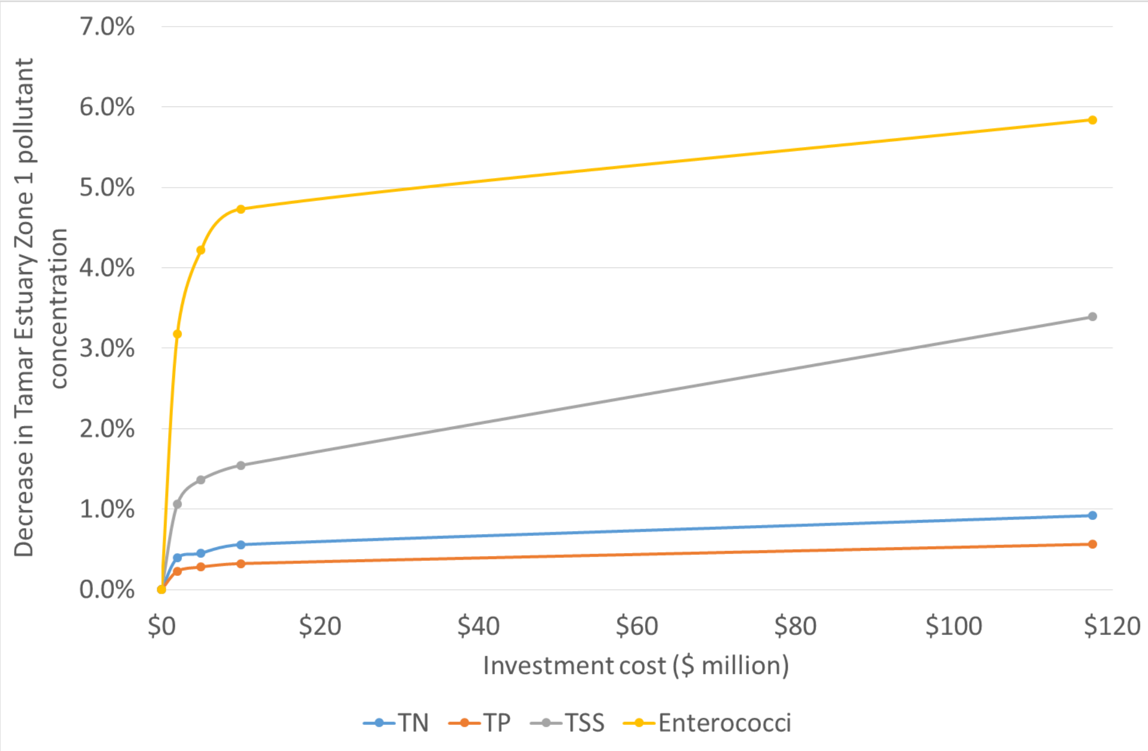

*Figure 15. Decrease in pollutant concentrations in **Tamar Estuary Zone 1** from balanced investment option*

Figure 15 shows the decrease in Tamar Estuary Zone 1 concentrations from investment in the balanced option. This figure demonstrates the cost effectiveness of this option for all budget

[4] For example – for a $10 million investment in the balanced option, the CAPER DSS estimates a decrease of 1560 tonnes of sediment as a result of the management actions. This action includes roughly 390km of streams with stock excluded, including 50km on dairy properties with a single wire fence and 340km on grazing properties with both stock exclusion and a 5m vegetated riparian buffer. If this reduces streambank erosion by 1cm per year, assuming a uniform streambank height of 1m then 6650 tonnes of sediment export through streambank erosion is avoided. This is over 4 times more than the reduction in sediment load estimated by the CAPER DSS. Similar calculations for the $2 million and $5 million investment find reduced sediment exports through avoided streambank erosion of 2.5 and 3.4 times respectively.

options. It also shows the decreasing marginal return to scale of investment with 30% to 55% of the potential decrease in concentration for all pollutants achieved with the first 1.7% of investment ($2 million option). Even with decreasing returns to scale of investment the $10 million investment still represents a very cost effective option for reducing Tamar Estuary Zone 1 concentrations with over 45% of potential sediment reduction, roughly 60% of potential nutrient reduction and over 80% of enterococci reductions achieved with only 8.5% of the fully funded investment cost. As was the case with loads, decreases in sediment concentrations are likely to be significantly underestimated by the modelling.

8 Additional benefits of the investment

This Investment Plan develops an investment proposal to reduce Tamar Estuary Zone 1 pathogen concentrations. While actions have been selected to maximise their contribution towards this goal, these actions can also be expected to have significant additional benefits throughout the freshwater system as well as further down the estuary, as illustrated in Figure 16. This section briefly describes some of these benefits. These include:

- Immediately after actions are undertaken:
    - Reduced stock trampling of the river and consequent turbidity and stream health impacts
    - Reduced pathogens in the rivers and estuary from direct manure inputs to streams and effluent runoff from dairy farms.
    - Pathogens are very rapidly reduced by fixing intrusion of sewage into the separated stormwater system.
- Medium term
    - Riparian vegetation grows providing streambank stability and reduced streambank erosion.
    - Riparian vegetation increases river shading and reduces stream temperatures, improving instream habitat and stream health.
    - Riparian vegetation provides corridors for the movement of flora and fauna increasing the connectivity of populations and their resilience to change.
    - Further improvements in water quality are experienced as riparian vegetation provides a filter for runoff from grazing properties and improved effluent management reduces overloading of nutrient in soils and reduces losses through runoff and infiltration.
- Long term
    - The landscape becomes more resilient to change. Fencing and off-stream water ensures increasing numbers of stock (through intensification and/or conversion of grazing into dairy) are unable to access the stream. Riparian buffers filter increased pollutant exports off paddocks caused by intensification of land use.
    - Flora and fauna corridors provided by riparian vegetation allow for species retreat under climate change and variability, increasing the resilience of flora and fauna populations to these changes.

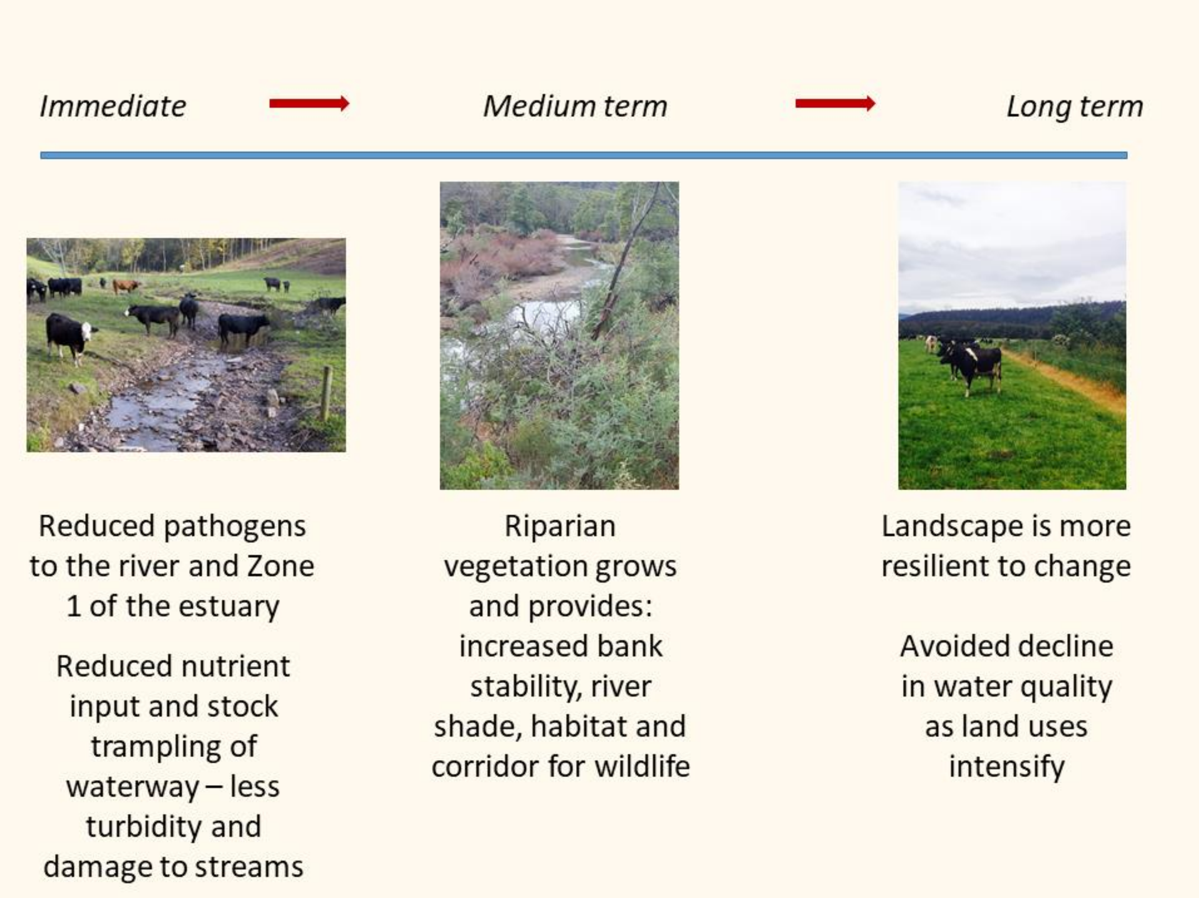

FIGURE 16. TIMEFRAME AFTER WORKS UNDERTAKEN FOR ENVIRONMENTAL BENEFITS TO BE REALISED

Many of these benefits are difficult to quantify. Two types of benefits are able to be assessed with the CAPER DSS model:

- Localised water quality benefits in the freshwater system
- Long term resilience of water quality to intensification and/or conversion of grazing to dairy provided by the investments.

