Biodiversity and Water Quality Improvement Plan for Circular Head

December 2016

R.Kelly and M.White

isNRM Pty Ltd

CITATION:

Kelly, R. and White, M. (2016). Biodiversity and Water Quality Improvement Plan for Circular Head, Cradle Coast NRM, Burnie, December 2016.

Executive Summary

This Biodiversity and Water Quality Improvement Plan (BWQIP) has been developed for the Duck, Montagu and Welcome River catchments in Circular Head. These catchments occupy the North-west corner of Tasmania, and together cover roughly 1550 km^2. These catchments contain significant beef and dairy industries with 11% of the beef cattle and 40% of the dairy cattle in the State located in Circular Head. The Duck and Montagu Rivers also drain to important oyster growing areas. There is a significant history of landscape modification in these catchments, with drains being used to reclaim natural swamp lands to make them suitable for farming. Winter rainfall in the area is very heavy with significant volumes of runoff and saturated soils being a challenge to farming and a driver for pollutant export during these months. The Circular Head area also contains very significant biodiversity assets, including unique landscapes, as well as important and threatened flora and fauna species and communities.

This BWQIP is intended to:

- Provide a comprehensive whole-of-catchment picture of water quality and biodiversity in the Circular Head catchments.
- Develop an understanding of the drivers of any water quality issues and the levers that can be used to address these.
- Identify priority activities to address water quality issues.
- Identify threats to biodiversity values in Circular Head and identify priority activities to address these in light of the adoptability of actions.

It is recognised that the BWQIP will need to be implemented by a range of key stakeholders in order to improve water quality so catchment stakeholders have been engaged throughout its development. This BWQIP aims to provide direction to all catchment stakeholders on the role they can play in protecting and improving water quality in the Circular Head catchments.

Biodiversity values and threats

The Circular Head area is very rich in biodiversity assets and includes threatened and locally important species and communities that occur nowhere else. The area contains an internationally listed Important Biodiversity and Bird Area (IBA). Several different high value landscapes are identified, with common sets of values and threats:

- *Seascape transition landscape* – consisting of the coastal foreshore zone, where there is a transition from saltmarsh to terrestrial vegetation. This area is part of the IBA. Key threats are poor water quality, stock access, drainage and construction of levees, clearing and fragmentation of vegetation as well as inappropriate 4WD and quad bike use on beaches.
- *Riparian landscapes* – consisting of the near stream zone, these are highly degraded in some parts of the catchments but contain significant environmental values. These areas are key to aquatic ecosystem health, and are home to the Giant Freshwater Crayfish (GFC) and Azure Kingfisher, as well as other threatened and locally important flora and fauna species and communities. The greatest threats to these landscapes are stock access and clearing and fragmentation or remnant vegetation.
- *Wetland and coastal lagoon landscape* – consisting of swampy areas in the lower catchments, particularly the Duck and Montagu River catchments. These areas are home to threatened frog and bird species and form an important part of the IBA. They are threatened by poor water quality, stock access, drainage and levee construction and clearing and fragmentation of native vegetation.
- *Grey Goshawk landscape* – consists of the Blackwood swamp forests on flats and rises which are home to grey goshawks as well as a range of threatened and interesting flora and fauna, including threatened freshwater snails. Clearing and fragmentation for primary production is the key threat to this landscape.

- *Wild river connected landscape* – covers a significant area of the Welcome River catchment down to Welcome Inlet. This landscape is unique and provides resilience to environmental change, including from climate change, allowing species to retreat. This area contains numerous threatened and locally important species and communities, including ovata forest, some of which is likely to be unmapped. Key threats to this landscape are clearing and fragmentation as well as stock access to remnants.
- *Robbins Island* – contains significant wetlands and remnants as well as Aboriginal cultural heritage, migratory birds and locally important and threatened species. Grazing is the key threat to these values.
- *Coastal mosaic landscape* – the western edge of the Welcome River catchment (draining directly to the ocean) contains a unique and interesting mix of coastal scrub and grassland species. This area contains many species that are found nowhere else, including velvet tussock and the Preminghana Billy button, rare orchids and the Marrawah skipper. Threats to these values include stock access to drains (for the Marrawah skipper) as well as inappropriate 4WD and quad bike use.

Water Quality

Sources of pollutants

Agricultural activities are the main source of pollutants in the catchments, with very little urbanisation present. Smithton sewage treatment plant drains directly into Duck Bay, contributing roughly 8% of Total Nitrogen (TN) and 6% of Total Phosphorus (TP) but relatively little sediment (TSS) or faecal coliforms (roughly 1% each). Sewer overflows also occur sporadically into Duck Bay. These have not been quantified due to a lack of data on their frequency, volume and concentration. There are no point source contributions in the Montagu or the Welcome River catchments.

The main source of diffuse pollutants in all catchments is beef grazing and dairy. These areas contribute more flow per unit area than other land uses as they predominantly occur in the wetter areas of the catchment. Even so, as would be expected given the more intensive nature of these land uses, these areas contribute greater relative loads than either their relative flow or area.

In the Duck River catchment, beef grazing covers 35% of the catchment but contributes approximately 50% of the diffuse TN, TP and TSS, with contributions to faecal coliform loads relatively similar to contributions to area. Dairy areas, consisting of both the milking platform and support blocks, contribute 24% of the area of the catchment, over 40% of the TN, 50% of the TP and 64% of the faecal coliforms. Their relative contribution to TSS is similar to their contribution to flow, at 30%.

In the Montagu River catchment, there is a similar story, although a greater proportion of this catchment is retained as forest cover. Beef grazing and dairy cover roughly 14% of the catchment each, but contribute respectively roughly: 40% and 50% of the TN; 35% and 60% of the TP; 30% of the TSS; and 24% and 74% of the faecal coliforms.

In the Welcome River catchment the dominant agricultural land use is dairy, with 26% of the catchment covered (including both the milking platform and support blocks) compared to 15% for beef grazing. Dairy contributes heavily to TN (61%), TP (70%) and faecal coliform (82%) loads as well as making a smaller but still significant contribution to TSS (40%). By contrast beef grazing in this catchment covers 15% of the area but contributes 25% to 30% of the TN, TP and TSS and 17% of the faecal coliforms.

Load Targets

This BWQIP sets load targets for the Duck River, Montagu River and Welcome River catchments respectively. These targets are based on feasible levels of adoption of recommended actions, derived in discussion with key stakeholders. They assume programs such as education and incentives are implemented, as outlined in the Plan. Load targets have been provided for summer, winter and annual loads, with relative impacts on summer loads expected to be greatest. Targeted load reductions presented in this Plan are shown in the table below.

	Summer	Winter	Annual
Duck River			
TN	-23%	-5%	-10%
TP	-24%	-8%	-12%
TSS	-9%	-4%	-5%
Faecal coliforms	-14%	-3%	-6%
Montagu River			
TN	-9%	-5%	-6%
TP	-12%	-8%	-9%
TSS	-5%	-3%	-3%
Faecal coliforms	-11%	-3%	-5%
Welcome River			
TN	-11%	-5%	-7%
TP	-14%	-7%	-8%
TSS	-8%	-3%	-5%
Faecal coliforms	-16%	-4%	-7%

Recommendations

Biodiversity

Recommendations for protecting and improving biodiversity values in Circular Head are provided below.

Education and on-ground works

- Exclude stock from streams, wetlands and coastal lagoons and foreshore areas wherever possible.
    - The lower Duck River and its tributaries should be a particular focus of stock exclusion given its high value for GFC, potential water quality benefits and its generally degraded character.
- Stock should be fenced out of drains, particularly in the Welcome River catchment where the Marrawah skipper lives in drains and is impacted by stock access.
- Detailed mapping of the seascape transition landscape as well as wetlands and coastal lagoons is required. This mapping should be used, along with an economic evaluation of production costs and benefits of fencing areas out, to target and inform discussions with farmers around rehabilitation of these landscapes.
- The connected wild river landscape of the Welcome River catchment should be protected through:
    - protection and improvement of condition for small extent ovata and woodland forest communities through restricting stock access to remnants and reducing or avoiding clearing
    - restricting stock access to streams is also important
    - better mapping of ovata is required to prioritise areas for protection and ensure good planning and management decisions are to avoid negative impacts.
- Quad bike and 4WD access to Anthony Beach, Shipwreck Point and Perkins Beach as well as in the coastal mosaic landscape on the western edge of the Welcome River catchment should be managed. In the first instance this should focus on education and involvement of

recreational users in works to protect values in these areas (such as construction of fencing). If this does not adequately protect biodiversity values in these areas, restrictions to recreational use of these areas should be considered.

- In terms of specific small scale projects, efforts should also be made to implement actions in the PPP from DPIPWE's species prioritisation project. This provides a very good list of specific projects that can be undertaken at a range of budgets to secure individual threatened flora and fauna species.
- Education activities focused on increasing community understanding of local biodiversity values and threats to these should be undertaken. This could include field days focused on the Giant Freshwater Crayfish, tree identification and general natural values in the area to increase the understanding of the local community. These should be hands on and promote case studies where farmers have taken positive action to protect and improve biodiversity and should include discussion of both the costs and the economic benefits to the farmer.

Planning and management

- A management plan should be developed for Robbins Island to identify priority areas, develop offsets and areas to be reserved. As part of this, a baseline survey of natural values including geomorphological and archaeological surveys should be carried out.
- RAMSAR listing should be sought again for the seascape landscape around Duck Bay and Robbins passage with efforts made to engage local landholders in the process and to address any of their concerns. The previous application can be used as the basis for a new application.
- The Statewide Planning Scheme should include protection for important vegetation rather than for threatened vegetation only.

Monitoring and Research

- A desktop review analysis of natural values information such as TasVeg, threatened flora and fauna data, other priority species (locally significant) should be undertaken with a view to identifying specific priority issues and areas where data needs to be fixed and sites or values need to be better mapped or studied before meaningful management options can be developed.
- Long term monitoring needs to be undertaken. This should continue existing monitoring projects as well as involve commencement of additional projects focused on key values and habitats.

Water Quality

Grazing and dairy areas are the main diffuse sources of pollutant loads to the Circular Head catchments. Duck Bay also has point source contributions from the Smithton STP and sewer overflows, largely from the Davies st pump station. Recommended management actions to reduce pollutant loads in the catchment are summarised below, based on the analysis and stakeholder feedback detailed in this Plan.

Maximising oyster lease opening periods in the short term

In the long run, the oyster industry will be most benefitted by reductions in the export of pathogens to the estuary. However in the short term, closure periods could be minimised by the installation of continuous salinity monitoring at the oyster leases. This monitoring would allow for a lead time between the flow trigger being met at Scotchtown weir and water quality at the lease being impacted. This would allow time for some oysters to be lifted or harvested before the closure takes effect. In addition it may allow the leases to be reopened earlier than is currently the case using only sporadic salinity measurement. A funding proposal has previously been developed jointly by the oyster and dairy industries. This proposal estimated that 5 salinity probes would be required, at an upfront cost of $50,000, with an additional $10,000 a year being required to clean the probes to ensure they are working properly. Options for funding this proposal should be further investigated. Any changes to monitoring would need to be overseen by TSQAP to be able to be used as part of the closure system.

Grazing management

- Best practice fertiliser use should be encouraged. Improved fertiliser management represents a win-win solution for improving water quality, particularly when used as part of environmental accreditation and marketing of beef products, and should be encouraged on all beef grazing farms.
- Where possible stock should be fenced out of streams both for its benefits to water quality as well as for benefits to stream bank stability and stream condition. While this action has relatively small modelled benefits for water quality, benefits of reduced stock trampling, increased streambank erosion and subsequent increases in stream turbidity are likely to be substantial but were not included in the modelling.
- Riparian revegetation in beef grazing areas should focus on broadscale adoption of narrower buffers with farmers encouraged to increase buffer width over time where possible. Wider buffers should be the focus in stream sections where additional biodiversity benefits are the greatest, for example where they act to connect native vegetation remnants and can be used as corridors for native flora and fauna. Areas targeted should also include those where increased stream bank stability or stream shading are required or where riparian vegetation could benefit threatened species or communities. Where riparian vegetation includes restricting stock access to streams, benefits to water quality will be greater

Dairy management

- Efforts should be focused on reducing milk shed water use in at risk areas of the catchment (low lying flats) where sufficient storage volumes are difficult to achieve. The benefits from this action are likely to come in the form of reduced storage volumes required and associated costs of effluent storage. This investment would mean that more farmers could be expected to have sufficient storage or at least levels of storage that are sufficient for longer periods of time. This would in turn have benefits for water quality. Programs focused on reducing milk shed water use may include a program of monitoring milk shed water use and helping farmers to identify peak times when excess water use is occurring and strategies for managing this.
- Effective effluent storage and management is important but the difficulty of achieving it varies through the catchments depending on location.
    - In lower risk areas such as those occurring on the red soils and low lying hills, best practice effluent management should be possible to achieve on farm with traditional solutions. Efforts should focus on helping farmers to bring their systems and practices in line with best practice. Sufficient effluent storage should be provided for on dairy farms. This storage should be well-designed and placed to ensure effluent can be applied to an adequate area of the farm, and such that storages are unlikely to leach or overflow effluent.
    - In high risk flatter areas of the catchment best practice effluent management is much more complex due to physical difficulties with building storages and the higher costs of their construction. Innovative solutions such as off-site spreading, above ground storages or communal storages may be required to achieve best practice. Assistance should be provided with developing innovative options on a case by case basis and ensuring that longer periods of storage are available even if providing sufficient storage for the entire season is not possible. The primary focus in these

areas should be on reducing the generation of effluent to be stored through reduced milk shed water use.

- Partnerships between Dairy Tasmania and Cradle Coast NRM are an important vehicle for achieving management outcomes. Programs such as the FertSMART program and Clean Rivers should continue to be supported.
    - Best practice fertiliser use should be encouraged by programs such as FertSMART. It is expected that best practice fertiliser management will be very effective at reducing nutrient loads if it is applied broadly across the catchment. These programs represent a win-win solution for improving water quality and should be encouraged on all dairy farms.
    - Programs to assist farmers in fencing stock out of drains and ephemeral streams (not hump and hollow) should continue to be undertaken. These may include a mix of education on the benefits to farmers of drain fencing as well as incentives to undertake these works.
    - Where possible, stock should be fenced out of streams both for its benefits to water quality as well as for benefits to stream bank stability, stream condition and biodiversity.
- Riparian revegetation in dairy milking platform areas should be focused on stream sections where the greatest biodiversity benefits can be achieved, rather prioritised on the basis of any potential impacts on water quality. Narrower buffers that are more easily adoptable and so more broadly applied can be expected to have greater impacts on diffuse catchment loads. Farmers should still be encouraged to develop wider buffers where possible, particularly where these buffers can act as corridors for wildlife, protect threatened species or communities or connected fragmented remnants, given the greater biodiversity benefits of wider rather than narrower buffers. Areas targeted should be those where increased stream bank stability or stream shading are required or where riparian vegetation could benefit threatened species or communities. Where riparian vegetation includes restricting stock access to streams, benefits to water quality will be greater. To maximise water quality benefits, riparian vegetation in areas where flows move as sheets flow through the riparian zone, rather than as channelized flows through a drain network should be a priority.
- Low rate winter irrigation on high risk flats where it is difficult to develop sufficient levels of storage should also be trialled and, if successful, encouraged through extension programs. This action is promising both in terms of reducing pollutant load exports where it is difficult for farmers to have sufficient storage, as well as in terms of reducing the size and cost of storages required for providing storage that is sufficient for longer periods of time.

Point source management

- Taswater should continue to invest in infrastructure improvements designed to reduce the frequency and volume of sewer overflows, particularly from the Davies st Pump Station.
- The proposed summer reuse scheme for Smithton STP is very effective in reducing pollutant loads over summer, particularly nutrients, but also to a lesser extent pathogens. Taswater are encouraged to progress this option further.
- Upgrades to the Smithton STP to remove all pathogens from the discharge are also likely to have benefits to winter water quality and reduce pressures on oyster growers. Taswater are encouraged to progress these upgrades.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 PURPOSE AND SCOPE OF THE BWQIP

This Biodiversity and Water Quality Improvement Plan (BWQIP) has been developed for the Duck, Montagu and Welcome river catchments in Circular Head. It is intended to:

- Provide a comprehensive whole-of-catchment picture of water quality and biodiversity in the Circular Head catchments.
- Develop an understanding of the drivers of any water quality issues and the levers that can be used to address these.
- Identify priority activities to address water quality issues.
- Identify threats to biodiversity values in Circular Head and identify priority activities to address these in light of the adoptability of actions.

It is recognised that the BWQIP will need to be implemented by a range of key stakeholders in order to improve water quality so catchment stakeholders have been engaged throughout its development. This BWQIP aims to provide direction to all catchment stakeholders on the role they can play in protecting and improving water quality in the Circular Head catchments.

2 BWQIP DEVELOPMENT PROCESS

The BWQIP has been developed through a combination of desktop analysis of existing data sets, expert opinion and community consultation. A set of simple modelling tools (see Kelly and White, 2015) have been used to assess:

- Current loads across the catchment
- Sources of pollutants
- The relative effects of various management actions on water quality

Biodiversity values, threats to these values and key management actions for addressing these threats have been identified using a combination of GIS data analysis, literature review and expert elicitation.

These assessments have informed discussions with key stakeholders about priority actions to be undertaken in the catchment and recommendations that appear in this BWQIP. The role of key stakeholders in the development of the BWQIP is crucial to ensuring recommendations are adopted.

The BWQIP has been developed using the five steps shown in Figure 1.

Figure 1. BWQIP development process

2.1 Consultation undertaken to develop the BWQIP

A key stakeholder reference group was set up to oversee development of the BWQIP. Three workshops were held with this group to get feedback on key elements of the BWQIP. Experts in biodiversity and ecology were also consulted in the process to develop priorities for protecting and improving biodiversity values.

2.1.1 Scoping workshop

A scoping workshop was held with the reference group to identify:

- What they value about the waterways and catchment. Questions asked were:
  - What do you value most about the river, its tributaries and estuary?
  - What do you use the waterways for?
  - What should we be aiming to protect and improve?
- What issues they see in the catchment and what do they perceive is causing these issues. Questions asked were:
  - What water quality issues are there in the catchment?
  - What issues do you see impacting on biodiversity?
  - What are the sources of these issues?
- What management actions and potential future scenarios they feel we should explore when developing the BWQIP.

Feedback was gathered using a facilitated discussion and individual feedback forms. A full summary of discussions is contained in Appendix 1. The main outcomes were:

- Values – people value the catchment and its waterways for

- Its' biodiversity values especially migratory and shore birds, disease free devil population and burrowing and freshwater crayfish.
    - Water quality and quantity essential to the economy and local industry, to underpin agriculture, irrigation and oyster production.
    - Recreation in terms of fishing, boating, kayaking and bushwalking, focused on the lower catchment.
    - Safe drinking water.
    - Aesthetic and tourist values.
- Issues people saw a range of issues impacting both water quality and biodiversity in the catchment:
    - Dairy, beef and cropping runoff affecting nutrient, sediment and pathogen loads to the rivers and estuaries.
    - Oyster closures especially in light of potential expansion of the dairy industry in the catchment.
    - Forestry operations and forest roads and their impacts on turbidity and soil erosion.
    - Sewer and stormwater discharges.
    - Loss of riparian vegetation.
    - Disturbance of acid sulfate soils, especially around Scopus creek.
- Actions – Several actions were mentioned as potentially able to improve water quality and biodiversity. These included upgrading wastewater treatment plants, sewage and stormwater network, better timing of fertiliser and spray application, monitoring of turbidity leaving forestry areas being harvested fencing cattle out of waterways.

2.1.2 Scenario workshop

Two additional key stakeholder workshops were run to obtain advice on the feasibility of potential management actions and impediments to their adoption. At these workshops a set of preliminary management scenarios were presented to show the potential leverage of various scenario options on water quality. The results of the desk top analysis of biodiversity values and threats were also presented. The purpose of these meetings was to get stakeholder feedback on how realistic results from the model were, the feasibility and likely levels of adoption of various actions and impediments to their adoption. The first workshop included key stakeholders with a range of interests while the second workshop focused on dairy management and brought together industry representatives and dairy farmers to obtain further feedback and refine scenario assumptions and recommendations. Specific advice provided is summarised throughout relevant sections of this WQIP. A detailed summary of feedback received is provided in Appendix 2.

2.1.3 Expert elicitation workshops

Two expert elicitation workshops were held to obtain expert opinion on key biodiversity values, threats and priority actions on a subcatchment scale across the Circular Head region. Discussions were structured around mapping and spatial data analysis as well as the results of a literature review focused on biodiversity values, threats and management actions for the Circular Head region. Maps and data used to seed discussions at these workshops are provided in Appendix 3 along with a summary of specific values identified in each subcatchment and threats to these values. Actions to manage these threats are also summarised. Section 4 provides a synthesis of this feedback and recommendations for protecting and improving biodiversity in Circular Head.

3 OVERVIEW OF THE CIRCULAR HEAD CATCHMENTS

The Circular Head catchments: the Duck, Montagu and Welcome river catchments; are the three most westerly catchments on the north-west tip of Tasmania. The location of these catchments is shown in Figure 2.

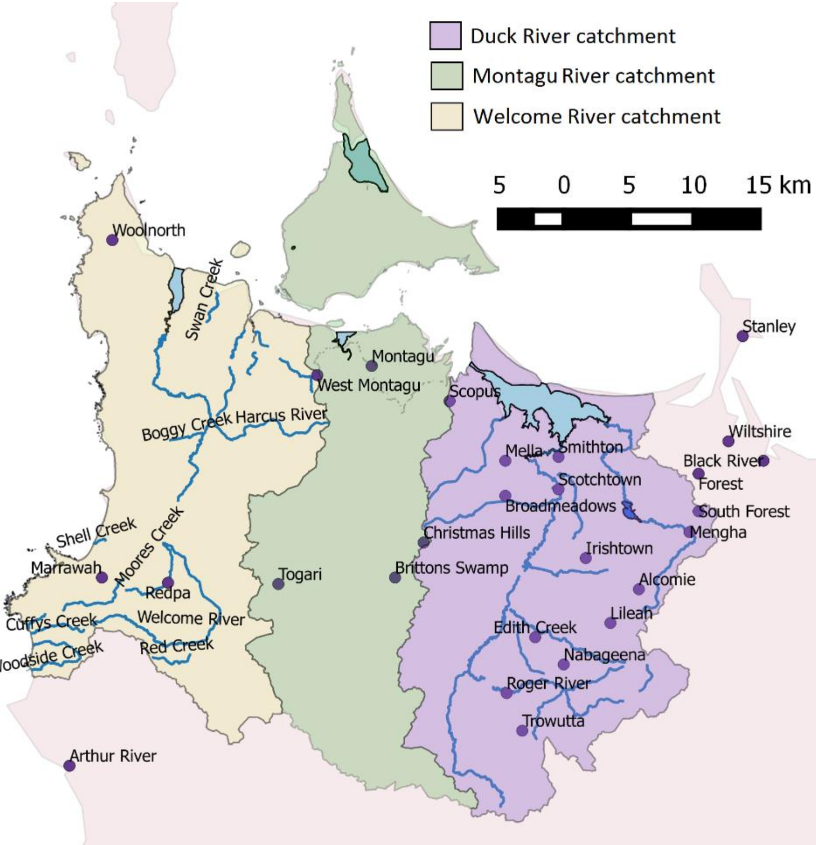


FIGURE 2. LOCATION OF THE CIRCULAR HEAD CATCHMENTS

3.1 Duck River Catchment

The Duck River catchment is dominated by agricultural, urban and exotic vegetation (59%). However, significant areas of wet eucalypt forest and woodland and non-eucalypt forest and woodland occur in the catchment (18% and 8% respectively). Production forestry along with zones of nature conservation including rainforest are scattered throughout the catchment but are most prevalent in the upper and western areas (Hydro Tasmania, 2008; DPIWE, 2010). Moorland, sedgeland, rushland and peatland (2%) are scattered throughout the catchment. In the lower reaches of the river there are vast areas where willows (*Salix fragilis*) and blackberries (*Rubus fruticosus*) dominate riparian zones. Scrub, heathland and coastal complexes occur around the mouth of Duck Bay. However much of this is in the form of fragmented remnants due to clearing for the development of agricultural land. Land use in the Duck River catchment is shown in Figure 3.

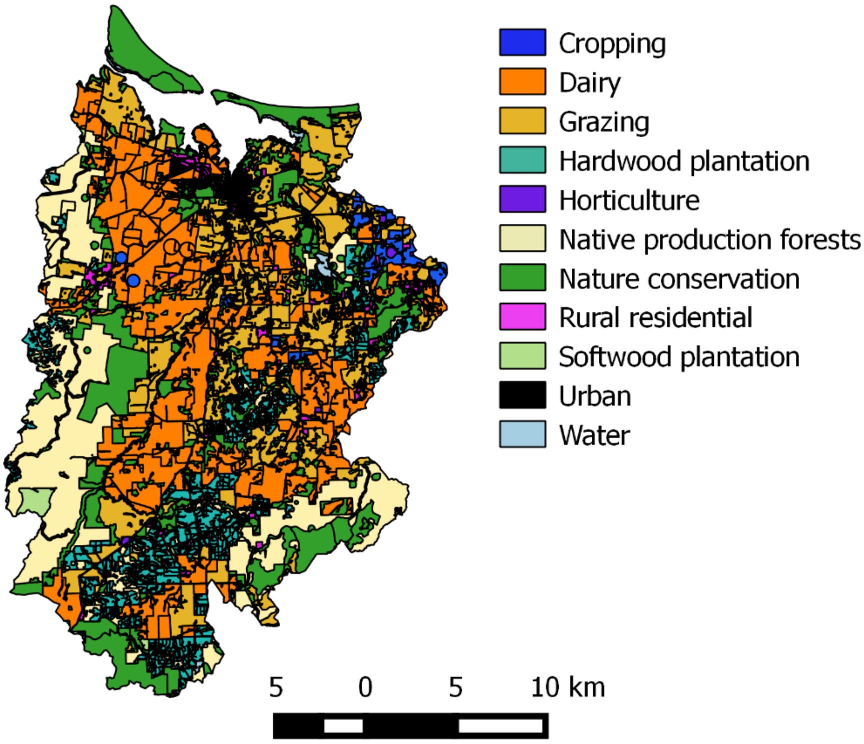


FIGURE 3. LAND USE IN THE DUCK RIVER CATCHMENT. NOTE 'DAIRY' INCLUDES BOTH SUPPORT BLOCKS AND THE MILKING PLATFORM (SOURCE: DPIPWE (2016))

Agriculture, mainly dairy and beef are the primary industries in the catchment; dairy accounts for 26% and grazing modified pastures which include beef production and runoff pastures for dairy heifers and silage production account for 18% of the catchment. Some of the most productive areas in the catchment occur throughout the middle and lower sections however much of this is low lying land that is susceptible to flooding during winter months (DPIWE, 2003a). To improve agricultural land in the lower sections of the catchment there has been extensive land draining (Hydro Tasmania, 2008; DPIWE, 2010; Richley, 1978 in Pinto and Graham, 2000; DPIWE, 2000).

The catchment is quite urbanised and there are a number of settlements. Around Smithton extensive swamp paperbark forest used to occur on riparian land, however this has progressively been reclaimed through clearing and landfill activity (Strategic Projects Office, 2013). The Eastern Foreshore at Smithton supports a range of land uses including industrial processing (e.g. McCain Foods Australia Pty Ltd and Tasmanian Dairy Products plant), natural riparian habitat, passive recreation and car parking. Furthermore the foreshore is used for shipping and community access to the waterway for recreation (Strategic Projects Office, 2013).

To the south of Duck Bay, land is zoned rural. Smithton has its sewerage works in Kemps Bay. On Deep Creek, one of the Duck Rivers main tributaries, there is a major water storage: Lake Mikany. Downstream from the lake there is a town water supply pump station on Deep Creek where water is extracted. This has a major influence on the flow regime in Deep Creek (Ling *et al.*, 2009; Hydro Tasmania, 2008; DPIWE, 2000). Major users of the water from the lake are the townships of Smithton and Stanley and an industrial user (Ling *et al.*, 2009). Other smaller communities also use the water including Rosebery, Tullah, Wynyard, Somerset, Waratah and Yolla (DPIWE, 2000).

Marine farming and commercial fish processing are carried out in Duck Bay and surrounding areas. Existing Pacific oyster marine farms are concentrated in Duck Bay (they are also in Big Bay and at the mouth of the Montagu River) however existing oyster leases are closed for sales of oysters when water quality is poor. In recent times they are generally closed for 200 days or more per year due to poor water quality derived from the catchment.

3.1.1 Biodiversity

The Duck River catchment is home to many terrestrial and aquatic species. The coastal region is also a significant area for a large and diverse range of migratory bird species (being part of the Robbins Passage wetlands) (Spruzen *et al.*, 2008 in Broad and Cotching, 2009). Native vegetation cover in the Duck River catchment is shown in Figure 4.

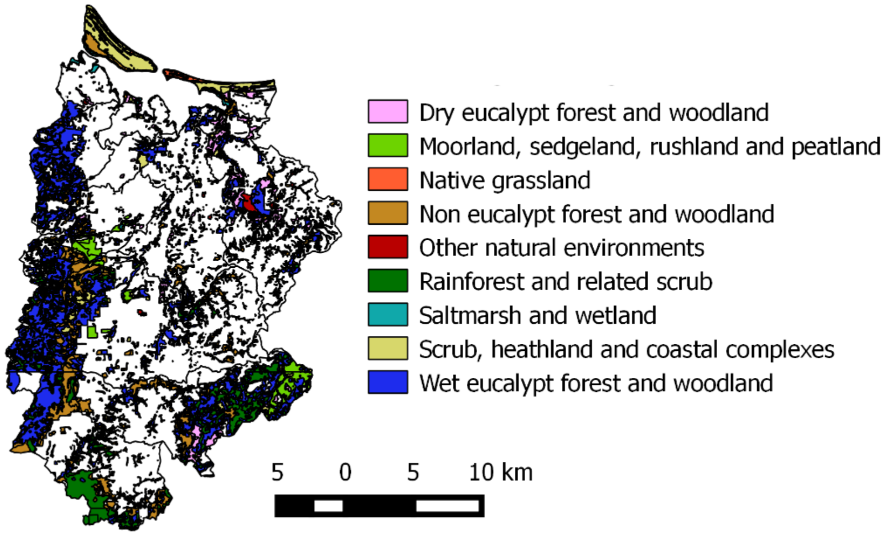


Figure 4. Native vegetation cover in the Duck River catchment (Source: DPIPWE (2013) TasVeg3.0)

Amongst the diverse range of life in the catchment there are a number of species that may occur in the Duck River catchment that are regarded as endangered species. These include the Australian Grayling (*Prototroctes maraena*); Green and gold frog (*Litoria raniformis*); Freshwater snails (*Beddomeia topsiae* and *Beddomeia wiseae*); and the giant freshwater lobster (*Astacopsis gouldi*).

A number of other species that occur or are likely to occur in the Duck River catchment are listed as threatened under the *Tasmanian Threatened Species Act 1995.* These include the eastern barred bandicoot (*Perameles gunnii*); grey goshawk (*Accipiter novaehollandia*); wedge-tailed eagle (*Aquila audax fleayi*); the swift parrot (*Lathamus discolor*); spotted tailed quoll (*Dasyurus maculatus maculatus*) and; the northwest velvet worm (*Ooperipatellus cryptus*) that has been found to occur in areas to the west of the catchment (Pinto & Graham, 2000).

The overall health of macroinvertebrate community in the Duck River has been significantly impaired by elevated concentrations of turbidity and nutrients in the waterways. Poor water quality in the middle and lower reaches of the river has caused a major change in the composition of macroinvertebrate community toward taxa that are more pollution tolerant. Sensitive fauna is only at sites in the headwaters of the catchment above agricultural areas. Similarly, this situation was also found on sites located on tributary streams to the Duck River (DPIWE, 2003).

The majority of the species discussed rely on terrestrial riparian habitat that could be indirectly influenced by excessive de-watering. Therefore, the flow of the Duck River should be maintained for the protection of the endangered Giant freshwater lobster (in particular), macroinvertebrate species water requirements and other vulnerable species.

Several threats that directly or indirectly impact flora and fauna in the Duck catchment include:

- Alterations in the natural flow conditions in waterways (e.g. water extraction)

- Pollution by fertilisers, pesticides and effluent
- Predation by introduced animal species and/or overfishing
- Siltation of waterways
- Habitat changes (e.g. draining of swamps, channelization, stock trampling)
- Removal of riparian vegetation resulting in loss of in-stream large woody debris and shading

3.1.2 Water Quality

Isolated periodic studies and ongoing water quality monitoring show that the Duck River and its tributaries have impacted water health resulting in a relatively unhealthy system (Murphy, Crawford and Barmuta, 2002). Overall the 'State of the Rivers' water quality monitoring program has found that areas of the Duck River catchment have issues with low dissolved oxygen at times, high nutrient levels (total phosphorous and total nitrogen), high faecal counts, generally high turbidity and occasional elevated salinity levels in tributaries (Green, 2001).

A significant impact on the water quality of rivers in the catchment appears to be land management practices. It is thought that elevated nutrient export in the Duck River catchment is caused by a combination of factors including intensive dairy farming and paddock draining, destabilisation of river beds and banks by stock, lack of riparian buffering and high rainfall (DPIWE, 2003).

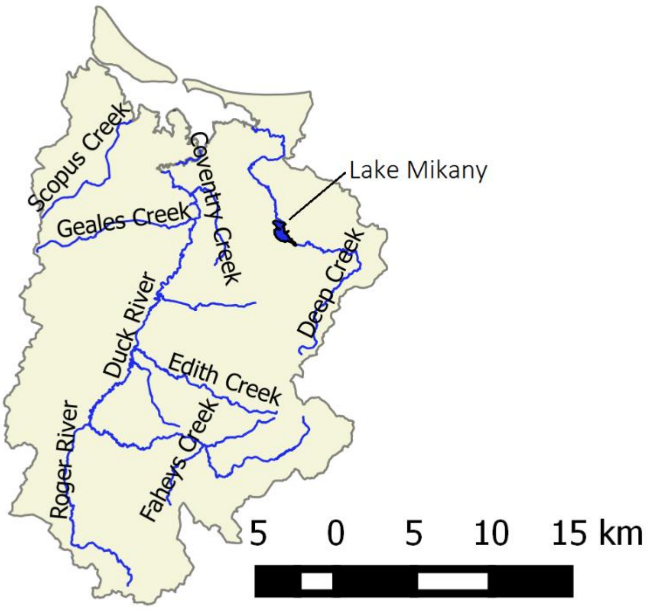


FIGURE 5. RIVERS AND CREEKS IN THE DUCK RIVER CATCHMENT (SOURCE: DPIPWE, LIST)

Consistently high turbidity levels greater than 15 NTU have been found at several sites throughout the catchment. In most cases the median range of turbidity and suspended solids have been higher in Duck River (upstream of Scotchtown Road) compared to readings at Deep Creek (see Figure 5). However, overall the most turbid water is generally found in the lower Duck River reaches where more intensive dairying and agriculture takes place. In Deep Creek it is thought that a potential influence on turbidity in the lower reach is the White Hills quarry (now closed), which is located less than 2 km upstream of the water treatment plant on Deep Creek (DPIWE, 2003).

High faecal bacteria counts have also been found to be highest at lower sites in the catchment and into Duck Bay. Sites with the highest levels in the catchment are Scopus Creek at Montagu Road and Bolduan's drain at Scopus where there is intensive dairy farming, and Edith Creek at Edith Creek where there are extensive open drains, dairy effluent input and a lack of riparian buffering. Nutrient concentrations have also been found to be high in Coventry Creek and White Water Creek (DPIWE, 2003). Overall, it has been noted that 'dairy pastures' and grazing modified pastures' in the lower catchment have much greater TP losses than the mid catchment and much greater losses than the upper catchment and eastern areas (Broad and Cotching, 2009).

At times, the lower Duck River has also been found to be seriously deficient in dissolved oxygen to the point of being inhospitable to fish and crayfish. Past studies attributed this poor water quality in the lower Duck River appears to by effluent runoff, stock access and the presence of dead animals in the river (Lynch and Blühdorn, 1997). At this time it was felt that low dissolved oxygen in Edith Creek may be due to effluent from the cheese factory and Abattoir Leachate was likely to contribute to low dissolved oxygen in Coventry Creek. It was stated that high biological oxygen demand (BOD) in these two tributaries is also influenced by the same inputs.

Conductivity in the Duck River is significantly higher than conductivity in Deep Creek. While readings naturally increase toward to lower reaches of the river, some areas throughout the catchment have high conductivity due to reasons other than tidal influence. For example, high conductivity in Coventry Creek is likely to be indicative of the level of impact of leachate from the Blue Ribbon abattoir upstream (DPIWE, 2003). Conductivity in catchment water may also be influenced by groundwater input (especially over drier months) that is affected by naturally occurring soils (dolomite and red ferrosols) as well as acid mine drainage (Mella) and leachate from waste depot sites (off Montagu Road and; near Duck River). Groundwater in the catchment may also be contaminated with hydrocarbons, metals and nutrients.

Catchment activities significantly influence poor water quality outcomes in Duck Bay. Nutrient levels (NO_x-N and PO_4-P) and high ranges of turbidity in surface waters are commonly high to very high, particularly in estuary areas closest to the river mouth. SiO4-Si concentrations have also been found to be high in Duck Bay all of which suggests significant anthropogenic influences on the estuary system (Murphy *et al.*, 2002).

3.2 Montagu River Catchment

The main land uses in the Montagu catchment are forestry and agriculture (DPIWE, 2000). However, forest areas have been fragmented throughout the catchment by wide spread clearing; dairying activities (the most intensive land use) occupy nearly 20% of the catchment (Weber & Holz, 2007). Figure 6 shows land use in the Montagu River catchment.

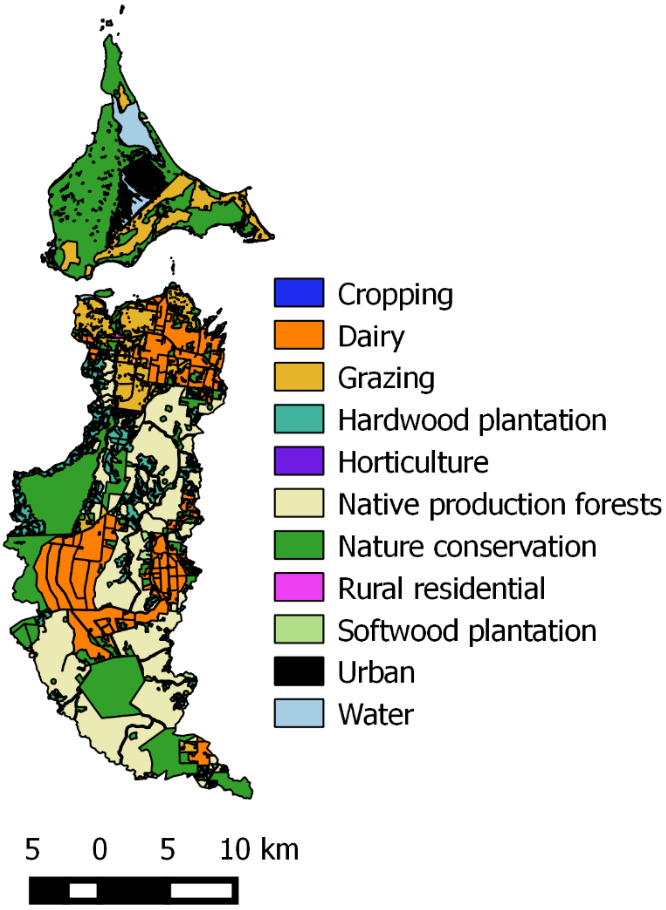


FIGURE 6. LAND USE IN THE MONTAGU RIVER CATCHMENT. NOTE 'DAIRY' INCLUDES BOTH SUPPORT BLOCKS AND THE MILKING PLATFORM (SOURCE: DPIPWE (2016))

Tall open forests naturally dominate the upper catchment even though sections of Bond Tier and Christmas Hills have been converted to eucalypt and pine plantation (TASVEG, 2002 in DPIWE, 2003). Riparian vegetation in the region can be over 40 metres in width and instream substrate is diverse with limited silt accumulation (DPIWE, 2003).

However, from Roger River Road downstream for the next 4km in-stream substrate is dominated by clay (50%) with gravel being the largest substrate class. Low silt and detritus cover here may suggest that this reach is relatively high energy (Houshold, 2002 in DPIWE, 2003). Off the Bass Highway, in-stream substrate in the Montagu River is dominated by bedrock (60% of substrate available). Around 20% of the substrate cover can be accounted for by erosion of bedrock material that has produced pebble and gravel material (DPIWE, 2003).

Around the Togari district much of the current dairying area, previously swamps dominated by tea trees and rainforest, have been cleared and drained (DPIWE, 2003; Weber & Holz, 2007). The river and most of the tributaries have been realigned and straightened in certain sections with long stretches being channelised to promote better flow and drainage for neighbouring land (DPIWE, 2000; Weber & Holz, 2007). Fixters Creek is an example of a tributary of the Montagu River that is used to drain the Brittons Swamp subcatchment (Weber & Holz, 2007). Many ancillary drains have also been dug down to underlying dolomite to make agricultural production possible in low-lying areas (Holz, 2009). 'Hump and hollow' surface drainage is the most common method used to reduce the effects of water logging in paddocks.

Downstream of Togari (and Brittons Swamp), the Montagu River flows through forested landscapes or pastures used for beef cattle grazing (Holz, 2009). Many sites in the middle reaches of the Montagu River are subject to moderate to extreme disturbance and had been reduced to no riparian cover, Thorpes Plains and a lower site off Quillums Road being exceptions. Through much of the developed zones, willow (*Salix fragilis*) and blackberries (*Rubus fruticosus*) occur. At most sites in the middle reaches of the Montagu River, in-stream substrate is generally dominated by fine sediments (silt, clay and gravel) with minor bedrock elements (DPIWE, 2003).

The main channel of the Montagu River flushes toward the east in Robbins Passage where there are large intertidal sand flats along the coastline, no major seagrass beds and five marine leases that concentrate on Pacific Oyster production (DPIWE, 2010). Catchment activities that impact water quality can be a risk to the oyster leases during times of flood (DPIWE, 2003) with these leases generally closed for most or all of the year. The plains in the region support open heath and sedgeland native vegetation communities. However, substantial areas of this land system have been cleared and drained for grazing, dairying and restricted cropping activities (DPIWE, 2003; DPIWE, 2010).

3.2.1 Biodiversity

The Montagu River catchment is home to many terrestrial and aquatic species. Significantly, the catchment also borders part of the Robbins Passage wetlands, the largest and most diverse community of migratory and resident shorebirds in Tasmania (Spruzen *et al.*, 2008 in Broad & Cotching, 2009). Figure 7 shows the native vegetation cover in the Montagu River catchment.

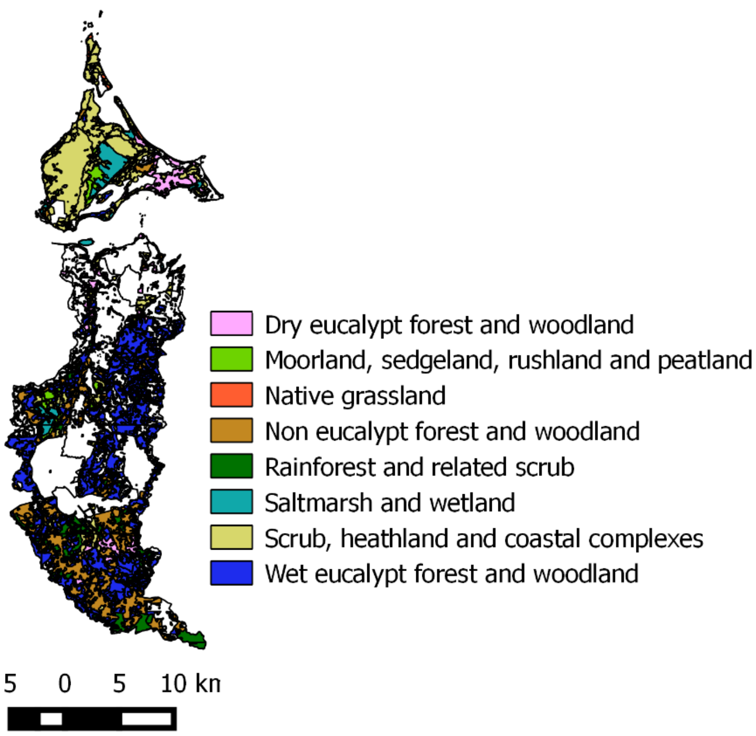


Figure 7. Native vegetation cover in the Montagu River catchment (Source: DPIPWE (2013) TasVeg3.0)

Four species of Freshwater Crayfish occur in the catchment, two of which *Astacopsis and Parastacoides* are only found in Tasmania. Five different frog species have been recorded and 59 macroinvertebrate taxa from edgewater sampling of habitats in the Montagu River catchment.