This section provides an estimate of some of these additional benefits from the balanced investment options presented in this paper.

8.1 Localised Water Quality Benefits

While the actions described in this Investment Plan have been targeted towards decreasing pathogen concentrations in Tamar Estuary Zone 1, they can also be expected to have significant water quality benefits within the freshwater system. This section describes the benefits of the balanced investment options in terms of pollutant loads for three local freshwater assets:

- The North Esk river
- The Meander river
- Trevallyn Dam

1.1.1 North Esk River

Figure 17 shows the North Esk River, its catchment and the location of the 3 STPs – Hoblers Bridge, Norwood and Western Junction – contained in the catchment. The North Esk River catchment is dominated by grazing but also includes urban areas in its lower sections.

Figure 17. North Esk river catchment and STPs

Figure 18 shows the relative contribution of STPs and diffuse catchment sources to pollutant loads coming out of the North Esk River catchment. This figure shows that the STPs are a significant source of nutrients, accounting for roughly 20% of TN and 40% of TP. Diffuse catchment loads are the primary source of all pollutant loads and account for almost all the pathogen and sediment loads from the catchment.

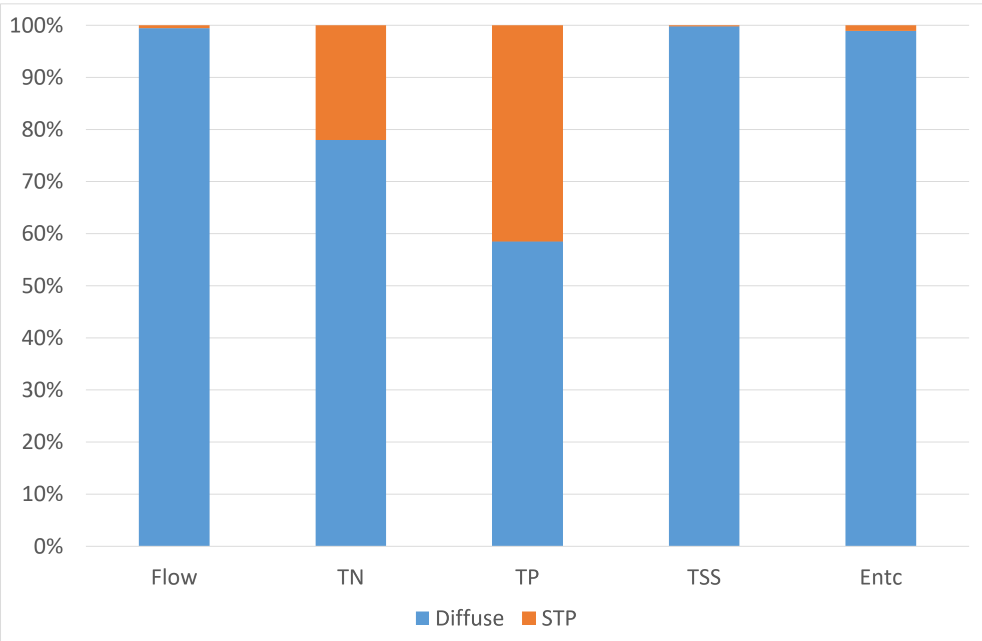

Figure 18. Contribution of point and diffuse sources to pollutant loads from the North Esk river catchment

Figure 19 shows the impact of the balanced investment options developed in this Investment Plan on diffuse loads from the North Esk River catchment. The North Esk was determined to be the highest priority catchment for grazing actions given the greater benefit of actions in this catchment on pollutant concentrations in Tamar Estuary Zone 1. Given this, all investment in the North Esk grazing is undertaken for both the $5 and $10 million options.

The $2 million balanced investment can be expected to decrease enterococci loads in the North Esk by nearly 8%. A further investment up to $5 million or $10 million in the balanced option leads to decreases of nearly 12% of enterococci loads. Decreases in nutrient loads are smaller but still substantial, at between 5% and 6% for all budgets. Decreases in sediment loads are estimated at approximately 2%. As discussed previously this is likely to be a significant underestimate as the modelling does not account for stream bank erosion. Increased riparian vegetation and reduced stock access to streams can both be expected to have significant benefits for improved bank stability and lead to large decreases in stream bank erosion. Using the same method as was applied in Section 7, avoided sediment exports from streambank erosion on stream sections with stock excluded and riparian vegetation added is 860 tonnes, compared with TSS reductions of 217 tonnes estimated by the model. This means that the sediment reduction is likely to be at least 5 times greater than estimated.

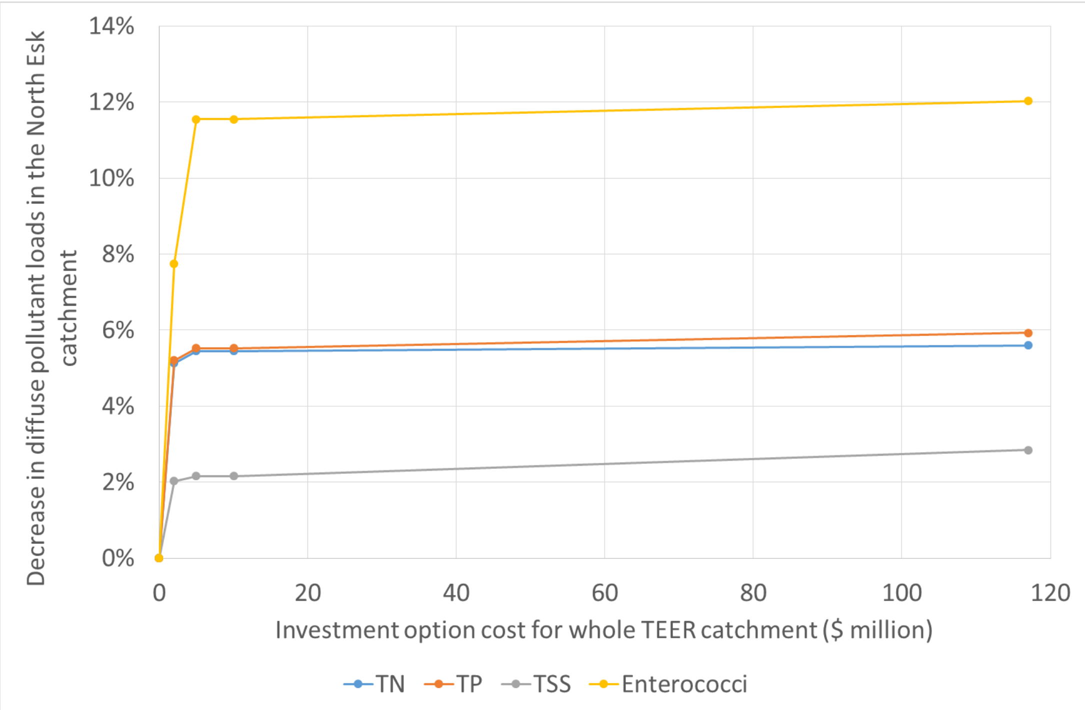

FIGURE 19. IMPACT OF BALANCED INVESTMENT OPTIONS ON DIFFUSE CATCHMENT LOADS FROM THE NORTH ESK RIVER CATCHMENT

1.1.2 Meander River

Figure 20 shows the Meander River, its catchment and the location of the 3 STPs – Deloraine, Westbury and Carrick – contained in the catchment.

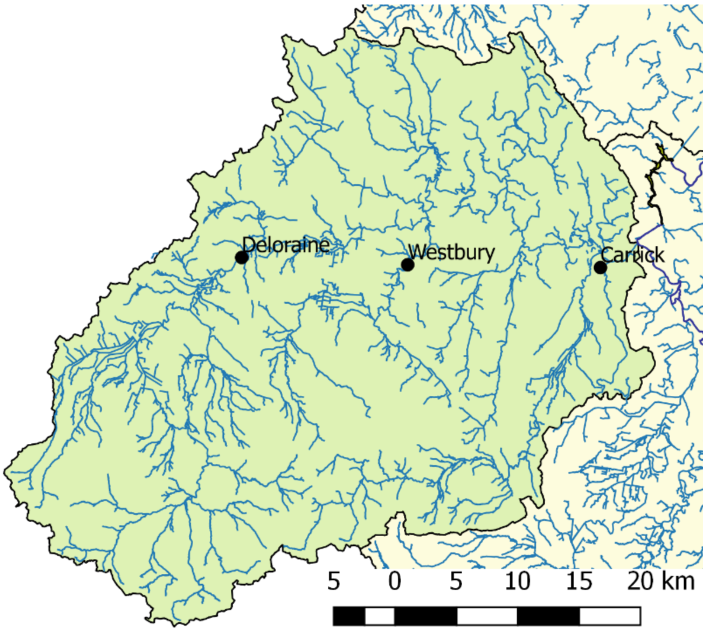

Figure 20. Meander river catchment and STPs

Figure 21 shows the relative contribution of STPs and diffuse catchment sources to pollutant loads coming out of the Meander River catchment. This figure shows that the STPs make a larger contribution to nutrients than other pollutants but even then, more than 95% of nutrients come from diffuse sources. Almost no sediment or pathogens are contributed by STPs relative to diffuse catchment loads.

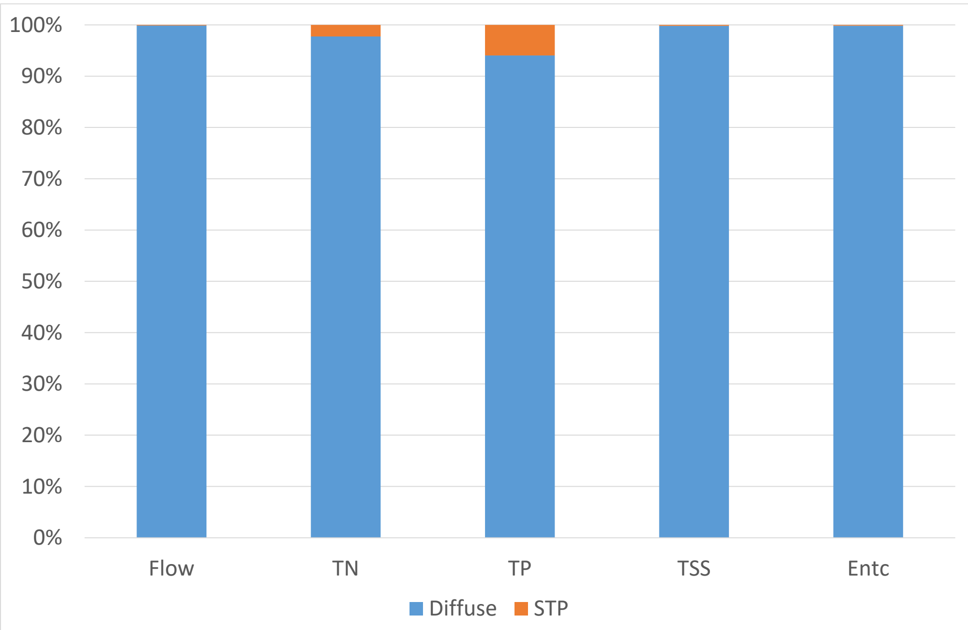

Figure 21. Contribution of point and diffuse sources to pollutant loads from the Meander river catchment

Figure 22 shows the impact of the balanced investment options developed in this Investment Plan on diffuse loads from the Meander River catchment. The Meander River catchment is the location for many of the dairy management actions as well as a significant proportion of grazing management actions for higher budget investment options. This figure shows the increased impact of further investment on the Meander as greater investments allows for more actions in both dairy and grazing management in the Meander River catchment. This figure shows the very large decrease in pathogen loads that can be expected from the Meander River from all investment options (roughly 19% to 40% decreases depending on the scale of the investment). Decreases in diffuse nutrient loads vary from 3% to 8% for TN and 4% to 12% for TP. Decreases in sediments appear smaller at only 1% to 4% depending on investment option. As was the case with the North Esk, sediment load reductions are likely to be significantly underestimated given that streambank erosion impacts are not modelled.

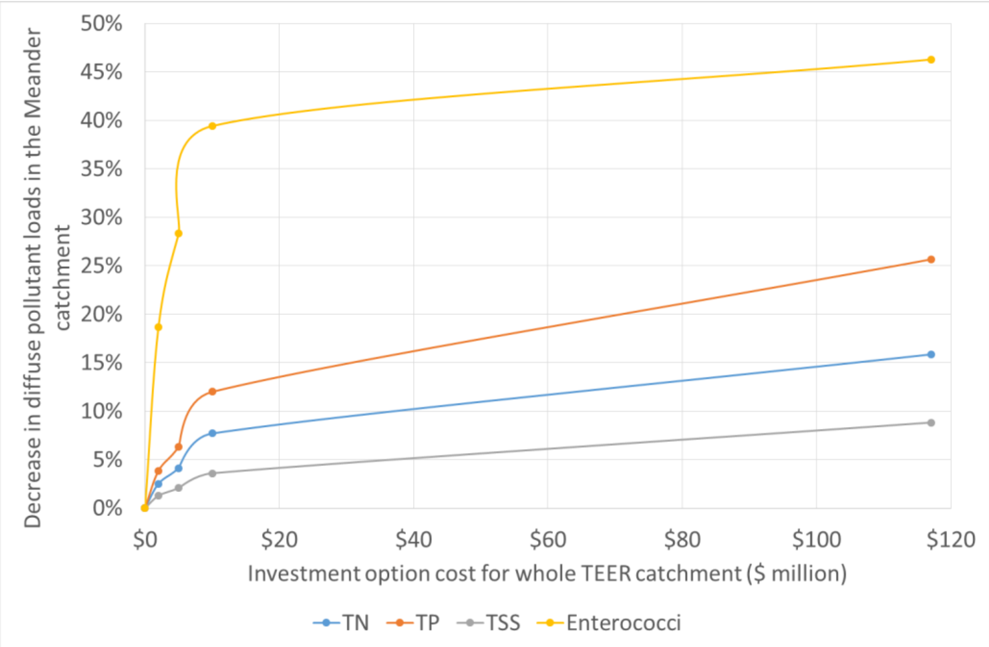

FIGURE 22. IMPACT OF BALANCED INVESTMENT OPTIONS ON DIFFUSE CATCHMENT LOADS FROM THE MEANDER RIVER CATCHMENT

1.1.3 Trevallyn Dam

Figure 23 shows the Trevallyn Dam catchment, consisting of the Meander, Brumbys-Lake, South Esk and Macquarie river subcatchments. The locations of the 14 STPs (Deloraine, Westbury, Carrick, Cressy, Longford, Perth, Evandale, Nile, Conara, Campbelltown, Fingal, St Marys, Ross and Kalangadoo) feeding into the river above Trevallyn Dam are shown.

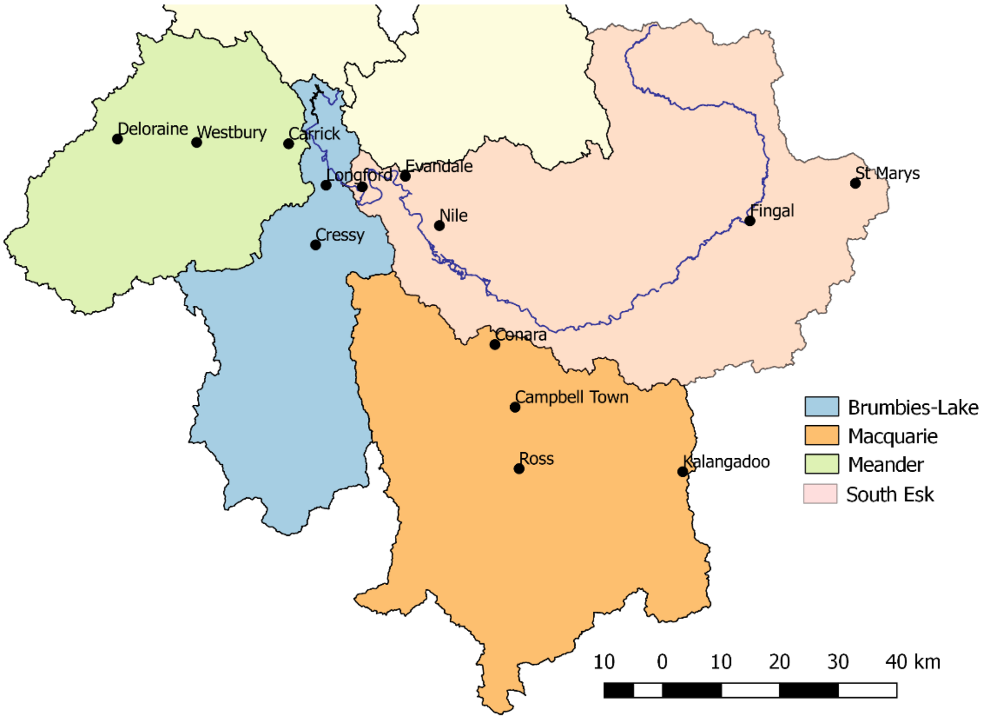

FIGURE 23. TREVALLYN DAM CATCHMENT AND STPS

Figure 24 shows the relative contribution of STPs and diffuse catchment sources to pollutant loads exported to Trevallyn Dam. This figure shows that the STPs contribute 6% of TP and 3% of TN loads to Trevallyn Dam with the bulk of nutrients coming from diffuse sources. They make almost no sediment or pathogen contribution relative to diffuse catchment loads.