Seven out of the fifteen species of freshwater fish found in north-west Tasmania have been recorded in the Montagu River catchment. High numbers of native fish species and low numbers of introduced fish species such as the brown trout have been noted (DPIWE, 2003). Fish diversity within the main channel and major tributaries has been found to be high despite channel modifications. In contrast, macroinvertebrate numbers trend lower in areas where there is agriculture and localised disturbance (DPIWE, 2003).

Two plant and six animal species that are either aquatic or obligate riparian taxa that are known to occur in the Montagu River catchment are listed in the *Tasmanian Threatened Species Act 1995* (the Harsh ground fern, Variable sallow wattle, Dwarf Galaxiid, Australian grayling, Giant freshwater crayfish, hydrobiid snail, Keeled snail and Northwest velvet worm) (DPIWE, 2003). The *Beddomeia fultoni,* hydrobiid snail Gastropoda has only been found to occur in the Montagu River catchment in the tributaries of Farnhams Creek and Fixters Creek (Ponder *et al.*, 1993 in DPIWE, 2003). *Tasmaphena lamproides,* the Keeled snail Gastropoda has a main population in north-west Tasmania; one particular spot where it is located is in the Togari forest block to the north and west of Christmas Hills. One of the main populations of *Ooperipatellus cryptus,* the Northwest velvet worm is also centred around the Christmas Hills area (Forest Practices Board, 1998 in DPIWE, 2003).

These eight species are regarded as endangered because the casual factors relating to their decline continue to operate and hence reduce the prospects of long-term survival of the species (Bryant & Jackson, 1999 in DPIWE, 2003). Several threats which impact directly or indirectly on flora and fauna in the Montagu River catchment include:

- Alterations in the natural flow conditions in waterways (e.g. water extraction, forestry operations)
- Pollution by fertilisers, pesticides and effluent
- Predation by introduced animal species and/or overfishing
- Siltation of waterways
- Habitat changes (e.g. draining of swamps, channelisation)
- Removal of riparian vegetation

3.2.2 Water Quality

The Montagu River catchment is not highly urbanized but anthropogenic intervention throughout the catchment does drive poor water quality outcomes. Channelisation and drainage enhancement practices direct up to 80% of rainfall during winter into runoff. ‘Hump and Hollow’ practices and land clearing change hydrology, soil health and habitat and increase losses of contaminants (Opus, 2004 in Holtz, 2009). Runoff from dairies can cause bacterial contamination, elevated turbidity, high biological oxygen demand (BOD) and nutrient enrichment in waterways (Green, 2001; DPIWE, 2003). Unrestricted stock access to streams is also a common water quality problem that causes localized muddying, erosion and faecal contamination (Green, 2001). There is potential for acid sulphate soil leaching due to disturbed soils and the refuse disposal site at Togari that closed approximately 1995 is suspected as a major groundwater pollutant of nutrients, metals and hydrocarbons (Green, 2001). Further water resource issues that have been identified in the catchment include a decline of fish stocks, siltation, prolific growth of aquatic plants and algae during summer months in some parts of the catchment, spread of introduced marine pests and the loss of seagrass beds (Green, 2001; DPIWE, 2003).

The dairy industry in the Montagu catchment has been identified as a major driver of poor water quality outcomes (DPIWE, 2003). Research into losses from ‘hump and hollow’ drainage in the Togari area suggests that runoff from this area may contribute up to 70% of the total phosphorus load leaving the Montagu catchment each year (DPIWE, 2003). Past studies suggest that this is the main cause of nutrient enrichment within the middle and low stretches of the Montagu River. Very high concentrations of phosphorous and nitrogen have been found in tributaries draining the Brittons Swamp and Togari intensive agricultural regions (in particular Fixters Creek) (DPIWE, 2003).

Average turbidity in the Montagu River can exceed ANZECC trigger levels. It is highest in the Montagu River's main tributaries of Farnhams Creek (at Farnhams Creek Road 18.2 NTU and at Barcoo Road 20.6 NTU) and Fixters Creek (off Riseborough Road 24.4 NTU). The likely cause of high turbidity in the tributaries is agriculture and the result of current land practices (DPIWE, 2003). The lowest recorded dissolved oxygen concentrations have also been found in Farnhams Creek at Barcoo Road (0.2 mg/l) and Fixters Creek at the Bass Highway, Brittons Swamp (0.9 mg/l). High concentrations of ammonium have also been identified in the Montagu River at Togari during summer months. Note rivers and creeks in the Montagu River catchment are shown in Figure 8.

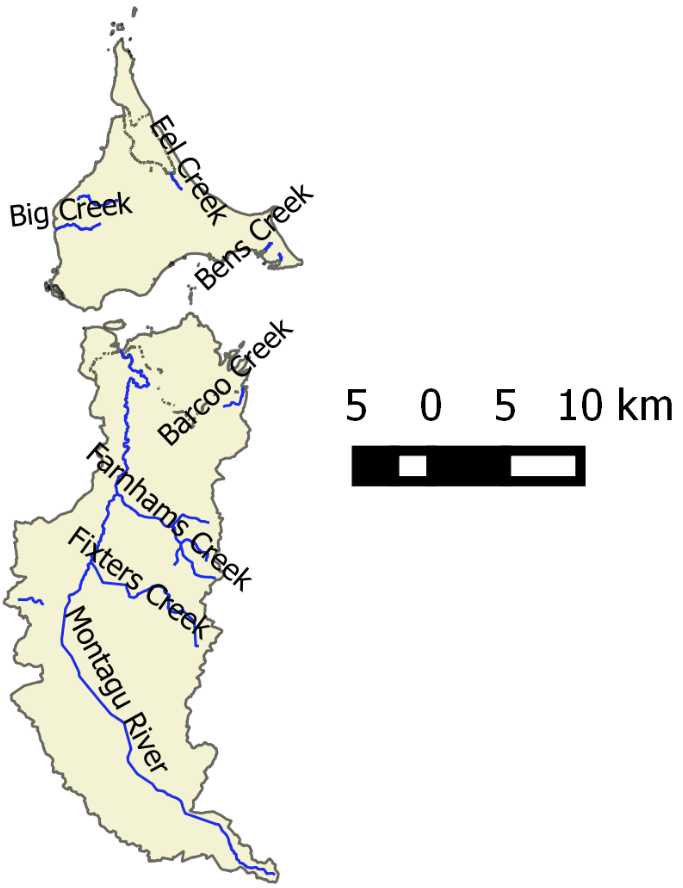


FIGURE 8. RIVERS AND CREEKS IN THE MONTAGU RIVER CATCHMENT (SOURCE: DPIPWE, LIST)

Interestingly, despite the level of in-stream and water quality alteration that has occurred in the middle regions of the catchment, river condition and riverine health improves as the Montagu River flows through forested land between 14 Mile Plain and Stuarts Road. Hence, the condition of the lower reach of the Montagu River is comparable to that that at the top of the catchment at Roger River. Both the upper and lower sites (in general) of the Montagu River have diverse in-stream habitat and only limited silt accumulation with the presence of healthy riparian vegetation communities (DPIWE, 2003).

In regard to groundwater on a locality scale, Holz (2009) found no clear trend of increasing concentrations in catchment groundwater of nutrients as the proportion of intensively grazed pastures increased. It was also found that water quality in shallow aquifers appears to be more impacted by local hazards and conditions rather than regional trends (Holz, 2009).

3.3 Welcome River Catchment

The Welcome River is a highly modified catchment that has been cleared for agriculture, grazing and forestry. Drains have been developed throughout the catchment which direct surface water into the main channel. Furthermore, considerable lengths of the river itself have been extensively altered upstream of Harcus River Road through straightening, cattle trampling, degradation of the riparian zone and dredging (SKM, 2003). Land use in the Welcome River catchment is shown in Figure 9.

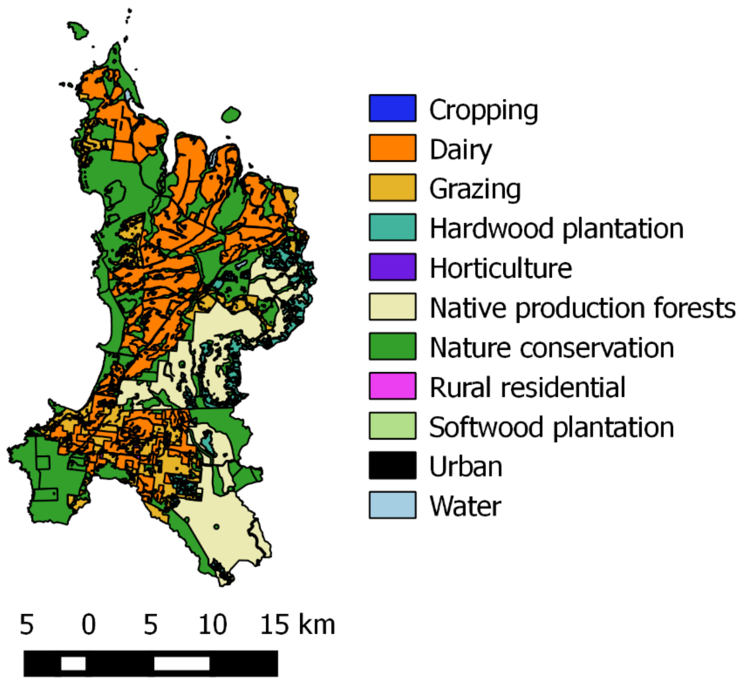


Figure 9. Land use in the Welcome River catchment. Note 'Dairy' includes both support blocks and the milking platform (Source: DPIPWE (2016))

Upstream of Comeback Creek the river flows through both swamp forests and farmland modified river channels and several sections have had riparian vegetation cleared on private land. There are a number of private in-stream and off-stream dams with unknown capacities, a privately constructed weir and associated infrastructure for water extraction (SKM, 2003). Native vegetation in the region are threatened by weed infestations particularly blackberry (*Rubus fruticosus*) and Scotch Thistle (*Cirsium vulgare*). Ribbon weed is also threatening the geomorphic structure of the river system leading to the development of a multi-level channel through small alluvial flats.

Farmland becomes dominant between Comeback Road to Harcus River Road and a riparian strip is only present on one side of the channelized waterway. There is little large woody debris (LWD) and in one section spoil material from channelization on the rivers western bank has formed an artificial levee populated with weeds such as scotch thistle (SKM, 2003). Livestock access to streams results in physical disturbance, additional nutrient input and/or sediment disturbance in the waterway and potentially contributes to acid sulphate leaching (SKM, 2003).

From Harcus River Road to the Woolnorth Gauge the river meanders through large swamp forest and farmland but is mostly natural. The natural channel of the river varies in width and there is a significant amount LWD that can cause flow barriers at times. The region receives large quantities of sand and sediment from upstream but it has been shown that the river de-silts over time when sediment input has diminished (Houshold and Jerie, 2001 in DPIWE, 2003). Diverted flows from the Harcus River Drain are received in this reach. This reach also drains into the lower Harcus River.

Around the margins of the Welcome Inlet and the estuary, significant *Melaleuca* Swamp forests occur and expansive sand flats. The estuary region has been recognised as significant for providing habitat for migratory bird species. While the region is not infested with rice grass (*Spartina anglica*) from the nearby mouth of the Montagu River, the high inputs of nutrients into the River from the catchment increase the probability of infestation (North, 1998 in SKM, 2003).

3.3.1 Biodiversity

Throughout the catchment remaining riparian vegetation stands retain important species such as *Melaleuca* swamp forest and *E. brookeriana*, which are both priority vegetation types under the Tasmanian RFA. While current understanding of the remaining swamp regions is lacking particularly in respect to the faunal and floral communities that inhabit these areas and their response to changing patterns of inundation, these swamp communities do provide a significant amount of LWD both in the river itself and on its margins which create important habitat for fish and macroinvertebrates. Figure 10 shows native vegetation cover in the Welcome River catchment.

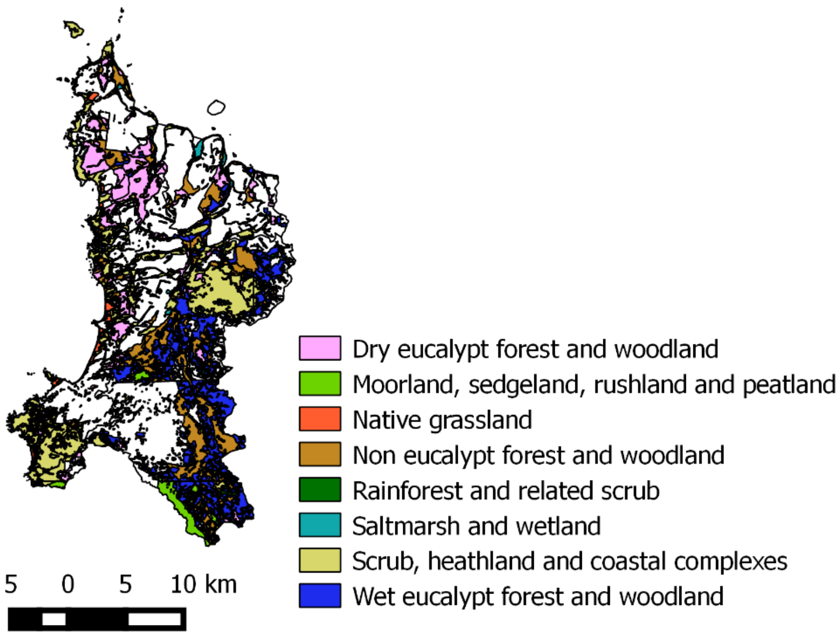


FIGURE 10. NATIVE VEGETATION COVER IN THE WELCOME RIVER CATCHMENT (SOURCE: DPIPWE (2013) TASVEG3.0)

From Comeback Road down the River various fish assemblages have been identified with relatively high diversity (nine species of freshwater fish and the exotic brown trout). While some species such as the Pygmy perch, common jollytail, mountain galaxias, Tasmanian mudfish and eels are common in the swampy habitats, the climbing galaxias and river blackfish have adapted to the channelized habitat of the middle reaches (SKM, 2003).

Three freshwater crayfish species *Engaeus fosser*, *Geocharax sp*. and the *Astacopsis gouldi* (Freshwater crayfish) (listed as 'Vulnerable' under the Tasmanian *Threatened Species Protection Act* 1995) inhabit swampy areas dominated by tea-tree and/or *Acacia melanoxylon* (Horwitz, 1990 in DPIWE, 2003).

Twenty-eight macroinvertebrate taxa typical of low gradient, slow flowing coastal river systems have been identified in the Welcome River. Sampling using the AUSRIVAS approach found that sites throughout the river had significantly fewer families than expected, however greater numbers of macroinvertebrate families were collected in the highest sites in the catchment. It was suggested that this could be due to potential mild to moderate impact on habitat, water quality or both resulting in the loss of families (SKM, 2003).

Furthermore, the Welcome Inlet, estuary and coastal region, is used by several water bird species including migratory waterbirds (SKM, 2003). Migratory birds from East Asian-Australasian flyway occur within the region as well as the orange-bellied parrot that is nationally endangered. Large numbers of swans and ducks also occur in the area as well as local populations of hooded plovers, red capped plovers and pied oystercatchers (SKM, 2003).

The flora and fauna within the catchment are subject to a number of threats. These include:

- Loss of habitat through vegetation clearing, livestock trampling, drainage diversion;
- Habitat invasion by weed infestation particularly blackberry (*Rubus fruticosus*) and Scotch Thistle (*Cirsium vulgare*) and aquatically Ribbon Weed and rice grass (in the estuary);
- Water quality through added nutrients and sediments from livestock, fertilisers, pesticides, drainage diversion and acid sulphate leaching from soil, and;
- Low flows due to water off-takes, dams and summer flows.

3.3.2 Water Quality

The Welcome River catchment is not highly urbanized but anthropogenic intervention throughout the catchment drives poor water quality outcomes. This includes developed drainage channels and land clearing that add sediment to the system; earthworks, agriculture and mining that disturb acid sulphate soils; runoff of fertilisers and excrement from stock that add nutrients to the system; and major groundwater pollutants such as the historic Marrawah waste depot site (metals, hydrocarbons and nutrients). Figure 11 shows the rivers and creeks in the Welcome River catchment. Note the Welcome catchment considered in this Plan is based on the CFEV layer and contains areas that drain directly to the ocean rather than into the Welcome River.

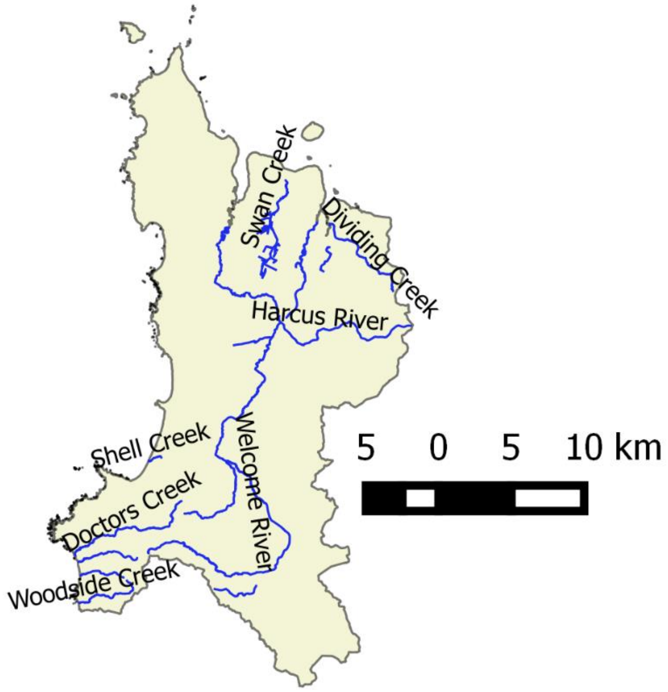


FIGURE 11. RIVERS AND CREEKS IN THE WELCOME RIVER CATCHMENT (SOURCE: DPIPWE, LIST)

Monthly water quality monitoring (since 1999) along with other periodic studies has shown that the water in the Welcome River can experience high salinity and very low dissolved oxygen levels. It is believed that these findings are seasonal; partly related to low summer river flows and groundwater inflows (DPIWE, 2000a in Green 2001; Koehnken,(2012).

Low pH values in the Welcome River may also be seasonal with Koehnken (2012) identifying elevated values during summer. It was noted that warm summer conditions and low summer flows are favourable to algal activity that drives an increase in pH. SKM (2003) also suggested that low pH may be due to acid-sulphate drainage in the catchment (SKM, 2003).

Total nutrient concentrations in the waterway can exceed ANZECC trigger levels at times (DPIWE, 2000a in Green 2001). Total nitrogen (TN), nitrate, ammonia, total phosphorous (TP) and dissolved reactive phosphorus in various studies have been identified as exceeding the recommended ANZECC guideline limits in the Welcome River. However they show strong seasonal signals with higher concentrations associated with winter when surface runoff is a major contributor to the River (Koehnken, 2012).

Sites throughout the Welcome River including those in upper regions have recorded turbidity levels outside ANZECC recommended guideline range limit (majority of exceedences below 6 NTU). It is believed that significant modification of the Welcome River through land clearance, channelization and stock access to the waterway contribute to this condition. Koehnken (2010) found that turbidity in the Welcome River was elevated during winter flows and suggested that this was ‘undoubtedly related to surface runoff in the catchment’. However, it has also been noted that lower values in lowland rivers can be attributed to low flowing rivers and/or well-vegetated catchments (ANZECC, 2000 in SKM, 2003).

Pesticides have also been detected in the Welcome River. At Woolnorth on the Welcome River MCPA was sampled once in 2010. At another site in the Welcome River at Sandtrack Bridge detections of 2,4-D (2012, twice in 2014); Dicamba (2012) and MCPA (2012, 2014) have occurred (ASCHEM, 2014).

3.4 Subcatchments used in the Analysis

Results in this Plan are based on modelling, data analysis and feedback. Figure 12 to Figure 14 show the subcatchment boundaries used by the modelling and referred to throughout this report.

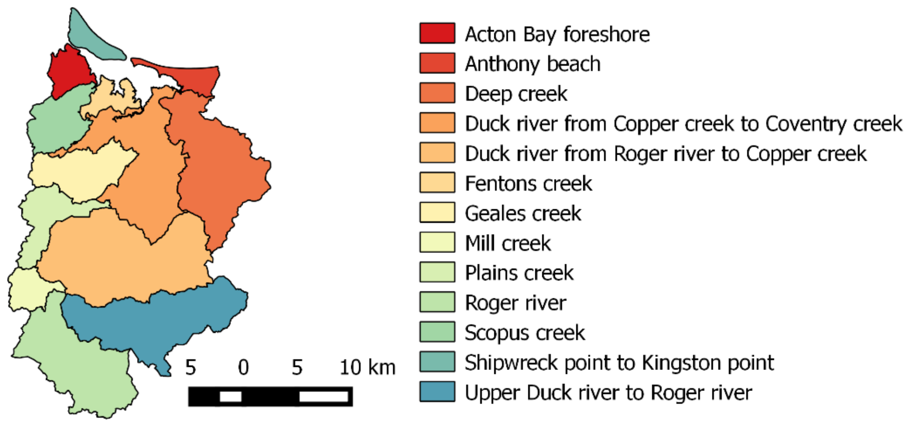


FIGURE 12. SUBCATCHMENTS OF THE DUCK RIVER CATCHMENT USED IN THE ANALYSIS

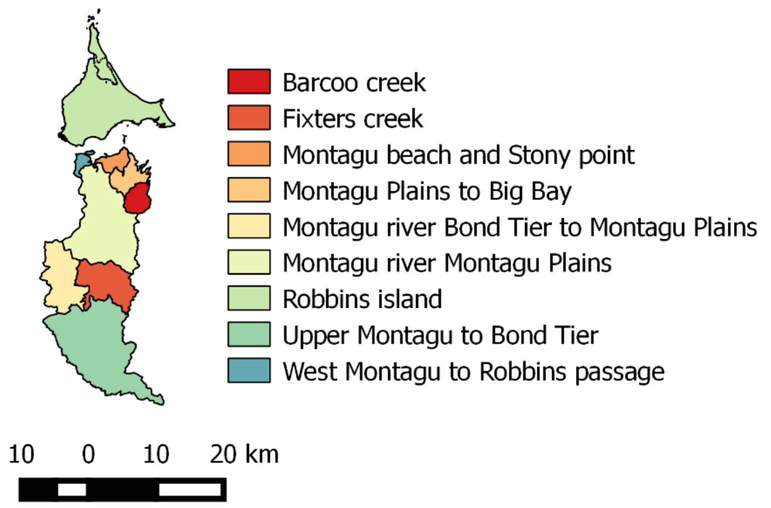


Figure 13. Subcatchments of the Montagu River catchment used in the analysis

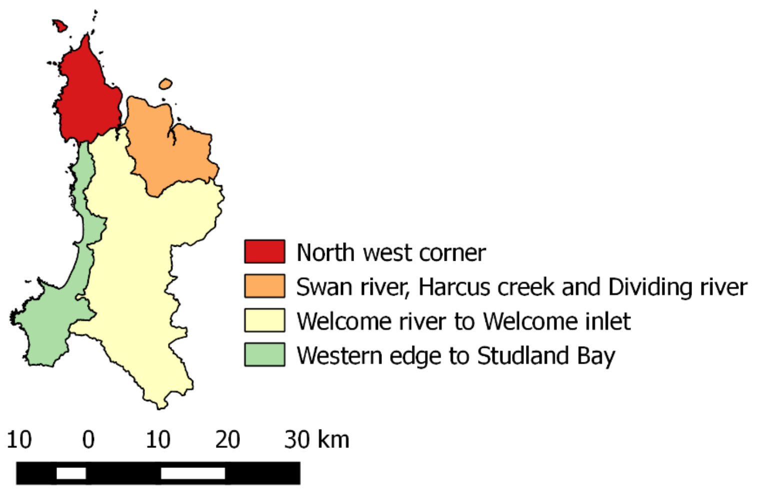


Figure 14. Subcatchments of the Welcome River catchment used in the analysis

Biodiversity

4 BIODIVERSITY VALUES, THREATS AND POTENTIAL MANAGEMENT ACTIONS IN CIRCULAR HEAD

As briefly described in Section 3, the Circular Head area contains many unique and important biodiversity values, including specialised habitats, threatened and important species that occur nowhere else and intact connected landscapes that provide resilience to many flora and fauna species and communities. Many of these values are under threat from human activities, such as farming practices, changes to the flow regime, poaching and recreational access. This section provides a summary of feedback from the expert panel workshops which were used to refine values and threats and prioritise actions. A summary of key stakeholder feedback on the feasibility of management actions is then provided. The section finished with a set of recommended actions for protecting and improving biodiversity values in the area. A brief summary of the literature review conducted to inform this prioritisation was given in Section 3. Detailed maps and data tables used to support discussions are given in Appendix 3.

4.1 Expert panel feedback on values, threats and priority actions

Key biodiversity values, threats to these and prioritisation of management actions for the Circular Head catchments have been developed using an expert panel approach underpinned by a literature review and spatial data analysis. The approach applied considers biodiversity using a step wise hierarchy using a values-threats-action matrix:

- A preliminary list of potential biodiversity **values** for the catchments was created using values identified from a literature review. The extent to which these values are relevant to individual subcatchments in the Circular Head region has been estimated using spatial data analysis. Two expert elicitation workshops were held to validate and refine these values for each subcatchment.
- **Threats** to values for the catchment were initially identified using a literature review. These were refined and prioritised using the expert panel at the workshops.
- A broad list of potential management **actions** were also been identified using literature review. These were refined in the context of their relevance to regions of the catchment and prioritised given their relative importance in addressing key threats to values. Key stakeholder feedback on the feasibility of landholders to implement these actions on farm was obtained through a key stakeholder workshop.

Data tables and maps showing results of the spatial data analysis are given in Appendix 3. This section summarises the feedback obtained from experts and key stakeholders during the workshops. It was found in discussions with experts that there are several unique 'landscapes' that can be considered in the Circular Head region, with common values and threats to the values in each landscape. Indicator species have been named as part of these landscapes as a focus for action, however it is recognised both that there are numerous other important species and communities in these landscape and that management of these indicator species will benefit a whole range of species and communities. The focus is on protecting and improving the habitat value of these indicator species in each landscape, acknowledging that this will in turn provide protection for a number of threatened and locally important species and communities. Recommended actions have been developed for each of these landscapes as well as more generally.

The biodiversity landscapes identified in the expert panel workshops are shown in Figure 15. Values, threats and priority actions in each of these landscapes is described below. In some cases whole subcatchments have been mapped where the landscape is contained within the subcatchment even though the landscape does not cover the entire subcatchment.

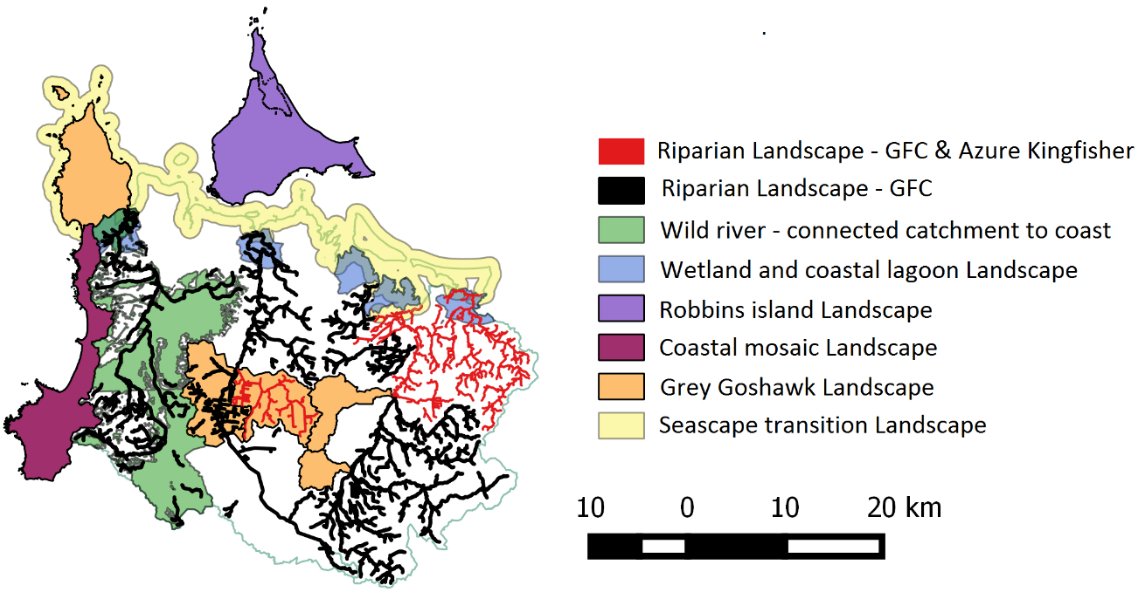


FIGURE 15. LANDSCAPES FOR BIODIVERSITY MANAGEMENT IN CIRCULAR HEAD

4.1.1 Seascape transition landscape

The seascape transition landscape refers to the coastal foreshore zone linking marine and coastal habitat with terrestrial habitat areas. This landscape is characterised on the seaside by threatened saltmarsh communities which provide important breeding and feeding areas for fish and birds of international importance, such as the pied oyster catcher and little terns. Moving away from the marine environment towards the terrestrial environment the landscape passes through *melaleuca ericifolia* to eucalyptus forest. The melaleuca provides an important buffer between terrestrial land uses and the marine environment and along with the swamp forest provides protection to many threatened plant species. This area is listed internationally as an Important Bird and Biodiversity Area (IBA) recognised by BirdLife International. This landscape contains numerous listed threatened species and communities, including *limonium australe* (sea lavender), orange bellied parrots and saltmarsh. Anthony beach on Duck Bay is the most important site for little terns in Tasmania. The Northwest corner of Tasmania has the best preserved patches of saltmarsh-melaleuca-eucalypt transition in the State.

Subcatchment areas considered in this plan that form part of the seascape transition zone at the coastal strip of the following subcatchments (as shown in Figure 15):

- Action Bay foreshore
- Fentons creek
- Anthony beach
- Shipwreck point to Kingston point
- Barcoo creek
- Montagu river to Big Bay
- Montagu beach and Stony point
- West Montagu to Robbins passage
- North west corner
- Swan river, Harcus creek and Dividing river
- Welcome river to Welcome inlet

Threats to values in the seascape transition landscape are:

- Loss of the interface between the coast and marine is a significant threat to biodiversity values.
- Rice grass competes with saltmarsh communities and other weeds in the melaleuca stands threaten their viability
- Poor quality water running off into the marine environment has impacts on saltmarsh and other aquatic species and communities.
- Livestock accessing transition landscapes are a major threat through grazing, deposits of manure and associated decreased water quality and trampling of vegetation.
- Construction of levees and drainage of naturally swampy areas reduces habitat for bird life and impacts on native vegetation communities in the seascape transition landscape.
- Dogs, 4WD and quad bikes on beaches are a threat to birds especially on Anthony Beach, Shipwreck point and Perkins beach

Key management actions for addressing these threats recommended by the expert workshop are:

- Exclude livestock from boggy foreshore areas and protect/regenerate melaleuca as a buffer to saltmarsh to minimise impacts of adjacent land use on saltmarsh
- Improve and protect water quality running off the catchment
- Avoid clearing and fragmentation of native vegetation in the seascape transition landscape
- Remove rice grass
- Manage weeds in the melaleuca stands
- Remove levees where possible and avoid constructing new levees in the seascape transition landscape
- Map values and target rehabilitation and protection works based on this mapping.
- Allow retreat and monitor for impacts of changes in climate, depends on priorities developed through seascape mapping

A major recommendation of the expert panel was that more detailed mapping of the wetlands and seascape transition landscape is required to enable planning and prioritisation works to repair and protect wetlands and biodiversity values in this landscape. This mapping needs to document the width of the seascape landscape, acknowledging the variable widths of this in different areas of the region and places where it is resilient versus those that require further protection. It was felt that this mapping along with an economic valuation of potential lost production from excluding stock from these landscapes could be used to underpin discussions around possible management actions with farmers. It was felt that these areas are naturally poor value for farming so the economic argument for removing them for production was likely to be stronger than for riparian areas, which tend to have very high production values. It was felt that working with farmers to exclude stock and allow these marginal paddocks fringing the coast to return to their natural state would be a workable priority for action.

When considering priority areas for willow and other weed removal it was stated that this should be targeted towards onsite values and impacts and be focused on restoration and rehabilitation. It was felt that these weeds would have largely localised impacts and would not spread quickly, which, along with the significant cost of weed management activities, justifies a more targeted approach.

It was stated that the Big Bay conservation area has been significantly damaged by grazing, levees and drainage. Actions to exclude stock and remove levees to allow restoration of the saltmarsh communities would be of major benefit to biodiversity in this area.

Swan River, Harcus Creek, Dividing River and Welcome Inlet were seen to be good areas for the functional expansion of saltmarsh. This would involve the removal of levees to allow saltmarsh communities to expand. It was felt that there would be major conservation benefits of a measurable increase in saltmarsh extent or function.

Quad bikes and 4WD are a major threat to bird life on Anthony Beach and from Shipwreck point to Kingston point. It was felt that simply restricting access doesn't work as these activities simply move elsewhere and cause similar levels of damage to new environments. It was felt that an educative approach, where users 'own their impacts' through, for example, monitoring and constructing fences, would achieve better outcomes. Dogs need to be managed through controlled access, with fencing to ensure dogs off lead can't get to within 300m of where birds nest.

It was stated that the largest stands of *eucalyptus viminalis* forest in the North-west are contained in the area around Anthony Beach and Shipwreck point to Kingston point, although much of this is not mapped. This area contains two EPBC listed orchids and critical sites for at least five other orchid species. The area of most value extends to Pegs beach and Black beach. It was felt that detailed mapping of the vegetation in these areas is required to enable protection and that the site would be ideal for State purchase and protection (it currently sits on private land).

West inlet was also mentioned as providing major habitat for the Green and Gold frog in the past. This area was also a key Aboriginal landscape, rich in biodiversity and a critical food area for Aboriginal people. As such it can be expected that this area as well as the seascape transition landscape more generally also contains significant Aboriginal heritage values.

Feedback indicated that a previous RAMSAR nomination for the seascape landscape around Duck Bay and Robbins passage was unsuccessful even though it fulfilled more of the criteria than Tasmania's currently RAMSAR listed site. This was apparently rejected due to local landholder concerns. It was recommended that RAMSAR listing be sought again with efforts made to engage local landholders in the process and to address any of their concerns. It was felt that RAMSAR listing would have many benefits in terms of attracting more funding and increasing tourism through improved reputation and marketing opportunities for the area.

4.1.2 Riparian landscapes

Riparian landscapes have been mapped in Figure 15 using two different colours to represent two coarse differences in habitat. Feedback indicates that in all the mapped areas, riparian landscapes provide significant habitat for giant freshwater crayfish. In some catchments, in particular areas in Deep creek, the lower reaches of the Duck river (from Copper creek to Coventry creek) and Fixters creek in the Montagu river catchment, riparian areas also provide habitat for the Azure Kingfisher, which nests in holes drilled in the bank and hunts whitebait from perches in the riparian zone. These birds need intact riparian vegetation and flowing water and, along with the giant freshwater crayfish, are a good indicator species for the health of rivers and creeks in the area. Areas along the Duck estuary and all along the Duck River into Deep Creek also form part of the internationally recognised Important Bird and Biodiversity Area (IBA). The Duck River from Roger River to Copper Creek provides one of the only sites outside of King island and the Arthur River for the lime fern, which is listed as endangered by the *Threatened Species Protection Act 1995*. These plants grow on acidic limestone secretions on the riparian flats of this section of the Duck River.

Subcatchments that were identified as having very significant riparian landscapes in the Circular Head region, as mapped in Figure 15, are:

- Deep creek
- Duck river from Copper creek to Coventry creek
- Duck river from Roger river to Copper creek
- Fixters creek
- Geales creek
- Mills creek and Plains creek
- Montagu river Bond Tier to Montagu Plains
- Roger river

- Scopus creek
- Upper Duck river to Roger river
- Upper Montagu to Bond Tier

Major threats to the biodiversity values of these landscapes nominated were the clearing and fragmentation of vegetation, livestock access to the riparian zone and stream, weeds including willows, and poaching of whitebait and giant freshwater crayfish.

It was felt that simply excluding stock from the riparian zone with fencing placed to naturally avoid flood impacts and boggy areas was likely to protect the majority of values in these landscapes. While wider buffers would no doubt provide greater benefits than narrower buffers on the same stretch, it was stated that overall the greatest benefits are likely to be achieved by focusing on simply excluding stock from streams and providing off-stream water. This will allow native riparian vegetation to regenerate (with seed stock naturally persisting for 100 years for some species), banks to stabilise and water quality to improve. Removal of willow and other weeds needs to be targeted to where it is having significant on-site impacts, with a focus on restoration and rehabilitation, not just weed removal.

Poaching of whitebait is a big issue, especially around Deep creek. Reducing poaching is likely to require both education as well as greater enforcement of penalties.

In Scopus creek, runoff from acid sulfate soils is a threat to aquatic species. Soils in these areas need to be carefully managed to minimise any acid drainage. This requires education about the on and offsite impacts of disturbing these soils as well as education about ways in which these can be managed to avoid acid leaching.

The lower Duck River and its tributaries are very degraded, with high levels of sedimentation, willows, and stock accessing streams with associated manure and consequently poor water quality in the stream. Given its importance to GFC it was felt that the highest priority area for action in the riparian landscape in Circular Head is the lower Duck River from Poilinna rd to the mouth, and associated tributaries. The focus should be on stock exclusion from the stream through broad scale provision of off-stream water and fencing to exclude stock.

4.1.3 Wetlands and coastal lagoon landscape

Wetlands and coastal lagoons provide key habitat for threatened frogs, the Green and Gold frog and the striped marsh frog as well as for numerous bird species. They form an important part of the internationally recognised Important Bird and Biodiversity Area (IBA) in the region. This landscape occurs in parts of the coastal fringe of the Action Bay foreshore, Fentons Creek, Deep Creek, Montagu River Bond Tier to Montagu Plains, Montagu River Montagu Plains and Welcome River to Welcome Inlet subcatchments.

Key threats to the values in this landscape are changes to the hydrology of the area, particularly through drainage and construction of levees, livestock access and clearing and fragmentation of native vegetation.

Experts recommended that the values in these landscapes need to be better mapped to help prioritise areas for rehabilitation and protection, similar to recommendations for the seascape transition landscape. This will help identify areas where, for example, removal of levees may be a priority. Native vegetation needs to be protected from further clearing and fragmentation and livestock need to be fenced out of wetlands and coastal lagoons.

4.1.4 Grey Goshawk landscape

It was stated that landscapes which provide habitat for grey goshawks in the Circular Head region are typified by Blackwood swamp forests occurring on flats and rises throughout the catchment. Mill and Plains Creeks, Fixters Creeks, the Montagu River from Bond Tier to Montagu Plains, and the

North west corner of Tasmania in the Welcome River catchment were identified as containing key habitat areas for the grey goshawk. These areas contain numerous interesting and threatened forest dependent fauna, including threatened freshwater snails.

The greatest threats to these areas come from habitat fragmentation from clearing forest for primary production and grazing.

It was felt that protection of this landscape needs to come at a policy level, through the Statewide Planning scheme giving serious protection for important vegetation, not only threatened vegetation. Implementation of the permanent native forest estate policy, which would cover grey goshawk habitat and require a plan regardless of the scale of clearing in this landscape is needed to manage clearing and fragmentation of this landscape, its greatest threat.

4.1.5 Wild River – connected catchment to coast landscape

It was stated that the main section of the Welcome River catchment contains a unique connected catchment to coast landscape, where the river and its riparian foreshore largely exist in a wild state. Connected landscapes such as this one are considered to be key to allowing retreat and movement of fauna and flora with changes in temperature and sea level due to climate variability and climate change. They are fundamental to the resilience of many ecosystems in the face of environmental change. This area contains significant riparian vegetation, giant freshwater crayfish, and numerous other threatened and endangered species and communities. There are stands of *eucalyptus viminalis* which are unique in the North west coast and are a priority for protection. It was felt that this species is also likely to exist in some of the other mapped vegetation communities. There are also communities such as ovata forest and woodlands that have a small extent and so require protection to ensure their long term viability. It was stated that better mapping is required to determine the extent of ovata forest in the region, with expert opinion suggesting that if there is ovata present in places it is not currently mapped in TasVeg then this is likely to be some of the most important for this vegetation community in the State.

Experts stated that threats to this wild river landscape are clearing and fragmentation of vegetation and stock access to remnants and streams. Priority actions were considered to be protection and improvement of condition for small extent ovata and woodland forest communities through restricting stock access to remnants and reducing or avoiding clearing. Restricting stock access to streams is also important. Better mapping of ovata is required to prioritise areas for protection and ensure good planning and management decisions are to avoid negative impacts.

4.1.6 Robbins Island landscape

Expert advice suggests that Robbins Island is a priority landscape area for improved management. The island contains a remarkable diversity of flora and fauna, with the largest areas of intact saltmarsh in the State containing important invertebrate assemblages. Robbins Island, along with Wallaby Island, is a key habitat area for migratory birds and is known to contain many threatened plants and locally important species. It was felt that there are likely to be significantly valuable biodiversity assets there that are not mapped, in particular it was felt that there is almost certainly many threatened plant species that occur at Arthur River and King Island that aren't currently documented. There are significant wetland habitats and remnant vegetation patches with the island home to Green and Gold frogs. It was also felt that there are likely to be significant Aboriginal heritage values on the island.

Grazing is felt to be the main threat to biodiversity values, particularly in areas such as Mosquito Inlet where it is impacting on saltmarsh and subsequently important invertebrate assemblages. Windfarms were also seen to be a potential threat to some bird species.

It was recommended that a management plan should be developed for Robbins Island to identify priority areas, develop offsets and areas to be reserved. As part of this, a baseline survey of natural values including geomorphological and archaeological surveys should be carried out.

4.1.7 Coastal mosaic landscape

The Western edge of the Welcome River catchment to Studland Bay is considered by ecological experts to be a very interesting and unique area. It contains a mosaic of coastal scrub mixed with grasslands which is either unmapped or else mapped simply as coastal scrub or heathland. This area contains velvet tussock grass, which is found nowhere else. It is also incredibly important for many plants including a suite of threatened orchids, amongst them a critical population of the windswept spider orchid and rare greenhoods as well as annual herbs that occur around 4WD tracks and windswept heathland that don't occur anywhere else on the North west coast. This area is also important habitat for the Tasmanian Devil.

The Mount Preminghana (also known as Mount Cameron West) area contains the rare Preminghana billy button, which only occurs in a 0.1ha site in the Preminghana Indigenous Protected Area. This area also contains numerous Aboriginal values, including rock carvings.

The main threat to biodiversity values in this landscape is unrestricted or unregulated 4WD access. Many important plant species occur on the edge of 4WD tracks. Access to middens and wetland areas needs to be controlled or else access restricted if control is not successful. Experts stated that the broader issue in this landscape is that the area is being used in a very different way than in previous generations, both Aboriginal and European. The carrying capacity of the landscape to cope with these changes is an issue and current uses have the potential to significantly damage the functioning of this landscape.

The Marrawah skipper is a threatened species of butterfly that is endemic to Tasmania and known only from the coastal and near-coastal areas of northwest Tasmania. It lives in the sedge along drains and is threatened by stock access. The main management action to protect this species is the ensure stock are fenced out of drains.