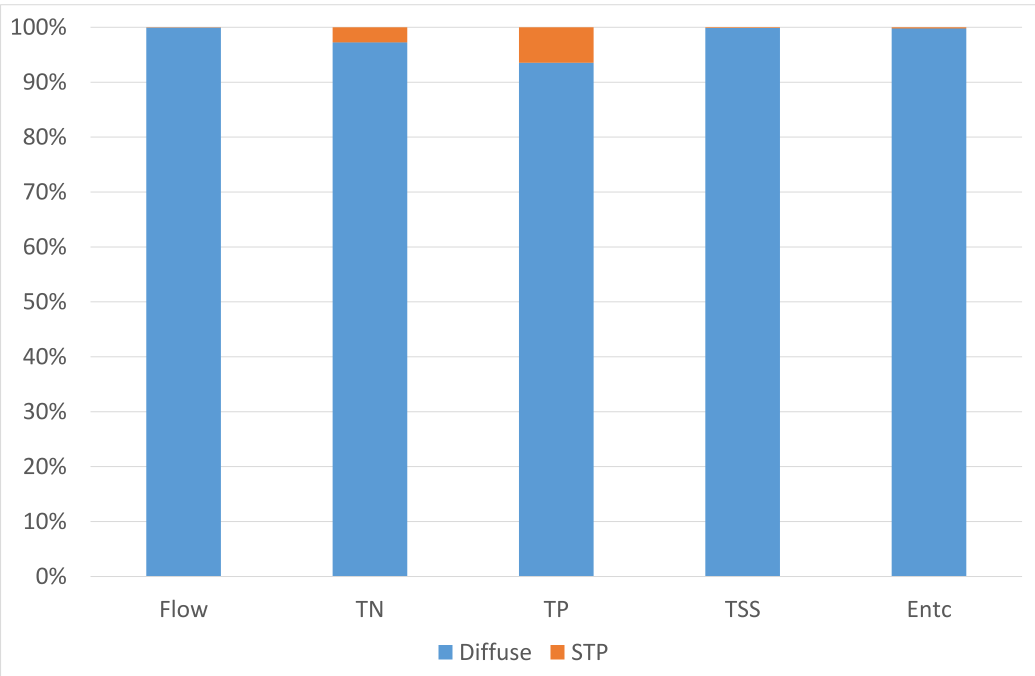

FIGURE 24. CONTRIBUTION OF POINT AND DIFFUSE SOURCES TO POLLUTANT LOADS TO TREVALLYN DAM

Figure 25 shows the impact of the balanced investment options developed in this Investment Plan on diffuse loads to Trevallyn Dam. Both grazing and dairy management actions are included in all investment options in catchments contributing to the Dam. This figure shows the very large decrease in pathogen loads that can be expected to Trevallyn Dam from all investment options (roughly 12% to 26% decreases depending on the scale of the investment). Decreases in diffuse nutrient loads vary from 1 to 5%. Decreases in sediments appear smaller at only 0.3% to 1.4% depending on the investment option. As was the case with the North Esk and Meander river catchments, sediment load reductions are likely to be significantly underestimated given that streambank erosion impacts are not modelled.

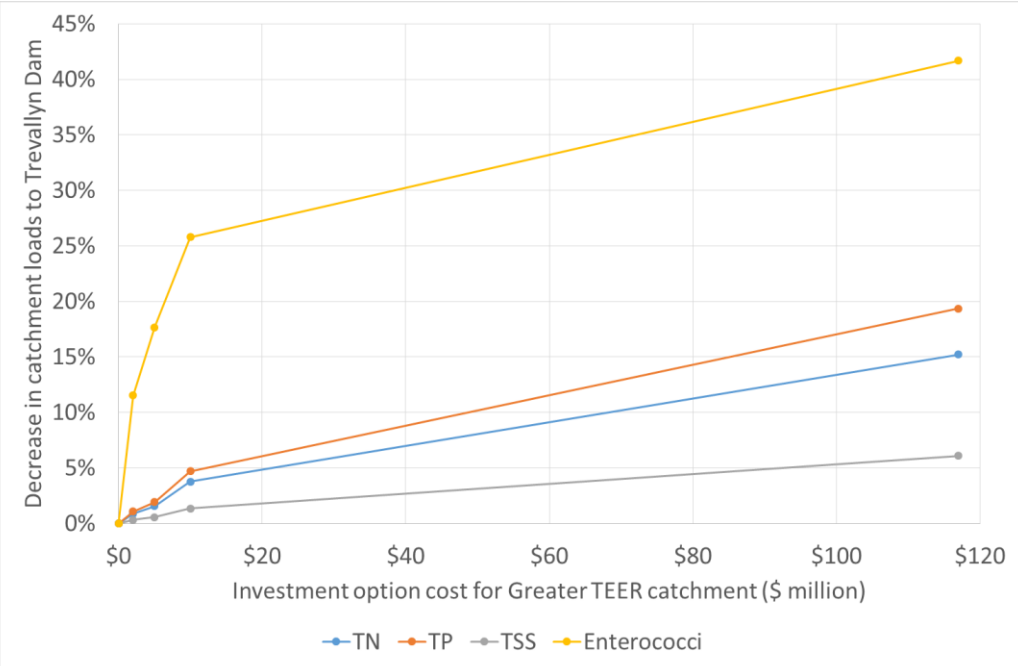

FIGURE 25. IMPACT OF BALANCED INVESTMENT OPTIONS ON DIFFUSE CATCHMENT LOADS TO TREVALLYN DAM

8.2 Long term resilience of water quality to intensification and/or conversion of grazing to dairy

The Water Quality Improvement Plan for the TEER catchment explored the potential impacts of planned expansion of the dairy industry both with and without best management practice adoption. This case study showed the benefits of sustainable development and the potential for expansion to occur with minimal impact so long as high levels of best management practice adoption occur. The scenario used in the WQIP was provided by Dairy Tasmania. In this scenario 38,000 additional dairy cows are incorporated into the catchment through either broad scale or intensive development using conversion of either grazing or cropping areas. Dairy Tasmania provided estimates of both areas and increased stock numbers for subcatchments of the TEER catchment under the scenarios.

Investments in fencing and off-stream water on dairy farms provide water quality benefits through reduced manure deposition in the stream as well as reduced trampling of stream banks and instream habitats. If expansion occurs through increased stocking rates on existing dairy farms, this fencing will effectively be excluding a larger number of stock and so avoiding further declines in water quality from increasing numbers of dairy cows accessing the stream. Riparian vegetation and stock exclusion on grazing properties also has the potential to provide a buffer to expansion of the dairy industry where these properties are converted to dairy in the future. Stocking rates on dairy milking platforms are generally higher than on beef and sheep grazing properties so over time fences are excluding a larger number of stock and reducing direct deposits of manure to the stream. In addition riparian buffers have the potential to filter higher pollutant exports off paddocks from more intensive agricultural practices so long as runoff is allowed to pass as sheet flow through these buffers rather than being channelized into drains that bypass the riparian zone. In this way these investments in both dairy and grazing can be expected to provide a buffer against potential declining water quality from intensification in the future. This section uses one of the dairy expansion scenarios analysed in the WQIP to illustrate this benefit: intense expansion with conversion of grazing to dairy.

Figure 26 shows the estimated trajectory of future catchment loads with and without these investments for all pollutants.