4.2 General comments and recommendations

The expert group recommended that a desktop review analysis of natural values information such as TasVeg, threatened flora and fauna data, other priority species (locally significant) be undertaken with a view to identifying specific priority issues and areas where data needs to be fixed and sites or values map need to be better mapped or studied before meaningful management options can be developed.

They stated that long term monitoring is incredibly important to flag when changes are occurring. For example devil monitoring data which has been collected since the 1970s has suddenly become very important to show the impacts of facial tumour disease. They stated that this monitoring data needs to be collected over decades, not just a few years.

In terms of managing riparian corridors for biodiversity the first priority is to get stock out of streams and remnants. Ecological experts suggested that farmers will naturally fence around boggy areas and that given many species don't go far past the banks, this will fence out the key areas for protecting many riparian values. Starting with fences that exclude a tree length of the riparian zone, planting along the fence and working towards wider corridors over time was seen to be the best approach to maximising biodiversity outcomes. This approach will achieve improvements in water quality, and riparian vegetation and the natural stream condition will come back to some extent immediately. The same general approach should be used in coastal foreshore areas. It was felt that for the greatest biodiversity benefit it is better to have long lengths of stream or foreshore with narrow buffers where stock is excluded than having wider buffers around smaller focused patches of vegetation. Experts indicated that most vegetation types, particularly forest vegetation will come back simply with stock exclusion. For saltmarsh, tidal connectivity is the greatest issue, with fencing above this line required to protect biodiversity values in this landscape. Buffers can be widened out where there are good localised values and a landowner is willing (for example a good buffer might be 100m in one spot and 2m in another). Placing fences to minimise flood loss will provide some width with multiple benefits associated with broad scale narrow buffers.

In terms of specific small scale projects, efforts should also be made to implement actions in the PPP from DPIPWE's species prioritisation project. This provides a very good list of specific projects that can be undertaken at a range of budgets to secure individual threatened flora and fauna species.

Experts stated that education is key to ensuring the ongoing protection of biodiversity values in the area. This should include, for example, field days focused on the Giant Freshwater Crayfish, tree identification and general natural values in the area to increase the understanding of the local community of the biodiversity values they have and the potential for their own actions to have both positive and negative impacts. These should be hands on and promote case studies where farmers have taken positive action to protect and improve biodiversity and should include discussion of both the costs and the economic benefits to the farmer.

4.3 Feasibility of management actions

In general stakeholders felt that using terms such as 'biodiversity' is often alienating to farmers and other community members. It was felt that a focus on the benefits offered to species and communities that are more noticeably valued by the community, for example the benefits to woodland birds of healthy remnant vegetation and the links between clearing remnants and the loss of birds, is likely to encourage greater action than focusing on 'biodiversity protection'. Many barriers to the adoption of actions to protect biodiversity were identified. Table 1. Summary of feedback from key stakeholders on potential biodiversity management actionsTable 1 summarises feedback from key stakeholders on the adoptability and potential options to overcome barriers to adoption of management actions. A detailed description of these discussions is in Appendix 2.

TABLE 1. SUMMARY OF FEEDBACK FROM KEY STAKEHOLDERS ON POTENTIAL BIODIVERSITY MANAGEMENT ACTIONS

Actions	Likely level of adoption	Attitudes towards adoption	Options to overcome barriers
Fence off remnant vegetation	Low	Unlikely to see value in fencing small remnants Concerns about pests such as wallabies Likely to clear remnants to make irrigation easier Concern about fire hazards	Incentives to include wallaby proof fences Focus on benefits to woodland birds and other 'desirable' species Target education towards school children, benefits of remnants
Create vegetation corridors	Very low	Unlikely unless it is a riparian corridor Loss of productive land and issues with pests such as wallabies and possums	Focus on riparian corridors Fund wallaby proof fences where required by the landholder
Weed management	Variable	Dependant on the specific weed - economic threat to farming then adoptable Also depends on neighbouring properties as wasted effort unless the neighbours control weeds too	Targeted to mutual benefit for environment and farmer Engage neighbouring groups of landholders to ensure efforts on one farm aren't wasted
Pest control	Variable	Dependent on pest – deer, wallabies, possums and dogs named as pests but not seen as economic priorities for management; disease risks of cats for dairy cows was highlighted and more likely to act to manage this pest	Education focused on health risks for dairy cows from cats and appropriate control methods

Replacing introduced vegetation with native vegetation	Not adoptable	Would not take out existing vegetation but may plant extra vegetation	No action
Fencing wetlands	Low	Fenced areas seen to be hard to manage in terms of weeds and pests	Allow narrow buffers so weed management is easier
Hygiene control (weeds and pathogens)	High	Economic and on-farm benefits make these programs highly adoptable. Circular Head Council already ran a successful education program. Quality assurance programs starting to include hygiene practices.	Partnerships to ensure roll out of appropriate education programs for environmentally important weeds and pathogen control
Maintain stream characteristics and woody debris	Not adoptable	Economic imperative is to straighten streams and remove debris, avoid flooding. Argued that most farmers would manage the Montagu as a drain.	No action
Poaching	Unsure	Lobster and whitebait poaching both significant problems inn Circular Head.	Investigation and actions against poachers. Increased community awareness.
Reduce rubbish dumping	High	High leverage in the community because of the visibility of the problem. Big issue for farms and State Forests. Silage wrap is a major source of rubbish entering waterways. Questions over the usefulness of programs and musters	Education Targeted collection and clean up campaigns

Tourism and recreation		Impacts in terms of spreading weeds into areas that not previously accessed Also impacts on Aboriginal heritage sites especially middens	Signage and education
Acid sulphate soils	Not adoptable	Issue at Scopus creek Also soils present at northern end of Togari. Problem likely to occur in peat around summertime when groundwater is drawn down, then acid flushes with rains in April. Unlikely that farmers will stop using groundwater voluntarily	No action
Farm Water Action Plans & Certification schemes	High	Driver for best management practice adoption	Encourage certification programs that include actions to protect biodiversity TI continue to require FWAP from farmers accessing TI water

4.4 Recommendations for protecting and improving biodiversity values

Recommendations for protecting and improving biodiversity values in Circular Head are provided below.

4.4.1 Education and on-ground works

- Exclude stock from streams, wetlands and coastal lagoons and foreshore areas wherever possible.
    - The lower Duck River and its tributaries should be a particular focus of stock exclusion given its high value for GFC, potential water quality benefits and its generally degraded character.
- Stock should be fenced out of drains, particularly in the Welcome River catchment where the Marrawah skipper lives in drains and is impacted by stock access.
- Detailed mapping of the seascape transition landscape as well as wetlands and coastal lagoons is required. This mapping should be used, along with an economic evaluation of production costs and benefits of fencing areas out, to target and inform discussions with farmers around rehabilitation of these landscapes.

- The connected wild river landscape of the Welcome River catchment should be protected through:
    - protection and improvement of condition for small extent ovata and woodland forest communities through restricting stock access to remnants and reducing or avoiding clearing
    - restricting stock access to streams is also important
    - better mapping of ovata is required to prioritise areas for protection and ensure good planning and management decisions are to avoid negative impacts.
- Quad bike and 4WD access to Anthony Beach, Shipwreck Point and Perkins Beach as well as in the coastal mosaic landscape on the western edge of the Welcome River catchment should be managed. In the first instance this should focus on education and involvement of recreational users in works to protect values in these areas (such as construction of fencing). If this does not adequately protect biodiversity values in these areas, restrictions to recreational use of these areas should be considered.
- In terms of specific small scale projects, efforts should also be made to implement actions in the PPP from DPIPWE's species prioritisation project. This provides a very good list of specific projects that can be undertaken at a range of budgets to secure individual threatened flora and fauna species.
- Education activities focused on increasing community understanding of local biodiversity values and threats to these should be undertaken. This could include field days focused on the Giant Freshwater Crayfish, tree identification and general natural values in the area to increase the understanding of the local community. These should be hands on and promote case studies where farmers have taken positive action to protect and improve biodiversity and should include discussion of both the costs and the economic benefits to the farmer.

4.4.2 Planning and management

- A management plan should be developed for Robbins Island to identify priority areas, develop offsets and areas to be reserved. As part of this, a baseline survey of natural values including geomorphological and archaeological surveys should be carried out.
- RAMSAR listing should be sought again for the seascape landscape around Duck Bay and Robbins passage with efforts made to engage local landholders in the process and to address any of their concerns. The previous application can be used as the basis for a new application.
- The Statewide Planning Scheme should include protection for important vegetation rather than for threatened vegetation only.

4.4.3 Monitoring and Research

- A desktop review analysis of natural values information such as TasVeg, threatened flora and fauna data, other priority species (locally significant) should be undertaken with a view to identifying specific priority issues and areas where data needs to be fixed and sites or values need to be better mapped or studied before meaningful management options can be developed.
- Long term monitoring needs to be undertaken. This should continue existing monitoring projects as well as involve commencement of additional projects focused on key values and habitats.

Water Quality

5 CURRENT WATER QUALITY AND SOURCES OF POLLUTANTS IN CIRCULAR HEAD

Pollutant loads in the catchment have been estimated using the MiniCAPERDSS; a simple empirical model of the effects of land use and management on pollutant loads (see Kelly and White, 2015). Unless otherwise noted, all the water quality analysis and results in this BWQIP are based on this model.

The MiniCAPER DSS is a simple version of the CAPER DSS that has been developed for the Tamar Estuary and Esk Rivers catchment. The CAPER DSS is generally used where:

- a detailed catchment water quality model, such as the Source Catchments model, has been calibrated and verified, and
- a receiving water quality model is available to capture the impacts of changes in catchment water quality on the estuary.

By comparison, the MiniCAPER DSS uses a simple hydrological component based on observed streamflow from monitoring gauges in the catchment and rainfall surfaces provided by the Bureau of Meteorology. Substantial effort is generally put into the development of a comprehensive user interface for applications of the CAPER DSS in order to make it available to a range of end-users. The MiniCAPER DSS has been developed for in-house use and so uses a simple, functional interface to allow scenarios to be run and analysed without the overheads of the more detailed CAPER DSS interface.

The conceptual framework behind the MiniCAPER DSS developed for Circular Head is shown in Figure 16.

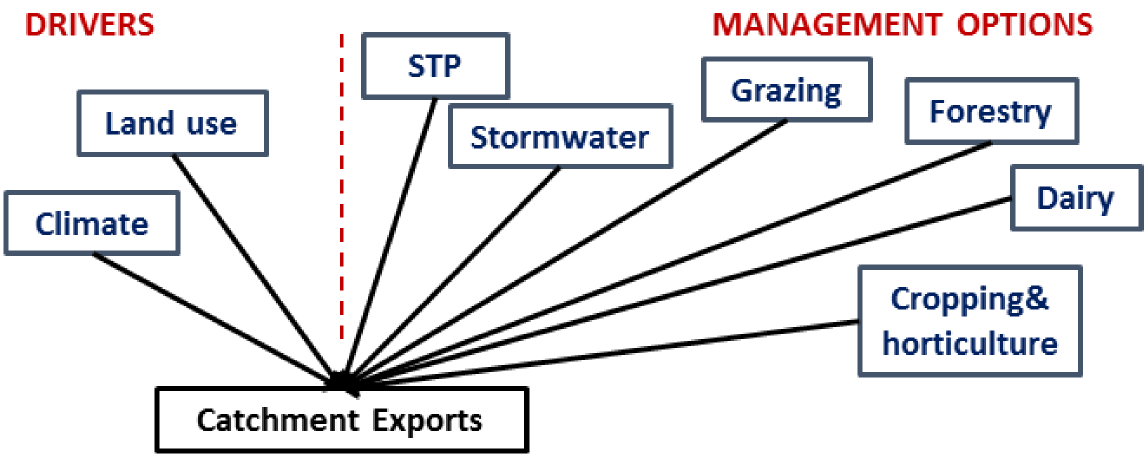


FIGURE 16. GENERALISED CONCEPTUAL FRAMEWORK

The catchment water quality model consists of a simple hydrological model which calculates quick and slow flows and a series of management modules. A description on the MiniCAPER DSS and can be found in Kelly and White (2015). Note that the approach to modelling flows as well as the dairy management module have both been modified for use in Circular Head. Loads from the Smithton STP have been estimated using data provided by TasWater.

As with all models the MiniCAPER 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 land use and management on total annual loads. 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 to total loads of various land uses and point sources 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).

5.1 Where do pollutants come from?

Estimates of loads from diffuse and point sources (point sources in this BWQIP consist of Sewage Treatment Plants) were made using the MiniCAPER DSS. There are no point source discharges in the Montagu or Welcome Rivers. The Duck River has a sewage treatment plant at Smithton that discharges directly into Duck Bay. The model indicates that the majority of pollutants entering the Duck River catchment are from diffuse sources rather than point sources. Figure 17 represents the proportion of diffuse pollutants, total nitrogen (TN), total phosphorus (TP), total suspended sediment (TSS) and enterococci, entering the catchment compared to that contributed by sewage treatment plants. The STP makes its greatest relative contribution to nutrients, with nearly 8% of TN and 6% of TP coming from this point source. It provides relatively little TSS and faecal coliforms, reflecting the relative simplicity of removing these pollutants from STP discharges compared to treatment for nutrients.

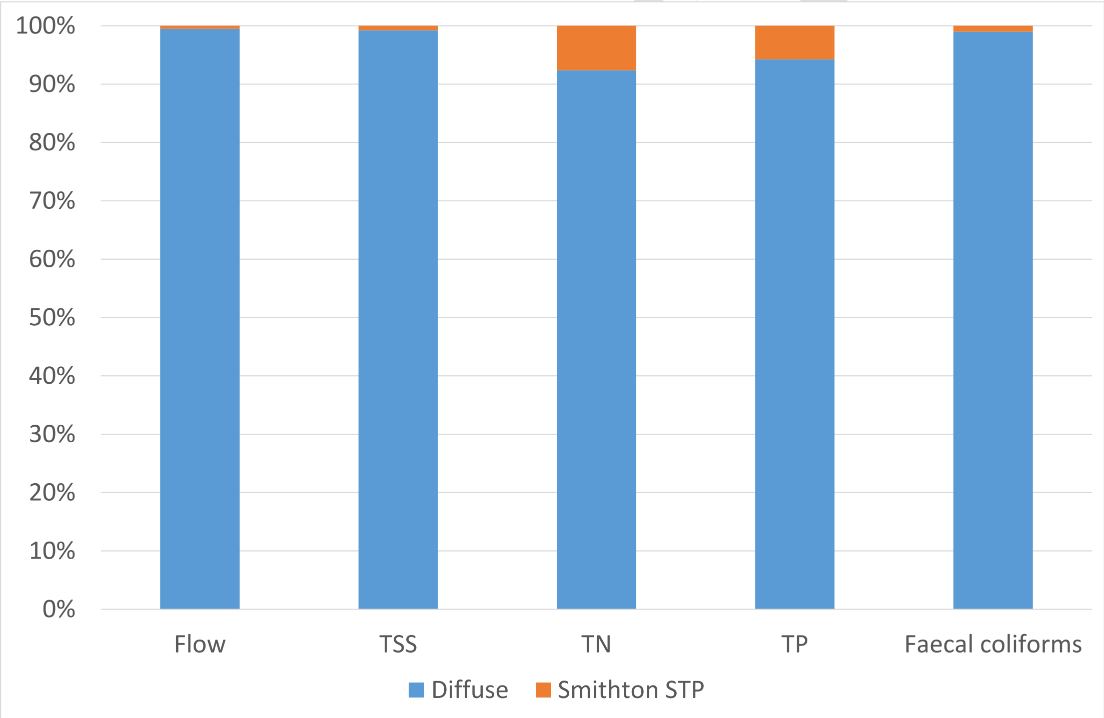


Figure 17. Diffuse pollutants versus point source pollutants in the Duck River Catchment. Note: TN – Total Nitrogen, TP – Total Phosphorus, TSS – Total Suspended Sediment

The MiniCAPERDSS was used to estimate the proportion of area and diffuse pollutants contributed by each land use in the catchment (greenspace, grazing, dairy, broadacre cropping, horticulture, rural residential, hardwood plantations, softwood plantations, native production forest and urban). These are shown in Figure 18 to Figure 20 for the Duck, Montagu and Welcome Rivers respectively.

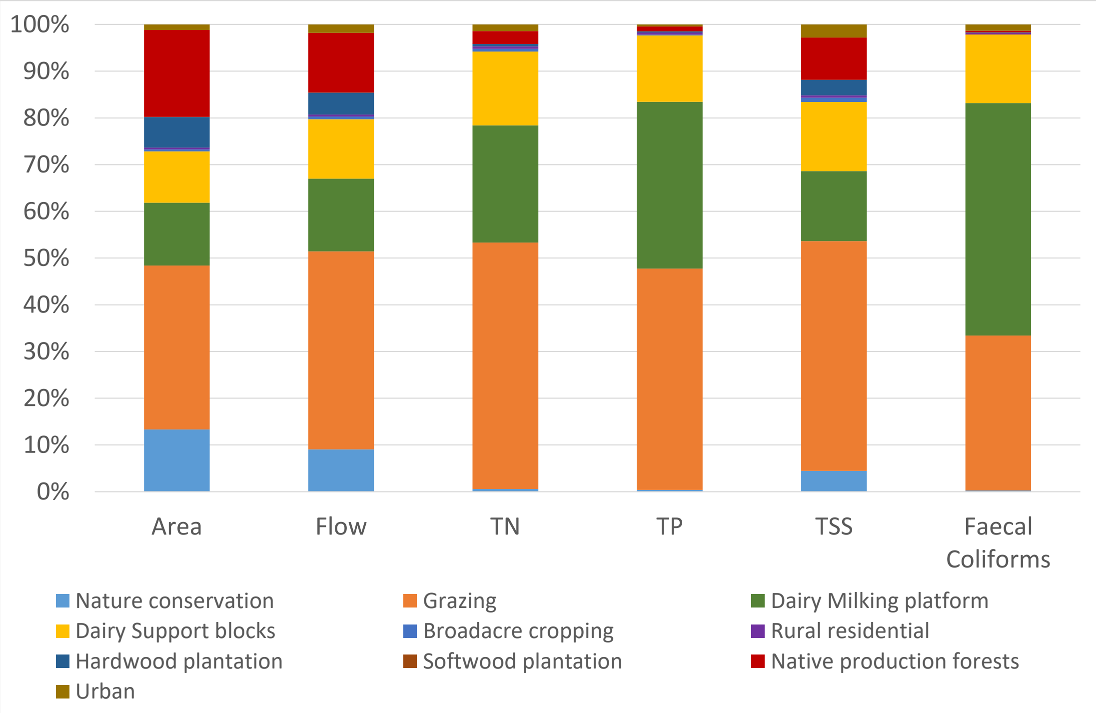


FIGURE 18. SOURCES OF DIFFUSE POLLUTANTS IN THE DUCK RIVER CATCHMENT. NOTE: TN – TOTAL NITROGEN, TP – TOTAL PHOSPHORUS, TSS – TOTAL SUSPENDED SEDIMENT

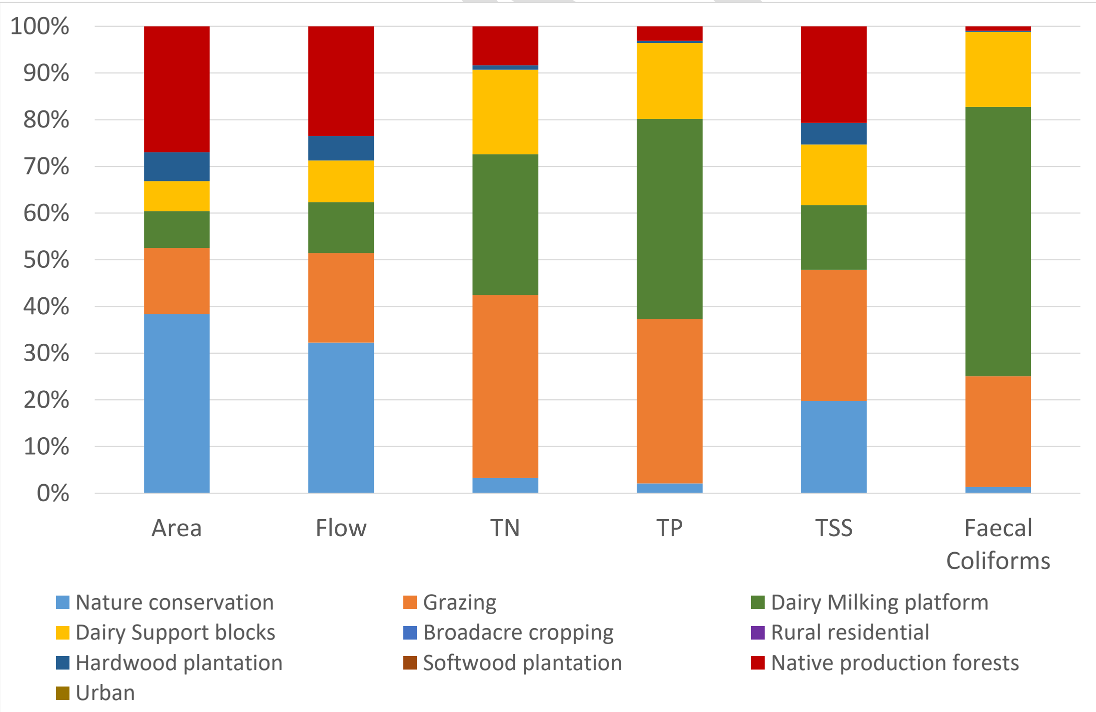


FIGURE 19. SOURCES OF DIFFUSE POLLUTANTS IN THE MONTAGU RIVER CATCHMENT. NOTE: TN – TOTAL NITROGEN, TP – TOTAL PHOSPHORUS, TSS – TOTAL SUSPENDED SEDIMENT

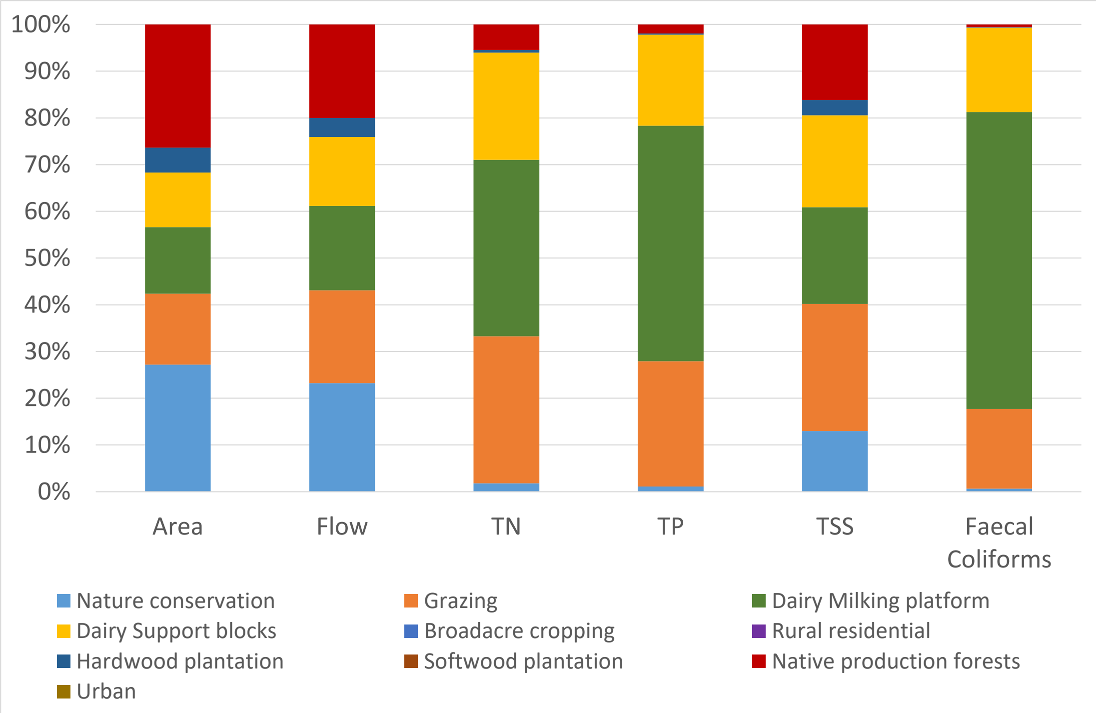


Figure 20. Sources of diffuse pollutants in the Welcome River Catchment. Note: TN – Total Nitrogen, TP – Total Phosphorus, TSS – Total Suspended Sediment

The contribution that each land use makes to pollutant loads depends not only on controllable factors such as land management but also on characteristics such as rainfall.

In all these catchments, nutrient and pathogen exports are dominated by grazing and dairy areas. Note that contributions from dairy are split between the milking platform and support blocks. The dairy milking platform contributes significantly greater relative TN, TP and faecal coliform loads compared to these other areas because of its greater intensity of use. These areas are also frequently subject to both high rainfall and man-made drainage systems such as hump and hollow that very rapidly export flows and loads from paddocks to the stream. Forested areas produce relatively more sediments (TSS) than nutrients or pathogens, although these are still smaller than either their relative contribution to flow or area.

5.2 Subcatchment Pollutant Loads

Pollutant loads for each subcatchment have been estimated using the MiniCAPERDSS. The following sections describe the relative contribution of subcatchments to total loads for each of the three catchment systems as well as the contributions of different land uses to areas, flows and loads for each subcatchment.

5.2.1.1 Duck river catchment

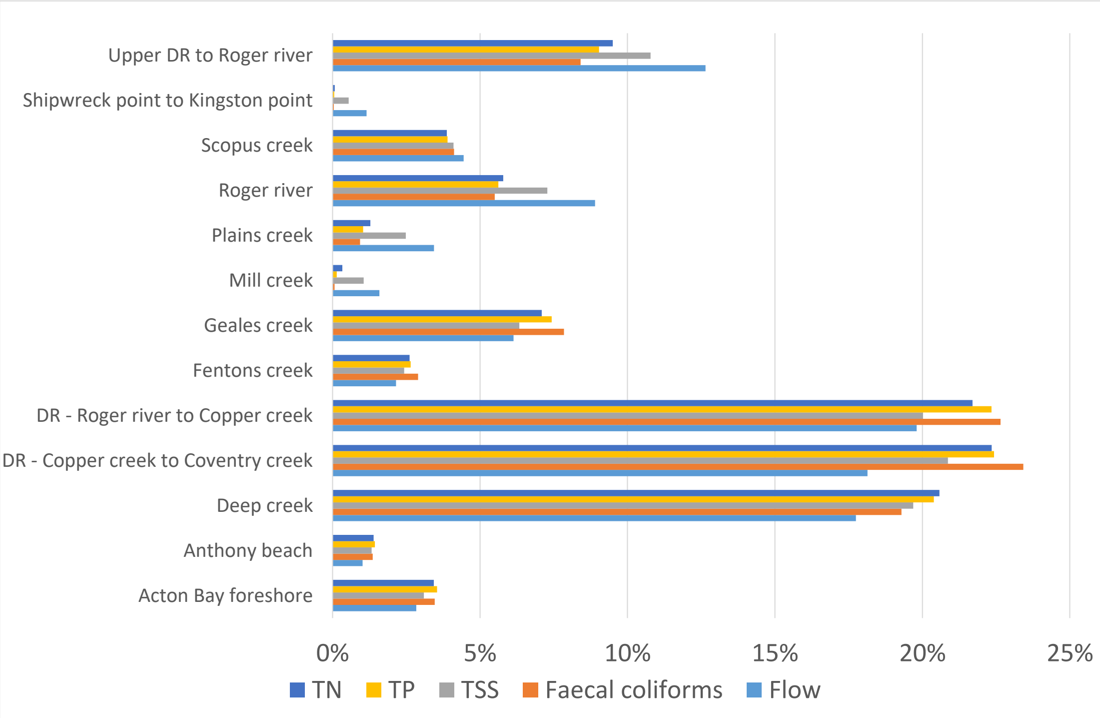


FIGURE 21. PROPORTION OF POLLUTANTS COMING FROM INDIVIDUAL SUBCATCHMENTS OF THE DUCK RIVER CATCHMENT. NOTE: DR IN THE AXIS LABEL REFERS TO 'DUCK RIVER'

Figure 21 shows that the majority of both flows and pollutants in the Duck River catchment are generated from the areas directly adjoining the Duck River rather than tributaries. Deep Creek is the exception to this, producing roughly 20% of pollutant loads. The Upper Duck River to Roger River produces nearly 10% of pollutant loads but this is lower than the relative flow coming from this subcatchment area. Geales Creek, Scopus Creek and the Roger River also produce significant proportions of pollutant loads (less than 5% for Scopus Creek and over 5% for the Roger River and Geales Creek).

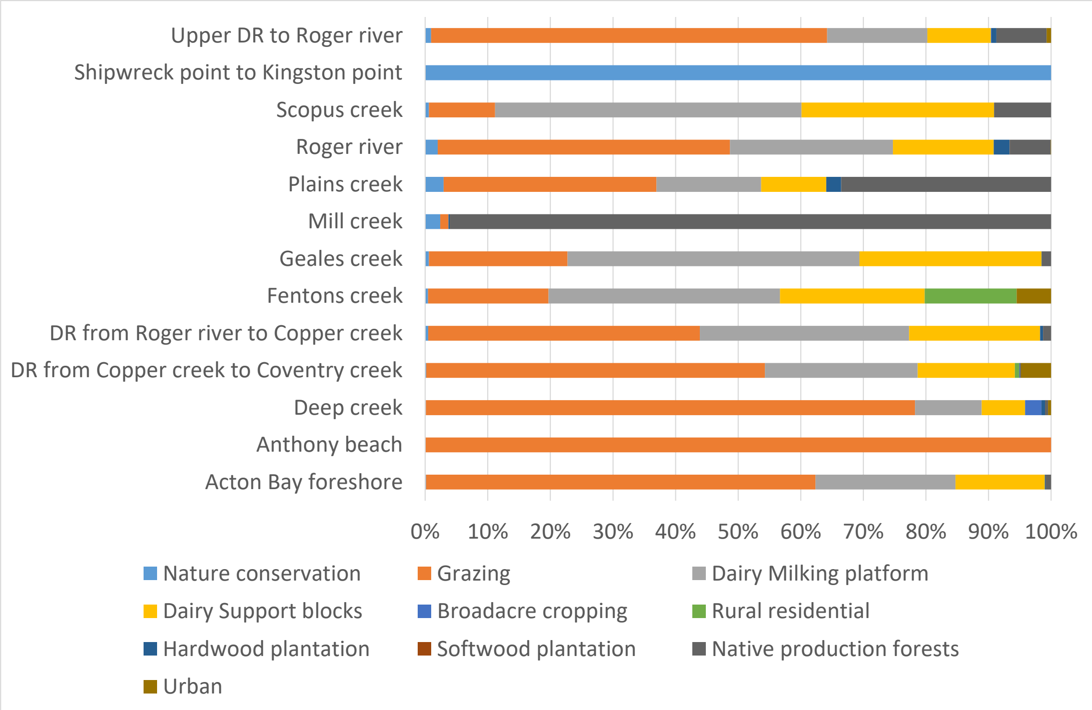


FIGURE 22. RELATIVE LAND USE CONTRIBUTION TO TOTAL NITROGEN (TN) BY SUBCATCHMENT FOR THE DUCK RIVER CATCHMENT. NOTE: DR IN THE AXIS LABEL REFERS TO 'DUCK RIVER'

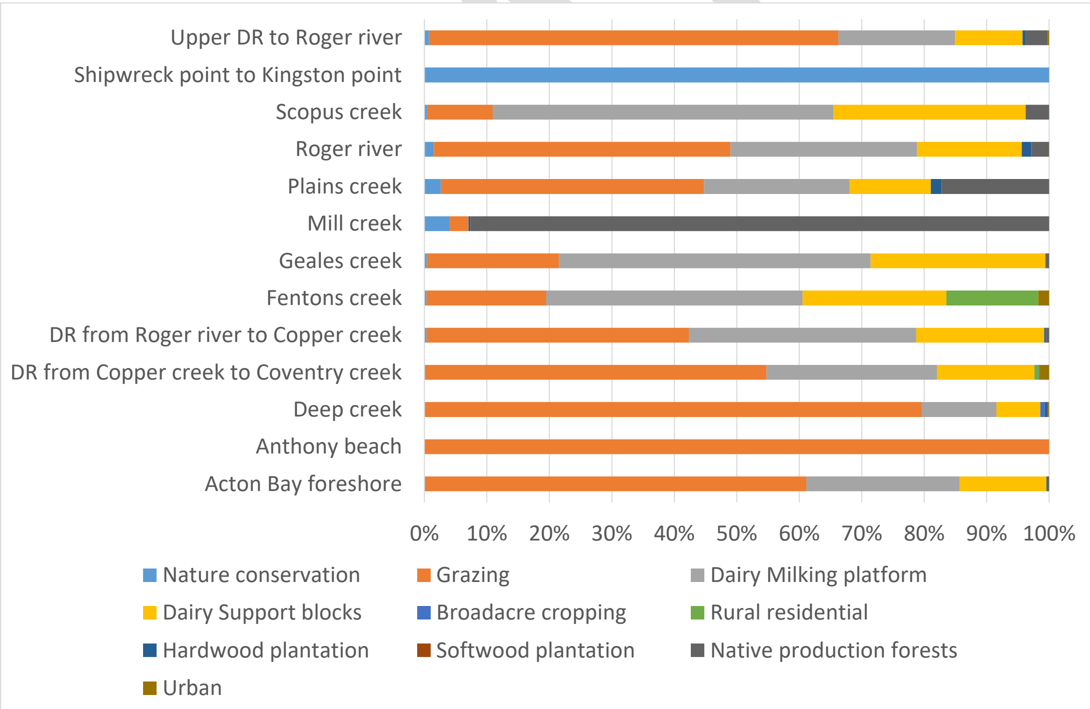


FIGURE 23. RELATIVE LAND USE CONTRIBUTION TO TOTAL PHOSPHORUS (TP) BY SUBCATCHMENT FOR THE DUCK RIVER CATCHMENT. NOTE: DR IN THE AXIS LABEL REFERS TO 'DUCK RIVER'

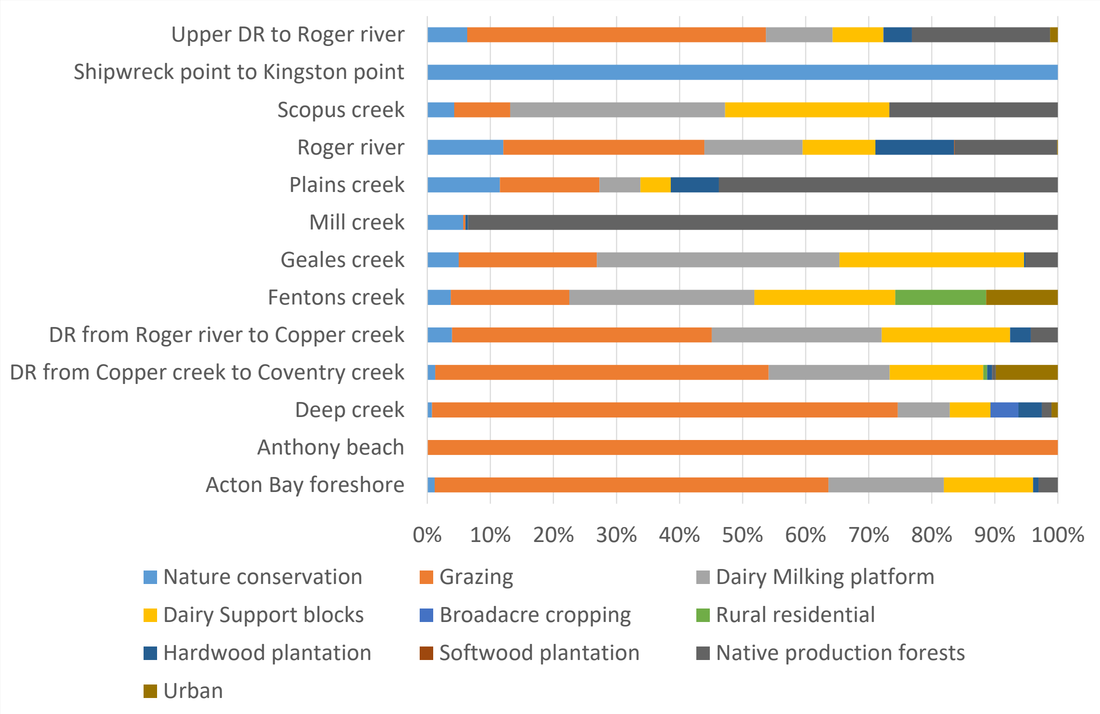


FIGURE 24. RELATIVE LAND USE CONTRIBUTION TO TOTAL SUSPENDED SEDIMENT (TSS) BY SUBCATCHMENT FOR THE DUCK RIVER CATCHMENT. NOTE: DR IN THE AXIS LABEL REFERS TO 'DUCK RIVER'

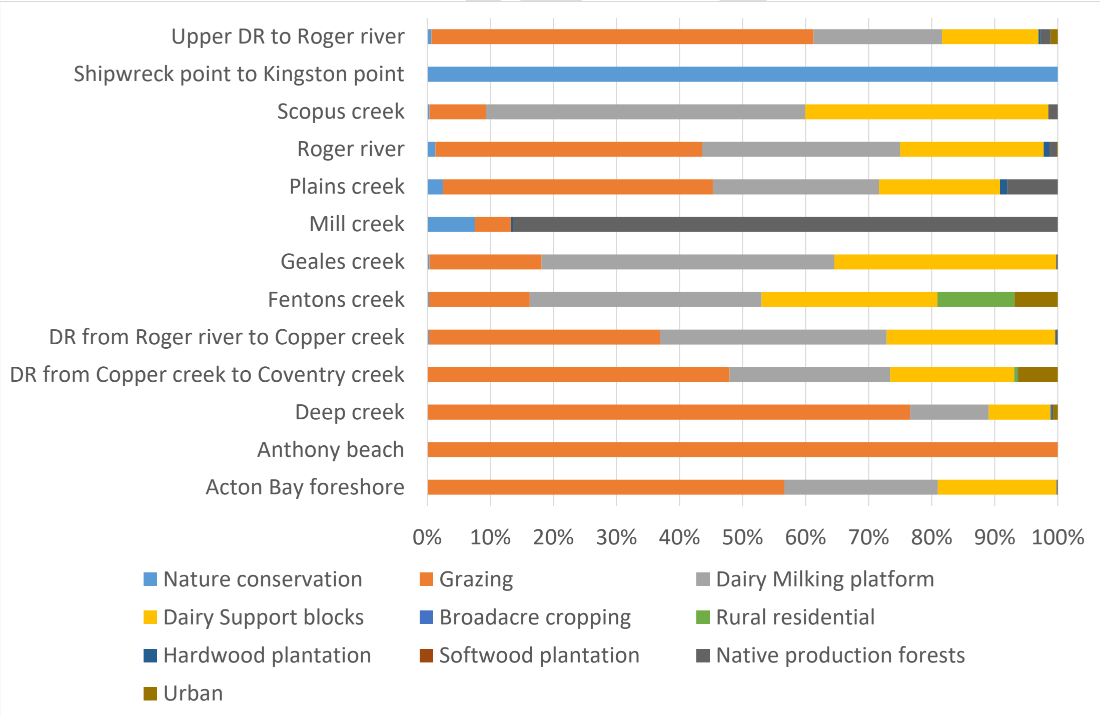


FIGURE 25. RELATIVE LAND USE CONTRIBUTION TO FAECAL COLIFORMS BY SUBCATCHMENT FOR THE DUCK RIVER CATCHMENT. NOTE: DR IN THE AXIS LABEL REFERS TO 'DUCK RIVER'

Figure 22 to Figure 25 show that pollutant loads in most catchments are dominated by grazing and dairy. Where substantial forestry areas occur, these areas contribute significant proportions of TSS. Fentons Creek is affected by rural residential uses with over 10% of pollutants coming from this land use. Urban areas contribute over 10% of the sediments, over 5% of TN and over 8% of faecal coliforms in Fentons Creek and the Duck River from Copper Creek to Coventry Creek.

5.2.2 Montagu river catchment

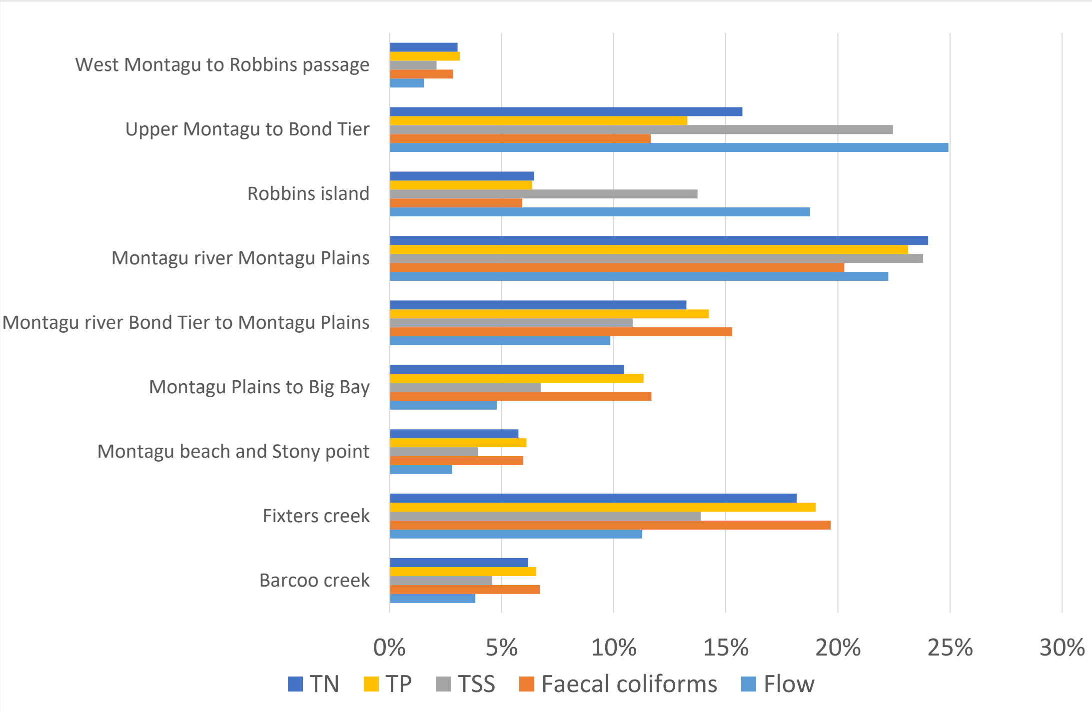


FIGURE 26. PROPORTION OF POLLUTANTS COMING FROM INDIVIDUAL SUBCATCHMENTS OF THE MONTAGU RIVER CATCHMENT

Figure 26 shows the proportion of flows and loads from subcatchments of the Montagu River catchment used in the analysis. This figure shows that areas that dominate the production of flows, the upper Montagu to Bond Tier and Robbins Island, produce relatively lower proportions of total pollutants although these are still substantial. Montagu plains is the greatest contributor to pollutant loads, generally in excess of its relative contribution to flows (with the exception of faecal coliforms which are relatively lower than flow contributions). Fixters Creek, Montagu River from Bond Tier to Montagu Plains and Montagu River to Big Bay are also major contributors to pollutant loads, all at greater levels than their relative contribution to flows.