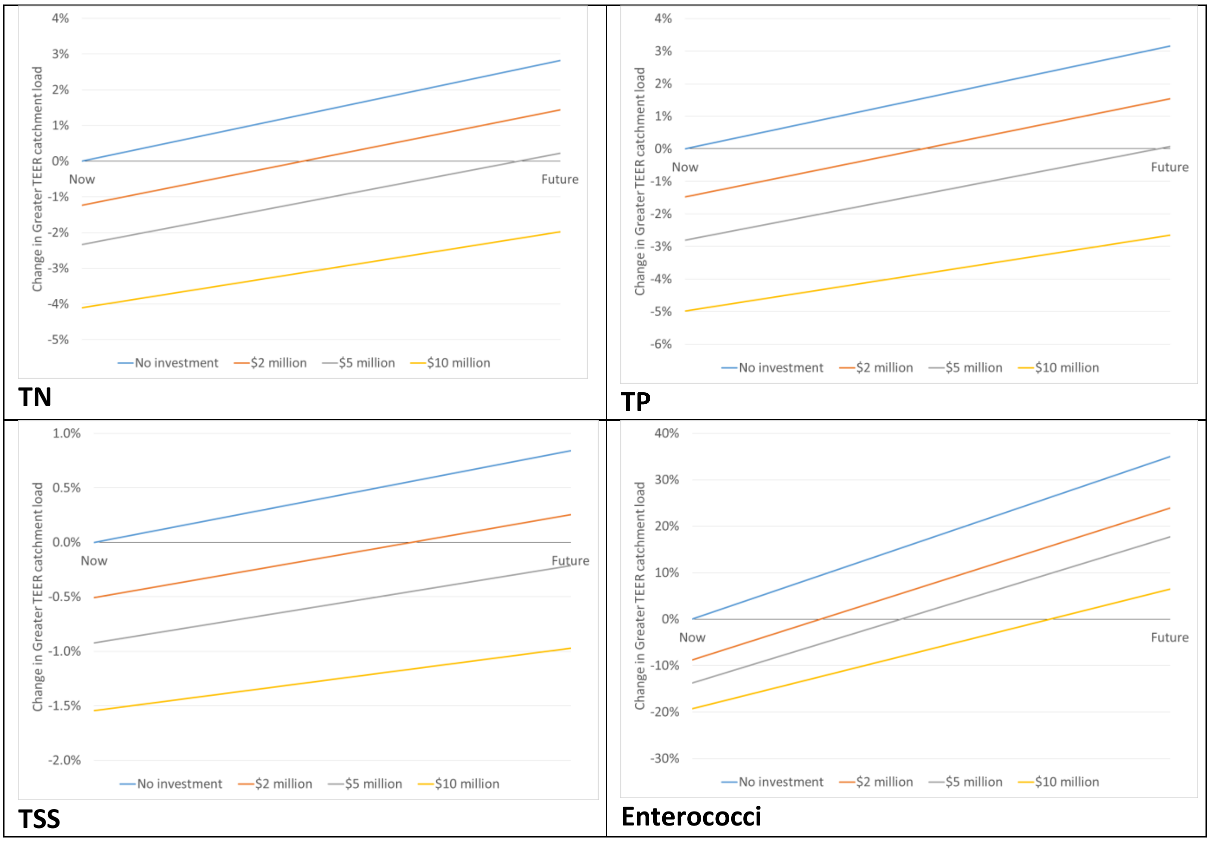

FIGURE 26. TRAJECTORY OF FUTURE GREATER TEER CATCHMENT LOADS WITH AND WITHOUT BALANCED INVESTMENT UNDER DAIRY EXPANSION THROUGH INTENSE CONVERSION OF GRAZING TO DAIRY

This figure demonstrates clearly the role these investments play in avoided future decline in water quality. Without any investment this level of expansion can be expected to lead to 1% increases in Greater TEER catchment TSS loads, 3% increase in nutrient loads and 35% increase in enterococci loads. An investment in the $5 million balanced option leads to effectively no net increase in nutrients and a net decrease in sediments. Enterococci can still be expected to increase but the increase is half that experienced without investment, and can potentially be offset with other improved management practice on existing and new dairy farms. The $10 million investment provides improvements in nutrient and sediment loads with increases in enterococci loads reduced from 35% to 6%.

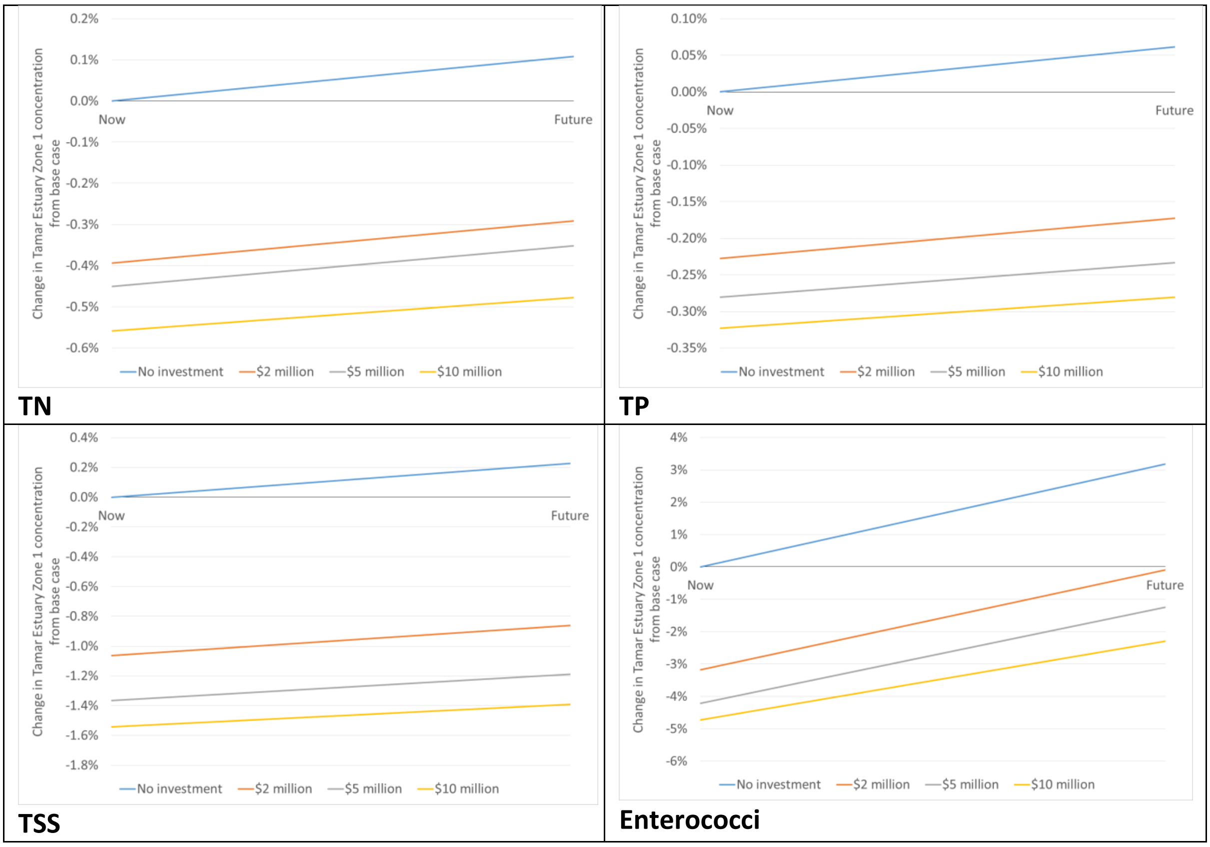

Figure 27. Trajectory of future Tamar Estuary Zone 1 concentrations with and without balanced investment under dairy expansion through intense conversion of grazing to dairy

Figure 27 shows the trajectory of Tamar Estuary Zone 1 concentrations with and without the proposed balanced investments. This figure shows that for Zone 1 of the estuary any of these levels of investment have the potential to avoid declining water quality in terms of all these pollutants. Even the $2 million investment is shown to allow expansion to occur with no net increase in Tamar Estuary Zone 1 enterococci concentrations. Higher levels of investment provide improvements in enterococci concentrations even with significant expansion and intensification of dairy. Results for nutrients and sediments show all levels of investment lead to improvements in water quality with greater levels of investment providing greater water quality improvements.

These results demonstrate clearly that the investments proposed in this Investment Plan have the capacity to not only provide improved water quality and stream health now, but also to protect against potential future decline in water quality as a result of agricultural intensification.

9 Implementation

The balanced options presented in this Technical Report provide an investment pathway to reduce the impact of catchment activities on pathogen and other pollutant concentrations in Tamar Estuary Zone 1. The actions in this Investment Plan will need to be implemented in partnership with a number of key organisations. It is expected that grazing and dairy action programs would be implemented by NRM North in partnership with Dairy Tasmania and the Tasmanian Farmers and Graziers Association. Past experience in on-ground investments indicates that a planned investment of $1 million per year is appropriate.

It could be expected that finding farmers willing to undertake and co-fund investments may become progressively harder over time as the most able and willing are generally early adopters in any program. However this may be off-set to some extent by the momentum created by the relatively large scale of investment, with local landholders seeing the benefit of actions on neighbouring farms and the creation of new behavioural norms amongst local farming communities. The program will need to be flexible in terms of the approaches used to ensure ongoing adoption over time (for example the use of market based mechanisms or higher incentive rates for more difficult works may need to be considered). The increasing use of quality assurance schemes in agricultural industries can be expected to assist in uptake of these improved management activities over time.

Works to address sewage intrusion into Launceston's stormwater system would be led by City of Launceston Council in partnership with TasWater as required. It is expected that these works would be undertaken over a 2 to 5 year period, depending on the scale of investment.

10 References

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Appendix 1. The TEER CAPER DSS

The CAPER DSS is a decision support system originally designed to support the development of Water Quality Improvement Plans. It has been designed to allow end-users to assess the relative contribution various point and diffuse sources make to catchment loads as well as the potential impact of changes in land use and management. It produces catchment load estimates in terms of average annual or seasonal loads, and in some cases, where downstream impacts on an estuary are important, also models the impact of changes in catchment load exports on estuary water quality.

The first CAPER DSS was developed for the Great Lakes in NSW to support the Great Lakes WQIP which was launched in 2009 (GLC, 2009). Since then the DSS has been applied to develop WQIPs in Darwin Harbour, Botany Bay, Sydney Harbour, the Tamar Estuary and Esk (TEER) catchments, and more recently, using a simplified approach, to several other smaller catchments in Tasmania (see Kelly and White (2015) for more details). It has been constantly modified and adapted for each of the catchments and estuaries that it has been developed for. It is built on an integrated model that pulls together components representing the links between climate, land use, management practice and catchment and estuary water quality. Different components are included in each new catchment case study to allow for the specific pollutant sources and relevant management actions to be considered. The interface has also been continuously modified to meet the changing needs of new applications.