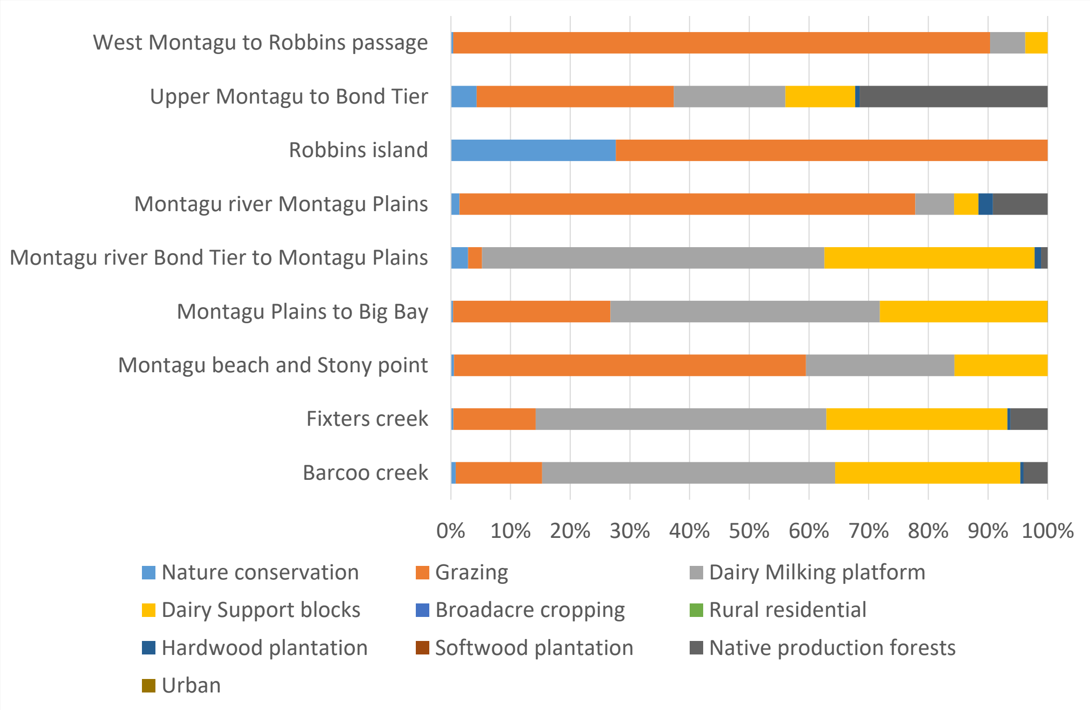


FIGURE 27. RELATIVE LAND USE CONTRIBUTION TO TOTAL NITROGEN (TN) BY SUBCATCHMENT FOR THE MONTAGU RIVER CATCHMENT

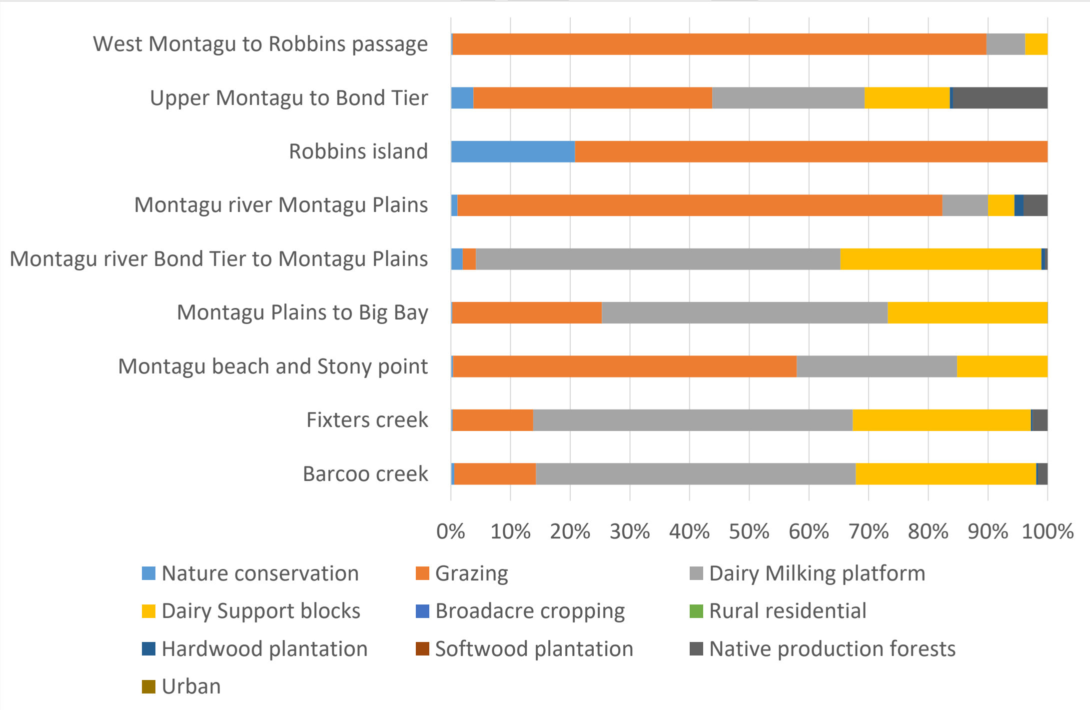


FIGURE 28. RELATIVE LAND USE CONTRIBUTION TO TOTAL PHOSPHORUS (TP) BY SUBCATCHMENT FOR THE MONTAGU RIVER CATCHMENT

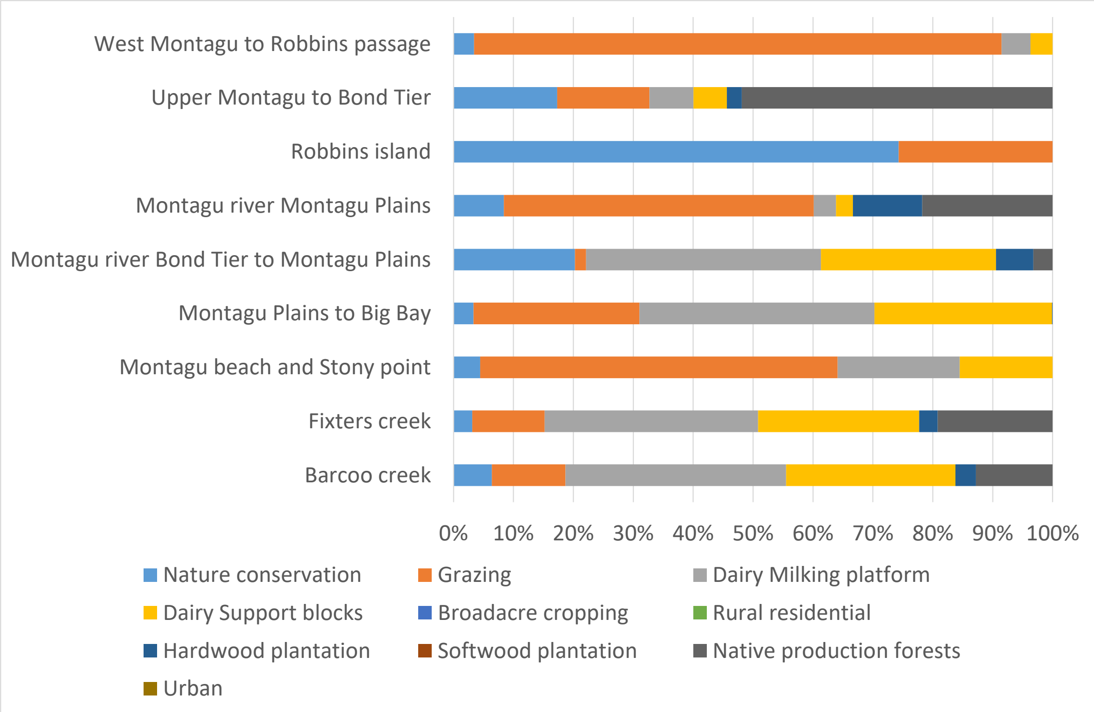


FIGURE 29. RELATIVE LAND USE CONTRIBUTION TO TOTAL SUSPENDED SEDIMENT (TSS) BY SUBCATCHMENT FOR THE MONTAGU RIVER CATCHMENT

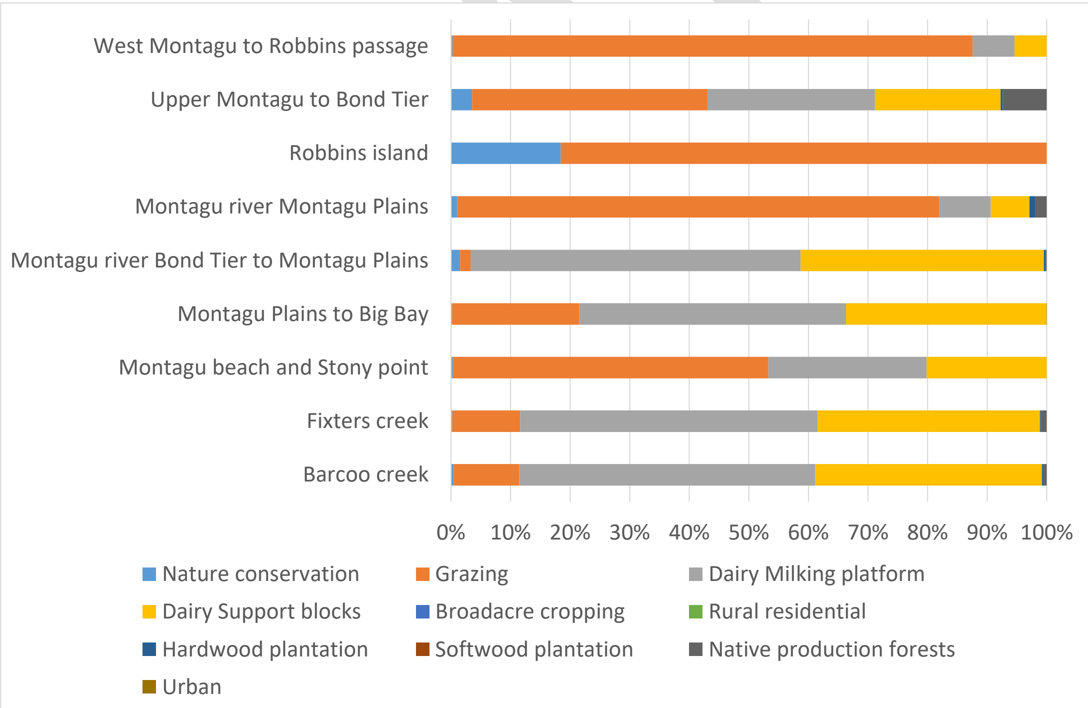


FIGURE 30. RELATIVE LAND USE CONTRIBUTION TO FAECAL COLIFORMS BY SUBCATCHMENT FOR THE MONTAGU RIVER CATCHMENT

Figure 27 to Figure 30show that in the Montagu River subcatchments, nutrients and faecal coliforms are almost entirely coming from dairy and grazing areas, with some contribution from native production forests and nature conservation areas where these are relatively extensive land uses. Forest areas produce relatively more sediments than nutrients or pathogens. Grazing and dairy areas are still generally an important source of sediments.

5.2.3 Welcome River catchment

The Welcome River catchment has been split into 4 major subcatchment areas. Note that because of the nature of this 'catchment' not all these areas drain to the Welcome Inlet, for example the Western edge drains directly to the ocean. Figure 31 shows the relative contribution of each subcatchment to flows and loads.

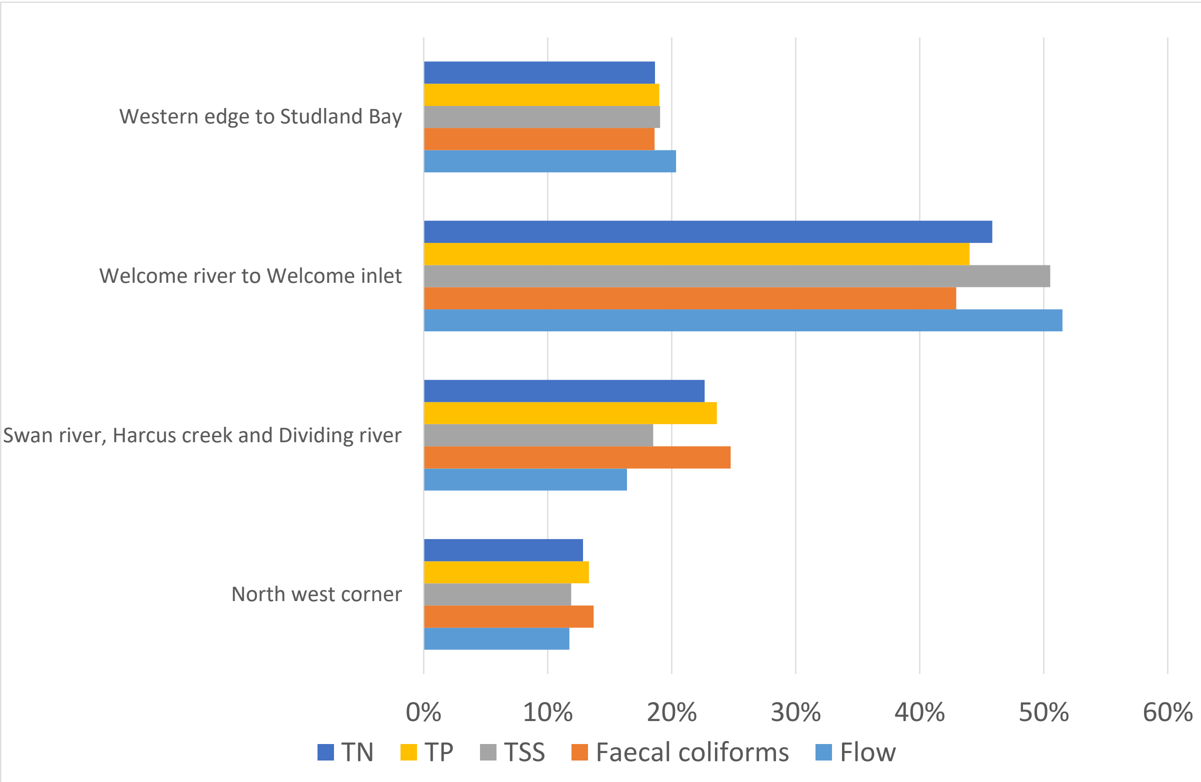


FIGURE 31. PROPORTION OF POLLUTANTS COMING FROM INDIVIDUAL SUBCATCHMENTS OF THE WELCOME RIVER CATCHMENT

This figure shows that the majority of loads and flows come from the Welcome River to Welcome Inlet (between 40 to 50%). Relative flows are slightly greater than relative loads in this catchment. The other catchments produce between 10 and 20% of flows and loads, with the pollutant loads most elevated compared to relative flows in the Swan River, Harcus and Dividing River subcatchment.

Figure 32 to Figure 35 show the relative contribution of each land use to these subcatchment loads.

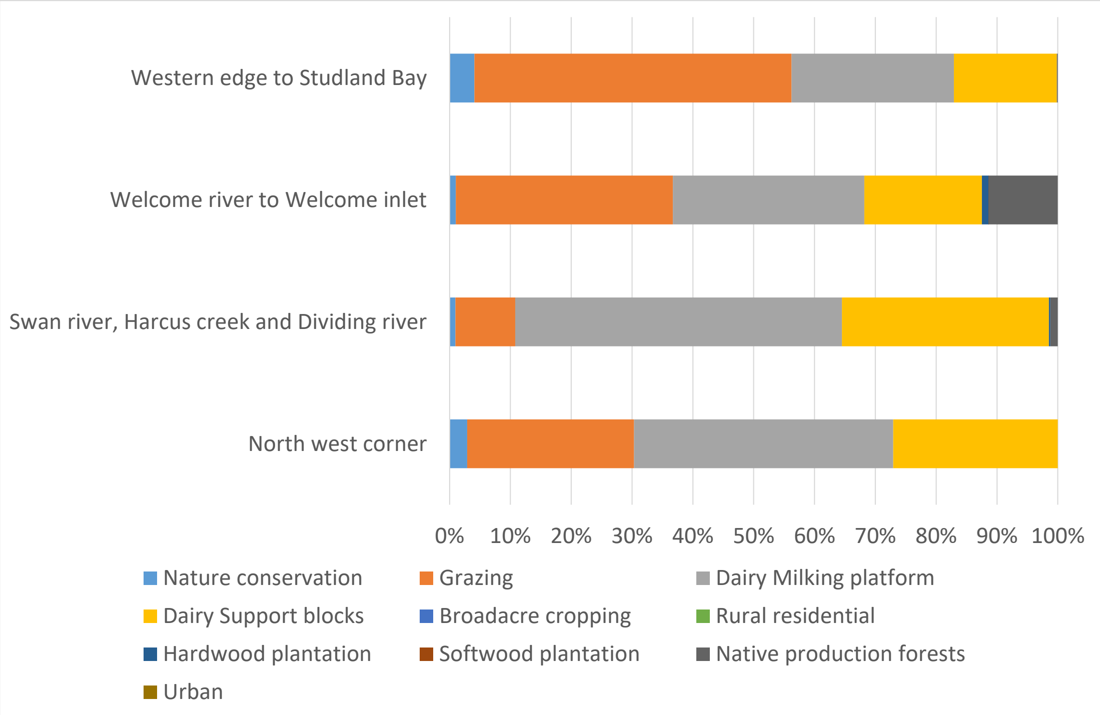


FIGURE 32. RELATIVE LAND USE CONTRIBUTION TO TOTAL NITROGEN (TN) BY SUBCATCHMENT FOR THE WELCOME RIVER CATCHMENT

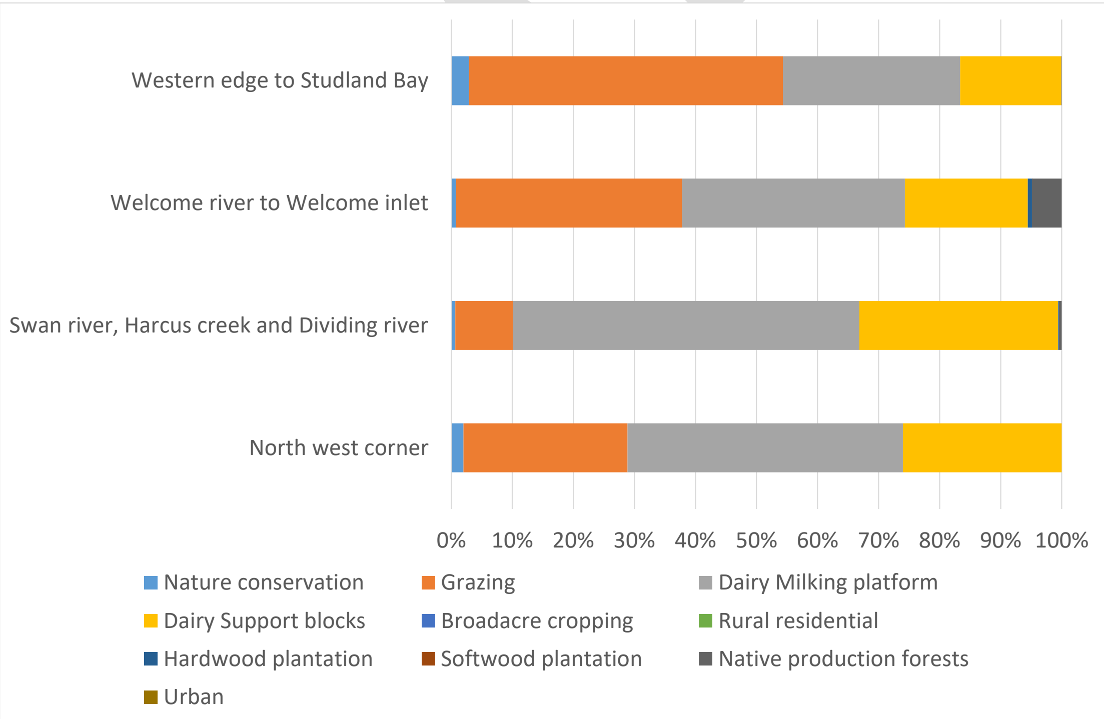


FIGURE 33. RELATIVE LAND USE CONTRIBUTION TO TOTAL PHOSPHORUS (TP) BY SUBCATCHMENT FOR THE WELCOME RIVER CATCHMENT

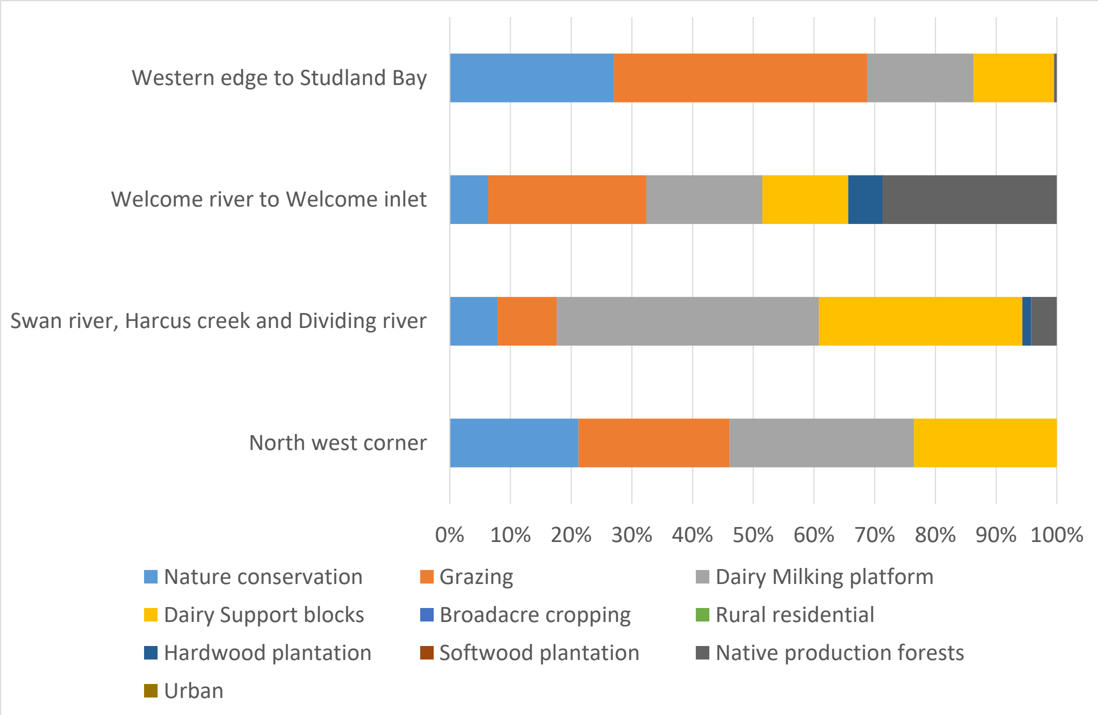


Figure 34. Relative land use contribution to Total Suspended Sediment (TSS) by subcatchment for the Welcome river catchment

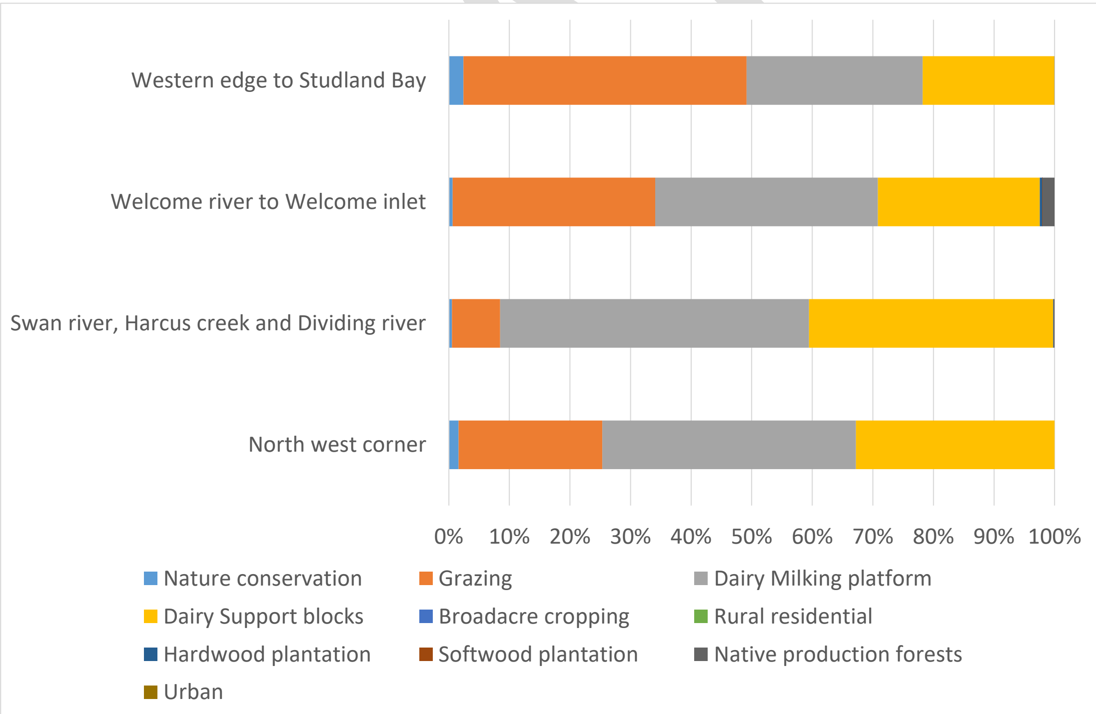


Figure 35. Relative land use contribution to Faecal Coliforms by subcatchment for the Welcome river catchment

These figures show that in all the Welcome River subcatchments, pollutant loads are dominated by grazing and dairy areas. Native production forests and nature conservation areas do produce significant proportions of sediments where these land uses are extensive, such as the Welcome River to Welcome Inlet subcatchment.

The next sections look at the impacts of poor water quality on the oyster industry in Duck Bay before exploring a range of options for improving water quality in all three Circular Head catchments.

6 Impacts of Water Quality on the Oyster Industry in Circular Head

The oyster industry in Circular Head was estimated to be worth $1.87 million in 2006 and to employ 41 permanent and 15 casual staff. Oyster leases can be found in Duck Bay as well as in Robbins passage, fed by the Duck and Montagu River systems. Figure 36 shows the location of oyster leases in the Circular Head region.

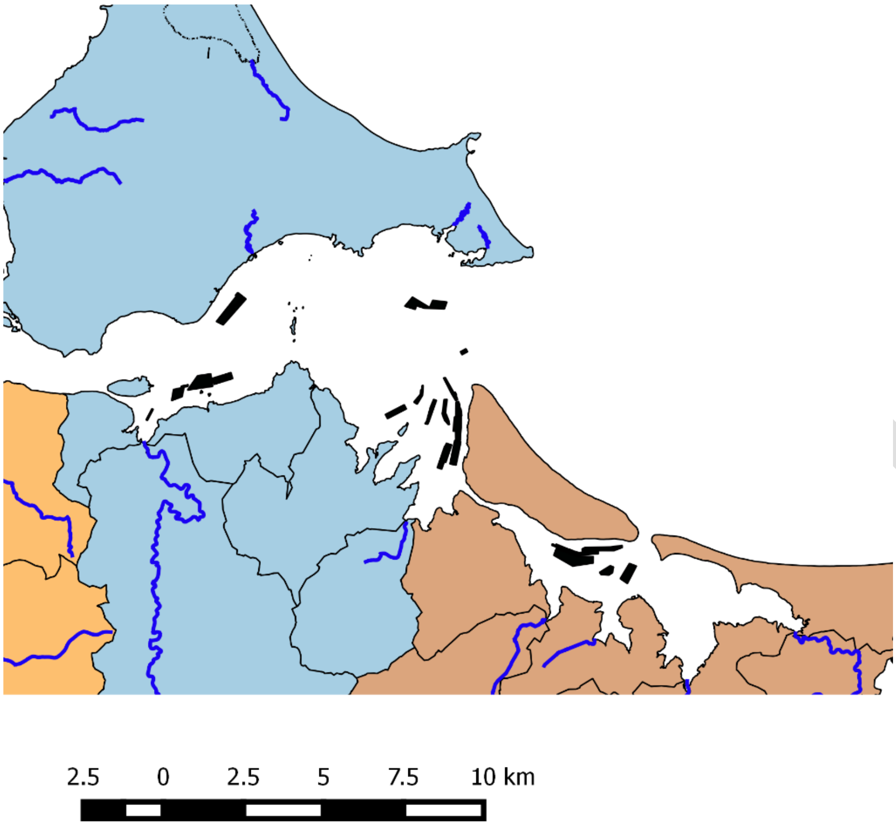


Figure 36. Oyster leases in Duck Bay and Robbins passage

Oysters in Circular Head are harvested for consumption as well as being relayed as juvenile stock to other oyster growing areas. Juvenile stock may be relayed elsewhere in Tasmania as well as to mainland Australia – in particular Tasmania supplies a large amount of juvenile stock to South Australia. While the recent outbreak outbreak of POMS disease has not affected oyster farms in the North-west of Tasmania, it has led to limits on the movement of spat from Tasmania, with an immediate ban on movement likely to be followed up by restrictions to movement for the foreseeable future.

The safety of oysters for human consumption affected by pathogens such as ecoli, thermotolerant coliforms and viruses, heavy metals and biotoxins such as algae. These pollutants can come from diffuse sources or from sewer spills. Oyster leases are closed when pollutant levels are too high to be safe for human consumption. Two major triggers are used to close the leases: a runoff event from the catchment, indicating a diffuse pollution event; or, a sewer spill from urban areas.

6.1 Closure system

When oyster leases are closed, oyster farmers are unable to harvest and sell adult stock. Juvenile stock can be sold or adult stock relayed to other leases to depurate but this stock needs to be quarantined for a period of time. If a closure occurs close to the time when adult stock would be ready for harvest, then stock are likely to grow too large to sell or will at least lose value. As noted above, POMS disease has also impacted on the ability of Tasmanian oyster growers to relay juvenile stock, limiting this as an option to reduce the economic impacts of closures.

6.1.1 Diffuse pollution events

Closures triggered by diffuse pollution events are based on salinity and/or flow triggers. These are used as surrogates for pathogens, in particular thermotolerant coliforms, which affect the safety of oysters for human consumption. The Tasmanian Shellfish Quality Assurance Program (TSQAP) are responsible for regulating opening and closures of oyster leases. They determine flow and salinity trigger values based on analysis of flow, salinity and pathogen data. At least 5 samples of thermotolerant coliforms are collected each year. At least the last 30 observations (generally 6 years of data) are then used to develop relationships between flow, salinity and thermotolerant coliforms from which the trigger values are created. TSQAP conduct a comprehensive assessment of all factors affecting the oyster fishery every 3 years and then conduct an annual review of trigger levels to ensure they remain fit for purpose. Currently leases are closed in Duck Bay when flow at Scotchtown weir is 2.5 cumecs or salinity at the lease is 32.5ppt. Leases in Robbins passage are closed when flow in the Montagu River reaches 0.8 cumecs.

Flows in the Duck River at Scotchtown weir versus the flow trigger of 2.5 cumecs are shown in Figure 37. Figure 38 shows the flows in the Montagu River at Stuart Rd versus the flow trigger of 0.8 cumecs.

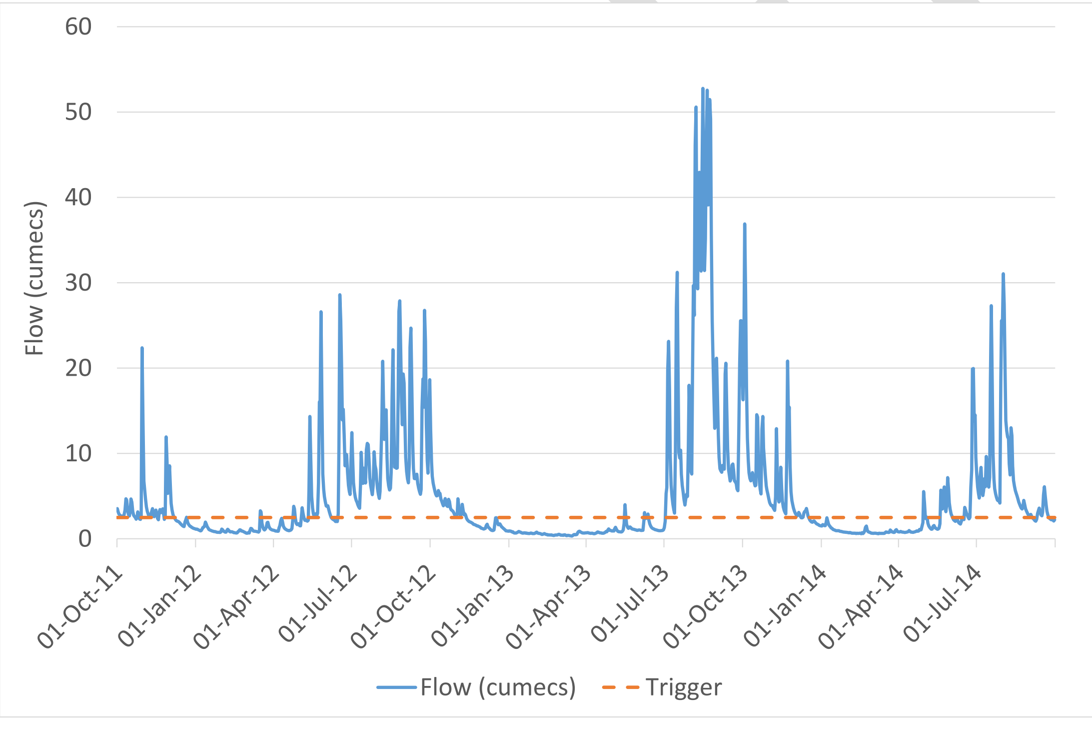


Figure 37. Flows in the Duck River at Scotchtown weir versus the flow trigger for closures

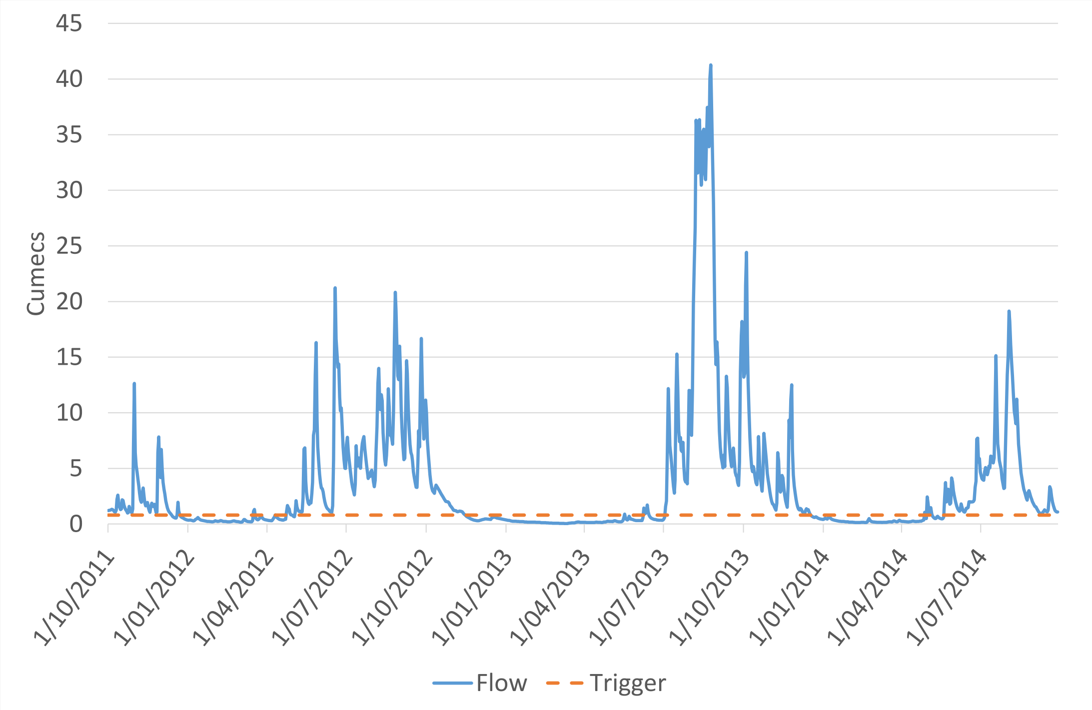


FIGURE 38. FLOWS IN THE MONTAGU RIVER AT SCOTCHTOWN WEIR VERSUS THE FLOW TRIGGER FOR CLOSURES

These figures show that flows in both these rivers are greater than the trigger value for half the year, with some small isolated peak flows that would lead to lease closures during periods when the leases would otherwise be open.

The trend in the number of days that leases in Duck Bay are closed as well as the salinity trigger value over the last 20 years is shown in Figure 39.

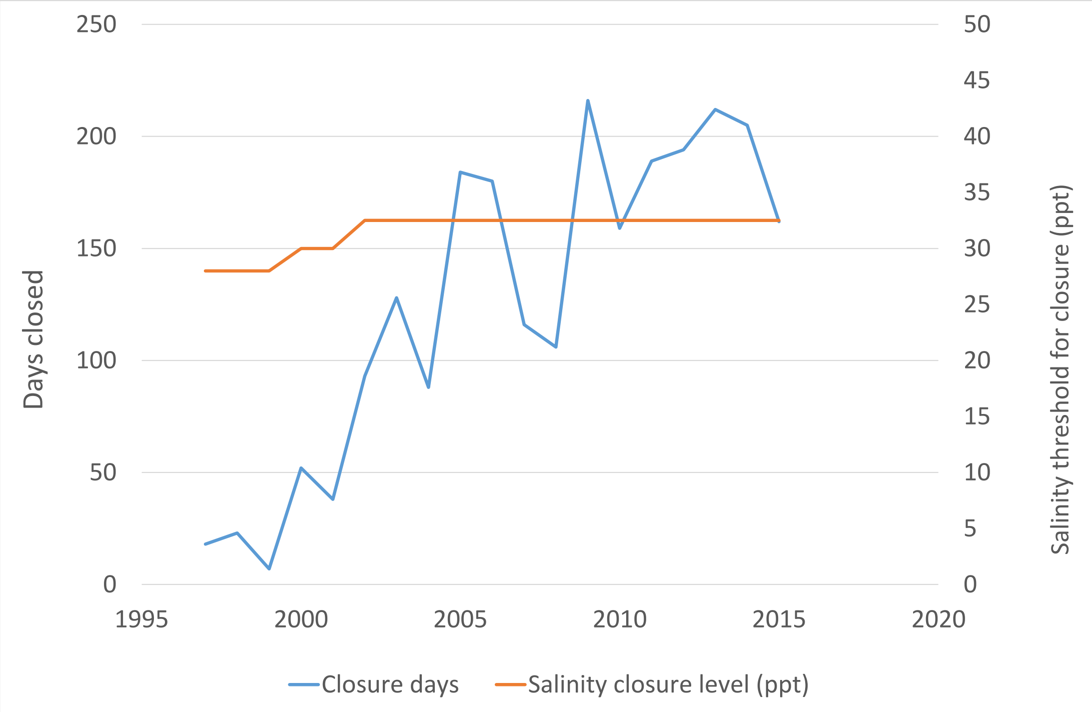


FIGURE 39. TREND IN THE NUMBER OF DAYS EACH YEAR LEASES ARE CLOSED AND THE SALINITY TRIGGER VALUE IN DUCK BAY

This figure shows very clearly the steep upward trend in the number of closure days over this period, corresponding largely to the increases in the salinity trigger value. From 2011 to 2015 the average number of days the leases were closed was over 190 per year, compared with an average of 16 days from 1997 to 1999.

The costs for monitoring water quality at the leases are split between oyster growers and the State Government. Currently only sporadic salinity measurements are taken at the lease due to the costs associated with taking samples. Given this, closures for diffuse pollution are based on flow triggers at the weir only – 15km upstream of the estuary. Given the tidal influence on the leases it's likely that this flow gauge is poorly related to the salinity at the leases, meaning there is potentially at least a lag time where the flow trigger is met but the lease could remain open for harvesting or during which time oysters could be lifted to avoid impacts from diffuse pollution, or even that there are periods where the lease could have been reopened based on salinity measurements but wasn't because continuous monitoring wasn't available. Ideally pathogen levels would be used as the basis of these decisions but the slow turn-around time of samples and the cost of monitoring for pathogens means a salinity surrogate is the most effective means of regulating closures for the moment.

6.1.2 Sewer overflows

The second cause of oyster lease closures in Duck Bay is overflows from the sewer system. These overflows can occur from the sewage treatment plant but in general occur in the sewerage system before this, either due to failure in the mains or pump station failure. No overflows from the sewage treatment plant occurred for the financial years 2012/13 to 2014/15 (more recent data could not be sourced, although anecdotal evidence suggests overflows have occurred in the intervening years).

When overflows do occur they come from either the Davy st Pump station or from failure in the mains. Section 9 of the Plan describes causes of sewer overflows in more detail.

TasWater have to notify TSQAP of when a sewage spill or pump station failure occurs. A Situation Report is compiled including the location, time and estimated volume of the spill. The report also includes an assessment of who is likely to be impacted and to what extent based on tides in the Bay.

TasWater have to undertake testing for thermotolerant coliforms at multiple sites to estimate the impacts of the spill. Oyster leases remain closed for 21 days following a sewage spill to ensure any contamination of the oysters by viruses and bacteria is no longer an issue.

6.2 Recommendations

In terms of reducing the frequency and duration of oyster lease closes, improvements in water quality in terms of pathogen concentrations are required. This will require addressing both the frequency and volume of sewage overflows as well as improving the quality of runoff from the catchment. The rest of this Plan details actions that are recommended to improve water quality, both in terms of diffuse pollutants from the catchment and as point sources from the sewage treatment plant and sewer overflows.

In the short term before changes in management can be expected to take effect, closure periods could be minimised by the installation of continuous salinity monitoring at the oyster leases. This monitoring would allow for a lead time between the flow trigger being met at Scotchtown weir and water quality at the lease being impacted. This would allow time for some oysters to be lifted or harvested before the closure takes effect. In addition it may allow the leases to be reopened earlier than is currently the case using only sporadic salinity measurement. A funding proposal has previously been developed jointly by the oyster and dairy industries. This proposal estimated that 5 salinity probes would be required, at an upfront cost of $50,000, with an additional $10,000 a year being required to clean the probes to ensure they are working properly.

Recommendation. Options for funding a proposal for continuous salinity monitoring in Duck Bay should be further investigated. Any changes to monitoring would need to be overseen by TSQAP to be able to be used as part of the closure system.

7 Dairy management in Circular Head

Dairy is a major economic and social contributor to Circular Head and the Tasmanian economy with approximately 40% of all dairies in Tasmania located in the Circular Head region. Productivity gains have been achieved by intensification of land use with some farmers achieving an increase in production on the same area of land of over 300% in 30 years. Intensification of production has associated off-site consequences that are due in part to methods of production as well as physical processes that occur in the landscape of Circular Head. Dairy covers approximately 14% of the total area of the Montagu catchment and 24 to 26% of the Duck River and Welcome River catchments respectively, with dairy areas split roughly in half between support blocks and the milking platform. Dairy is a significant source of off-site pollutants in the Circular Head catchments, producing nutrients, sediments and pathogens at a rate much higher than its relative area. Figure 40 and Figure 41 show the relative contribution of the dairy milking platform and dairy support blocks respectively to catchment area and loads.

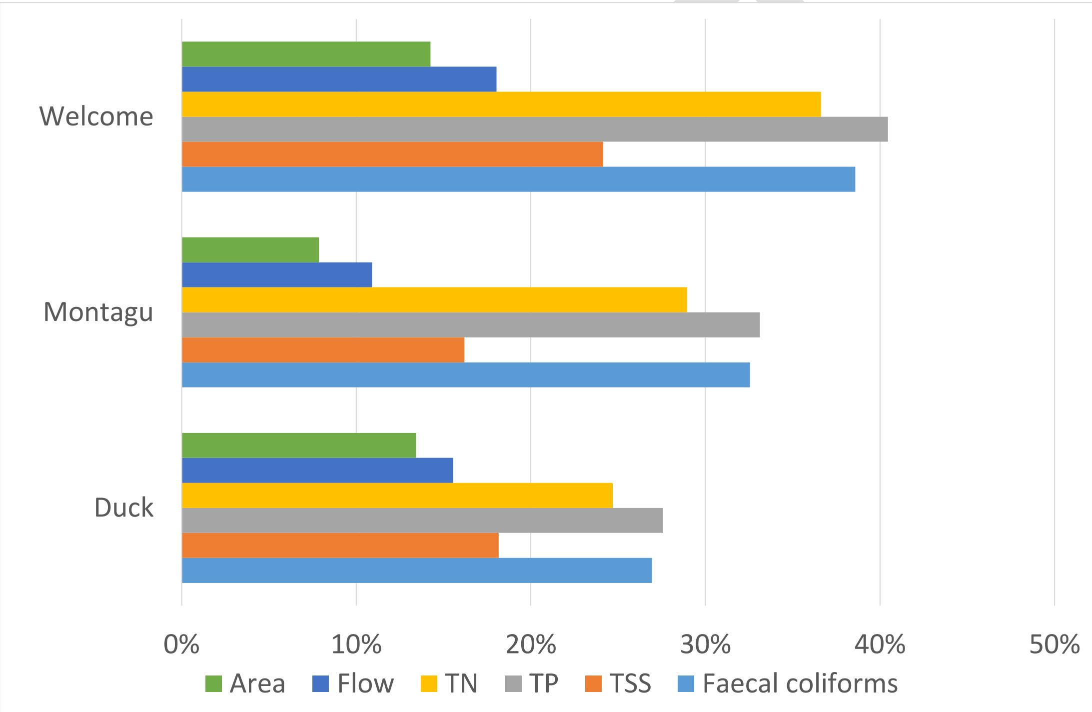


Figure 40. Relative contribution of dairy milking platform to area and catchment loads

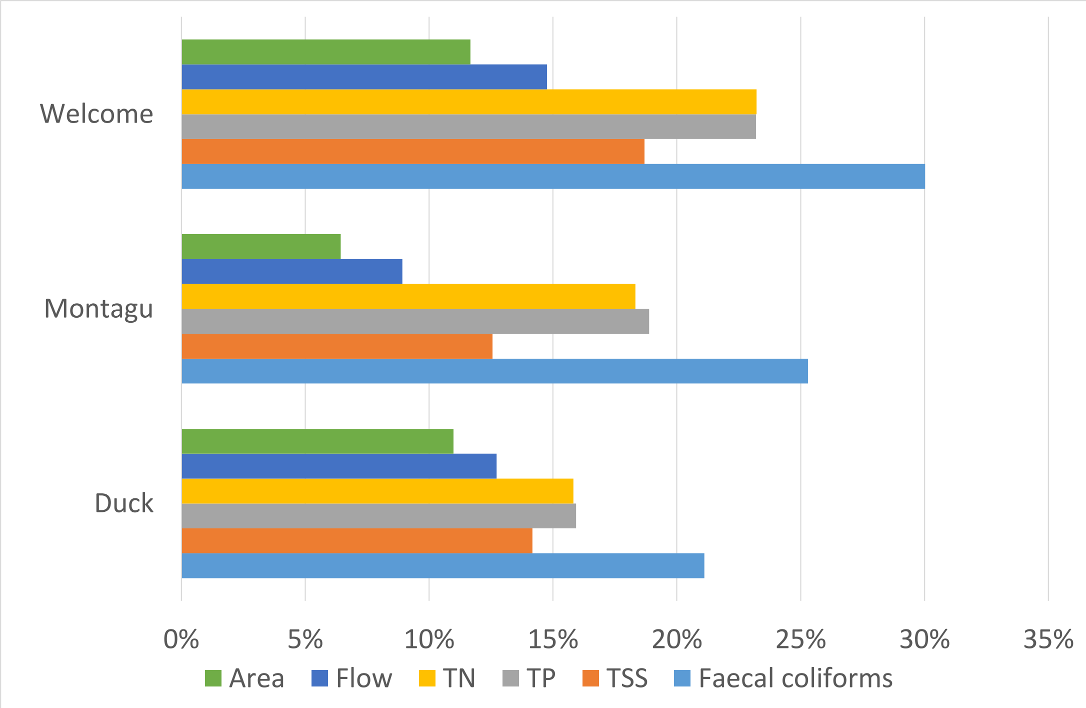


FIGURE 41. RELATIVE CONTRIBUTION OF DAIRY SUPPORT BLOCKS TO AREA AND CATCHMENT LOADS

These figures show that combined, dairy areas produce 40 to 60% of TN, 44 to 64% of TP, 30 to 43% of TSS and 50 to 70% of faecal coliforms. This is greater than both their relative area (14 to 26%) and relative contribution to flows (20 to 33%). The more intensive use of the milking platform leads to greater pollutant exports relative to area and flows from this part of the farm.

Figure 40 shows:

- Flows from dairy milking platform areas are slightly greater than their relative area in all catchments. This is because dairy milking platforms tend to be in wetter areas of the catchment where greater runoff per unit area occurs. This will account for some of the elevated loads from these areas as runoff and flows are a major driver of pollutant exports. However contributions to pollutant loads generally exceed these relative flow contributions, indicating that flow does not account for the majority of the difference.
- Dairy milking platforms contribute roughly between 2 and 4 times as much TN as their relative area, producing 25% of TN loads from the Duck river catchment, 29% from the Montagu river catchment and 37% from the Welcome river catchment.
- These areas contribute from 28% to 40% of TP loads, at a rate of between 2 and 5 times their relative area.
- Dairy milking platform areas are not a major contributor to sediments but still contribute more than their relative area or flow, with TSS loads roughly 1 ½ to 2 times their relative area and 1 to 1 ½ times their relative flow.
- These areas contribute 27% to 39% of the faecal coliforms from these catchments with the greatest relative contribution in the Welcome river catchment. These relative loads are between 2 and over 4 times the relative contribution of dairy milking platforms to area.

Figure 41 shows that the lower intensity of use on support blocks means that relatively less pollutants will be exported from these areas than from the milking platform. Pollutants are still exported at a sometimes significantly greater rate than the relative contribution of dairy support blocks to either area or flows. The greatest relative proportions occur in the Montagu with these least relative contribution of dairy to the Duck river catchment. Support blocks contribute:

- Between 9 and 15% of flows at a rate 1.16 to 1.39 of their relative area.
- Between 16 and 23% of nutrients, at a rate 1.4 to 2.94 times their relative area.
- Between 13 and 19% of TSS, at a rate 1.29 and 1.95 times their relative area.
- Between 21 and 30% of faecal coliforms, at a rate 1.92 and 3.93 times their relative area.

It is clear from these results that managing exports of nutrients and pathogens from dairy areas is key to improving water quality. Managing these areas likely to lead to smaller but still significant relative improvements in sediment loads.

Management of pollutant exports from dairy areas in Circular Head is made difficult by the very wet nature of these catchments and the extensive drainage systems that have had to be used to make some areas viable for farming. Paddocks in these areas are saturated for most of winter, meaning that runoff and pollutant exports are generated very readily. Extensive use of drainage approaches such as hump and hollow then move this water off paddocks directly to the stream very quickly. Providing sufficient effluent storage to ensure that effluent does not need to be irrigated out onto wet paddocks is very difficult, given the need for 7 months or more of storage in some areas. Finding sufficient paddocks onto which to irrigate this volume of effluent during summer months without generating runoff or over fertilising areas is a second issue. High groundwater levels in many areas mean that storages need to be lined or built above ground, both expensive options.

There are a wide range of actions that have been considered to reduce pollutant exports from dairy milking platforms in Circular Head:

- Increasing effluent storage to increase the period of time in which effluent does not end up being applied to wet paddocks;
- Reducing milk shed water use to reduce the generation of effluent, again reducing pressures to apply effluent to paddocks during wet periods;
- Allowing for small volumes of effluent irrigation over winter applied at a slow rate during relatively drier (but still wet) conditions;
- Moving stock off water logged paddocks to a feed pad as a standoff area;
- Managing the timing of irrigation relative to fertiliser application;
- Using deficit irrigation, so irrigating only when soils are dry at the volumes required to adequately wet the soils;
- Managing fertiliser application to the right rate and timing to minimise runoff due to rainfall events;
- Excluding stock from streams;
- Excluding stock from drains (not hump and hollow);
- Revegetating riparian zones; and,
- Retaining laneway runoff on farm.

The MiniCAPERDSS has been used to estimate potential percent reductions in pollutant loads in the catchment with the implementation of these management actions. Two sets of scenarios were run. The first shows the potential leverage of each of these options for reducing pollutant loads, assuming 100% adoption of actions could be achieved. First the interaction between management actions on farm is explored, demonstrating that the best action often depends on the current management practices of the farm before the highest impact options at a catchment level are described. The second set of scenarios uses feedback from key stakeholders about the relative adoptability of each of the actions in Circular Head to estimate a 'feasible' impact of each action on water quality.

7.1 Leverage of potential management actions

The first question to consider when recommending management practice adoption is: how effective would this practice be if it were adopted by 100% of farms? This question relates to the leverage of individual management practices in reducing pollutant export. The leverage of individual practices around effluent and stock management depends to a large extent on the level of effluent storage available to the farmer. The interactions between these practices and levels of storage at a farm scale is first described before the leverage of individual management practices at a catchment scale for reducing pollutant loads is considered.

7.1.1 Interactions between management practices at a farm scale

The most effective management action for farmers to adopt to manage their effluent depends to a certain extent on the volume of effluent storage they currently have or are able to invest in. In some cases a change that would reduce pollutant export from one farm has the potential to exacerbate it when applied to another farm. This section demonstrates some of these interactions before the leverage all management actions at a farm scale is explored.

Four base levels of storage on farm were considered, with the same set of management actions applied to each. Where sufficient storage isn't available, increases in storage to each of the relevant base levels are also considered.

Figure 42 compares the impacts of these actions on farms with differing base effluent storage levels.

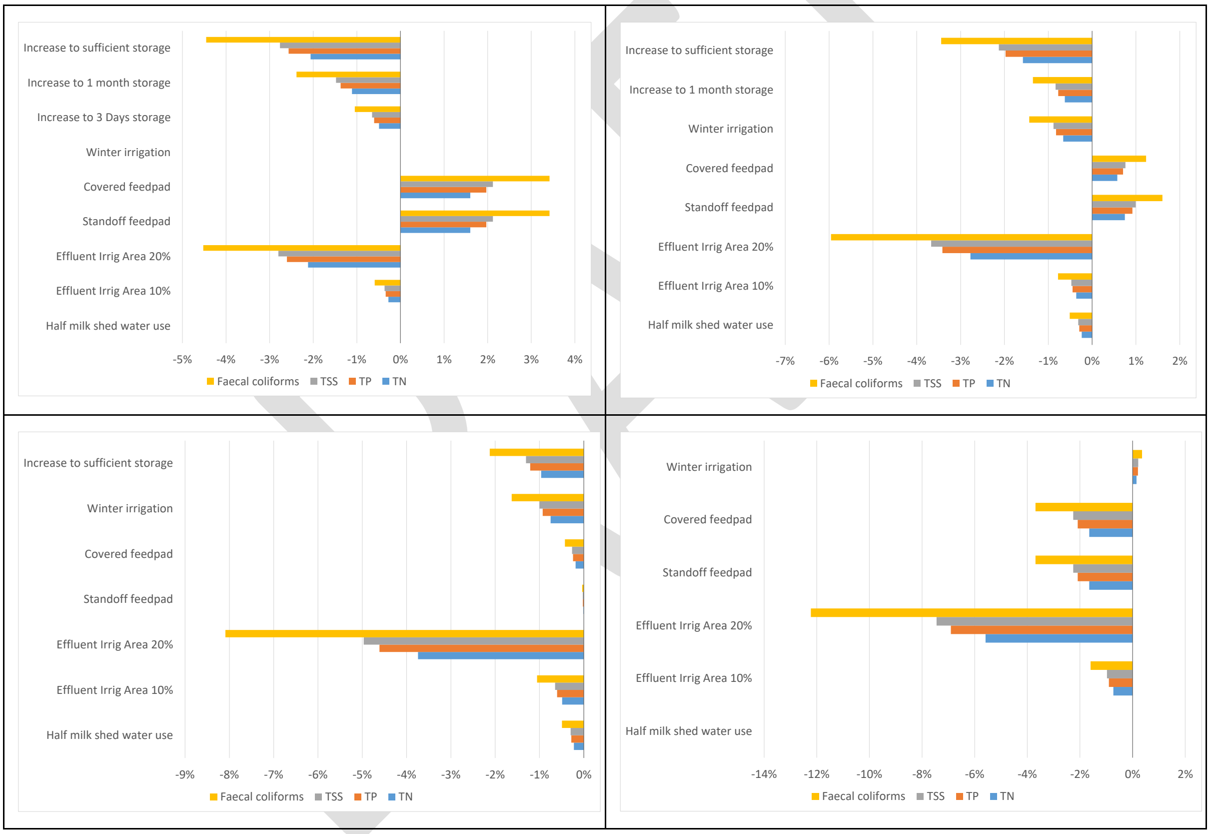


FIGURE 42. IMPACTS OF EFFLUENT MANAGEMENT PRACTICES GIVEN DIFFERENT BASE EFFLUENT STORAGE LEVELS

This figure shows that increasing effluent storage always has benefits. Increasing storage capacity from a direct application system to only 3 days of storage will reduce pollutant exports from the farm by 0.5 to 1%, increasing to 1 month of storage would reduce loads by 1 to 2.5% while installing sufficient effluent storage with no other improvement in effluent management could be expected to reduce loads exported off the farm by 2 to 4.5%. Relative impacts are always smallest on nutrients and greatest on pathogens.

The figure also shows that in all cases, increasing effluent irrigation area is a very effective way of reducing pollutant exports. Greater effluent irrigation areas means paddocks are more likely to be able to use the nutrients applied without them running off.

Other actions vary in their value depending on how much effluent storage is available on the farm:

- Where the farm has no storage no actions except increasing effluent area or increasing storage will reduce pollutant load exports. Using feedpads as standoff areas can be expected to increase pollutant exports from the farm as this load is concentrated to a small area and allowed to runoff the farm, as opposed to being spread more evenly across the paddock. This doesn't account for the benefits to the soil of reduced pugging.
- Where small amounts (3 days) of storage is available allowing for slow rate winter irrigation on soils that are not actively running off can lead to decreases (0.7 to 1.4%) in pollutant load export. Additionally halving milk shed water use can also decrease pollutant exports by 0.2 to 0.5%. Using feedpads as standoff areas can still be expected to increase pollutant exports, but by less than was the case with direct application systems.
- Where farmers have a month of storage these actions are can lead to greater relative improvements than was the case with 3 days of storage, with a 0.2 to 0.5% decrease from halving milk shed water use and a 0.8 to 1.6% from slow rate winter irrigation. In this case covered feedpads are also an option worth exploring with 0.2 to 0.4% decreases in pollutant exports expected. Uncovered feedpads could be expected to have no net benefit.
- Where farmers have sufficient effluent storage, decreases in milk shed water use aren't expected to have water quality benefits. Both covered and uncovered feedpads could be expected to have benefits (noting that the volume of storage required would increase under this option). These options are relatively similar in terms of their outcome. Use of slow rate winter irrigation would be of no net benefit and could lead to small increases in pollutant export.

It should be noted that in these scenarios the total volume of storage was set based on the days of storage available either with or without a feedpad. This means that while the scenario shows no change in pollutant export from, for example, halving milk shed water use where a farmer has sufficient effluent storage, the actual benefit to the farmer is likely to be in reducing the size of the storage that is 'sufficient'. This will mean a less costly solution to managing effluent can be attained.

7.1.2 Leverage of management practices at a catchment scale

The estimated leverage of these management actions to decrease pollutant loads in the Circular Head catchments is shown in Figure 43 to Figure 50. For ease of reading and interpreting the results, actions have been split into two sets – a high leverage set and a lower leverage set. Actions not included in the analysis are those that were found to either have no impact or in some cases to increase pollutant loads (as described above in the farm scale results). These figures all assume that 100% adoption of the given management action occurs across the landscape.

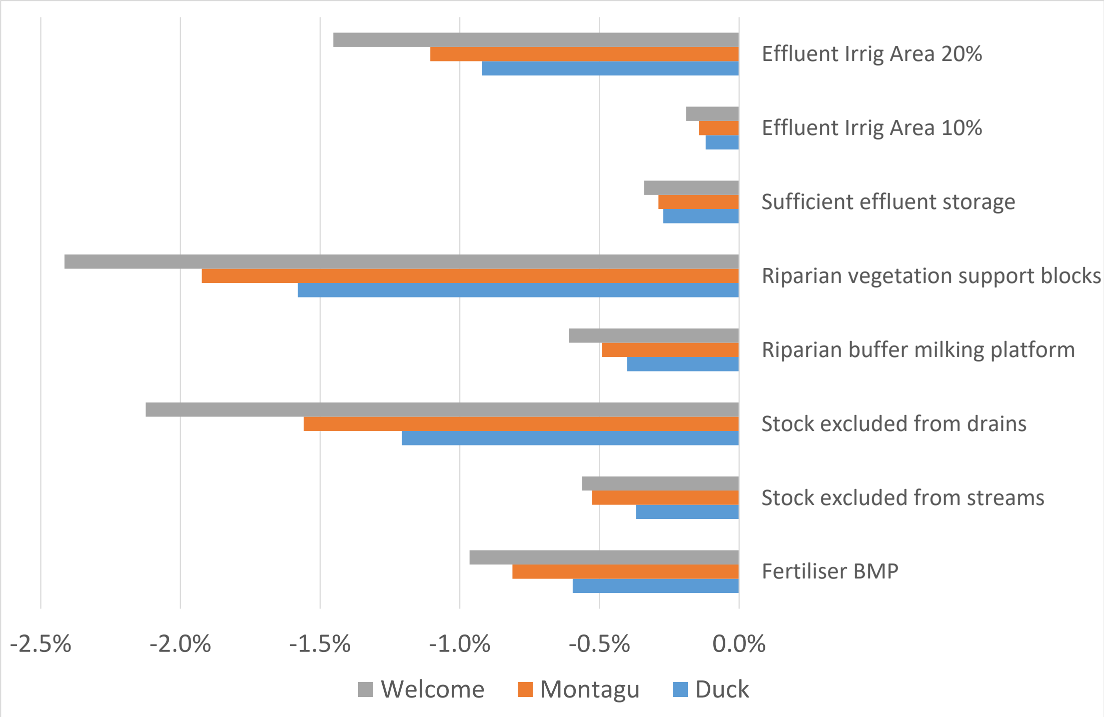


FIGURE 43. LEVERAGE OF HIGH IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING TOTAL NITROGEN (TN) LOADS IN THE CIRCULAR HEAD CATCHMENTS

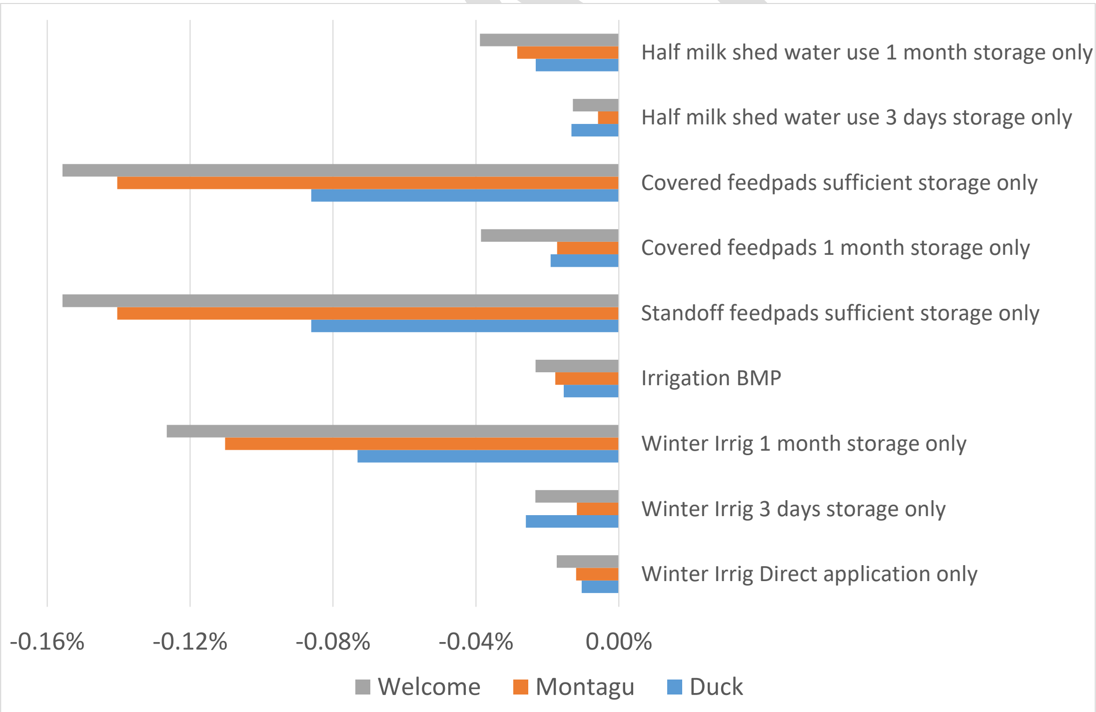


FIGURE 44. LEVERAGE OF LOWER IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING TOTAL NITROGEN (TN) LOADS IN THE CIRCULAR HEAD CATCHMENTS

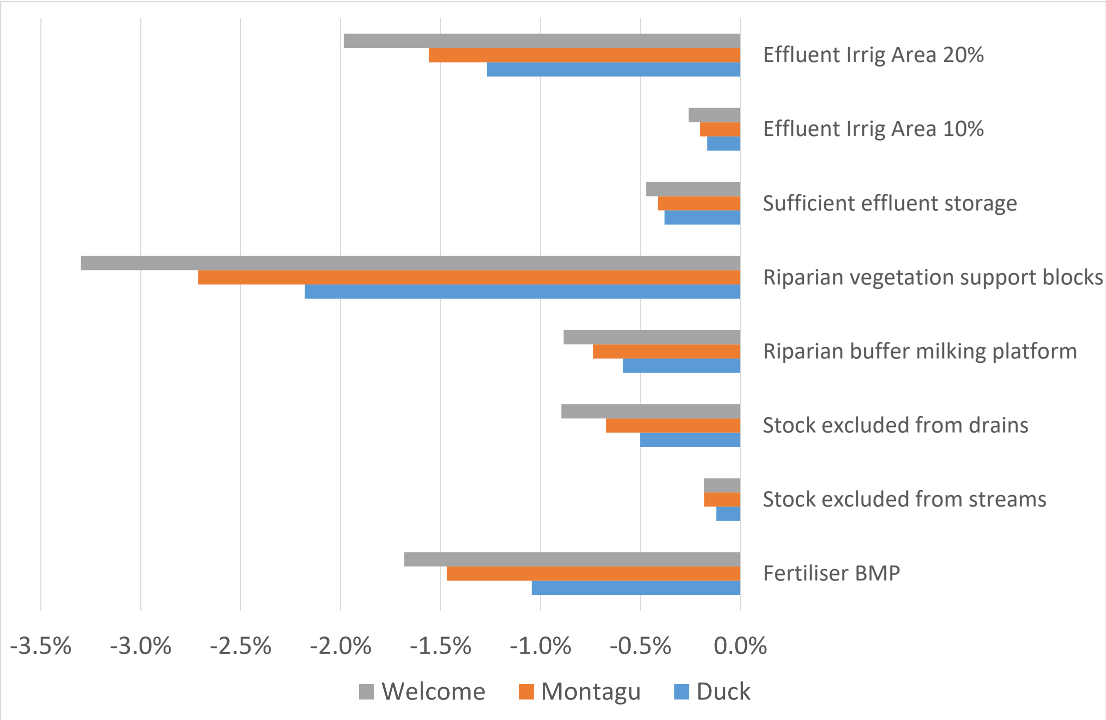


FIGURE 45. LEVERAGE OF HIGH IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING TOTAL PHOSPHORUS (TP) LOADS IN THE CIRCULAR HEAD CATCHMENTS

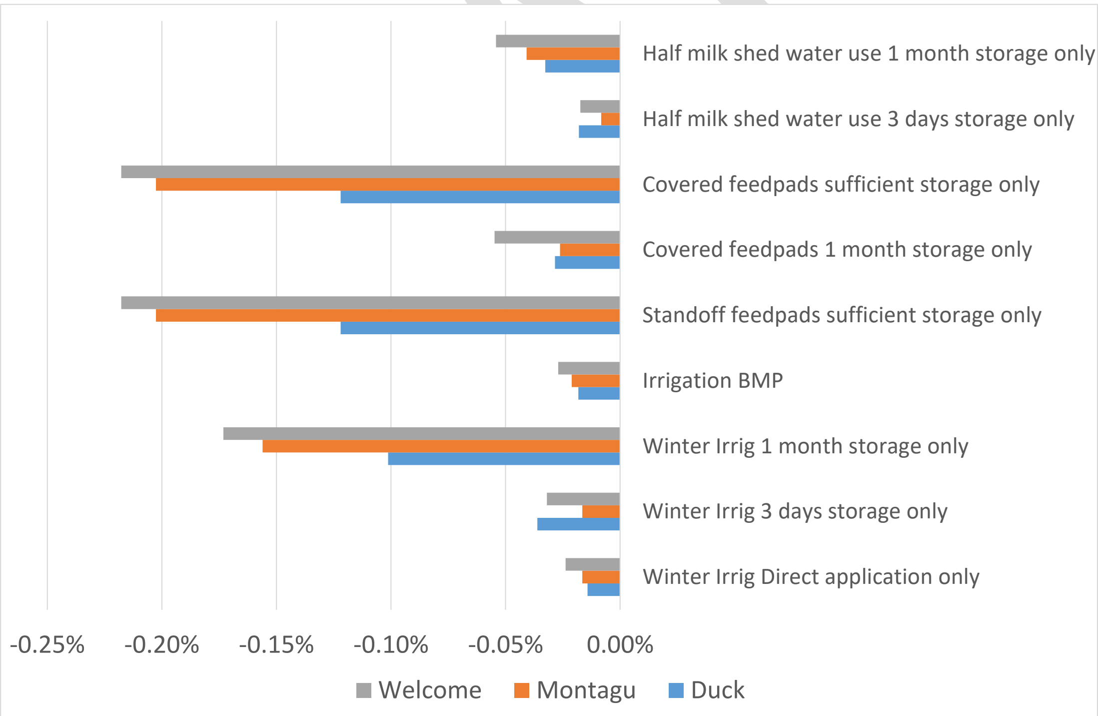


FIGURE 46. LEVERAGE OF LOWER IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING TOTAL PHOSPHORUS (TP) LOADS IN THE CIRCULAR HEAD CATCHMENTS

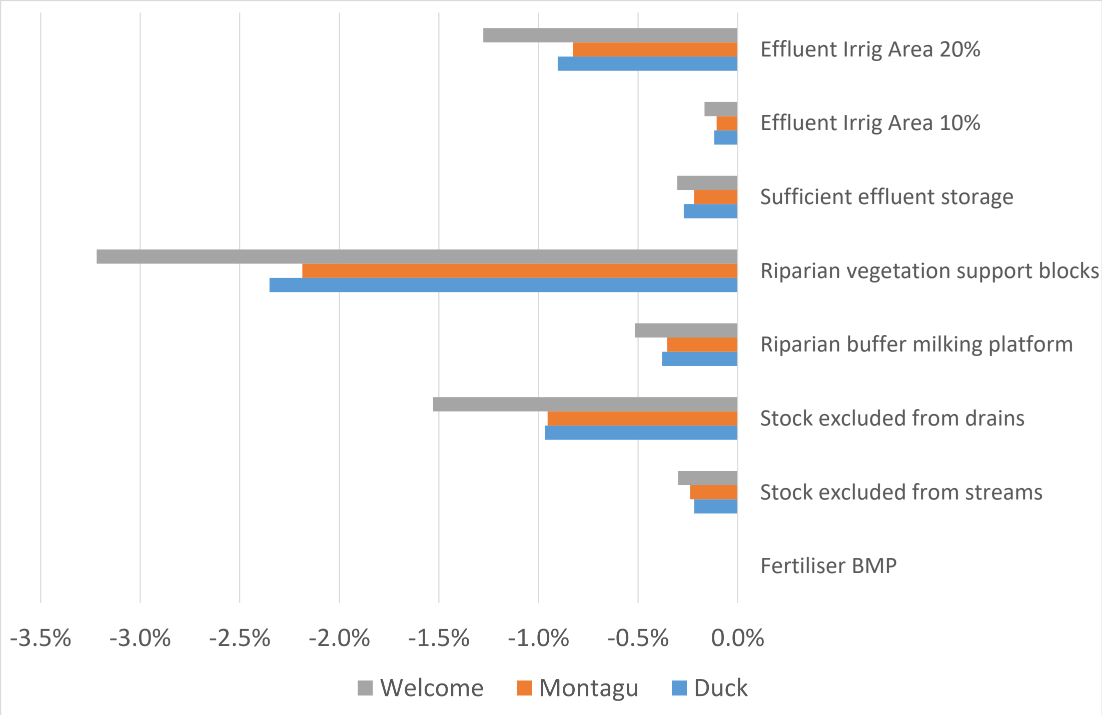


FIGURE 47. LEVERAGE OF HIGH IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING TOTAL SUSPENDED SEDIMENT (TSS) LOADS IN THE CIRCULAR HEAD CATCHMENTS

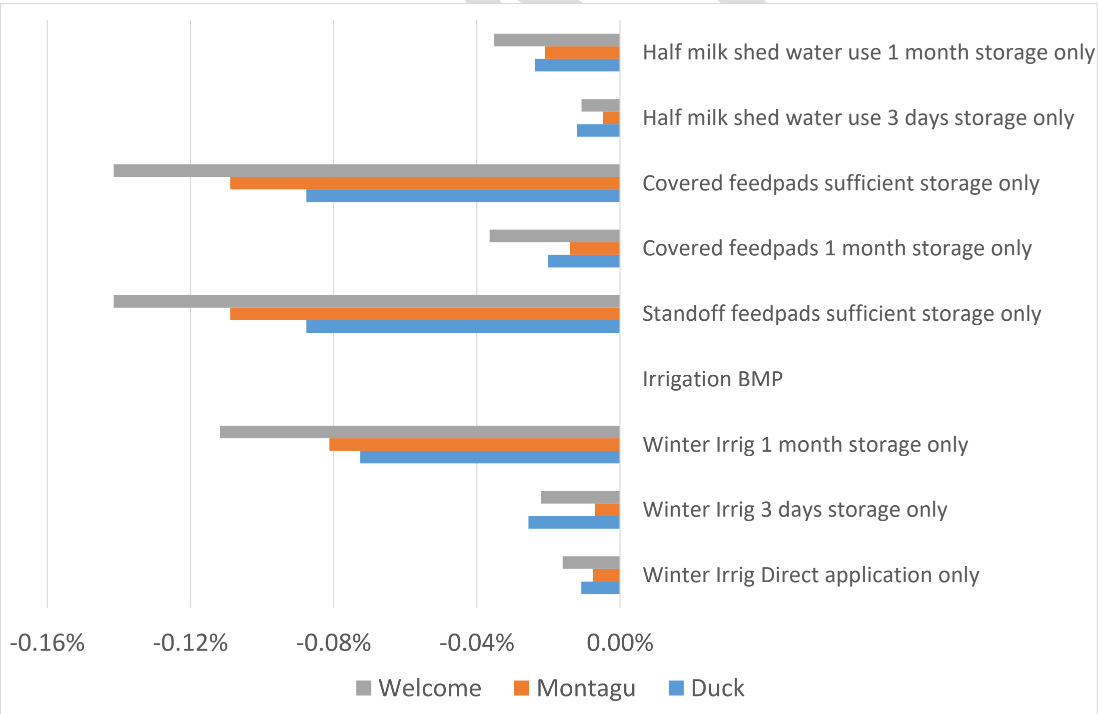


FIGURE 48. LEVERAGE OF LOWER IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING TOTAL SUSPENDED SEDIMENT (TSS) LOADS IN THE CIRCULAR HEAD CATCHMENTS

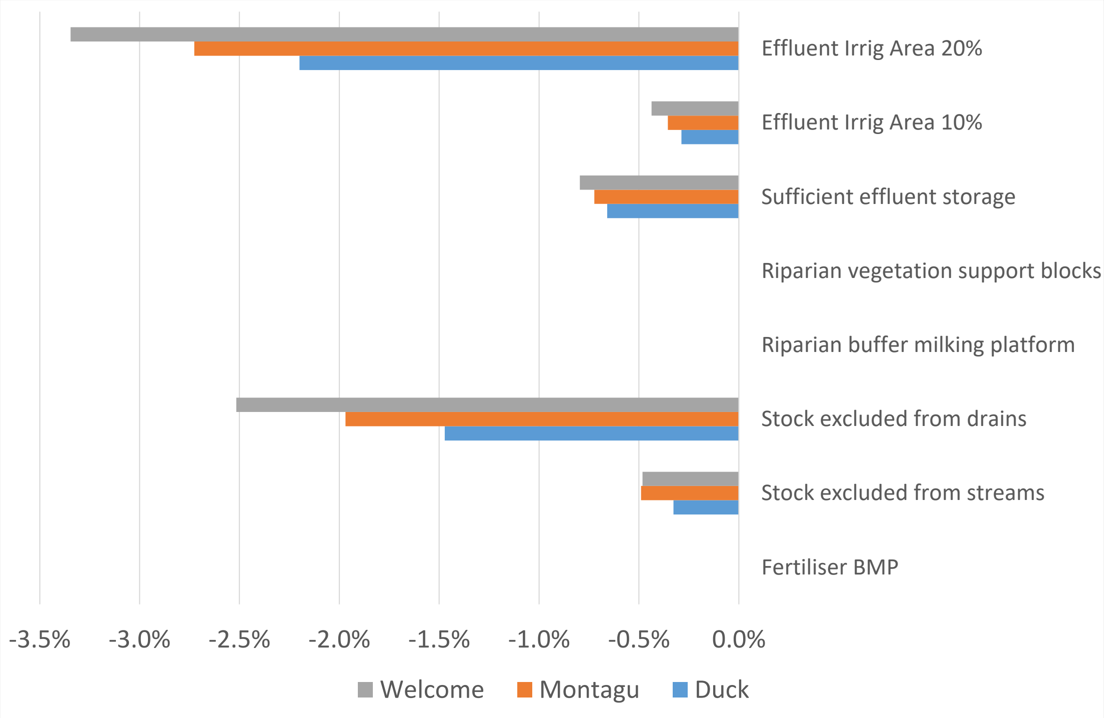


FIGURE 49. LEVERAGE OF HIGH IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING FAECAL COLIFORM LOADS IN THE CIRCULAR HEAD CATCHMENTS

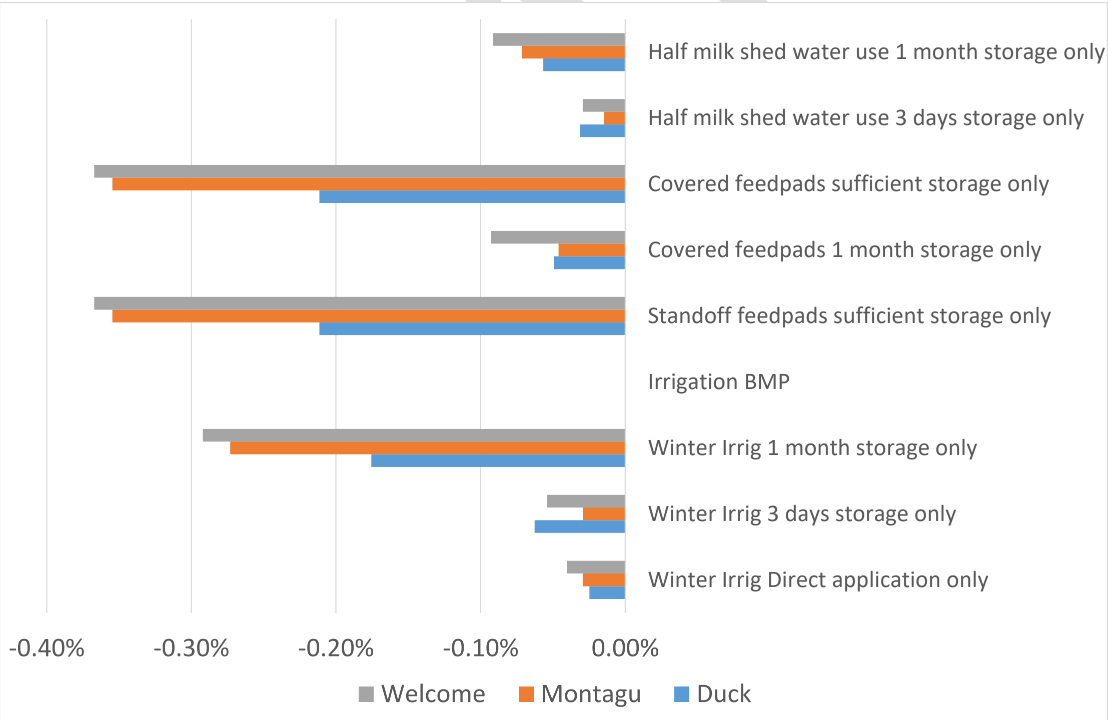


FIGURE 50. LEVERAGE OF LOWER IMPACT DAIRY MANAGEMENT ACTIONS IN REDUCING FAECAL COLIFORM LOADS IN THE CIRCULAR HEAD CATCHMENTS

These figures show that the benefits of each action for improving water quality depend to some extent on the pollutant being managed for as well as on the base level of management practices on the farm:

- Riparian vegetation on support blocks, and milking platform, stock exclusions from drains and streams, increased effluent irrigation area, provision of sufficient effluent storage and fertiliser BMP are generally the most effective actions across the board although their relative importance varies by pollutant targeted. Values in brackets are the average relative decreases in TN, TP, TSS and faecal coliforms across the 3 catchments respectively.
    - For all pollutants except faecal coliforms, for which there is insufficient information to model an impact, 100% vegetation of riparian buffers on support blocks is the most effective single action (2.0%, 2.7%, 2.6%, NA). Note that this action is likely to reduce pathogen exports even though these are not included in the model. Increasing effluent irrigation area to 20% of the farm (1.0%, 1.4%, 0.9%, 2.4%) and excluding stock from drains (1.6%, 0.7%, 1.2%, 2.0%) are also key actions with large leverage to impact on most pollutants.
    - Fertiliser BMP (0.8%, 1.4%, NA, NA) is very effective for reducing nutrient exports.
    - Ensuring sufficient effluent storage (0.4%, 0.6%, 0.4%, 1.0%), riparian vegetation on the milking platform (0.5%, 0.7%, 0.4%, NA) and excluding stock from streams (0.5%, 0.2%, 0.3%, 0.4%) are also very effective actions across the board.
- Actions with lower impacts on pollutant exports are generally those being applied to smaller sections of dairy, such as those farmers with a specified level of storage. Cumulatively these actions can lead to more significant changes. The impacts of these actions also demonstrates the interplay between the most effective management strategies with different levels of storage.
    - For those with little to no storage, slow rates of winter irrigation on drier summer days (saturated soils but not actively running off) can have benefits in reducing pollutant exports. This action is not effective for farmers who already have sufficient storage as it does not reduce the frequency or volume of winter effluent spills on these farms. Cumulatively across farmers who would benefit this action would be expected to reduce average exports across the three catchments by – TN: 0.1%, TP: 0.2%, TSS: 0.1%, faecal coliforms: 0.3%.
    - Reducing milk shed water use is effective where farmers have some storage but not sufficient storage. There is no benefit for direct application systems. Reducing water use in these systems allows storage to stretch further and reduces the incidence of spills during wet periods. . Cumulatively across farmers who would benefit this action would be expected to reduce average exports across the three catchments by – TN, TP, TSS: <0.1%, faecal coliforms: 0.1%.
    - Using feed pads as stand-off areas is only effective where farmers have greater volumes of storage. In order to be effective where farmers have 1 month of storage feed pads need to be covered to ensure no runoff from the feed pad is entering the storage. Covers will reduce the total volume of storage required where they are used with sufficient effluent storage – that is, the sufficient storage volume will be less. Cumulative impacts of using covered feed pads for farmers with one month or sufficient storage average across the three catchments are – TN, TP, TSS: 0.1%, faecal coliform: 0.2%.
    - Best practice irrigation involving timing relative to fertiliser application and use of deficit irrigation is expected to have very small impacts, decreasing nutrient exports by <0.1%.

These results describe the leverage of actions assuming 100% adoption of each action could be achieved. Feedback received from key stakeholders indicates that there are various impediments to the adoption of these actions.

7.2 Feasibility of management solutions

A scenarios workshop was held with key stakeholders to discuss the feasibility and barriers to adoption of these issues and to obtain assumptions relating to the level of adoption of actions that could be expected. A detailed description of these discussions is provided in Appendix 2. In summary:

- Decreasing milk shed water use was seen to be highly adoptable and programs would be likely to lead to significant decreases in water use. These programs could focus on monitoring of milk shed water use over a 2 to 3 week period and working with farmers to identify times where water use was highest and reasons for these peaks. It was said that programs should focus on ‘high risk’ farms located on the flats.
- Increasing and improving effluent storage was seen to be very difficult on the flats due to the increased costs of constructing storages as well as the difficulty of irrigating effluent out safely in these areas. It was felt that over time 100% compliance could be expected in drier, red soil areas of the catchment due to regulation but that major investment would be required to improve effluent storage on high risk farms on the flats. Increasing storage levels on the high risk flats to 1 to 2 months was seen to be feasible.
- Options for managing the speed and timing of delivery of effluent were seen to be difficult in North-west Tasmania to be adoptable for farms on the flats, however there is limited experience in implementing this management action in the Northwest of Tasmania.
- Removing stock from wet paddocks was seen to be largely unadoptable given that the major driver of drainage systems such as hump and hollow is to allow access to paddocks during these wet periods. It was very unlikely that many farmers would be willing to consider this management option.
- Irrigation management was not seen as a major action for which there would be broad scale adoption in the North-west of Tasmania.
- Fertiliser management was seen as a win-win option that could reduce farm costs and increase profitability. As such it was considered that 90% adoption should be achievable over time.
- Excluding stock from streams in dairy areas was seen as adoptable so long as a single wire fence with a narrow buffer was allowed. There are some health benefits to keeping dairy stock out of streams which means education could increase the adoption of this action with incentives also likely to be required for broad scale adoption.
- Excluding stock from drains and ephemeral streams was seen to be highly adoptable give that there are benefits to the farmer from avoided costs of maintenance of the drain system.
- Revegetating riparian buffers was seen to be an action that is hard to get broad scale adoption of. Narrower buffers are more likely to be adopted with very little adoption expected for 10m or 20m buffers even with incentives. Issues raised included the loss of productive land, weeds and pests. Even narrow buffers with incentives were expected to have low levels of uptake.

Final assumptions for the rates of adoption of each action applied to determine ‘feasible’ impacts on pollutant loads from each action are summarised in Table 2.

TABLE 2. RATES OF ADOPTION ASSUMED TO CONSTRUCT FEASIBLE ADOPTION SCENARIOS, BASED ON KEY STAKEHOLDER FEEDBACK

Option	Rate of adoption
Decrease in milk shed water use	50% decrease in milk shed water use in 'low storage' farms on 80% of 'at risk' farms located on the flats
Increase effluent storage	90% sufficient on red soils, 30% to 1 to 2 months storage on high risk flats
Increase effluent irrigation area	100% of farms increase to 20%
Manage winter effluent irrigation rate and timing	20% adoption on high risk flats focused on farms with some effluent storage
Remove stock off wet paddocks	0% adoption – not included in analysis
Irrigation management	0% adoption – not included in analysis
Fertiliser management	90% adoption
Exclude stock from streams	70% adoption (not including ephemeral streams)
Exclude stock from drains and ephemeral streams	80% adoption
Revegetate riparian buffers – 5m with education only	2% adoption
Revegetate riparian buffers – 5m with upfront incentives	20% adoption
Revegetate riparian buffers – 10m with upfront incentives	2% adoption

7.3 Impacts of feasible management options

The impacts of these feasible management action adoption scenarios on pollutant loads are shown in Figure 51 to Figure 54.