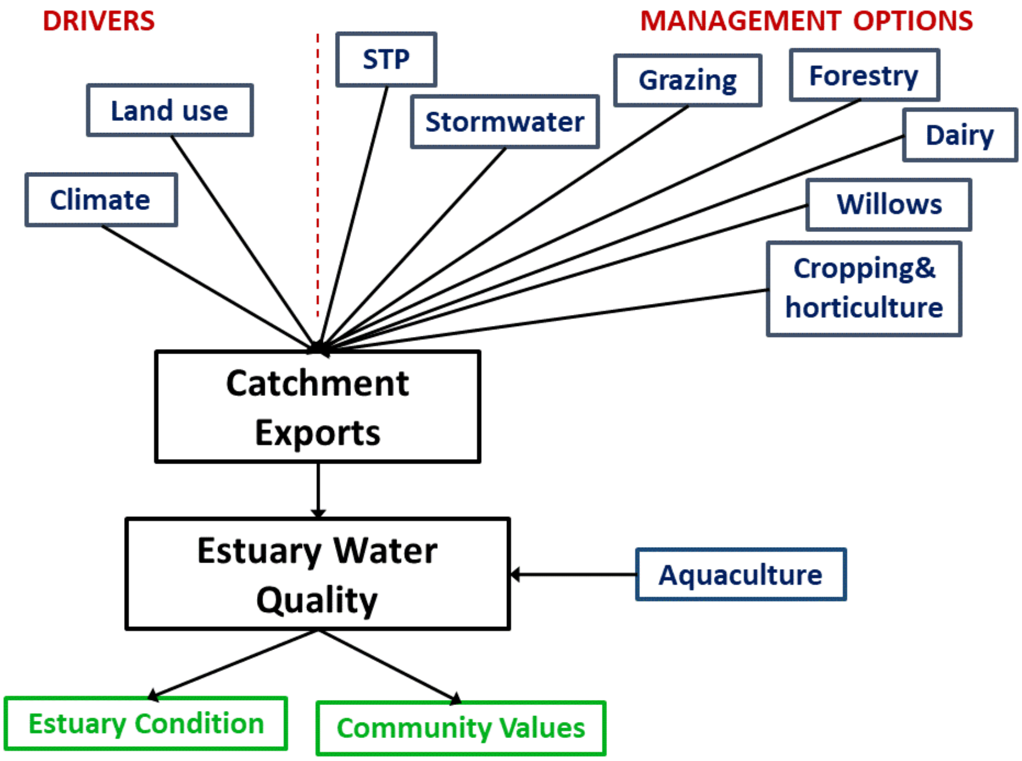

FIGURE 28. INTEGRATED MODEL FRAMEWORK UNDERLYING TEER CAPER DSS

The TEER CAPER DSS was modified from previous versions based on feedback received from stakeholders during the scoping phase of the TEER WQIP development. Unless otherwise noted, all the water quality analysis and results in this Technical Report are based on this model. The integrated model framework for the TEER CAPER DSS is shown in Figure 28. It consists of:

- A metamodel (ie. a simpler empirical model of model outputs), using flow duration curves, derived from a Source Catchments model developed for the TEER catchment (BMT WBM, 2010). This models pollutant loads from subcatchments and local government areas (LGAs) to allow scenarios to be created and analysed on either basis. This model outputs flow, total suspended sediments (TSS), total nitrogen (TN) and total phosphorus (TP) and enterococci.
- A metamodel of the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) model to allow various water sensitive urban design (WSUD) treatment train options to be investigated (McArthur, 2014).
- A metamodel of combined system overflows based on a results from a detailed hydraulic model of Launceston combined sewer-stormwater system provided by staff at City of Launceston Council.
- An empirical model of sewage treatment plant (STP) loads based on data provided by TasWater as well as a metamodel of hydraulic model outputs for the STP at Ti Tree Bend.
- An empirical model of aquaculture operations based on data provided by Van Diemen Aquaculture.
- Models of the impact of management actions in agricultural (cropping, horticulture, grazing and dairy) and production forestry areas on pollutant loads and concentrations using empirical and literature information sources including: riparian vegetation and streamside reserves, restricting stock access to stream, improved fertilizer management, groundcover management, irrigation management, effluent management and the management of drains and laneways in dairy areas.
- A metamodel of a receiving water quality model (McAlister *et al.*, 2009) estimating the impacts of changes in diffuse and point source pollutant loads on estuary water quality. This metamodel uses a tracer approach to produce map based spatial impacts on pollutant concentrations in the estuary.

As with all models the CAPER DSS has limitations and should be applied carefully. It has been developed to be ‘fit for use’ using the best available information. The DSS has been developed to allow the effects of alternative scenarios on total catchment loads to be compared and explored. It is best used to consider the relative magnitude and direction of changes in average annual loads and average estuary concentrations resulting from changes in land use and management. This provides sufficient information to discriminate between management options, allowing them to be ranked in terms of their relative effectiveness in reducing total loads. It also allows the relative contributions of various land uses and point sources to total loads to be estimated. The model is not intended to be predictive of specific loads in any given year or to understand in detail temporal and spatial patterns of pollutant export and flows (eg. daily and subdaily pollutant concentrations and following rainfall events).

Appendix 2. Method for deriving assumptions on riparian vegetation and stock access to streams

This Appendix briefly describes the method which has been used to derive assumptions in the CAPER DSS (updated version 2017) for both the extent of riparian vegetation and stock access to streams. Note that slightly different assumptions are used in the dairy and grazing areas to reflect differences in fencing and stock exclusion practices in these land uses.

A2.1 Data

An analysis of spatial data was conducted using:

- 2015 land use data (the most recent version) provided by DPIPWE
- Woody extent vegetation cover provided by NRM North
- CFEV data on rivers – note that Order 1 streams were removed from the analysis as many of these are small topographic features and drains rather than streams
- Data on the extent of previous NRM projects on dairy farms such as Clean Rivers and roaming cows provided by NRM North
- A layer providing subcatchment and Local Government area boundaries used within the DSS.

Figure 29 shows an example of the data used for the North Esk. Red dots represent bare soil, pale yellow dots are areas without trees but not bare soil and blue dots contain trees.

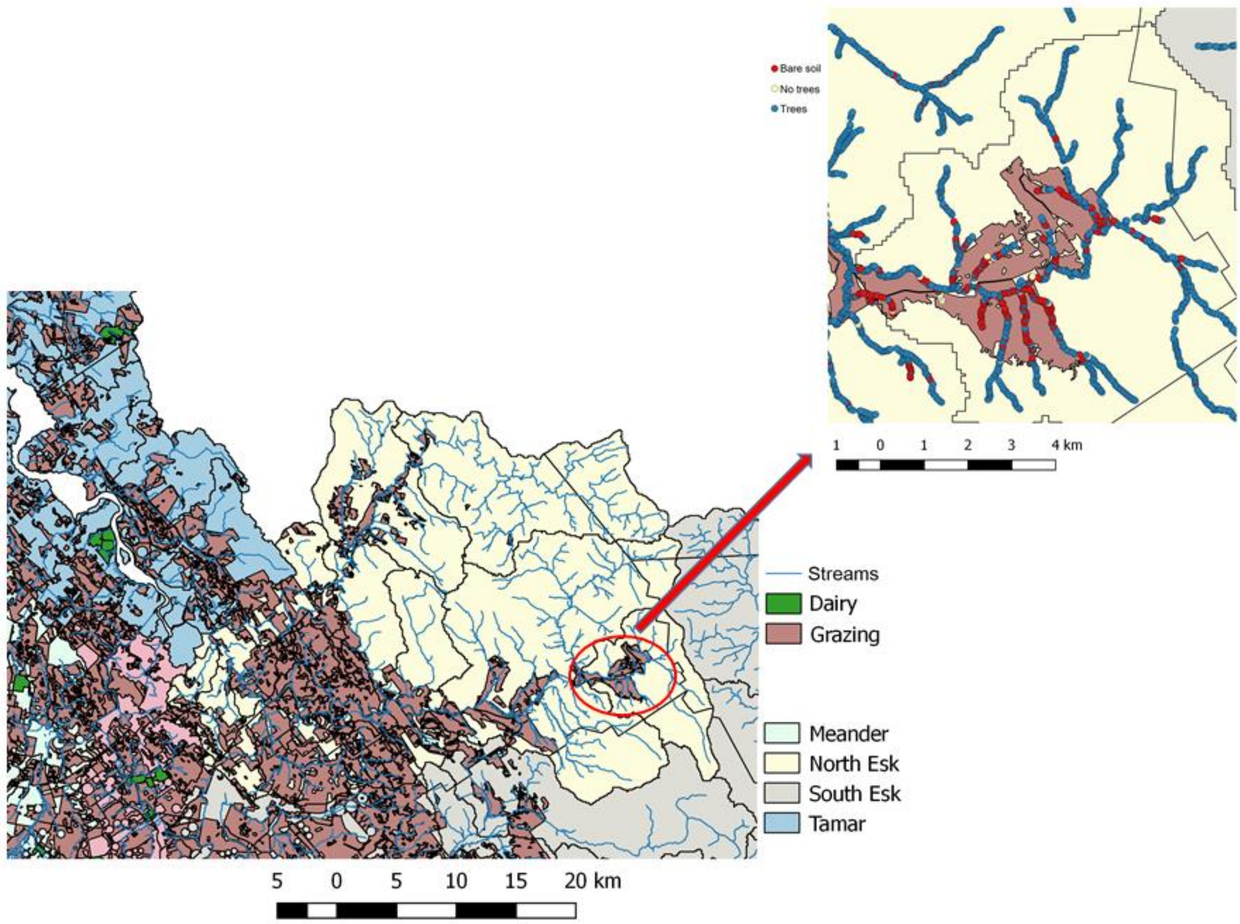

FIGURE 29. EXAMPLE OF THE USE OF WOODY VEGETATION TO DETERMINE RIPARIAN VEGETATION EXTENT IN A GRAZING AREA

A 10m buffer was run across all CFEV streams of order greater than 1. This buffer was then intersected with the land use layer, woody vegetation extent and the Subcatchment-LGA layer (as shown above).