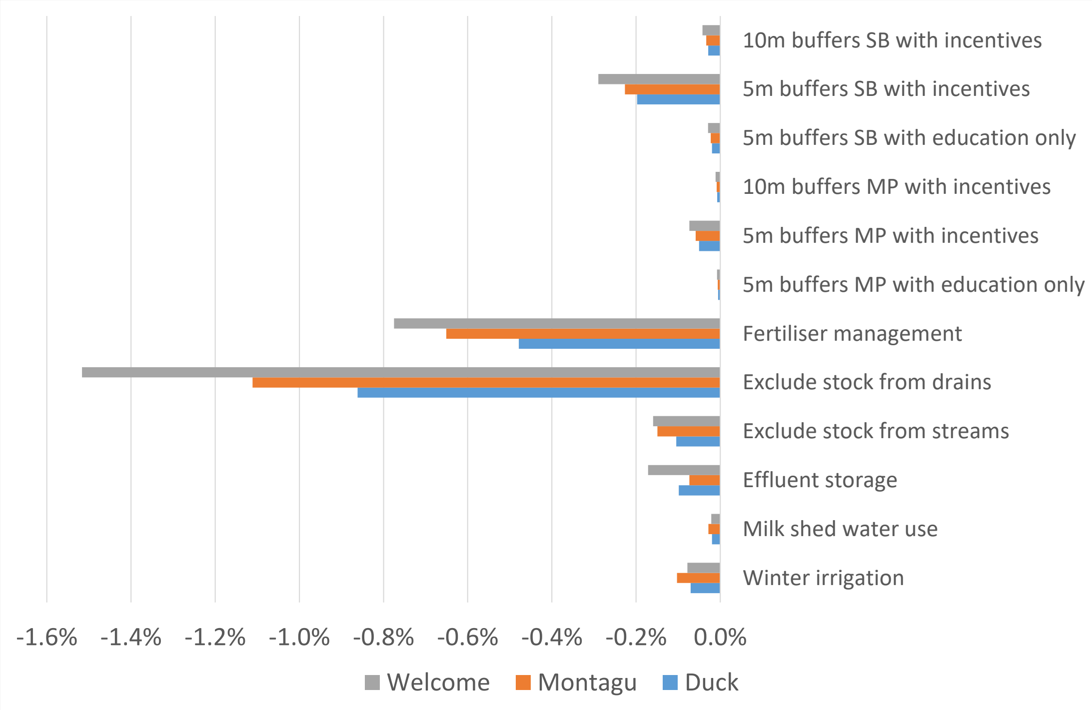


Figure 51. Impacts of feasible Dairy management action adoption in reducing total Nitrogen (TN) Loads in the Circular Head Catchments

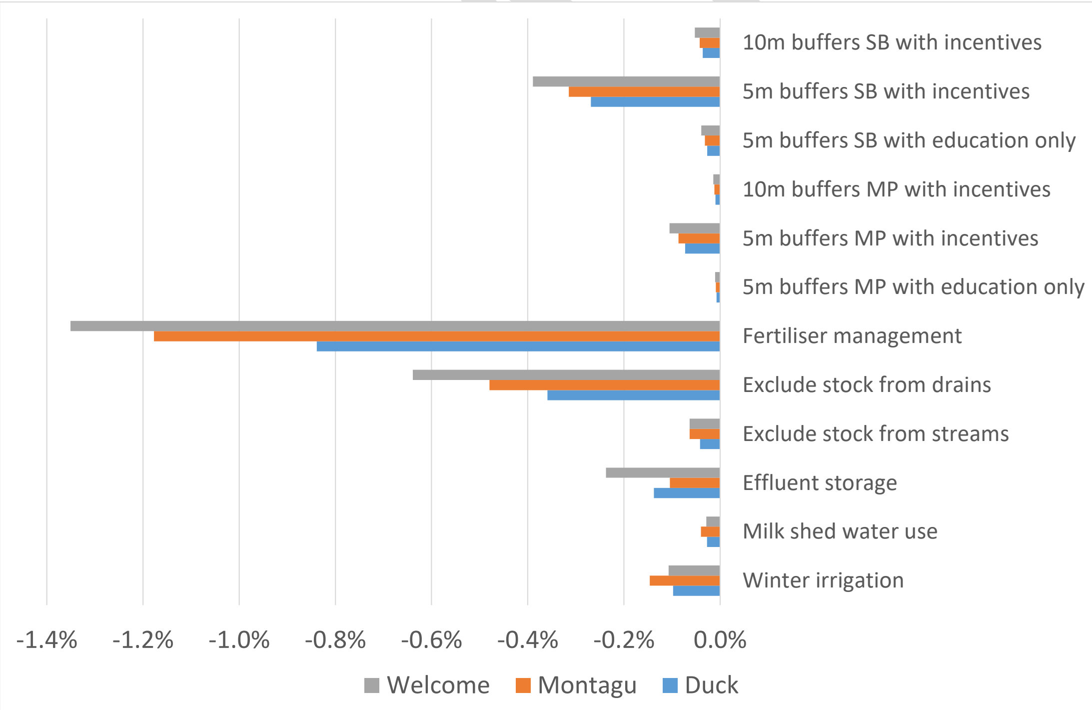


Figure 52. Impacts of feasible Dairy management action adoption in reducing total Phosphorus (TP) Loads in the Circular Head Catchments

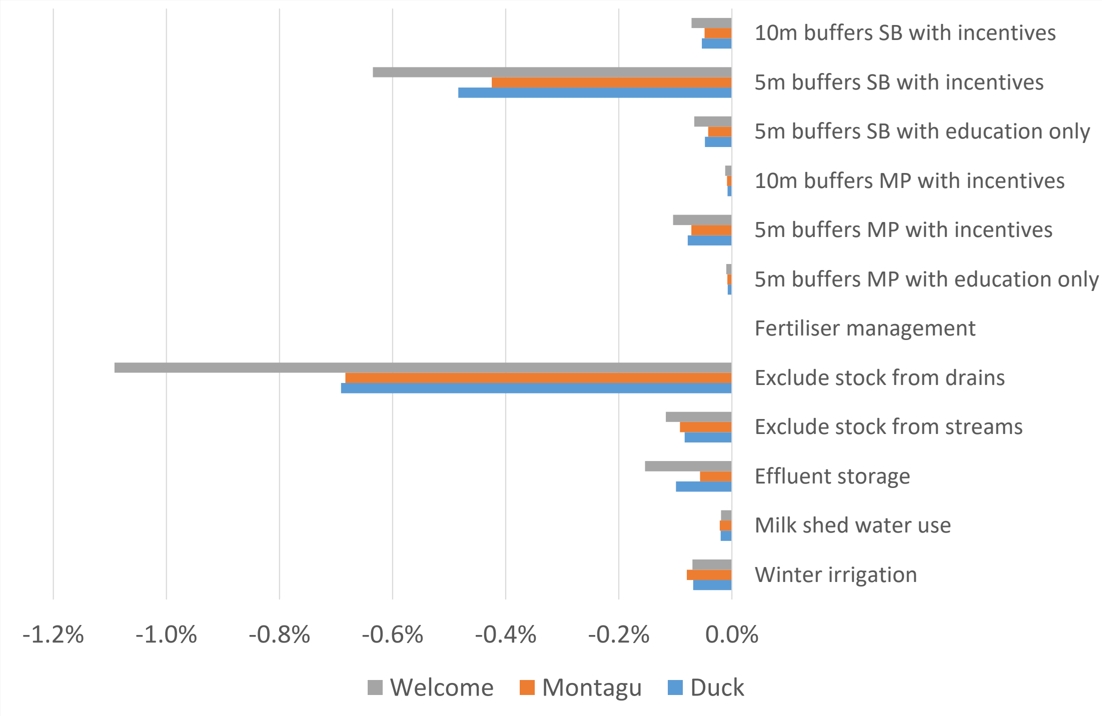


FIGURE 53. IMPACTS OF FEASIBLE DAIRY MANAGEMENT ACTION ADOPTION IN REDUCING TOTAL SUSPENDED SEDIMENT (TSS) LOADS IN THE CIRCULAR HEAD CATCHMENTS

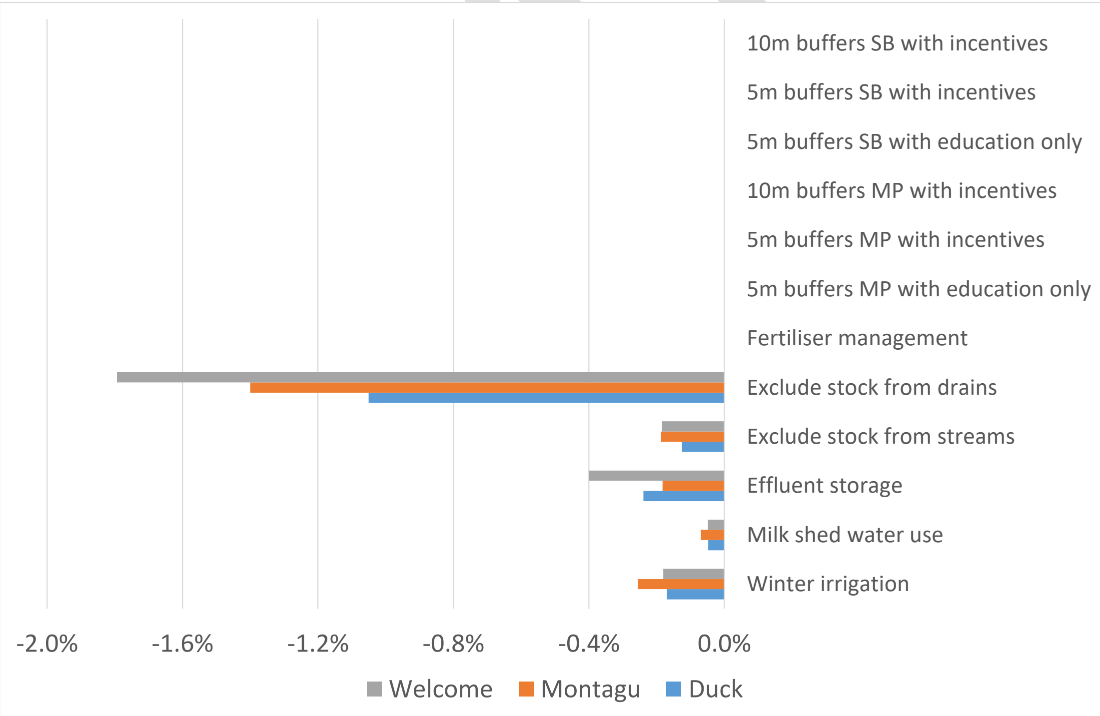


FIGURE 54. IMPACTS OF FEASIBLE DAIRY MANAGEMENT ACTION ADOPTION IN REDUCING FAECAL COLIFORM LOADS IN THE CIRCULAR HEAD CATCHMENTS

These figures show that the relative importance of the various feasible management actions in reducing pollutant loads varies by the type of pollutant being managed for.

- In all cases excluding stock from drains is a key management action. This was considered to be highly adoptable as there are on-farm benefits in terms of reduced maintenance of drains. The greatest impacts are in the Welcome river catchment, with the smallest impacts observed in the Duck river catchment. Changes in diffuse pollutant loads from this action are estimated as: TN: 0.9% to 1.5%; TP: 0.4 to 0.6%; TSS: 0.7 to 1.1%; and, faecal coliforms 1.1 to 1.8%.

- Fertiliser management is very important for controlling nutrient exports off dairy areas. It is also highly adoptable given the economic benefits of reduced fertiliser costs of improved fertiliser management. Changes in loads for TN of 0.8 to 1.4% and TP of 0.9 to 1.5% have been estimated.
- Three actions that have a similar magnitude of impact are excluding stock from streams, increasing effluent storage and implementing winter irrigation on farms in the high risk flats where they have some storage but not sufficient storage. While there were small differences in the effectiveness of these actions in reducing pollutant loads, in general the magnitude of impacts was very similar both across actions as well as across pollutants. The smaller impact of these actions is likely to be due at least to some extent, to the limited application and lower adoption rate of each action. Estimated impacts are:
    - Exclude stock from streams – TN: 0.1 to 0.2%, TP: 0.0 to 0.1%; TSS: ~0.1%; faecal coliforms: 0.1 to 0.2%. Note that these changes do not include the benefits of reduced stream bank erosion and less stirring up of bottom sediments that could be expected from less stock trampling of these areas. As such the benefits of this action for reducing TSS in particular are likely to be underestimated.
    - Winter irrigation – TN, TP, TSS: ~0.1%; faecal coliforms: 0.2 to 0.3%.
    - Effluent storage – TN, TP, TSS: 0.1 to 0.2%; faecal coliforms: 0.2 to 0.4%.
- Reducing milk shed water use is of most benefit in reducing the total volume of storage required to provide a certain period of storage. This means that in the modelled scenarios no impact was observed where either direct application systems are used or sufficient storage was available. The benefit of reduced milk shed water use would be to reduce the size and thus the cost of providing sufficient storage on farm. In terms of the feasible adoption scenario reducing milk shed water use is applied to farms with some but not sufficient storage only. Given that this action is restricted to a smaller group of farms its modelled impacts are relatively small at the whole of catchment scale, at roughly 0.02 to 0.3% for TN and TSS, 0.03 to 0.04% for TP and 0.05 to 0.07% for faecal coliforms.
- Revegetating riparian buffers on either the milking platform or support blocks can be expected to have very small benefits for water quality. This is because of both the lower adoptability of this action and the extensive use of drains on the milking platform that mean the vast majority of paddock runoff is directed to the stream as channelized flow through the drain network rather than as sheet flow through the riparian buffer. It should be noted that no impact of riparian buffers on pathogen exports has been modelled as insufficient information was available to estimate an impact, although it is likely that some benefits through reduced pathogen exports could be expected. The most effective use of riparian buffers for managing water quality is pushing for adoption of narrow (5m) buffers using incentives. While a wider buffer has more benefits to water quality if applied to the same length of stream as a narrower buffer, wider buffers, even with incentives, can be expected to lead to low uptake and so little to no subsequent benefits for water quality. Benefits from riparian vegetation in dairy areas accrue from changes in stream health and condition, through for example increased shade and bank stability, as well as benefits for threatened species dependent on this habitat and biodiversity, rather than through changes in water quality. These potential benefits are captured in the Biodiversity section of this plan. Note that where creating riparian buffers includes restricting stock access to streams the cumulative benefits of these two actions for improving water quality can be expected. Estimated decreases in total diffuse catchment pollutant loads from implementing riparian buffer are

- On the milking platform: roughly 0.1% for 5m buffers with incentives, versus 0.01% for both 5m buffers with education only and 10m buffers with incentives.
- On support blocks: 0.02 to 0.07% for 5m buffers with education only, 0.2 to 0.7% for 5m buffers with upfront incentives and 0.02 to 0.6% for 10m buffers with incentives.

7.4 Feasible benefits of best management practice adoption

The feasible management options analysed outlined above combine to provide significant benefits to water quality. The expected total decrease in diffuse pollutant loads from these actions (assuming 5m buffers with incentives and all other actions as given above) is shown in Figure 55.

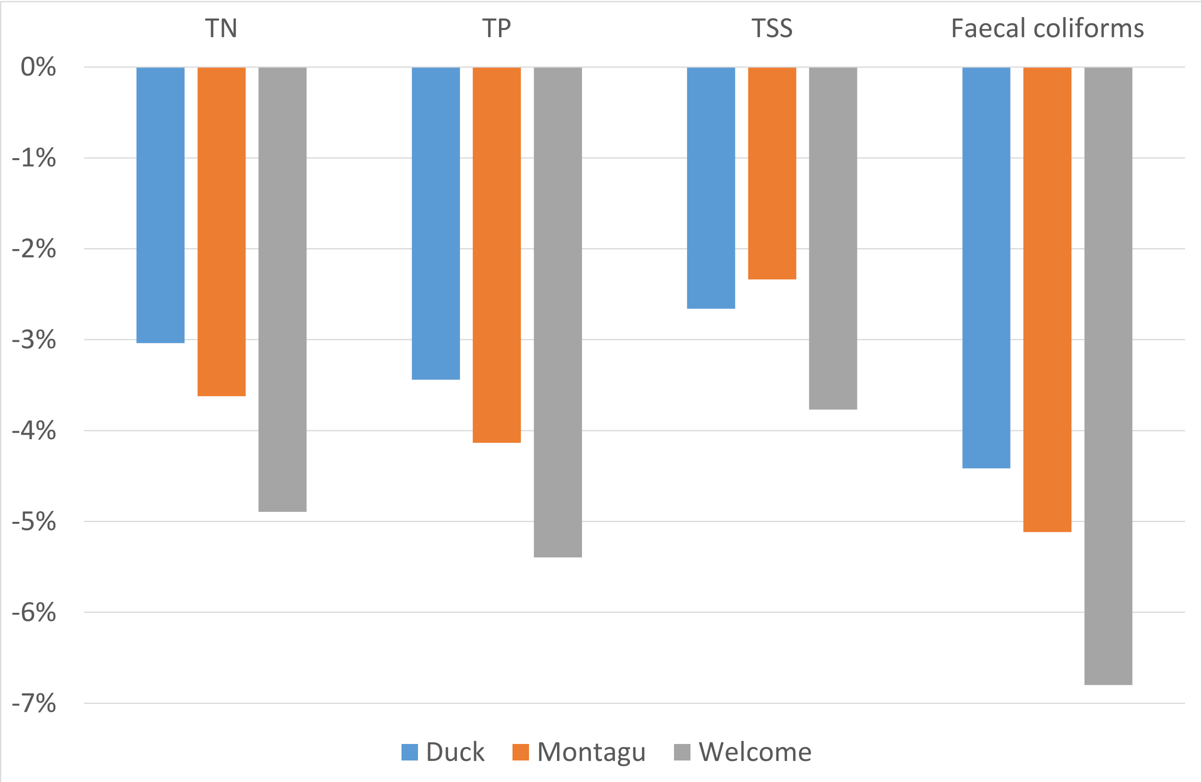


FIGURE 55. COMBINED CHANGE IN DIFFUSE POLLUTANT LOADS FROM FEASIBLE DAIRY MANAGEMENT OPTIONS IN THE CIRCULAR HEAD CATCHMENTS

This figure shows that feasible levels of adoption of dairy BMP on milking platform areas could decrease TN loads by 3 to 4.9% TP by 3.4 to 5.4%, TSS by 2.3 to 3.8% and faecal coliforms by 4.4 to 6.8%. Note that impacts on pathogen loads are likely to be underestimated as no impact of riparian buffers on pathogen exports was estimated. Similarly the benefits of reduced stock access to stream and increased riparian vegetation on stream erosion on TSS has not been included in the analysis. The effectiveness of these actions in reducing diffuse pathogen loads in the Duck river are particularly important given the impacts of pathogens on the oyster industry in Duck Bay.

7.5 Recommendations for Dairy Management

Improving water quality coming from dairy areas in Circular Head will require a range of management actions are adopted. Recommendations to improve water quality coming out of dairy milking platforms in Circular Head are:

- Efforts should be focused on reducing milk shed water use in at risk areas of the catchment (low lying flats) where sufficient storage volumes are difficult to achieve. The benefits from this action are likely to come in the form of reduced storage volumes required and associated costs of effluent storage. This investment would mean that more farmers could be expected to have sufficient storage or at least levels of storage that are sufficient for longer periods of time. This would in turn have benefits for water quality. Programs focused on reducing milk shed water use may include a program of monitoring milk shed water use and helping farmers to identify peak times when excess water use is occurring and strategies for managing this.

- Effective effluent storage and management is important but the difficulty of achieving it varies through the catchments depending on location.
    - In lower risk areas such as those occurring on the red soils and low lying hills best practice effluent management should be possible to achieve on farm with traditional solutions. Efforts should focus on helping farmers to bring their systems and practices in line with best practice. Sufficient effluent storage should be provided for on dairy farms. This storage should be well-designed and placed to ensure effluent can be applied to an adequate area of the farm, and such that storages are unlikely to leach or overflow effluent.
    - In high risk flatter areas of the catchment best practice effluent management is much more complex due to physical difficulties with building storages and the higher costs of their construction. Innovative solutions such as off-site spreading, above ground storages or communal storages may be required to achieve best practice. Assistance should be provided with developing innovative options on a case by case basis and ensuring that longer periods of storage are available even if providing sufficient storage for the entire season is not possible. The primary focus in these areas should be on reducing the generation of effluent to be stored through reduced milk shed water use.
- Partnerships between Dairy Tasmania and Cradle Coast NRM are an important vehicle for achieving management outcomes. Programs such as the FertSMART program and Clean Rivers should continue to be supported.
    - Best practice fertiliser use should be encouraged by programs such as FertSMART. It is expected that best practice fertiliser management will be very effective at reducing nutrient loads if it is applied broadly across the catchment. These programs represent a win-win solution for improving water quality and should be encouraged on all dairy farms.
    - Programs to assist farmers in fencing stock out of drains and ephemeral streams (not hump and hollow) should continue to be undertaken. These may include a mix of education on the benefits to farmers of drain fencing as well as incentives to undertake these works.
    - Where possible stock should be fenced out of streams both for its benefits to water quality as well as for benefits to stream bank stability and stream condition.
- Riparian revegetation in dairy milking platform areas should be focused on stream sections where the greatest biodiversity benefits can be achieved, rather prioritised on the basis of any potential impacts on water quality. Narrower buffers that are more easily adoptable and so more broadly applied can be expected to have greater impacts on diffuse catchment loads. Farmers should still be encouraged to develop wider buffers where possible, particularly where these buffers can act as corridors for wildlife, protect threatened species or communities or connected fragmented remnants, given the greater biodiversity benefits of wider rather than narrower buffers. Areas targeted should be those where increased stream bank stability or stream shading are required or where riparian vegetation could benefit threatened species or communities. Where riparian vegetation includes restricting stock access to streams benefits to water quality will be greater. To maximise water quality benefits, riparian vegetation in areas where flows move as sheets flow through the riparian zone, rather than as channelized flows through a drain network should be a priority.
- Low rate winter irrigation on high risk flats where it is difficult to develop sufficient levels of storage should also be trialled and if successful encouraged through extension programs.

This action is promising both in terms of reducing pollutant load exports where it is difficult for farmers to have sufficient storage, as well as in terms of reducing the size and cost of storages required for providing storage that is sufficient for longer periods of time.

8 Grazing management in Circular Head

Beef grazing makes substantial contributions to the Circular Head region. Data from the Australian Bureau of Statistics shows that in 2006 beef grazing contributed 13% of the total value of livestock slaughtered in Tasmania, with 11% of the meat cattle in Tasmania situated in Circular Head. Beef grazing covers approximately 35% of the total area of the Duck River catchment and 14% and 15% of the Montagu River and Welcome River catchments respectively. Beef grazing is a significant source of pollutants exported to rivers in the Circular Head catchments, producing nutrients, sediments and pathogens at a rate generally much higher than its relative area. Figure 56 shows the relative contribution of the beef grazing to catchment area and loads.

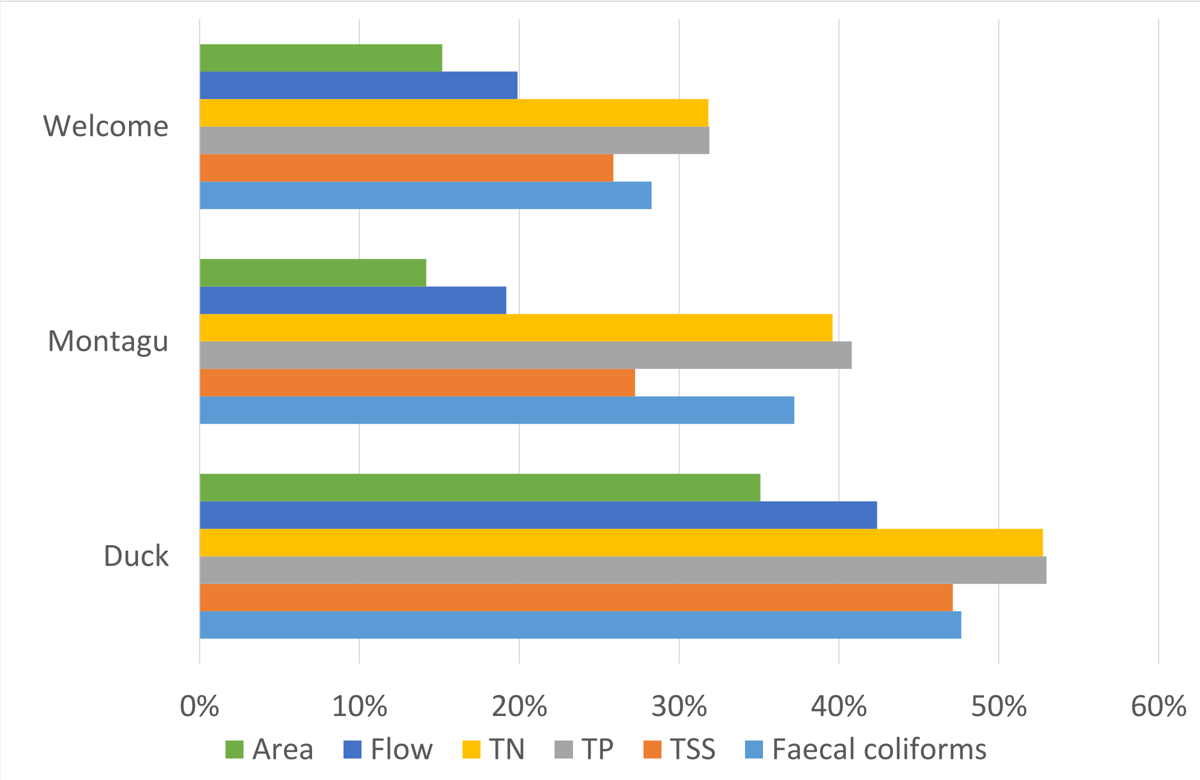


Figure 56. Relative contribution of beef grazing to area and catchment loads

Figure 56 shows:

- Flows from beef grazing areas are slightly greater than their relative area in all catchments. This is because beef grazing tends to occur in wetter areas of the catchment where greater than average runoff per unit area occurs. This will account for some of the elevated loads from these areas as runoff and flows are a major driver of pollutant exports. However contributions to pollutant loads generally exceed these relative flow contributions, indicating that flow does not account for the majority of the difference.
- Beef grazing areas contribute roughly between 1 ½ and 3 times as much TN and TP as their relative area, producing 53% of nutrient loads from the Duck river catchment, roughly 40% from the Montagu river catchment and 32% from the Welcome river catchment.
- Beef grazing areas contribute above their relative area in sediments, from 1.4 time to nearly 2 times their relative area. They produce 47% of the sediments from the Duck River catchment and 27% and 26% of the sediments from the Montagu and Welcome River catchments respectively.
- Beef grazing areas produce nearly 50% of faecal coliforms from the Duck River catchment and substantial proportions of faecal coliforms to the Montagu and Welcome River catchments (32% and 28% respectively)

It is clear from these results that managing exports of nutrients, sediments and pathogens from beef grazing is an important component of improving water quality in these systems.

Several actions that have been considered to reduce pollutant exports from beef grazing areas in Circular Head:

- Excluding stock from streams;
- Creating vegetated riparian buffers;
- Improving fertiliser management

The MiniCAPERDSS has been used to estimate potential percent reductions in pollutant loads in the catchment with the implementation of these management actions. As was the case with dairy management, two sets of scenarios were run. The first shows the potential leverage of each of these options for reducing pollutant loads, assuming 100% adoption of actions could be achieved. The second uses feedback from key stakeholders about the relative adoptability of each of the actions in Circular Head to estimate a 'feasible' impact of each action on water quality.

8.1 Leverage of potential management actions

The estimated leverage of these management actions to decrease diffuse pollutant loads in the Circular Head catchments is shown in Figure 57 to Figure 60. These figures all assume that 100% adoption of the given management action occurs across the landscape.

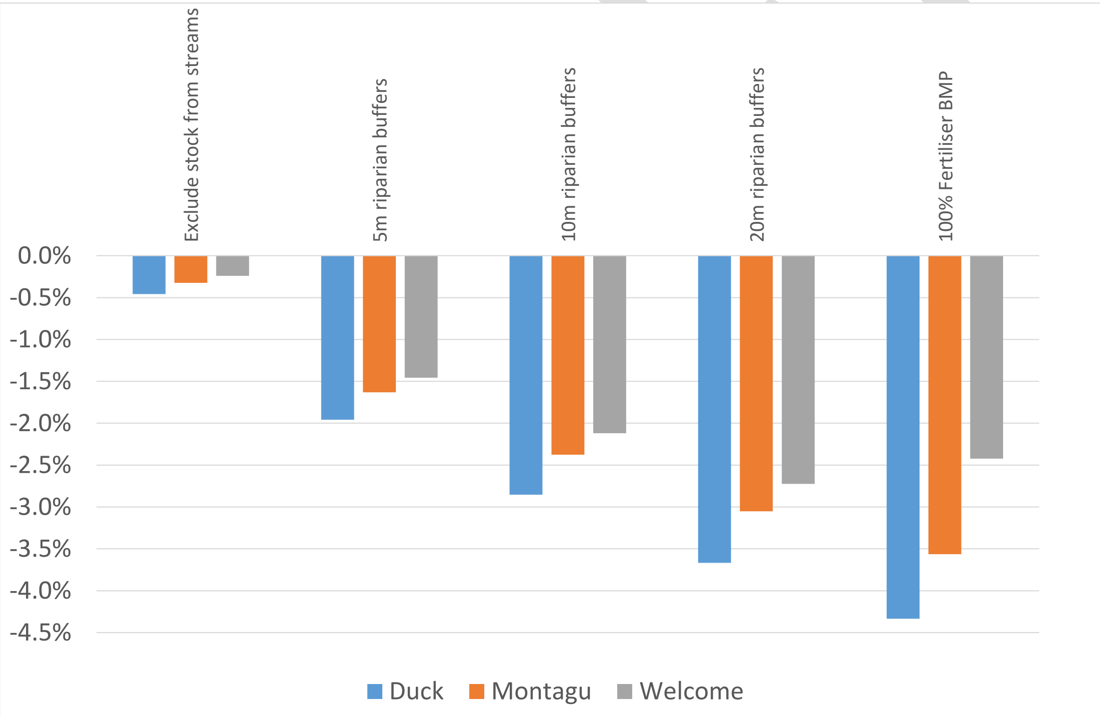


FIGURE 57. LEVERAGE OF GRAZING MANAGEMENT ACTIONS IN REDUCING TOTAL NITROGEN (TN) LOADS IN THE CIRCULAR HEAD CATCHMENTS

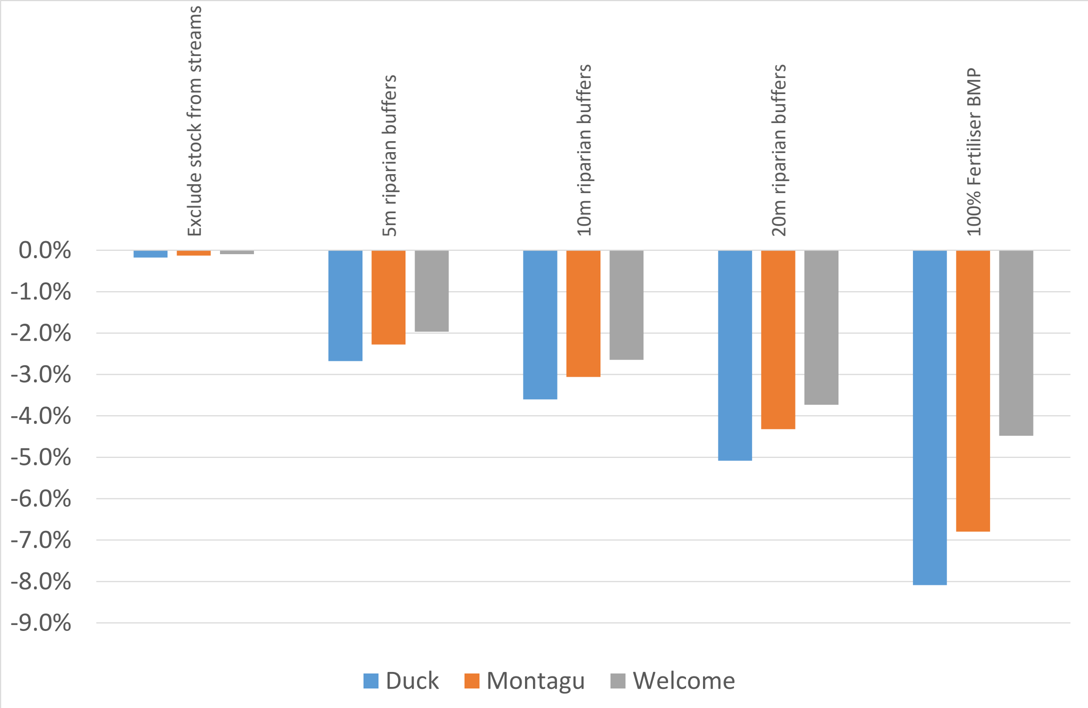


Figure 58. Leverage of grazing management actions in reducing total Phosphorus (TP) loads in the Circular Head Catchments

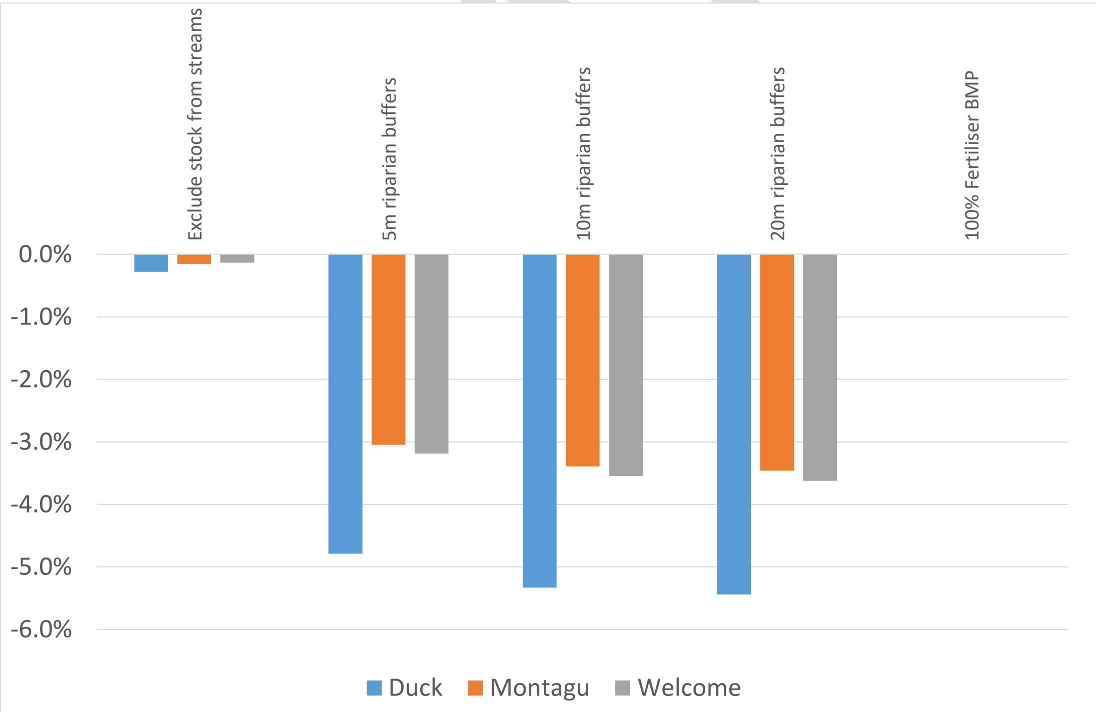


Figure 59. Leverage of grazing management actions in reducing total Suspended Sediment (TSS) loads in the Circular Head Catchments

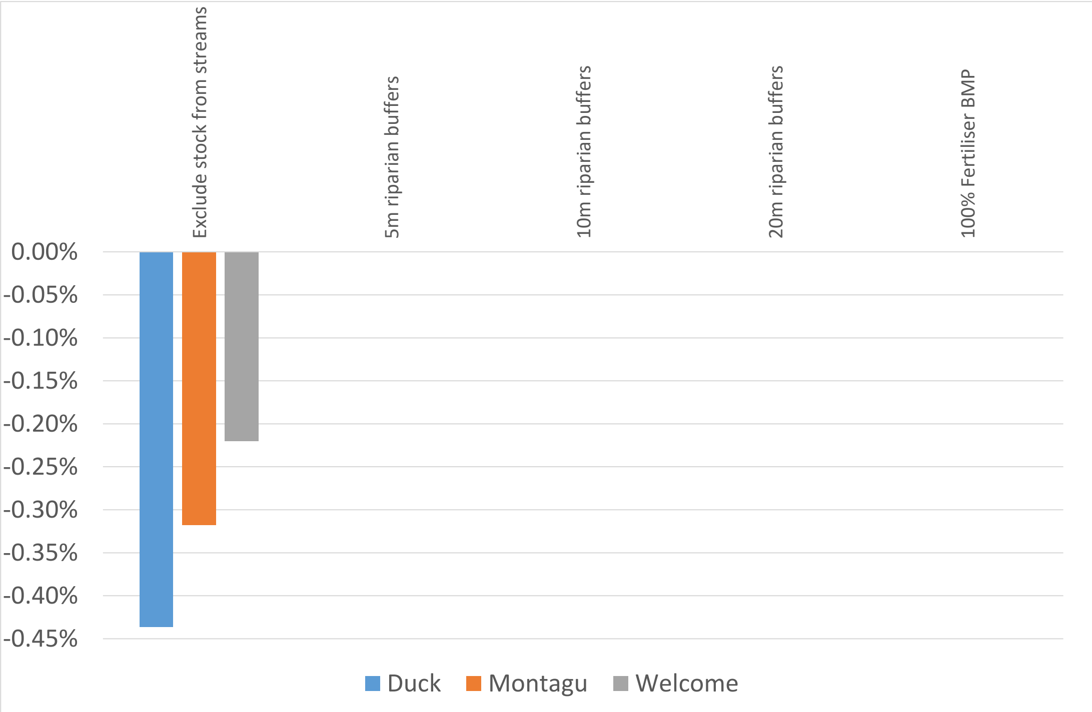


FIGURE 60. LEVERAGE OF GRAZING MANAGEMENT ACTIONS IN REDUCING FAECAL COLIFORM LOADS IN THE CIRCULAR HEAD CATCHMENTS

These figures show that the benefits of each action for improving water quality depend to some extent on the pollutant being managed for:

- Improving fertiliser management has the potential to substantially decrease nutrient loads in all catchments. Impacts are greatest in the Duck River catchment where over 4% of TN and 8% of TP could be removed. The smallest impacts are seen in the Welcome River catchment, although these are still substantial, removing 2.4% TN and 4.5% of TP. As would be expected, improved fertiliser management has no impact on sediments (TSS) or pathogens (faecal coliforms).
- Riparian buffers are the most effective management action for reducing sediments from beef grazing areas. As could be expected, wider buffers have a greater impact on pollutant loads, although the additional benefit of increasing the width of the buffer is much less than the initial benefit of having a narrow buffer – for example a 5m wide buffer in the Duck River catchment can be expected to remove roughly 5% of TSS, while doubling this width to 10m would only achieve an increased removal of 0.5% TSS. These buffers also have significant impacts on nutrients: a 5m buffer reducing TN by 1.5% to 2% and 2% to 2.7% of TP; a 10m buffer reducing TN by roughly 2% to 3% and TP by 2.6% to 3.6%; and, a 20m buffer reducing TN by 2.7% to 3.7% and TP by 3.7 to 5.1%. The modelling assumes that riparian buffers have no impact of faecal coliform exports as the literature provides very mixed estimates of their impact, with some studies showing increases and others decreases in pathogen exports where riparian revegetation occurs.
- Excluding stock from stream has very small impact on pollutant loads from beef grazing areas, although impacts on sediments are likely to be underestimated as the impacts of stock trampling on stream bank erosion are not accounted for. This action could be expected to decrease TN by 0.2% to 0.5%, and TP, TSS and faecal coliforms by 0.1% to 0.3% or less. This is the only action considered that has an impact on faecal coliforms.

These results describe the leverage of actions assuming 100% adoption of each action could be achieved. Feedback received from key stakeholders indicates that there are various impediments to the adoption of these actions.

8.2 Feasibility of management solutions

A scenarios workshop was held with key stakeholders to discuss the feasibility and barriers to adoption of these issues and to obtain assumptions relating to the level of adoption of actions that could be expected. A detailed description of these discussions is provided in Appendix 2. In summary:

- Fertiliser management was seen as a win-win option that could reduce farm costs and increase profitability. It was thought that there is currently more adoption of fertilizer BMP in Circular Head beef grazing than dairy because of environmental accreditation processes, such as those applied by Cape Grim. It was estimated that there is currently around a 30% adoption of fertilizer BMP in beef grazing and that this could increase to around 70% in the future.
- It was thought that the action of keeping stock out of streams could have a 70% adoption rate in the future in grazing areas if incentives are paired with good education and if farmers can see what the neighbours have done or are doing. It was felt that in some areas where beef grazing is highly profitable (such as Cape Grim) some farms are likely to take this action without any monetary incentive being offered. It was suggested that while incentives matter to get adoption on many farms, extension is important.
- Revegetating riparian buffers was seen to be an action that is hard to get broadscale adoption of. Narrower buffers are more likely to be adopted with very little adoption expected for 10m or 20m buffers even with incentives. Issues raised included the loss of productive land, weeds and pests. Even narrow buffers with incentives were expected to have low levels of uptake.

Final assumptions for the rates of adoption of each action applied to determine 'feasible' impacts on pollutant loads from each action are summarised in Table 3.

TABLE 3. RATES OF ADOPTION ASSUMED TO CONSTRUCT FEASIBLE ADOPTION SCENARIOS, BASED ON KEY STAKEHOLDER FEEDBACK

Option	Rate of adoption
Exclude stock from streams	70% adoption
Revegetate riparian buffers – 5m with education only	2% adoption
Revegetate riparian buffers – 5m with upfront incentives	20% adoption
Revegetate riparian buffers – 10m with upfront incentives	2% adoption
Revegetate riparian buffers – 20m with upfront incentives	1% adoption
Fertiliser management	70% adoption

8.3 Impacts of feasible management options

The impacts of these feasible management action adoption scenarios on pollutant loads are shown in Figure 61 to Figure 64.

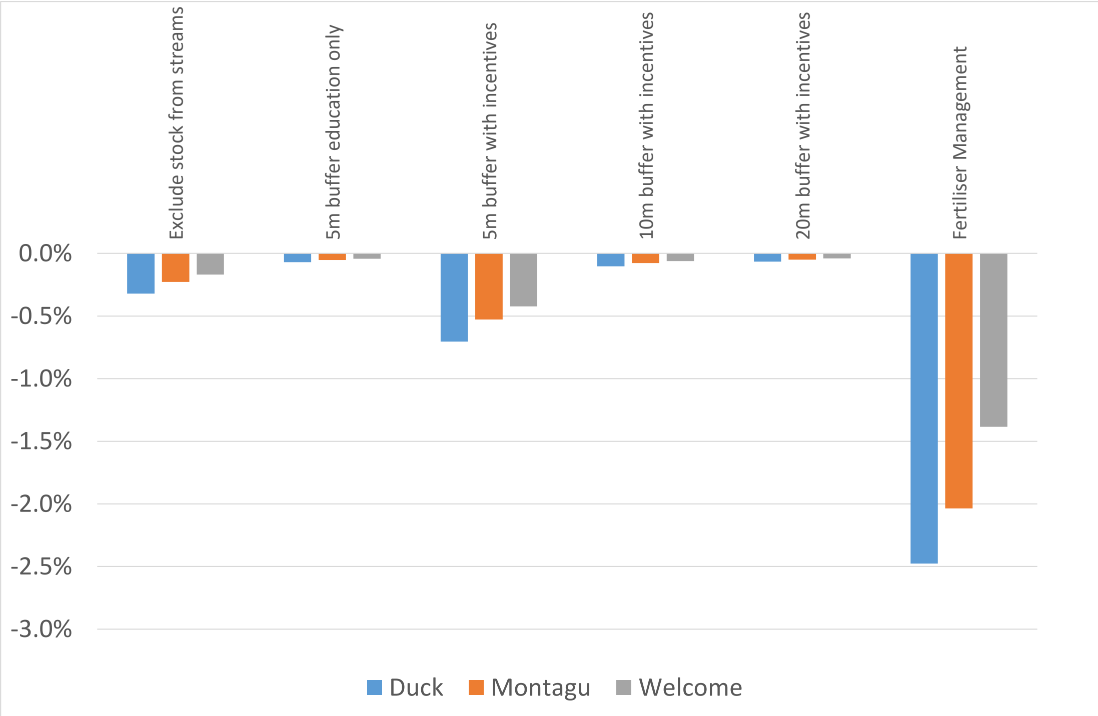


FIGURE 61. IMPACTS OF FEASIBLE GRAZING MANAGEMENT ACTION ADOPTION IN REDUCING TOTAL NITROGEN (TN) LOADS IN THE CIRCULAR HEAD CATCHMENTS

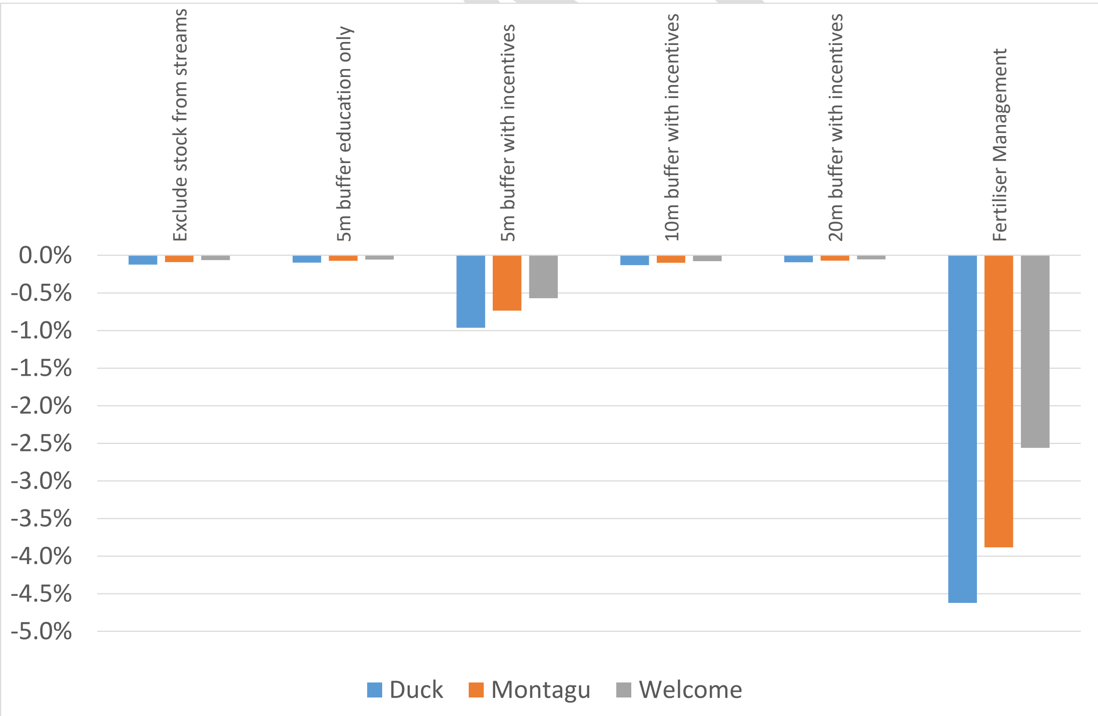


FIGURE 62. IMPACTS OF FEASIBLE GRAZING MANAGEMENT ACTION ADOPTION IN REDUCING TOTAL PHOSPHORUS (TP) LOADS IN THE CIRCULAR HEAD CATCHMENTS

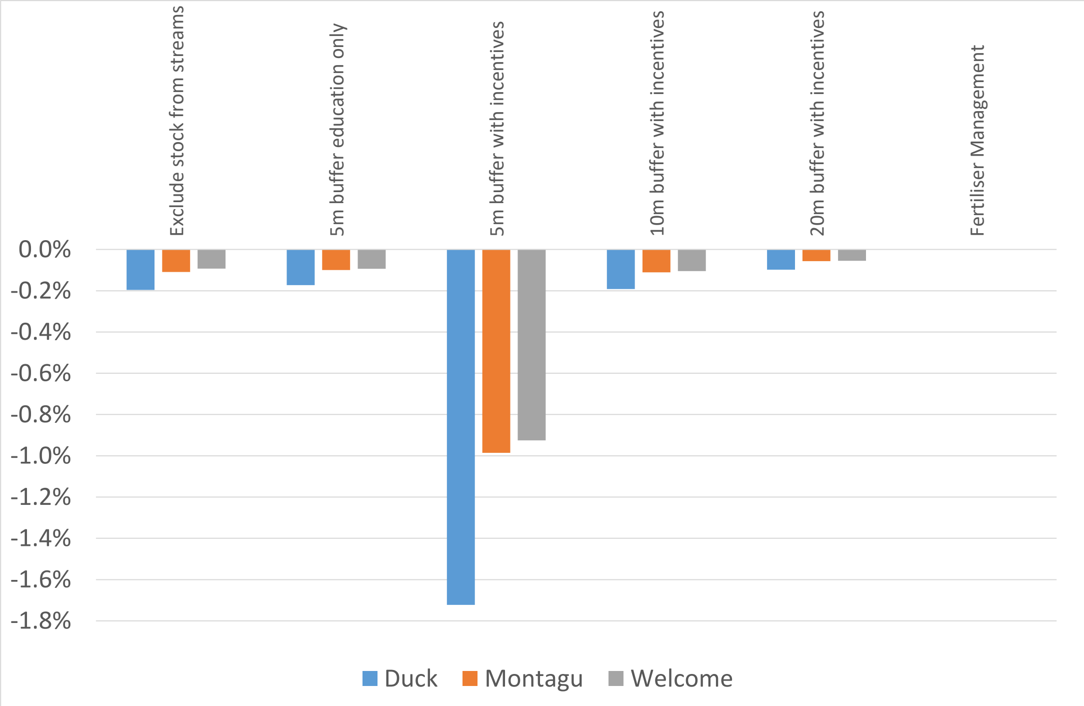


FIGURE 63. IMPACTS OF FEASIBLE GRAZING MANAGEMENT ACTION ADOPTION IN REDUCING TOTAL SUSPENDED SEDIMENT (TSS) LOADS IN THE CIRCULAR HEAD CATCHMENTS

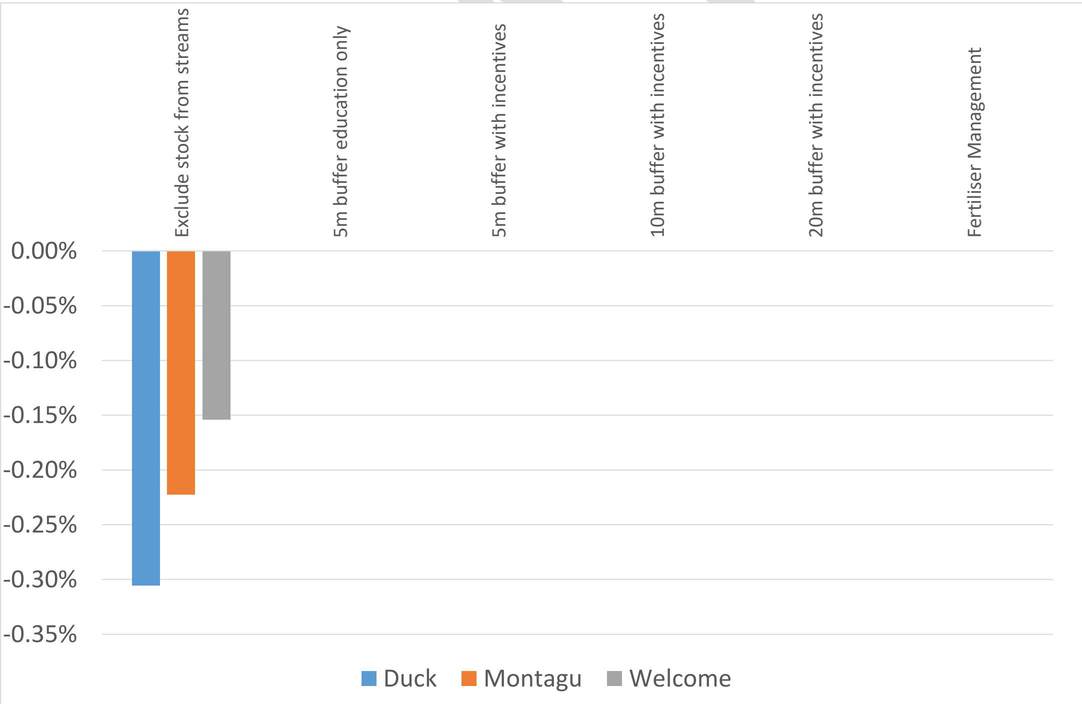


FIGURE 64. IMPACTS OF FEASIBLE GRAZING MANAGEMENT ACTION ADOPTION IN REDUCING FAECAL COLIFORM LOADS IN THE CIRCULAR HEAD CATCHMENTS

These figures show that the relative importance of the various feasible management actions in reducing pollutant loads varies by the type of pollutant being managed for:

- 5m buffers implemented with incentives are the most effective of all the scenarios relating to vegetated riparian buffers. While wider buffers can be expected to remove greater pollutant loads than narrow buffers if applied to the same length of stream, the much higher rates of adoption associated with narrow buffers (assuming incentives are provided) mean that the overall impact on water quality is greater for narrower buffers.

- The main impacts on nutrients comes from improvements in fertiliser management, with smaller but still important benefits from 5m buffers. Small benefits from reduced nutrient loads can also be expected from excluding stock from streams.
    - Feasible levels of adoption of improved fertiliser management can reduce TN by 1.4% to 2.5% and TP by 2.6% to 4.6%.
    - 5m buffers implemented using incentives can be expected to reduce TN by 0.4% to 0.7% and TP by 0.6% to 1%
    - Excluding stock from streams can be expected to remove 0.2% to 0.3% of TN and 0.1% of TP.
- The most important action for removing TSS loads is implementation of 5m riparian buffers with incentives. This action has the potential to decrease TSS loads by 0.9% to 1.7%. Excluding stock from streams is also estimated to decrease TSS loads by 0.1% to 0.2%, although this is likely to be significantly underestimated as the effects of stock trampling on streambank erosion are not accounted for in the modelling.
- The only action with an impact on faecal coliforms is excluding stock from streams, which can be expected to decrease loads by 0.2% to 0.3%. Riparian buffers are assumed to have no impact on pathogens in the modelling as available studies are unclear about the influence of buffers on pathogen exports.

8.4 Feasible benefits of best management practice adoption

The feasible management options analysed outlined above combine to provide significant benefits to water quality. The expected total decrease in diffuse pollutant loads from these actions (assuming 5m buffers with incentives and all other actions as given above) is shown in Figure 65.

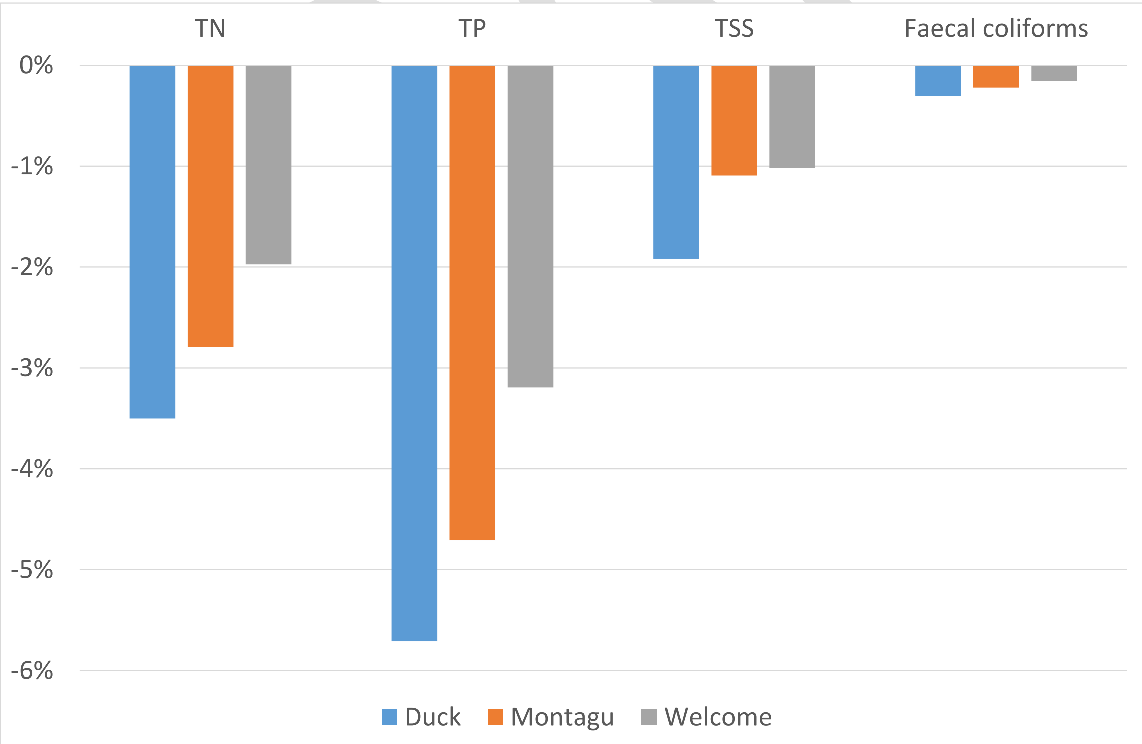


FIGURE 65. COMBINED CHANGE IN DIFFUSE POLLUTANT LOADS FROM FEASIBLE GRAZING MANAGEMENT OPTIONS IN THE CIRCULAR HEAD CATCHMENTS

This figure shows that feasible levels of adoption of BMP on beef grazing in the catchments could decrease TN loads by 2% to 4%, TP by 3% to 6%, TSS by 1% to 2% and faecal coliforms by 0.2% to 0.3%.

8.5 Recommendations for Grazing Management

Improving water quality coming from beef grazing areas in Circular Head will require a range of management actions are adopted. Recommendations to improve water quality coming out of beef grazing areas in Circular Head are:

- Best practice fertiliser use should be encouraged. Improved fertiliser management represents a win-win solution for improving water quality, particularly when used as part of environmental accreditation and marketing of beef products, and should be encouraged on all beef grazing farms.
- Where possible stock should be fenced out of streams and drains both for the benefits to water quality as well as for benefits to stream bank stability and stream condition. While this action has relatively small modelled benefits for water quality, benefits of reduced stock trampling, increased streambank erosion and subsequent increases in stream turbidity are likely to be substantial but were not included in the modelling.
- Riparian revegetation in beef grazing areas should focus on broadscale adoption of narrower buffers with farmers encouraged to increase buffer width over time where possible. Wider buffers should be the focus in stream sections where additional biodiversity benefits are the greatest, for example where they act to protect high value remnants or connect native vegetation remnants and can be used as corridors for native flora and fauna. Areas targeted should also include those where increased stream bank stability or stream shading are required or where riparian vegetation could benefit threatened species or communities. Where riparian vegetation includes restricting stock access to streams benefits to water quality will be greater.

9 MANAGING POINT SOURCE POLLUTION TO DUCK BAY

There are very limited urban areas in Circular Head and consequently relatively few point sources of pollution in these catchments. The Montagu and Welcome Rivers do not contain significant point sources of pollution. The Duck River catchment and Duck Bay do contain point sources in terms of both sewage treatment plant discharges from the Smithton STP located at Pelican Point, which discharges directly into the Bay as well as sewer overflows, which are caused either by failure of the pump station or the mains.

9.1 Sewage Treatment Plant Discharges

Figure 66 shows the relative loads of pollutants to Duck Bay produced from diffuse sources and the Smithton STP. Note that no consistent data was available to provide a load estimate from sewer overflows for comparison. This figure shows that on an annual scale, the STP is not a significant source of sediments or pathogens to Duck Bay, producing roughly 1% of each of these pollutants. It does however produce more significant nutrient loads, at 6% of TP and 8% of TN.

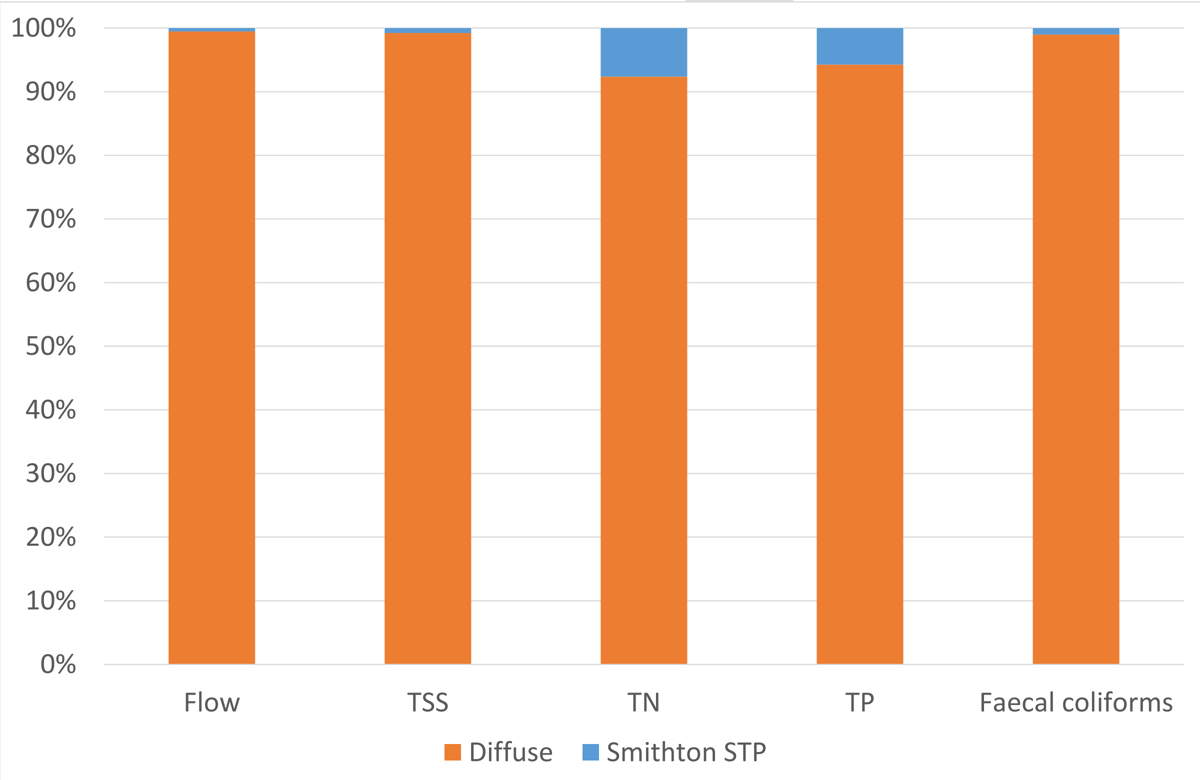


FIGURE 66. RELATIVE LOADS FROM DIFFUSE SOURCES AND THE SMITHTON STP IN THE DUCK RIVER CATCHMENT

The Smithton STP consists of 6 lagoons with a long retention time and has an issue with birds using the lagoons adding pathogens to the water during this part of the process. TasWater are currently exploring several options to reduce loads from the STP:

- Improved screening of the initial inflow
- Improved disinfection to remove all pathogens from the discharge
- Process optimisation to reduce the retention time
- Reuse of summer flows on a farm adjoining the Smithton STP site which would remove the entire summer discharge from the STP and, in dry years, would also potentially take discharges in other seasons as well.

Figure 67 shows the relative contribution of the STP to total pollutant loads to Duck Bay split by seasons (summer is October to March, winter is April to September).

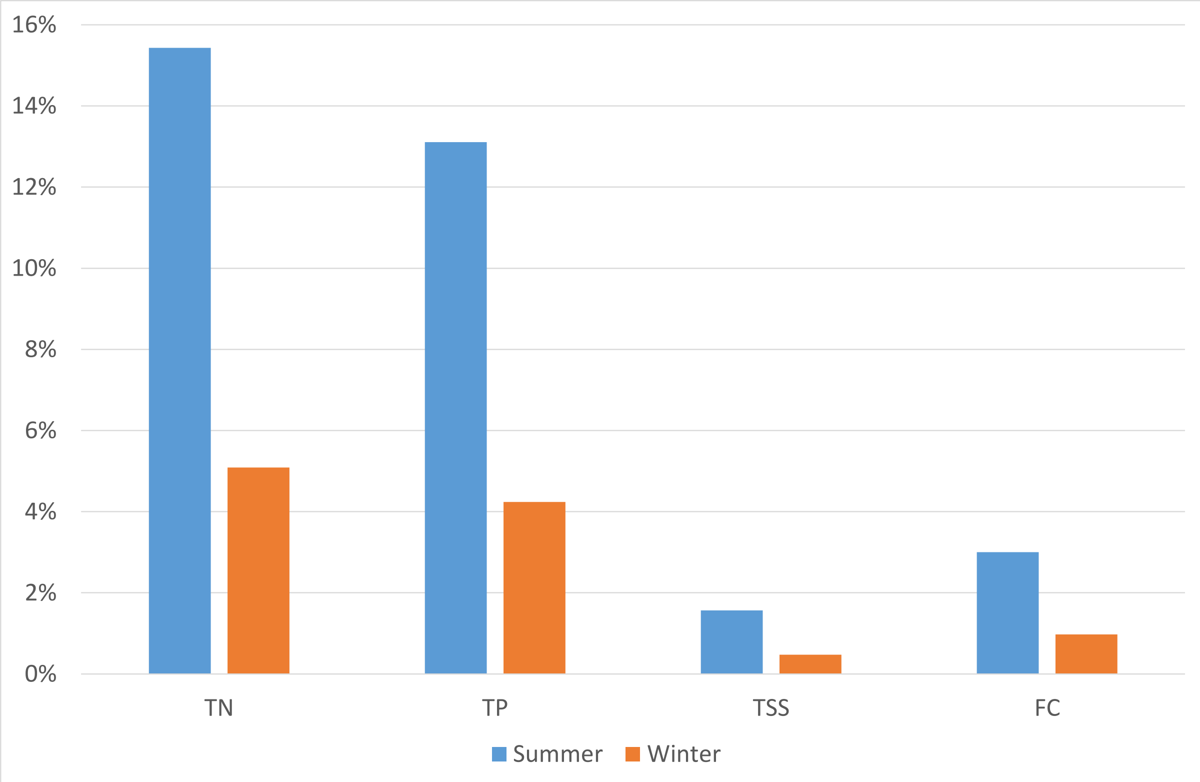


FIGURE 67. RELATIVE CONTRIBUTION OF SMITHTON STP TO SEASONAL LOADS TO DUCK BAY

This Figure shows that the STP contributes more to relative loads over summer than winter. This would be expected as STP loads and flows are relatively constant, while diffuse loads and flows are dominated by heavy rainfall and runoff events in winter. In summer the STP contributes roughly 15% of TN, 13% of TP, nearly 2% of TSS and 3% of faecal coliforms. Summer reuse can be expected to be a very effective strategy for removing these loads from the system and, given the relative importance of the STP in contributing to summer loads, could be expected to lead to significant improvements in water quality over this period. This is particularly the case for nutrients, but also to a lesser extent pathogens, which are of concern to oyster growers in the Bay. Other measures will also have water quality benefits over winter but these are likely to have a smaller relative impact on total loads to the Bay over this period.

9.2 Sewer overflows

Sewer overflows in Smithton occur due to either pump station failure or failure of the sewer mains (*D.Lester and B. Wood, pers comm*). Sewer overflows are of particular concern to the oyster industry as they typically contain high levels of pathogens and can trigger closure of oyster leases. There are a number of factors which influence these failures:

- Stormwater intrusion to the sewer mains in older deteriorating parts of the sewer network. This causes overflows of raw sewage during periods of high rainfall.
- Intermittent high volume, high flow trade waste causes wear and tear on the mains in the lower part of the system. This trade waste has also historically included sulfuric acid which was discharged in high volumes once a week. This causes erosion of the pipes and leads to greater mains failure.
- Pump station failure due to an older and degraded pump station. Pump station failure can cause overflows during both wet and dry periods. Failures during dry periods are of particular concern to the oyster industry as these trigger closures of the leases during periods where they would otherwise expect to be open due to the lack of diffuse catchment loads entering Duck Bay.

Current strategies Taswater is taking to reduce the frequency and volume of sewer overflows include:

- Mains refurbishment - A mains refurbishment program is currently being undertaken to remove older deteriorated pipes. This will reduce stormwater incursion to the pipes, reducing flow volumes in the system after rainfall events and the consequent risk of sewer overflows.
- Trade waste – TasWater have been working with trade waste customers to treat trade waste before it enters the sewerage system and to develop systems where high volume, infrequent discharges are avoided and smaller more consistent discharge volumes are maintained. Both of these actions will reduce the wear and tear on pipes and will mean that mains refurbishment works on some of the older mains will last longer with a lower risk of failure.
- Pump station upgrades – an upgrade of the Davis st pump station is currently being undertaken. It is expected this will reduce the risk of pump station failure and lead to a reduction in the frequency and volume of sewer overflows, particularly during dry weather.

10 LOAD TARGETS AND TRAJECTORIES

Load targets for the Circular Head catchments have been developed based on feedback from key stakeholders on impediments to the adoption of management actions in the Circular Head catchments. It should be noted that the load targets and trajectories assume no change in land use, such as dairy expansion or urban growth. The load target scenario assumes:

- Grazing management:
    - Exclude stock from streams - 70% adoption
    - Revegetate riparian buffers, 5m with upfront incentives - 20% adoption
    - Fertiliser management - 70% adoption
- Dairy management:
    - 50% decrease in milk shed water use in ‘low storage’ farms on 80% of ‘at risk’ farms located on the flats
    - Increase effluent storage - 90% of farms on red soils have sufficient storage, 30% of farms on high risk flats increase to 1 to 2 months storage
    - Increase effluent irrigation area to 20% of milking platform area, on 100% of farms
    - Low rate winter effluent irrigation during ‘drier’ periods - 20% adoption on high risk flats focused on farms with some effluent storage
    - Fertiliser management - 90% adoption
    - Exclude stock from streams - 70% adoption (not including ephemeral streams)
    - Exclude stock from drains and ephemeral streams - 80% adoption
    - Revegetate riparian buffers, 5m with upfront incentives – 20% adoption
- Smithton STP:
    - Summer reuse
    - Improve treatment to remove all pathogens from winter releases.

Assuming these levels of adoption can be achieved over the medium to long term (10+ years) then reductions in loads in the Circular Head catchments shown in Figure 68 to Figure 70 should be achievable. It is important to note that these assumptions have been used to derive a feasible scenario for setting load targets. Factors such as improvements in technology or changes in the cost of actions might mean that a different mix of management actions are adopted to reach these targets. The contribution of diffuse and point source loads changes for the Duck River catchment have been shown separately. Also given the importance of seasonality in oyster closures, load reductions are shown by season (summer – Oct to Mar, winter – Apr to Sept) as well as annually.

Note that no changes in sewer overflows are modelled. Reduced overflow frequency and volume could also be expected to have water quality benefits.

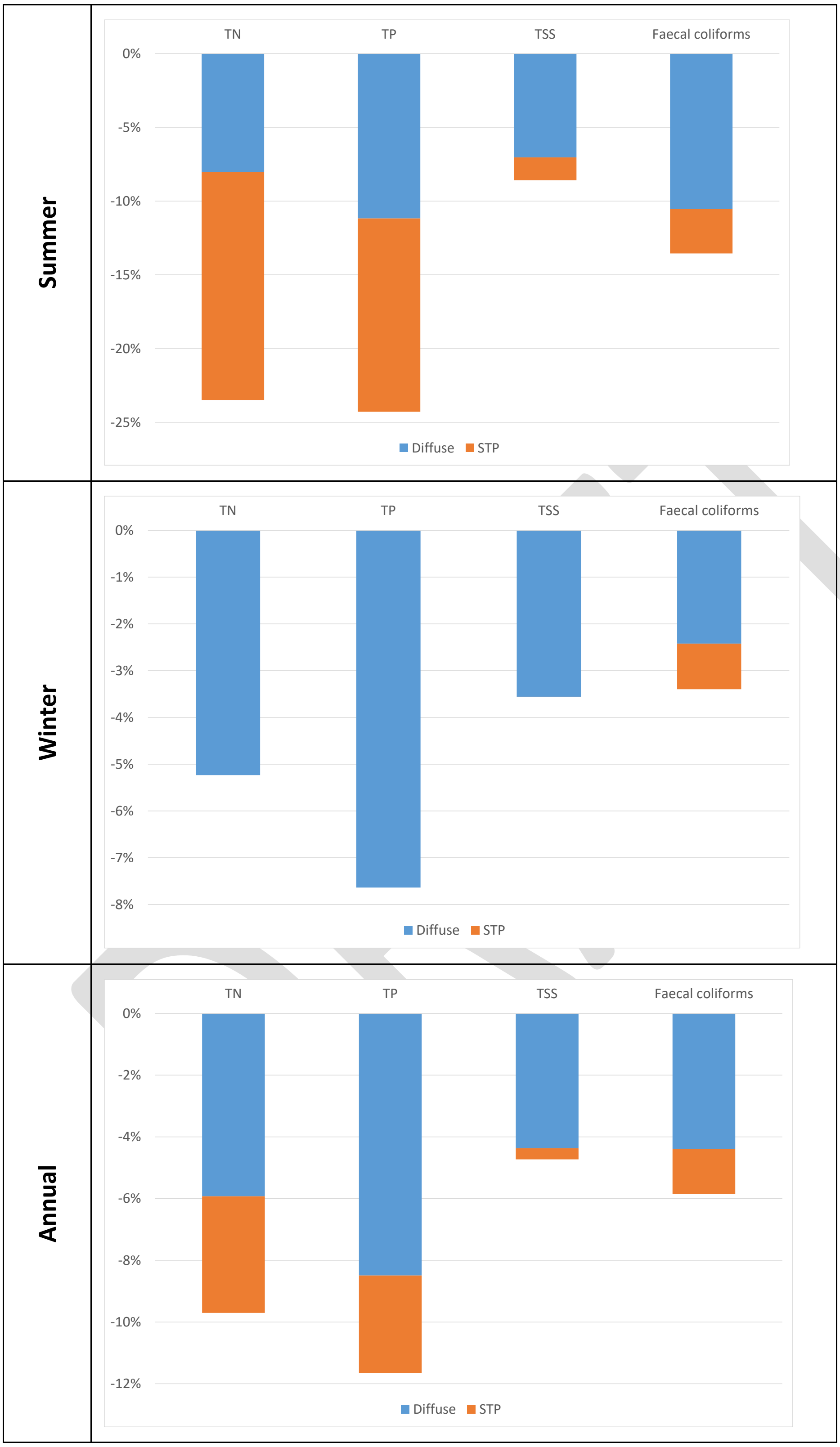


FIGURE 68. LOAD REDUCTION TARGETS FOR THE DUCK RIVER CATCHMENT (MEDIUM TERM - 2027)

FIGURE 69. LOAD REDUCTION TARGETS FOR THE MONTAGU RIVER CATCHMENT (MEDIUM TERM - 2027)

FIGURE 70. LOAD REDUCTION TARGETS FOR THE WELCOME RIVER CATCHMENT (MEDIUM TERM - 2027)

These figures show that it is possible to achieve substantial decreases in all pollutant exports from all three catchments. Impacts are the greatest in the Duck River catchment with substantial decreases in point source loads from STP upgrades and a move to summer reuse. Diffuse load reductions are also substantial. The greatest relative improvement in water quality can be expected during the summer months, from October to March, with smaller but still substantial decreases expected in winter loads across all three catchments.

These feasible load reduction targets are summarised in Table 4. Note that Base Case load estimates for all subcatchments are provided in Appendix 4.

TABLE 4. FEASIBLE LOAD REDUCTION TARGETS FOR CIRCULAR HEAD CATCHMENTS

	Summer	Winter	Annual
Duck River			
TN	-23%	-5%	-10%
TP	-24%	-8%	-12%
TSS	-9%	-4%	-5%
Faecal coliforms	-14%	-3%	-6%
Montagu River			
TN	-9%	-5%	-6%
TP	-12%	-8%	-9%
TSS	-5%	-3%	-3%
Faecal coliforms	-11%	-3%	-5%
Welcome River			
TN	-11%	-5%	-7%
TP	-14%	-7%	-8%
TSS	-8%	-3%	-5%
Faecal coliforms	-16%	-4%	-7%

11 Recommendations

11.1 Biodiversity

Recommendations for protecting and improving biodiversity values in Circular Head are provided below.

11.1.1 Education and on-ground works

- Exclude stock from streams, wetlands and coastal lagoons and foreshore areas wherever possible.
    - The lower Duck River and its tributaries should be a particular focus of stock exclusion given its high value for GFC, potential water quality benefits and its generally degraded character.
- Stock should be fenced out of drains, particularly in the Welcome River catchment where the Marrawah skipper lives in drains and is impacted by stock access.
- Detailed mapping of the seascape transition landscape as well as wetlands and coastal lagoons is required. This mapping should be used, along with an economic evaluation of production costs and benefits of fencing areas out, to target and inform discussions with farmers around rehabilitation of these landscapes.
- The connected wild river landscape of the Welcome River catchment should be protected through:
    - protection and improvement of condition for small extent ovata and woodland forest communities through restricting stock access to remnants and reducing or avoiding clearing
    - restricting stock access to streams is also important
    - better mapping of ovata is required to prioritise areas for protection and ensure good planning and management decisions are to avoid negative impacts.
- Quad bike and 4WD access to Anthony Beach, Shipwreck Point and Perkins Beach as well as in the coastal mosaic landscape on the western edge of the Welcome River catchment should be managed. In the first instance this should focus on education and involvement of recreational users in works to protect values in these areas (such as construction of fencing). If this does not adequately protect biodiversity values in these areas, restrictions to recreational use of these areas should be considered.
- In terms of specific small scale projects, efforts should also be made to implement actions in the PPP from DPIPWE's species prioritisation project. This provides a very good list of specific projects that can be undertaken at a range of budgets to secure individual threatened flora and fauna species.
- Education activities focused on increasing community understanding of local biodiversity values and threats to these should be undertaken. This could include field days focused on the Giant Freshwater Crayfish, tree identification and general natural values in the area to increase the understanding of the local community. These should be hands on and promote case studies where farmers have taken positive action to protect and improve biodiversity and should include discussion of both the costs and the economic benefits to the farmer.

11.1.2 Planning and management

- A management plan should be developed for Robbins Island to identify priority areas, develop offsets and areas to be reserved. As part of this, a baseline survey of natural values including geomorphological and archaeological surveys should be carried out.
- RAMSAR listing should be sought again for the seascape landscape around Duck Bay and Robbins passage with efforts made to engage local landholders in the process and to address any of their concerns. The previous application can be used as the basis for a new application.

- The Statewide Planning Scheme should include protection for important vegetation rather than for threatened vegetation only.

11.1.3 Monitoring and Research

- A desktop review analysis of natural values information such as TasVeg, threatened flora and fauna data, other priority species (locally significant) should be undertaken with a view to identifying specific priority issues and areas where data needs to be fixed and sites or values need to be better mapped or studied before meaningful management options can be developed.
- Long term monitoring needs to be undertaken. This should continue existing monitoring projects as well as involve commencement of additional projects focused on key values and habitats.

11.2 Water Quality

Grazing and dairy areas are the main diffuse sources of pollutant loads to the Circular Head catchments. Duck Bay also has point source contributions from the Smithton STP and sewer overflows, largely from the Davies st pump station. Recommended management actions to reduce pollutant loads in the catchment are summarised below, based on the analysis and stakeholder feedback detailed in this Plan.

11.2.1 Maximising oyster lease opening periods in the short term

In the long run, the oyster industry will be most benefitted by reductions in the export of pathogens to the estuary. However in the short term, closure periods could be minimised by the installation of continuous salinity monitoring at the oyster leases. This monitoring would allow for a lead time between the flow trigger being met at Scotchtown weir and water quality at the lease being impacted. This would allow time for some oysters to be lifted or harvested before the closure takes effect. In addition it may allow the leases to be reopened earlier than is currently the case using only sporadic salinity measurement. A funding proposal has previously been developed jointly by the oyster and dairy industries. This proposal estimated that 5 salinity probes would be required, at an upfront cost of $50,000, with an additional $10,000 a year being required to clean the probes to ensure they are working properly. Options for funding this proposal should be further investigated. Any changes to monitoring would need to be overseen by TSQAP to be able to be used as part of the closure system.

11.2.2 Grazing management

- Best practice fertiliser use should be encouraged. Improved fertiliser management represents a win-win solution for improving water quality, particularly when used as part of environmental accreditation and marketing of beef products, and should be encouraged on all beef grazing farms.
- Where possible stock should be fenced out of streams both for its benefits to water quality as well as for benefits to stream bank stability and stream condition. While this action has relatively small modelled benefits for water quality, benefits of reduced stock trampling, increased streambank erosion and subsequent increases in stream turbidity are likely to be substantial but were not included in the modelling.
- Riparian revegetation in beef grazing areas should focus on broadscale adoption of narrower buffers with farmers encouraged to increase buffer width over time where possible. Wider buffers should be the focus in stream sections where additional biodiversity benefits are the greatest, for example where they act to connect native vegetation remnants and can be used as corridors for native flora and fauna. Areas targeted should also include those where increased stream bank stability or stream shading are required or where riparian vegetation

could benefit threatened species or communities. Where riparian vegetation includes restricting stock access to streams, benefits to water quality will be greater

11.2.3 Dairy management

- Efforts should be focused on reducing milk shed water use in at risk areas of the catchment (low lying flats) where sufficient storage volumes are difficult to achieve. The benefits from this action are likely to come in the form of reduced storage volumes required and associated costs of effluent storage. This investment would mean that more farmers could be expected to have sufficient storage or at least levels of storage that are sufficient for longer periods of time. This would in turn have benefits for water quality. Programs focused on reducing milk shed water use may include a program of monitoring milk shed water use and helping farmers to identify peak times when excess water use is occurring and strategies for managing this.
- Effective effluent storage and management is important but the difficulty of achieving it varies through the catchments depending on location.
    - In lower risk areas such as those occurring on the red soils and low lying hills, best practice effluent management should be possible to achieve on farm with traditional solutions. Efforts should focus on helping farmers to bring their systems and practices in line with best practice. Sufficient effluent storage should be provided for on dairy farms. This storage should be well-designed and placed to ensure effluent can be applied to an adequate area of the farm, and such that storages are unlikely to leach or overflow effluent.
    - In high risk flatter areas of the catchment best practice effluent management is much more complex due to physical difficulties with building storages and the higher costs of their construction. Innovative solutions such as off-site spreading, above ground storages or communal storages may be required to achieve best practice. Assistance should be provided with developing innovative options on a case by case basis and ensuring that longer periods of storage are available even if providing sufficient storage for the entire season is not possible. The primary focus in these areas should be on reducing the generation of effluent to be stored through reduced milk shed water use.
- Partnerships between Dairy Tasmania and Cradle Coast NRM are an important vehicle for achieving management outcomes. Programs such as the FertSMART program and Clean Rivers should continue to be supported.
    - Best practice fertiliser use should be encouraged by programs such as FertSMART. It is expected that best practice fertiliser management will be very effective at reducing nutrient loads if it is applied broadly across the catchment. These programs represent a win-win solution for improving water quality and should be encouraged on all dairy farms.
    - Programs to assist farmers in fencing stock out of drains and ephemeral streams (not hump and hollow) should continue to be undertaken. These may include a mix of education on the benefits to farmers of drain fencing as well as incentives to undertake these works.
    - Where possible, stock should be fenced out of streams both for its benefits to water quality as well as for benefits to stream bank stability, stream condition and biodiversity.
- Riparian revegetation in dairy milking platform areas should be focused on stream sections where the greatest biodiversity benefits can be achieved, rather prioritised on the basis of any potential impacts on water quality. Narrower buffers that are more easily adoptable and so more broadly applied can be expected to have greater impacts on diffuse catchment loads. Farmers should still be encouraged to develop wider buffers where possible,

particularly where these buffers can act as corridors for wildlife, protect threatened species or communities or connected fragmented remnants, given the greater biodiversity benefits of wider rather than narrower buffers. Areas targeted should be those where increased stream bank stability or stream shading are required or where riparian vegetation could benefit threatened species or communities. Where riparian vegetation includes restricting stock access to streams, benefits to water quality will be greater. To maximise water quality benefits, riparian vegetation in areas where flows move as sheets flow through the riparian zone, rather than as channelized flows through a drain network should be a priority.

- Low rate winter irrigation on high risk flats where it is difficult to develop sufficient levels of storage should also be trialled and, if successful, encouraged through extension programs. This action is promising both in terms of reducing pollutant load exports where it is difficult for farmers to have sufficient storage, as well as in terms of reducing the size and cost of storages required for providing storage that is sufficient for longer periods of time.

11.2.4 Point source management

- Taswater should continue to invest in infrastructure improvements designed to reduce the frequency and volume of sewer overflows, particularly from the Davies st Pump Station.
- The proposed summer reuse scheme for Smithton STP is very effective in reducing pollutant loads over summer, particularly nutrients, but also to a lesser extent pathogens. Taswater are encouraged to progress this option further.
- Upgrades to the Smithton STP to remove all pathogens from the discharge are also likely to have benefits to winter water quality and reduce pressures on oyster growers. Taswater are encouraged to progress these upgrades.

12 References

ASCHEM (2014). *Pesticide Water Monitoring Program: Routine Monitoring Results*. Retrieved from http://water.dipw.tas.gov.au/wist/ui

Broad, S. T. and Cotching, W. E. (2009). Assessing the spatial variation of dairy farm total phosphorus losses in the Duck River, NW Tasmania. *18th World IMACS / MODSIM Congress, Cairns, Australia* 13-17 July 2009.

BOM (2014). Average annual, seasonal and monthly rainfall, Rainfall grids for October to April and May to September. Bureau of Meteorology, accessed December 2014, http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp?period=wet&area=oz#maps

DPIWE (2000). *Environmental Management Goals for Tasmanian Surface Waters: Catchments within the Circular Head and Waratah/Wynyard Municipal Areas January 2000*. Department of Primary Industry, Water and Environment, Tasmania.

DPIWE (2003). *Water Quality of Rivers in the Duck River Catchment: A Report Forming Part of the Requirements for 'State of Rivers' Reporting Part 1.* Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart. Technical Report No. WAP 03/08.

DPIWE (2003a). *State of the River Report for the Duck River Catchment.* Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart. Technical Report No. WAP 03/08

DPIWE (2003). *State of the River Report for the Montagu River Catchment.* Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart. Technical Report No. WAP 03/09.

DPIWE (2010). *Far North West Marine Fishing Development Plan May 1999*. Department of Primary Industry, Water and Environment, Tasmania.

DPIPWE (2013). *TASVEG 3.0*, Released November 2013. Tasmanian Vegetation Monitoring and Mapping Program, Resource Management and Conservation Division, Department of Primary Industries, Parks, Water and Environment.

DPIPWE (2014). The Water Information System of Tasmania, Department of Primary Industries, Parks, Water and Environment, accessed December 2014, http://wrt.tas.gov.au/wist/ui

Forest Practices Board (2000). Forest Practices Code, http://www.fpa.tas.gov.au/__data/assets/pdf_file/0020/58115/Forest_Practices_Code_2000.pdf

Green, G. (2001). *North-west rivers environmental review*: *A review of Tasmanian environmental quality data to 2001*. Supervising Scientist Report 167, Supervising Scientist, Darwin.

Holz, G. K. (2009). Seasonal variation in groundwater levels and quality under intensively drained and grazed pastures in the Montagu catchment, NW Tasmania. *Agricultural Water Management,* 96:2 p.2 55-266.

Hydro Tasmania (2008). *DPIW – Surface Water Models Duck River Catchment Version No: 2.1.* Hobart, Tasmania.

Kelly, R. and White, M. (2015). MiniCAPER DSS: Model Documentation Technical Report, Rivers and Waters for Life Program, NRM North, Launceston, December 2015.

Koehnken, L. (2012). *VDL Water Quality Monitoring Plan: VDL proposal for water quality monitoring in the Welcome and Harcus Rivers Draft- July2011*. Tasmania.

Ling F.L.N., Gupta V., Willis M., Bennett J.C., Robinson K.A., Paudel K., Post D.A. and Marvanek S. (2009). *River modelling for Tasmania. Volume 1: the Arthur-Inglis-Cam region*. A report to the Australian Government from the CSIRO Tasmania Sustainable Yields Project, CSIRO Water for a Healthy Country Flagship, Australia.

Lynch, T.P. and Blühdorn, D.R. (1997). *Reservation assessment and habitat requirements of the giant Tasmanian freshwater lobster, Astacopsis gouldi.* Report to the Tasmanian RFA Environment and Heritage Technical Committee.