A2.2 Assumptions used to derive input data for the DSS

In both dairy and grazing areas the proportion of the stream with riparian vegetation is set to the proportion of the 10m buffer with trees within that subcatchment-LGA. Both bare soil and areas without trees in the woody vegetation layer are assumed not to contain riparian vegetation.

In grazing areas, stock access is assumed to be restricted only in areas where riparian vegetation exists. It is also assumed that stock would only have access to streams from land within a 200m buffer of the stream (ie. grazing or dairy areas outside this buffer are assumed to have no stock access to the stream). Stock are assumed to be spread over time uniformly between paddocks within 200m of the stream and those further away (ie the proportion of stock with access on the average day is assumed to be equal to the proportion of area within 200m of the stream).

In dairy areas the use of single wire fences narrowly following the stream meant this assumption was inappropriate. In these areas the length of riparian vegetation used the same assumption as grazing but stock access to streams was assumed to be 100% on properties where works have previously been undertaken or equal to the riparian extent otherwise (as calculated for grazing). The proportion of dairy areas with stock access to streams is then the sum of the length of streams on properties where past works have been undertaken and the length of streams with a tree buffer on properties without works. As for grazing, dairy areas further than 200m from the stream are automatically assumed to have no access to the stream.

A2.3 Costs of works

Grazing – the cost per kilometre of stock exclusion and riparian revegetation works is assumed to be $21,000. This includes $4500 for revegetation, $1500 for off-stream water and $4500 fencing. Note that the cost of $10,500 is doubled to reflect that works need to take place on both sides of the stream. A 5m buffer is assumed in all the analysis.

Dairy – the cost per kilometre assumed $1500 for off-stream water and $4500 for fencing. Again this is doubled to reflect that actions must be taken on both sides of the stream. No riparian revegetation is assumed to take place.

A2.4 Potential lengths and costs

Grazing

In grazing areas it is assumed that up to 75% of currently unvegetated areas could potential be revegetated and have stock excluded. This is in-line with the feasible adoption scenario presented in the TEER WQIP.

Table 5 shows the potential lengths able to be revegetated using this assumption in each subcatchment-LGA combination used in the DSS as well as the costs associated with the actions. Costs for individual subcatchments where works are considered in the analysis are also shown. Note that costs are for works only and exclude the 15% overheads built into the scenarios.

Table 6 provides a summary of the total length of riparian revegetation and stock exclusion under each of the grazing investment scenarios (ie where the full budget is put into grazing action, not the balanced scenarios).

TABLE 5. POTENTIAL LENGTH (KM) AND COST OF RIPARIAN REVEGETATION AND STOCK EXCLUSION WORKS

Subcatchment	LGA	Potential length (km)	Total cost	North Esk	Upper Tamar	Brumbys-Lake	Meander	South Esk
Back creek	Northern Midlands	50.5	$1,060,500	$0	$0	$1,060,500	$0	$0
Barnards creek	Launceston	1.5	$31,500	$0	$31,500	$0	$0	$0
Ben Lomond rivulet	Northern Midlands	17.7	$371,700	$0	$0	$0	$0	$371,700
Black sugar loaf creek	Meander Valley	13.1	$275,100	$0	$0	$0	$275,100	$0
Black sugar loaf creek	West Tamar	3.1	$65,100	$0	$0	$0	$65,100	$0
Blanchards creek	Northern Midlands	46.3	$972,300	$0	$0	$0	$0	$0
Brushy rivulet	Meander Valley	3.2	$67,200	$0	$0	$0	$67,200	$0
Buffalo brook	Northern Midlands	3	$63,000	$0	$0	$0	$0	$63,000
Combined system	Launceston	0	$0	$0	$0	$0	$0	$0
Cormiston creek	West Tamar	1.9	$39,900	$0	$39,900	$0	$0	$0
Dairy creek	Northern Midlands	19.7	$413,700	$0	$0	$413,700	$0	$0
Dans Rivulet	Break O'Day	0	$0	$0	$0	$0	$0	$0
Dans Rivulet	Dorset	0	$0	$0	$0	$0	$0	$0
Distillery & Swedes creek	Launceston	1.2	$25,200	$25,200	$0	$0	$0	$0
Dry Bed creek	Break O'Day	0	$0	$0	$0	$0	$0	$0
Elizabeth river	Northern Midlands	20.8	$436,800	$0	$0	$0	$0	$0
Evercreech rivulet	Break O'Day	2.8	$58,800	$0	$0	$0	$0	$58,800
Ford river	Break O'Day	0	$0	$0	$0	$0	$0	$0
Ford river	Launceston	6.3	$132,300	$132,300	$0	$0	$0	$0
Ford river	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Fourteen Mile creek	George Town	19.3	$405,300	$0	$0	$0	$0	$0
Fourteen Mile creek	Launceston	0	$0	$0	$0	$0	$0	$0
Glen Morriston rivulet	Northern Midlands	10.3	$216,300	$0	$0	$0	$0	$0
Isis river	Northern Midlands	95.7	$2,009,700	$0	$0	$0	$0	$0
Jinglers creek	Launceston	1.1	$23,100	$23,100	$0	$0	$0	$0
Jinglers creek	Northern Midlands	1.9	$39,900	$39,900	$0	$0	$0	$0
Kings Meadows rivulet	Launceston	0.1	$2,100	$2,100	$0	$0	$0	$0

Kings Meadows rivulet	Meander Valley	0	$0	$0	$0	$0	$0	$0
Kings Meadows rivulet	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Kittys rivulet	Northern Midlands	10.3	$216,300	$0	$0	$0	$0	$0
Kittys rivulet	Southern Midlands	62.8	$1,318,800	$0	$0	$0	$0	$0
Lady Nelson creek	Launceston	1.2	$25,200	$0	$25,200	$0	$0	$0
Leiths creek	Meander Valley	20.5	$430,500	$0	$0	$0	$430,500	$0
Liffey river Bracknell	Meander Valley	2.3	$48,300	$0	$0	$0	$48,300	$0
Liffey river Bracknell	Northern Midlands	9.3	$195,300	$0	$0	$0	$195,300	$0
Liffey river	Meander Valley	8.9	$186,900	$0	$0	$0	$186,900	$0
Liffey river	Northern Midlands	9.8	$205,800	$0	$0	$0	$205,800	$0
Lower Blackman river	Northern Midlands	35	$735,000	$0	$0	$0	$0	$0
Lower Blackman river	Southern Midlands	4.4	$92,400	$0	$0	$0	$0	$0
Lower Break O'Day river	Break O'Day	24	$504,000	$0	$0	$0	$0	$504,000
Lower Brumbies creek	Northern Midlands	18.8	$394,800	$0	$0	$394,800	$0	$0
Lower Lake river	Launceston	0.1	$2,100	$0	$0	$2,100	$0	$0
Lower Lake river	Meander Valley	5.7	$119,700	$0	$0	$119,700	$0	$0
Lower Lake river	Northern Midlands	7	$147,000	$0	$0	$147,000	$0	$0
Lower Lake river	West Tamar	1.8	$37,800	$0	$0	$37,800	$0	$0
Lower Macquarie river	Northern Midlands	76.9	$1,614,900	$0	$0	$0	$0	$0
Lower Meander river	Meander Valley	37	$777,000	$0	$0	$0	$777,000	$0
Lower Meander river	West Tamar	5.1	$107,100	$0	$0	$0	$107,100	$0
Lower Nile river	Launceston	0	$0	$0	$0	$0	$0	$0
Lower Nile river	Northern Midlands	21.1	$443,100	$0	$0	$0	$0	$443,100
Lower North Esk river	Launceston	2.1	$44,100	$44,100	$0	$0	$0	$0
Lower North Esk river	Northern Midlands	10.9	$228,900	$228,900	$0	$0	$0	$0
Lower South Esk river	Northern Midlands	38.1	$800,100	$0	$0	$0	$0	$800,100
Lower St Patricks river	Launceston	1.4	$29,400	$29,400	$0	$0	$0	$0
Lower St Pauls river	Break O'Day	0	$0	$0	$0	$0	$0	$0
Lower St Pauls river	Northern Midlands	64.5	$1,354,500	$0	$0	$0	$0	$1,354,500

Lower Tamar	George Town	0.5	$10,500	$0	$0	$0	$0	$0
Lower Tamar	West Tamar	24.7	$518,700	$0	$0	$0	$0	$0
Macquarie river head	Northern Midlands	9.5	$199,500	$0	$0	$0	$0	$0
Meander Exton to Hagley	Meander Valley	34.5	$724,500	$0	$0	$0	$724,500	$0
Meander river headwaters	Central Highlands	0	$0	$0	$0	$0	$0	$0
Meander river headwaters	Meander Valley	2.3	$48,300	$0	$0	$0	$48,300	$0
Mid Lake river	Central Highlands	12.4	$260,400	$0	$0	$260,400	$0	$0
Mid Lake river	Northern Midlands	17.8	$373,800	$0	$0	$373,800	$0	$0
Mid Macquarie river	Northern Midlands	115.7	$2,429,700	$0	$0	$0	$0	$0
Mid North Esk river	Launceston	7.2	$151,200	$151,200	$0	$0	$0	$0
Mid South Esk river	Break O'Day	24.6	$516,600	$0	$0	$0	$0	$516,600
Mid South Esk river	Northern Midlands	36.7	$770,700	$0	$0	$0	$0	$770,700
Mid St Patricks river	Launceston	6.1	$128,100	$128,100	$0	$0	$0	$0
Mid St Pauls river	Northern Midlands	12.6	$264,600	$0	$0	$0	$0	$264,600
Mid to Low Lake river	Northern Midlands	62	$1,302,000	$0	$0	$1,302,000	$0	$0
Murfetts&Whitemore creeks	Meander Valley	32.8	$688,800	$0	$0	$0	$688,800	$0
Newnham creek	Launceston	0.4	$8,400	$0	$8,400	$0	$0	$0
Nth Esk Cora Linn	Launceston	3.8	$79,800	$79,800	$0	$0	$0	$0
Quamby brook	Meander Valley	26.8	$562,800	$0	$0	$0	$562,800	$0
River Tyne	Break O'Day	1	$21,000	$0	$0	$0	$0	$21,000
River Tyne	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Rosevears-Windemere	George Town	3	$63,000	$0	$0	$0	$0	$0
Rosevears-Windemere	West Tamar	3.5	$73,500	$0	$0	$0	$0	$0
South Esk headwaters	Break O'Day	0	$0	$0	$0	$0	$0	$0
South Esk headwaters	Dorset	0	$0	$0	$0	$0	$0	$0
St Pats river headwaters	Dorset	0	$0	$0	$0	$0	$0	$0
St Pats river headwaters	Launceston	0.5	$10,500	$10,500	$0	$0	$0	$0
Sth Esk Epping Forest	Northern Midlands	25.5	$535,500	$0	$0	$0	$0	$535,500
Sth Esk Evandale Perth	Northern Midlands	37.7	$791,700	$0	$0	$0	$0	$791,700

Storys creek	Break O'Day	1	$21,000	$0	$0	$0	$0	$21,000
Storys creek	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Supply River	West Tamar	38.4	$806,400	$0	$806,400	$0	$0	$0
Tin Dish rivulet	Southern Midlands	103.3	$2,169,300	$0	$0	$0	$0	$0
Tooms river	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Top of Tamar	Launceston	2.6	$54,600	$0	$54,600	$0	$0	$0
Top of Tamar	West Tamar	1.1	$23,100	$0	$23,100	$0	$0	$0
Tower rivulet	Break O'Day	8.2	$172,200	$0	$0	$0	$0	$172,200
Tower rivulet	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Upper Blackman river	Central Highlands	0	$0	$0	$0	$0	$0	$0
Upper Blackman river	Northern Midlands	3.4	$71,400	$0	$0	$0	$0	$0
Upper Blackman river	Southern Midlands	15.5	$325,500	$0	$0	$0	$0	$0
Upper Break O'Day river	Break O'Day	27.6	$579,600	$0	$0	$0	$0	$579,600
Upper Brumbies creek	Central Highlands	0	$0	$0	$0	$0	$0	$0
Upper Brumbies creek	Northern Midlands	37.1	$779,100	$0	$0	$779,100	$0	$0
Upper Lake river	Central Highlands	3.6	$75,600	$0	$0	$75,600	$0	$0
Upper Liffey river	Central Highlands	0	$0	$0	$0	$0	$0	$0
Upper Liffey river	Meander Valley	0.1	$2,100	$0	$0	$0	$2,100	$0
Upper Liffey river	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Upper Macquarie river	Northern Midlands	9.7	$203,700	$0	$0	$0	$0	$0
Upper Meander river	Meander Valley	19.4	$407,400	$0	$0	$0	$407,400	$0
Upper Nile river	Launceston	0.2	$4,200	$0	$0	$0	$0	$4,200
Upper Nile river	Northern Midlands	7.5	$157,500	$0	$0	$0	$0	$157,500
Upper North Esk river	Break O'Day	0	$0	$0	$0	$0	$0	$0
Upper North Esk river	Dorset	0	$0	$0	$0	$0	$0	$0
Upper North Esk river	Launceston	11	$231,000	$231,000	$0	$0	$0	$0
Upper North Esk river	Northern Midlands	0	$0	$0	$0	$0	$0	$0
Upper Quamby brook	Meander Valley	6.8	$142,800	$0	$0	$0	$142,800	$0
Upper South Esk river	Break O'Day	11.6	$243,600	$0	$0	$0	$0	$243,600

Upper St Pauls river	Break O'Day	0	$0	$0	$0	$0	$0	$0
Upper St Pauls river	Northern Midlands	1.7	$35,700	$0	$0	$0	$0	$35,700
Upper Tamar foreshore	George Town	0	$0	$0	$0	$0	$0	$0
Upper Tamar foreshore	Launceston	5.2	$109,200	$0	$109,200	$0	$0	$0
Upper Tamar foreshore	West Tamar	15	$315,000	$0	$315,000	$0	$0	$0
Total		*1630.1*	*$34,232,100*	*$1,125,600*	*$1,413,300*	*$4,966,500*	*$4,935,000*	*$7,709,100*

TABLE 6. TOTAL LENGTH OF RIPARIAN BUFFER AND STOCK ACCESS BY MAJOR CATCHMENT ALLOCATED UNDER SCENARIOS WITH ALL INVESTMENT IN GRAZING

All investment in grazing	North Esk	Upper Tamar	Brumbys-Lake	Meander	South Esk
$2 million	53.7	27.2	0.0	0.0	0.0
$5 million	53.7	67.2	23.0	22.8	35.6
$10 million	53.7	67.2	80.0	79.5	124.2

Dairy

The potential additional length of stream where it is assumed actions can be taken to exclude stock in dairy areas and their costs are given in Table 7. As was the case for grazing areas, costs are for works only and exclude the 15% overheads built into the scenarios. This assumes that 90% of remaining streams in dairy areas have stock excluded in line with the WQIP feasible adoption scenario. Note that subcatchments which currently have greater than 90% of stock exclusion are not allocated any works in these assumptions.

TABLE 7. POTENTIAL LENGTH OF STREAM FOR STOCK EXCLUSION WORKS IN DAIRY AREAS

Subcatchment	LGA	Potential length for stock exclusion (km)	Total cost
Back creek	Northern Midlands	3.4	$71,400
Black sugar loaf creek	Meander Valley	3.5	$73,500
Dairy creek	Northern Midlands	1.2	$25,200
Fourteen Mile creek	George Town	0.7	$14,700
Leiths creek	Meander Valley	7.9	$165,900
Liffey river Bracknell	Meander Valley	0.1	$2,100
Liffey river	Northern Midlands	0.6	$12,600
Lower Blackman river	Northern Midlands	11.5	$241,500
Lower Brumbies creek	Northern Midlands	0.4	$8,400
Lower Lake river	Northern Midlands	0.5	$10,500
Lower Tamar	West Tamar	2.6	$54,600
Meander Exton to Hagley	Meander Valley	2.4	$50,400
Meander river headwaters	Meander Valley	0.4	$8,400
Murfetts & Whitemore creeks	Meander Valley	9	$189,000
Upper Blackman river	Northern Midlands	2.3	$48,300
Upper Quamby brook	Meander Valley	4.8	$100,800
Total		*51.3*	*$1,077,300*

A2.5 Implications of uncertainty in the estimates of stream available for works

Given the lack of detailed catchment wide data on the locations of fencing and off stream water as well as other natural barriers to stream access it is necessary to estimate the length of stream available for revegetation in each catchment in creating the investment scenarios. As described above this involves applying assumptions over surrogate available spatial data sets. As with all such assumptions there are likely to be some inaccuracies that arise from this. These are considered to be within the bounds of reasonable uncertainty in the modelling:

- Limiting investment to less than 100% of remaining unfenced or unvegetated stream lengths means that there is room for error within the estimates in individual catchments.
- Impacts are effectively aggregated both in terms of load impact and impact on the estuary at catchment scales, meaning errors within individual catchments have the capacity to cancel each other out (ie. an overestimate in one subcatchment can be compensated for by an underestimate in the next subcatchment).
- All results are presented in terms of their relative magnitude and direction of change rather than as specific event based loads and concentrations. This means that very specific differences in management at small scales have less impact in terms of inducing errors in the outputs. For example when predicting daily loads and concentrations much more detailed,

high resolution information on management practices in specific locations is required given the influence of specific events (such as cows entering a stream during days in a specific time of year and specific location) than is the case when trying to represent aggregate behaviour over a longer time period.

As such the assumptions underlying the modelling and the model itself are considered to fit for purpose in estimating the relative load and concentration changes likely to result from changes in management and land use.