Murphy, R.J., Crawford, C. M. and Barmuta, L. (2002). *Estuarine Health in Tasmania, status and indicators: water quality: Technical report series no. 16*. Tasmanian Aquaculture and Fisheries, University of Tasmania.

Pinto, R. and Graham, B. (2000). *Environmental Water Requirements for Duck River*. Department of Primary Industries, Water and Environment, Hobart Technical Report No. WRA 00/13.

SKM (2003). *Welcome River Environmental Flows*: *Flow Recommendations Paper Final 24/12/2003*. Sinclair Knight Merz, Hobart, Tasmania.

Strategic Projects Office (2013). Eastern *Foreshore Smithton Landscape Development Plan Final, June 2013*. Circular Head Council and Waratah-Wynyard Council, Tasmania.

Weber, T.R and G. Holz (2007). Developing a catchment model for a rural dominated catchment in North west Tasmania, In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp:2340-2346. http://www.mssanz.org.au/MODSIM07/papers/43_s47/DevelopingACatchments47_Weber_.pdf

APPENDIX 1. CIRCULAR HEAD BIODIVERSITY & WATER QUALITY IMPROVEMENT PLAN KEY STAKEHOLDER WORKSHOP

A1.1. INTRODUCTION

A key stakeholder workshop was held to inform the development of a Biodiversity and Water Quality Improvement Plan for the Duck, Montagu and Welcome Rivers. The workshop was held in Smithton on 23 September 2015. The meeting had two main aims:

- To educate key stakeholders about the BWQIP and what it will do.
- To seek stakeholder input on scenarios, impacts and management actions to be considered by the Plan.

Workshop attendees and their affiliations are given in Table 5.

TABLE 5. KEY STAKEHOLDER WORKSHOP ATTENDEES

Name	Organisation
Stephen Clarke	Forico Pty Ltd
Bill Cotching	Soil Management Consultant
Robert Cox	Greenham Tasmania
Paul Ellery	Tasmanian Irrigation
Matthew Gunningham	Dairy farmer
Sue Jennings	Forestry Tasmania and Circular Head Landcare Group
Jacki Langton	Dairy Tas
Daniel Lester	TasWater
Brigid Morrison	University of Tasmania
Grant Pearce	Cradle Coast NRM
Cassie Plaza	Bolduans Bay Oysters & Oysters Tas
Desmond Poke	Bolduans Bay Oysters
Matthew Saward	Circular Head Council
Bill Wood	TasWater

The workshop discussion centred around three main themes:

- Values
  - What do you most value about the catchment, rivers and estuary?
  - What do you use them for?
  - What attributes would you like to see protected?
- Impacts
  - What are you most concerned about in terms of the biodiversity and future health of the catchment and rivers?
  - What changes do you see could harm the catchment and rivers?
  - What changes do you see that could benefit the catchment or rivers?
- Management actions

- What opportunities do you see to improve and protect our catchment and rivers?
- What actions do you think should be taken to protect and enhance biodiversity and water quality in the rivers and estuary?

Participants were also asked to complete and return an individual feedback form to ensure the views of the entire audience were heard

A1.2. Values

What do you most value about the catchment, rivers and estuary? What do you use them for? What attributes would you like to see protected?

The most common values people associate with the catchment and rivers related to biodiversity, irrigation, agriculture, oyster growing and product image ('*clean green'*), employment, recreation (boating and fishing), drinking water and aesthetics.

A1.2.1. Biodiversity

Many people indicated that they value the biodiversity of the catchment and freshwater systems that flow through it. Participants pointed out that the area, particularly around the Duck River mud flats, is internationally important with over 21 migratory species visiting. For shorebirds the area provides a key food supply for migration. Furthermore, the catchment is significant as it is a '*Tasmanian Devil* [facial tumour] *disease free area*' and home to species such as the burrowing crayfish and freshwater lobster. Mud flats and flora such as seagrass, rice grass and willows (in one case) were also valued as habitat for fauna.

Ecosystem services that the catchment provides were also acknowledged. One participant remarked about the need to '*value high conservation... forests within our freehold* [as they are] *critical to water catchments in providing basic services of nature*'. They followed up by saying that we should '*value and understand our role as custodian of upper catchment and the potential impacts of our operations on water quality and biodiversity. i.e. basic services of nature*'.

A1.2.2. Irrigation, Agriculture, the Oyster Industry, Production and Employment

Water is seen as essential for agriculture, irrigation and the oyster industry, underpinning employment and the economy throughout the catchment. Water quality needs to be safe for stock water as well as for irrigation and other agricultural activities. Water extraction from rivers is also highly valued and it was felt that the rivers in the catchment can provide a reliable source of water for agricultural because the area has '*high rainfall*'. One participant commented that they would value '*increased irrigation of pastures + crops* [because it gives them the] *ability to grow low cost feed*'. The production values within the freshwater system were also discussed with oyster growers raising issues around the need for clean water for aquaculture activities.

The river is also viewed by some as important for drainage. Two participants commented that they valued the river '*as a drainage system – particularly for agriculture*'.

Common values for many participants are the importance of retaining '*our clean green* [product] *image*' and future growth of agricultural production in Circular Head. One person summed up by saying that they '*do not want to see degradation of future potential of productivity of the district*' as a result of water quality issues.

A1.2.3. Recreation

The most common recreational activities undertaken in the catchment, as mentioned by the group of participants are: fishing, boating, kayaking and bushwalking. While the water based activities are valued, most commented that in many areas of the freshwater system the water quality is too poor for these types of activities to be safely undertaken. For example, a water quality issue exists in the middle of the catchment between Lake Mikany and the water supply take off point due to agricultural activities and leachate from a waste disposal site. One participant commented '*social - recreation - not much in upper catchments - poor quality water/ small rivers*'.

A1.2.4. Drinking water

Safe drinking water is highly valued by many participants. Hence, the upper catchment is also valued for the clean quality water supply originating from areas high in the catchment. Water quality is also important in Lake Mikany as this is where Smithton's town water supply is extracted from.

A1.2.5. Aesthetic Values and Tourism

The catchment is used for a variety of primary activities and industries. One participant commented that the '*diversity of land use provides good aesthetics to the view*'.

While tourism wasn't a noted priority value for many participants it was recognised that tourism can be affected by water quality in terms of aesthetic value, recreation, local production of produce and sales. Hence, water quality can affect opportunities to market produce throughout the year (particularly for the oyster industry) and in turn can reduce social capital of the area.

One participant summed up their thoughts by saying that all should '*Value collaboration/ co-operation with Government Statutory bodies and other stakeholders in maintaining/ enhancing water quality/ biodiversity'.*

A1.3. Impacts

What are you most concerned about in terms of the future health of the catchment and rivers? What changes do you see could harm the catchment, rivers and biodiversity? What opportunities do you see that could improve, protect or enhance waterways and biodiversity in the catchment?

There are a broad range of concerns people have about factors that could impact on the rivers and biodiversity in the catchment. These include cropping, beef and dairy practices, sewer, stormwater and farm discharge, weed species, local soils and lack of riparian vegetation. People also indicated various factors that could benefit the system.

A1.3.1. Agricultural: Dairy, Beef and Cropping

Participants expressed a broad range of concerns about the effect of dairy and/or beef farming on water quality in the catchment. These include dairy effluent release, hump and hollow drainage practices, a lack of riparian vegetation and fencing, stock access to streams, soil erosion from crossings on farms and expected intensification of the dairy industry in the catchment.

Concerns were raised about potential water quality impacts of expected intensification of dairy by 30 percent, which would require conversion of beef and forestry land. It was stated that with intensification of the dairy industry comes further land under hump and hollow practices. The benefits of hump and hollow practices in terms of providing effective drainage were recognised, with participants stating 'h*ump and hollow - gets water off farms more efficiently*', however it was also acknowledged that the practice does '*significantly modify landscape / drainage'*. One participant expressed concerns that '*increased area under hump & hollow drainage will potentially increase flood peaks + delivery of nutrients + bacteria to the river system*'. To cope with increased pressure, the options for building a wetland or to replace hump and hollow drainage was briefly discussed. Several stakeholders indicated that they felt wetlands are not a practical solution to water quality issues because of the considerable amount of land area they would occupy and that more innovative solutions should be considered.

Effluent systems were also considered. One participant pointed out that '*increased cow numbers lead to increased pressure on existing effluent systems*'. However it was noted that dairy effluent treatment is very stringent for new dairies and that notices are being served on 'rogue' dairies. Point sources off farms were felt to have a considerable effect on water quality. Some felt that poor water quality was '*90% driven by what comes off paddocks'.* While most participants agreed that '*point source (Dairy Effluent) plays a part*' in affecting water quality not all stakeholders agreed that dairy was the main contributing factor: '*90% of effluent coming off farms - not predominantly from dairies. (Point contamination)*'.

Stock access to streams was seen as another major issue contributing to poor water quality. Several participants pointed out that both the beef and dairy industry were at fault, with comments on water quality issues including '*intensive grazing practices - close to waterways. Beef and dairy'; 'Dairy farms & beef farms effluent run off / cattle in waterways'; 'Beef farmers - no. Riparian fencing - no effluent systems at stock yards';* and '*Soil erosion from crossings on farms*'. One participant stated '*Turbidity, nutrients, bacteria* [are all] *coming from stock access to streams + stream bank erosion*'. It was also suggested that pH readings in the water are not the result of point sources.

Irrigation and fertiliser practices were also briefly discussed. Site preparation activities and soil disturbance, '*heavy irrigation making low levels of water in streams'* and '*nutrients from excess fertiliser application + poor timing of application*' are all seen as contributing factors of water quality. One participant also commented about herbicides and that in 'o*ld testing - MCPA* [was] *over allowed levels*'.

It was questioned as to how water quality over the last 15 years has not improved considering many dairies had been converted to plantation. Some suggested that maybe the increase in intensity of farming or improved delivery of water/ effluent into the waterway may be the cause. In the '*old days*' cows got moved to higher ground during the wet season but now improved drainage means cows can be on the low lying paddocks 365 days per year. It was said that data on changes in water quality over time is lacking so there is no way of comprehensively reckoning these types of theories.

A1.3.2. Oyster Industry

Oyster growers are concerned about the expected expansion of the dairy industry by approximately 30%. Industry growth would mean some beef and plantation areas will be converted to allow for the expansion. Intensification of the dairy industry would mean more cows on the same land area which could further impact water quality issues and add to biotoxins in oysters. It was suggested that the estuary flushes twice a day which is what currently saves the oyster growing industry in the catchment because the tides provide a buffer for water quality. One participant commented that '*rainfall* [is] *used as a proxy for toxins* [in oysters]'. Another said '*freshwater is not a problem – it's what it washes down which causes the closures*'. It was suggested that the amount of rain that it takes to close down oyster growing areas has gone down over the last 20 years and that low amounts of rain can cause immediate closures. Salinity is monitored daily and flow is used as an indicator for *E. coli*. While oyster meat is sent to Sydney for testing, the data on meat has a slow turn around and the cost of testing to the oyster industry is prohibitive. Participants referred to a CSIRO study that identified sediment and nutrient levels in the catchment as the highest in the State. One stakeholder indicated that new technology might assist with monitoring in the future, with the possibility of micro GPS available in the next few years to track point sources.

One person summed up by saying that for the catchment '*Industry diversity is critical - not dairying at the expense of oysters*'. Plans for further plantations in the catchment were also questioned with regards to their possible impact on water quality.

A1.3.3. Forestry

As part of forestry operations, some participants had concerns about the effect of '*soil disturbance due to harvesting and site preparation activities*'; '*Soil erosion from crossings on... forestry areas'*; '*water run-off from road/ track network*' and '*herbicide / pesticide spraying'* on water quality. One participant stated that the '*Duck has highest turbidity and nutrient levels in the State - turbidity from Forest areas comes primarily from roads not harvesting*'. Another said that the '*Forest Industry has a* *duty of care with all waterways on their land. Highly regulated by FPC. Soil and water values are not negotiable*'. A forestry representative noted that '*....all operational aspects...* [of forestry] *are closely controlled and monitored in order to minimise impacts* [this is a] *precautionary principle/ approach adopted in all cases'.*

A1.3.4. Sewer and Stormwater Discharge

A common theme amongst participants was their concern around the impacts of point sources in the catchment. The aging sewer system was discussed with participants concerned about '*TasWater STP discharge into Bay - non compliant 30-40% of time*' and '*Sewage Treatment Plant Pump Station failure*'. Oyster closures are not uncommon as a result. Infiltration into the sewer was also mentioned as well as a groundwater report that had found the sewer leaking into groundwater. The sewage treatment plant currently discharges into Kemps Bay and Taswater will be expanding water quality monitoring in the estuary. One participant suggested '...*McCains, Greenham* [and the] *milk factory to contribute funding...*' toward fixing these types of problems as they are major trade waste customers contributing high flows to the system.

Storm water discharge is also a concern. As part of discussions it was said that '*stormwater* [is] *unmeasured'* and that stormwater outlets only have sediment traps. Along with the sewage treatment plant, several participants listed this in their top five concerns about water quality impacts with one person saying they were concerned about '*old infrastructure of storm water & no monitoring'.*

Other water quality issues briefly discussed included septics in the catchment, groundwater runoff and leachate from the Transfer Station/ Tip, and the unidentified source of a diesel spill or leak in March 2015 which took '*5 days for film to leave mudflats – couldn't pinpoint source*'.

Many people indicated that the solutions could be found for these issues with increased water quality monitoring, upgrading treatment and/or upgrading stormwater and sewer infrastructure.

A1.3.5. Weed Species

Two main weed species were discussed: Rice Grass and Willows. Rice Grass is a problem because it holds onto sediment, but when controlled it can accrete the sediment back into the waterways. It was said that there is approximately 30 hectares of Rice Grass in the catchment and it is estimated that it could be eradicated in approximately 10 years. One participant commented on the progress of eradication pointing out that '*rice grass accreting sediment after control* [is] *not yet happening in the Duck after 2 years control*'. Willows were also considered a pest flora species in the catchment.

A1.3.6. Soil and Riparian Vegetation

The altered landscape of the catchment due to human activity and its impacts on water quality was also raised. A lack of riparian vegetation has resulted in deficiencies in shade over water courses in some areas, depletions in oxygen and hence, probable habitat modification.

Local soils in the catchment can also contribute to poor water quality. Acid sulphate soils are flushing from Scopus Creek causing fish kills and at the top end of Geales Creek acid sulphate and peat soils are draining from a peat bog. While these types of processes can be natural, seasonal drying due to groundwater extraction for irrigation and bores collapsing (in Montagu and Welcome catchments) are increasing the loads and occurrences.

One participant commented that one thing that could be done to improve water quality from human impacts would be '*Paying due care to ground works + drainage operations to avoid erosion in the short term (whilst new vegetation establishes)*'.

A1.3.7. Sea Level Rise

Sea level rise is not currently a main concern of participants however it was mentioned during discussions as having potential implications for low level areas in the future. It was felt that Government departments such as Primary Industries and the Environmental Protection Agency are the best equipped to monitor, collect and advise of new information regarding sea level rise.

A1.4. Management Actions

What opportunities do you see to improve and protect the catchment and rivers? What actions do you think should be taken to protect and enhance biodiversity and water quality in the rivers and estuary?

People came up with a number of management actions they felt would improve water quality. The most frequently raised options were:

- Upgrading wastewater treatment plants, sewage and stormwater network. Suggestions included long detention period of 100 days, a new plant in a different location, better instrumentation on pump station overflows - SCADA system is improving, EPA could regulate and monitor, Reuse waste water for irrigation.
- Research hump and hollow and standing water in hollows and its effect on water quality.
- Possible introduction of a drainage trust on farms? For water off, farms pay for maintenance.
- Development of water quality performance indicators (some sort of shared index) that is accessible and means something to all those industries/ primary producers in the catchment.
- Better timing of fertiliser and spray application.
- Have the forestry industry measure turbidity to determine if harvesting and forestry areas in general are contributing to turbid water courses.
- Fence cattle out of waterways

Other options raised were:

- Increased water quality monitoring at points throughout the catchment
- Carbon charcoal filtering
- Protection of riparian areas and replanting of riparian vegetation
- Monitor road run-off
- Improve old dairy effluent systems
- Distribute dairy shed effluent over greater farm area.

- Extra management of road/ track crossings to minimise turbidity
- Incentives offered to Dairy and Beef farmers for water quality improvement

A1.4.1. Impediments to implementing actions

Participants explored some of the impediments to these actions being implemented. Several impediments were associated with sewage treatment and stormwater management. The large cost associated with improving old infrastructure and/or building a new treatment plant in another area is seen as a major impediment. While reuse of waste water for irrigation is a reasonably popular action, one participant felt that reusing the water from the Pelican Point Pump Station posed its own problems. Regulation and monitoring of discharge and water in the estuary was also favoured by many, however the cost of training staff, testing water and reporting could be inhibiting. It was questioned if any action or actions could be executed in a reasonable timeframe to keep up with new subdivisions and substantially increasing trade wastes from the area.

Similar to the impediments of water quality testing and monitoring as mentioned above, obstacles for the development of a shared water quality index (water quality performance indicators) include, cost of monitoring and reporting as well as who is responsible for the development of indicators and training people in monitoring/ testing. One participant also questioned who would bear the cost and responsibility for '...*central data facilitation*'.

Hump and hollow is a popular low maintenance method for effectively getting water off low lying paddocks. However, the drains are connected to the river system. Research into the effect of hump and hollow on water quality was seen as necessary however the cost of monitoring and research could be prohibitive. Participants referred to a study by Greg Holtz in Togari. Furthermore, the potential replacement of hump and hollow systems with another method for water removal was seen as difficult because of the time and cost involved in changing the landscape. Furthermore, cost involved with implementing a new system, education and maintenance of other methods were also seen as disincentives.

Timing of fertiliser and spray applications was seen as having potential impacts on water quality. One participant asked '...*is there significant difference between beef and dairy*'? They went on to point out that '*generally – ag. activities are exempt from D.As*'. Overall, inhibiting factors for best practice spray and fertiliser application were seen as relating to education and awareness and the cost of plans.

A common action mentioned by many participants is to have cattle and livestock fenced out of streams. This would stop animals excreting in waterways and adding to turbidity. One participant also recognised the added benefit of '*protection of riparian areas*'. However, several impediments and disincentives to fencing off waterways were mentioned. Common responses included the cost of fencing, loss of grazing land, weed growth in corridors, cost of planting buffers, wallabies, farmer cooperation and the lack of time farmers have to do the work. One participant also noted the difficulty in fencing streams on hilly country. Another complexity mentioned was '*disjointed farms – divided by creeks...*'. One participant summed up by saying '*bottom line would be just a single wire to keep cattle out of the actual streams. Can get most of the benefit, without most of the loss'*.

During forest harvesting, water quality is not currently measured. It was a common conception that turbidity should be monitored in order to determine the effect, if any, forestry operations have on water quality, as the '*Duck* [River] *is very turbid'.* Participants said that DPIPWE currently have 200 water quality monitoring sites in the region. It was questioned as to whether the forestry industry would be willing to collect turbidity data.

Monitoring road runoff was also mentioned as an action that may provide information about its contribution to poor water quality. One participant suggested the need to 'm*anage... road/ track crossings to minimise turbidity*' but suggested an impediment to this is '*forestry + farmers* *contractor's day to day operations*'. Other impediments suggested by another participant included '*training of staff in turbidity monitoring* [and] *reporting'*.

APPENDIX 2. STAKEHOLDER FEEDBACK ON FEASIBILITY AND IMPEDIMENTS TO ADOPTION OF POTENTIAL MANAGEMENT ACTIONS

A2.1. Introduction

A stakeholder forum was conducted to seek feedback from key stakeholders from the region on feasible scenarios for adoption of various management practices to inform the development of the Biodiversity and Water Quality Improvement Plan (BWQIP) for Circular Head catchments (Duck, Montagu and Welcome). The stakeholder forum was held in Burnie on the 15 June 2016. The meeting had three main aims:

- To present to key stakeholders preliminary results demonstrating
  - Where pollutants come from
  - The leverage of potential management actions
- To discuss issues causing oyster closures and short, medium and long term solutions to these
- To get key stakeholder feedback on:
  - Impediments to the proposed management actions being adopted
  - Likely rates of adoption with and without NRM programs such as education and incentives for works

The workshop consisted of presentations followed by facilitated discussions around three main themes:

- Current Situation
  - Catchment pollutants
  - Oyster Industry monitoring, closure process and impacts of closures
  - Potential short, medium and long term solutions
- Managing Pollutants
  - Where do pollutants come from – preliminary results
  - Potential management actions for Dairy and Grazing
  - Impediments to the proposed management actions being adopted
  - Likely rates of adoption with and without incentives
- Biodiversity
  - Values
  - Potential actions to protect biodiversity
  - Likely rates of adoption with and without incentives

Given the extraordinary season experienced by both the oyster growers and dairy farmers, with drought, floods, a crash in the milk price and an outbreak of POMS disease in Tasmania, the workshop began with a general discussion of the implications of these difficulties on both industries and their abilities to management water quality and its impacts.

A2.2. Current Situation

A2.2.1. Dairy Industry

Key stakeholders indicated that milk prices might be a long term issue and pressure on the dairy industry. The industry was running at 1% up until April 2015 even with the drought. However, the costs of investing in feed and the increasing price of irrigation has put extra strain on an industry which is currently being offering approximately 50 cents per kg for solids. Hence, there is a lot of angst at a National level as the milk price is dropping.

It was felt that farmers in the North-west are in a better position to manage in the current market compared to those in Victoria however in the long-term this is dependent on improvements in the price of milk internationally. Many farmers expressed hope that by the end of the year that they would be able to break even. It was a common opinion that Tasmanian farmers are generally resilient and good at managing volatility.

With regard to future dairying in Tasmania, most new ventures are expected to be developed around irrigation (e.g. Circular Head scheme). However, it was suggested that farmers in Circular Head would not be significantly impacted under current irrigation plans except one farmer at Arthur River.

Overall, some optimism was expressed for the next 6-12 months in the industry.

A2.2.2. Oyster industry

Unfortunately representatives of the oyster industry had to pull out of attending the meeting at the last minute. Pressures on the industry presented by the POMS disease were acknowledged and discussed and its implications for reducing movement of stock, one of the key management measures open to oyster growers during closures, was recognized as exacerbating the impact of oyster lease closures due to poor water quality.

A2.3. Oyster closures and options for reducing their impacts

A presentation describing the current closure system was provided. This presentation outlined the two different ways in which a closure could be triggers – through a diffuse pollution event tied to catchment runoff or through a sewage spill from the sewer system in Smithton. Impacts of oyster lease closures presented were:

- Oyster growers can't harvest and sell adult stock during closure
- They can sell juvenile stock or send adult stock to depurate elsewhere but stock needs to be quarantined for a period of time if relayed
    - POMS disease means that stock can't be relayed
- Adult stock can grow too large to sell or will lose value

In summary for diffuse pollution events:

- Closures are based on salinity and/or flow triggers
- At least 5 samples of thermotolerant coliforms are collected each year
- These are used to develop flow and salinity triggers for closure
    - Use at least last 30 observations – ie 6 years data
    - Comprehensive assessment of all factors affecting the oyster fishery every 3 years
    - Annual review of trigger levels
- Monitoring cost split between oyster growers and State Government
- Growers do salinity measurements at the lease – sporadic
- If there was a continuous salinity probe at the lease it would be possible to develop better relationships with flow at weir and salinity
    - This would allow for a lag time between flow and closure based on salinity – eg. 2 hours where they could lift or harvest some of their oysters
    - It would maximise open periods as know exactly when salinity has come back down rather than deciding to take a grab sample and finding value is now under threshold.

Funding for continuous salinity measurements at the leases was discussed as a possible short-term measure that could reduce pressure on the oyster industry and maximise the periods that they are open. During the discussion a previous funding application put in by Dairy Tas and the oyster growers to place salinity probes was discussed. This funding application was not successful. This application identified that 5 salinity probes would be required to adequately measure salinity levels for use in the closure process. It was noted that if this option was pursued then the costs would not just be for the upfront installation of the probes, but would also need to include the cost of weekly cleaning of the probes due to algal growth. This was estimated at a total annual cost of $125,000.

Medium to long term solutions for reducing closures from diffuse source pollutants were the focus of the next part of the workshop, where management actions to improve water quality were discussed.

The second trigger for closures related to sewer overflows. The Davy st pump station was seen as a significant cause of many of these issues. The closure process for sewer overflows is:

- Taswater have to notify TSQAP of when a sewage spill/pump station failure occurs
- TSQAP put together a Situation Report including location, time, estimated volume as well as tide information to figure out who likely to be impacted and to what extent
- Taswater have to do testing for thermotolerant coliforms at multiple sites to estimate the impacts
- The oyster fishery is automatically closed for 21 days after a spill
- They need to test for viruses in the meat before the lease can be opened again
- There is a 7 day turn around for meat samples to be processed as they need to be sent to Sydney for testing.

Representatives from TasWater indicated that TasWater are in the process of completing upgrades to the Davy st pump station that will reduce the frequency of overflow events causing fewer closures of oyster leases.

A2.4. Managing Pollutants to improve water quality

The second part of the workshop focused on discussion of the feasibility and adoptability of various management actions. Results of modelling presented showed that diffuse pollutants are the primary source in all catchments. Grazing and dairy operations were shown to be major controllable sources of all pollutants. Discussions are the feasibility and adoptability of various management actions are summarized below.

A2.4.1. Dairy Industry

A2.4.1.1. Effluent Storage and managing the timing and speed of effluent application

Specific effluent storage options and their potential adoption on farms in some cases with particular soil types were discussed.

Effluent storage is a particular issue in Circular Head, particularly on the floodplain areas of the catchments as these are very wet and require very large volumes of storage as well as large areas for irrigating out effluent. It was suggested that Councils could enforce storages on new developments but that for existing dairies Councils were less likely to enforce strict effluent storage standards.

In Circular Head, new effluent storage is regard as being very expensive due to high groundwater levels, soil types and large rainfall inputs. Circular Head was seen as the most expensive area in the State for providing adequate effluent storage. High groundwater liners would be required in many areas of Circular Head. It was said that managing timing and speed is tied to storage size, and it was felt that this was not as adoptable in Circular Head compared to places like New Zealand. It was stated that there are lots of constraints with these systems being adopted in North-west Tasmania, including issues around irrigators becoming bogged in the wet soils.

Over the next 10-20 years it was suggested that there are no excuses for inadequate effluent storage on good clays and 100% adoption should be the aim. For example, in the Duck catchment in particular there are good soils on the hillsides. It was suggested that on red soils and forest regions adoption would be easier than on flats like at Togari, where implementation would be very hard and expensive.

On the flats solutions have been trailed such as placing storage on hills and pumping to the storage. Then in summer a gravity feed is used to irrigate. One possible option for managing effluent in these areas that was suggested the use of communal storage such as on VDL. Another possible option is to install above ground storage tanks and/or lined ponds. The cost of doing this is also considered high and this option is site specific. It was suggested that to resolve issues around effluent storage in flat areas there would need to be 'major policy change and massive infrastructure investment'.

Retrofitting existing farms is difficult and this may only happen after the sale of a farm or with generational change. Even with farms changing hands, stakeholders suggested that only around 10-15% would retrofit without any investment incentive. At the end of the day it will all come down to the people involved. It was felt that having few owner operators would likely mean lower adoption as there would be less 'care factor'.

The importance of skill and good practice in spreading effluent to avoid pollutant runoff was also discussed. While engineering and technical solutions could help solve some of the problems, the effectiveness of these systems would be limited by human factors such as their management given the high maintenance required. Contractors who are employed to deal with effluent were also discussed. It was said that contractors spreading effluent onto dry ground offsite could possibly be considered as another possible option for north-west dairy farms operating on the flats.

A2.4.1.2. Milk Shed Water Use

Reducing water shed milk use was seen as a very adoptable action. The two main strategies identified to reduce water use were: 1) the use of new technology and 2) education of the person using the hose. Participants suggested that there could be a 50% decrease in the water used in dairy sheds using these strategies. An example was given that if education was provided and water was metered and it could result in the use of 40L/cow/day rather than 140L/cow/day. It is felt that water use needs to be monitored in order to collect data to help inform people. Programs that monitor milk shed water use over a 2-3 weeks period and help farmers identify times at which water use is elevated could be very effective at bringing down water use.

Grey water recycling was also briefly discussed as an option but most agreed that monitoring in the shed and education should be the primary strategies. It was agreed that education and on-farm monitoring should be aimed at all at risk farms with an aim to decrease water usage by 50%. It was agreed that the program should target high risk farms located on flats. There was some feeling that it would be hard to achieve 100% adoption as most people underestimate how much water they use and that it is an issue on their farm.

A2.4.1.3. Stock off Paddocks

Another management option to improve catchment water quality is to move stock off paddocks. However, participants suggested that farmers would be unwilling to do this given that the whole point of hump and hollow was to allow them to keep their stock on paddock during very wet periods. Soil pugging was not seen as a driver for change. It was suggested that no-one would adopt this management practice and hence there would be approximately 0% uptake. Participants suggested that because there is no profit motive involved then education programs would need to be repeated at least every 5 years.

A2.4.1.4. Irrigation Management

Participants suggested that irrigation management depends on associated tariffs. However, they felt that this did not have a substantial impact as long as the irrigation tended to be started early and ended early for the season.

A2.4.1.5. Fertiliser Management

Farmers see a clear economic advantage with regard to fertilizer best management practices (BMP). This is because farmers ultimately pay for the fertilizer used and cost savings will be made from the start. Also, milk companies are beginning to place pressure on farmers regarding fertilizer use. Hence, it is expected that 100% farm adoption of BMP for fertilizer use is possible.

There are currently 90 farms out of 400 statewide participating in the FERTSMART program. It was felt that it is imperative to emphasize to farmers that fertilizer management is an important thing and by being part of the program it shows good will, helps develop relationships with fertilizer service providers and enables professional development; all part of what CCNRM try to foster in the region.

This management action is seen as a win-win option because adopting this management strategy will see both farmer and public benefits.

A2.4.1.6. Exclude Stock from Streams

Ephemeral streams were discussed in relation to stock access and their impact on water quality. It was suggested that while it may be possible to aim to have all stock kept out of streams in North-east Tasmania and in the Midlands region, this would be a much harder proposal in the North-west of Tasmania because of the intermingling of streams and drainage networks. Participants expressed that people like doing the right thing however in order for farms to help 'clean-up' the rivers by keeping stock out of waterways incentives would need to be offered. Comments below exclude ephemeral streams. These were considered to act as part of the drain network.

It was felt that water troughs play an integral role in keeping stock out of streams. This is because if a trough is provided cattle will choose to drink from the trough rather than the river. However they are expensive and can be hard to manage. New technology coming online is expected to assist in water trough management.

A lack of data on where stock are currently accessing streams was seen as an issue for targeting where actions should be taken. Remote sensing of fences was seen as a good investment.

The most widely viewed potential adoptable technique in the North-west region to exclude stock from streams was seen to be the use a single wire with no or minimal buffer area. It was thought that potential adoption of this method to keep stock out of streams could be as high as 95%. However, it was noted that there is some resistance in the region and on ground action is up to individual farms. One participant felt that a 70% adoption rate would be the greatest level of adoption that could be expected.

For fencing in general to become a feasible option it was suggested that high priority areas need to be identified and targeted first. This should incorporate identifying the differences between flat areas and hills as well as the various impacts dairy farms have compared to beef grazing on water quality. This should include the associated health benefits/outcomes of fencing stock out of streams. Waterways that are already fenced off in the region can also be identified and mapped as part of the process.

A2.4.1.7. Exclude Stock from Drains and ephemeral streams

Stakeholders agreed that fencing stock out of drains was a very adoptable management option. A driver of this is the clear financial benefit associated with keeping stock out of drains; otherwise drains have to be re-dug every two years. Key stakeholder indicated that farmers would be interested in receiving education and any incentives associated with this action. The 'Clean Rivers' program run by Dairy Tasmania has already provided funding to some farms. It is expected that an 80% adoption is possible for fencing off drains and ephemeral streams over the next 10-20 years.

Improving spreader technology was also briefly discussed in relation to drains. As equipment and GPS get better the amount of effluent and fertilizer being thrown directly over drains and ending up in streams will reduce.

A2.4.1.8. Re-vegetated Buffers

The potential for developing vegetated buffers of various widths (5m- 20m) along stream-sides was discussed. Participants advised that 20 metre buffers were not adoptable, even with incentives. Even narrow buffers of 5 metres were considered to be difficult to adopt because people feel they are losing paddock space and grass area. Weeds that grow in buffer zones are also considered a disincentive. It was suggested that maybe any efforts toward the development of buffers along waterways in the north-west should be targeted at farms that change hands.

Table 6 shows that even with various incentives participants still felt that there would be low or no uptake on the establishment of vegetated buffers as a management option for improving water quality in North-west catchments.

TABLE 6. POTENTIAL INCENTIVES TO AID THE ESTABLISHMENT OF VARIOUS WIDTHS OF RIPARIAN BUFFER AND THE EXPECTED UPTAKE

	Education	Education and upfront incentives	Education, upfront incentives and maintenance
5 metres	1-2%	20%	Same as education and upfront only
10 metres	0%	<5%	Same as education and upfront only
20 metres	0%	<5%	Same as education and upfront only

It was suggested that improvement in technology available over time might help improve adoption rates.

A2.4.1.9. Laneways

It was suggested that there was not much that could be done in the way of improving laneway management. Laneways are very farm specific, and it was felt that farms are already doing as much as they can. Hence, laneways were not considered a significant management action because of the limited options for improvement.

It was explained that the impacts of laneway management depends on connectivity. There have been projects on the mainland that have drained to paddocks or to effluent systems before spreading. It was felt that the most important area to focus management on would be around the shed and draining this to an effluent system.

In the north-west stakeholders expect there to be little adoption of any improved laneway management options however it was suggested that an important step would be education. For example, participants suggested that using gravel for laneways would be likely to be adopted.

A2.4.1.10. Future scenarios – conversion and expansion

Previously, Managed Investment Schemes (MIS) encouraged the conversion of dairy land into plantations. With the failure of many MIS it is thought that land may become converted back to farms as these plantations are harvested. The Circular Head Progress Group has looked the continuing trend in cow numbers in the north-west focusing on conversion of these areas. It was felt that private farms are the most likely to resist putting land back into trees in the current financial climate. In particular it is expected that unsuccessful plantations may be converted to dairy rather grazing. In terms of expansion of dairying expected stakeholders felt it was important to consider the impact of two possible scenarios on water quality:

Option 1 – plantations converted to dairy

Option 2 – grazing converted to dairy

A2.4.2. Grazing

A2.4.2.1. Fertiliser

Participants agreed that fertilizer management should be a management action. It was thought that there is currently more adoption of fertilizer BMP in north-west beef grazing compared to dairy because of the client base. For example, Cape Grim has been through environmental accreditation processes and hence has already adopted fertilizer BMP practices as part of this accreditation. This is an important part of their marketing strategy.

It was estimated that currently in the north-west there would be around a 30% adoption of fertilizer BMP in grazing. However it is expected that this could increase to around 70% in the future.

A2.4.2.2. Exclude Stock from Streams

Participants highlighted that farmers in grazing areas are generally less motivated than dairy farmers to get stock out of streams. However, in some areas such as Circular Head it is thought that younger farmers would do it if incentives were offered. It was also thought that at Cape Grim, where grazing is highly profitable, some farms may act with no money incentive involved. Participants suggested that another approach may be to target the women/wives on the farms with information on keeping livestock out of streams as they tend to be proactive in moving farms towards implementing this action. Beef grazing was seen as being just behind dairy in adoption of this action in Circular Head with many grass management practices being transferred from dairy to beef in the area including rotational grazing and the use of electrics.

It was thought that the action of keeping stock out of streams could have a 75% adoption rate in the future in grazing areas if incentives are paired with good education and if farmers can see what the neighbours have done or are doing. Further to this it was suggested that it is not only incentives that matter, extension is also important because having trusted approachable people to help with works and provide advice makes a significant difference.

A2.4.2.3. Riparian Buffers

The conversation about riparian buffers in grazing was similar to that of dairy. Riparian buffers where seen as very hard to manage and maintain. Weed management is an issue and they are a havens for wallabies which is a disincentive to having buffers at all. It was suggested that wallaby proof fencing would need to be erected, not only around riparian areas and vegetation but around the boundary of properties. Negatives including the expense involved in this type of fencing and the problems boundary fencing could cause for adjoining properties was noted.

Generational change was viewed as a very important mechanism for change.

Likely rates of adoption for this practice were expected to be very similar to dairy.

A2.4.3. Forest Practices Code (FPC)

The benefits of implementation of the Forest Practices Code on water quality were presented. Discussion revolved around possible issues with the implementation of the Code, particularly as it relates to maintenance of forest roads. While the Code contains maintenance provisions it was noted that adherence to these was rarely audited and that the FPA could potentially look at greater monitoring of maintenance and impacts on water quality. It was noted that log trucks on forestry roads are comparable to dairy tankers with little effort being made towards good construction and maintenance of laneways and roads used by dairy tankers.

Small woodlots were highlighted as a potential issue as they may not be complying with the FPC as well as they should be.

A2.5. Managing for Biodiversity

A2.5.1. Values

Vegetation communities are valued by stakeholders. It was agreed that maintaining robust vegetation communities throughout the north-west is important.

It was noted that North-west Tasmania is a sanctuary for the largest number of migratory shore birds in Tasmania and that there are a number of threatened species in the Cradle Coast region.

Stakeholders felt that vegetation communities are more highly valued than threatened species. The use of the term ‘biodiversity’ when speaking to farmers was considered to be alienating and likely to decrease the willingness of farmers to adopt management actions.

Following this brief discussion, a number of management actions and their potential adoptability were considered for preserving or improving biodiversity in north-west Tasmania.

A2.6. Management Actions

A2.6.1. Fence off Remnants

Threats to remnant vegetation in Tasmania were acknowledged and it was felt that there is a lack of legislation to protect it.

There was a strong consensus that fencing of remnants would not be seen as a favorable action to adopt for farmers unless wallaby proof fencing was used (including wallaby proof boundary fencing as well). Electric fencing around remnants is not considered suitable. Issues with fire hazard from retained remnants was also raised.

It was said that farmers don’t see value in fencing small remnant areas. The value of the vegetation patch is landscape dependant not individual farm dependant. Farmers are more likely to clear remnants rather than keep them in order to clean up their paddocks and make irrigation easier. It was pointed out that small patches of vegetation are also susceptible to edge effects and weeds. Hence, it was felt that any vegetated area below 10ha was unlikely to viable in the long term.

Greening Australia initiatives in the Midlands were acknowledged as valuable lessons in riparian vegetation and the enhancement of vegetation corridors. However it was suggested that the management action of fencing in this region has a vastly different purpose compared to that of the North-west.

While Tasmanian farmers considered themselves as being likely to accept climate change issues, this does not extend to biodiversity and refugia. It was suggested that farmers are likely to wipe out remnants (e.g. for centre pivots) and that there would need to be financial compensation to prevent or reduce the occurrences.

A2.6.2. Vegetation Corridors

Getting farmers to fence for the creation of corridors throughout the landscape was seen as even harder than getting them to fence off remnants unless the corridor is a riparian buffer. This is because farmers see the corridor as a loss of productive land as well as bringing greater issues with pests such as wallabies and possums.

Participants viewed refugia as being similar to vegetation corridors and for the ‘normal’ person it was suggested it would be thought of as bush land.

Areas that fringe onto estuaries are seen as being no different to riparian areas and would have similar levels of adoption of actions.

A2.6.3. Weed Management

Management for control or eradication of weeds was only seen as an adoptable management action if the weeds posed an economic threat to farming. Hence, the adoptability of a weed management strategy would be dependent on the type of weeds targeted (e.g. thistle and pasture weed). It was also suggested that weed management is dependent on the neighbours too. Farmers will ‘give up’ managing weeds if their neighbours are not controlling them because they ‘can’t see a point’.

If weeds were only causing an environmental threat then farmers are not interested.

MCPA; a broad leaf herbicide, has been a water quality issue in the north-west. While it is seen as being the ‘best’ product for controlling weeds it was showing up in water quality monitoring, although it was not exceeding the concentration limits. The incidences of MCPA as part of monitoring have dropped and it believed this is to do with improved practices. There is a push to ban aerial spraying of herbicides through a new Code of Practice. This would have impacts on the willingness and capacity of farmers to control weeds.

A2.6.4. Pest Control

Deer, wallabies, possums and dogs were all named as pests. However, they were not considered to be causing a significant issue and hence farmers are not very interested in management actions for their control. The disease risk of cats and dairy cows was highlighted and participants felt that education could be offered on this topic even though there is not a high degree of interest.

A2.6.5. Replacing Vegetation

Replacing existing introduced vegetation with native species was not seen as an adoptable action. Participants suggest that they may plant extra vegetation but they will not be taking out what is already there to do so.

A2.6.6. Fencing Wetlands

Similar to previous views expressed on fencing riparian vegetation in dairy and grazing, wetlands were seen as very hard to manage and maintain in relation to weeds and pests. Therefore, fencing wetlands was not seen as a favorable management action.

A2.6.7. Hygiene (Weeds and Pathogens)

Circular Head Council has already run a program to educate people on good hygiene practices. With regard to biosecurity, quality assurance programs are also starting to include hygiene practices.

Participants suggest that these types of initiatives and associated management actions are likely to be adopted because of the economic and on-farm benefits. This is particularly the case if farms are bringing in fodder, which is happening more and more.

A2.6.8. Maintain Stream Characteristics and Woody Debris

Farmers do not want logs in drains or rivers because of the flood risk they pose. It was expressed that it is an economic imperative to straighten streams and remove debris because then water can move through faster and avoid flooding. It was suggested that the 'Montagu River is a drain!' and most farmers would aim to manage it as such.

A2.6.9. Poaching

Lobster poaching and illegal whitebaiting are seen as significant problems in the Cradle Coast region.

A2.6.10. Rubbish Dumping

Rubbish dumping is a big issue for farms and State Forests.

In areas where waste disposal is not easy, people are using silage bags to fill with rubbish and are using them to level paddocks by burying them. If bags are used along waterways and banks they can get washed out and rubbish ends up downstream. The problem of silage wrap making its way into rivers has been acknowledged as a problem particularly in the Arthur River.

Another issue is silage wrap getting into waterways. This has been experienced in the Arthur River.

It is felt that the issue of illegal rubbish dumping has high leverage in the community because the public are interested and it is a very visible issue. However, collections and musters were questioned as to whether they were a good solution. Stakeholders said that programs come and go following cycles of funding and visibility. This is on roughly a 5 year cycle of motivation which appears to be associated with the visibility of the problem.

A2.6.11. Tourism and Recreation

The aesthetics of the landscape are thought to be a big driver of tourism. Thus, it is thought important that farmers retain remnants from a tourism perspective.

However, while tourism benefits the region economically, impacts were also noted. Increasing tourism in the region spreads weeds into areas that have not been accessed before. Tourism also has impacts on aboriginal heritage sites particularly middens.

A2.6.12. Acid Sulphate Soils

Acid sulphate soils are an issue at Scopus Creek. These soils are also present at the northern end of Togari where associated issues seem to occur on a 5 year cycle. Problems are said to occur in peat around summertime when groundwater is drawn down, then flushes are experienced around April.

While there is an awareness of these soils and where they occur, farmers still pump groundwater from the areas. It is thought that it is unlikely that there will be any behavior change from the groundwater users, and very unlikely that they will stop water usage voluntarily.

A2.6.13. Birds

Farmer's value birds and they are interested in knowing what birds they currently have on their property. It was said that some farmers had noticed that birds quickly disappeared when they cleared remnants. It was suggested that an approach for encouraging farmers to retain remnants may be to use their interest in birds as a starting point. It may also be useful to target education toward school children.

A2.6.14. Impacts of Farm Water Access Plans and certification schemes

The Duck Irrigation Scheme is one of Tasmanian Irrigation's (TI) second suite of schemes. As part of the scheme, water will be sourced from the Duck River and Mill Creek. Farms need to put in a bid for water, and building will take place based on the current demand. The proposed scheme would service 32 farms.

Stakeholders talked about the Tasmanian Irrigation (TI) Scheme and how water users on a scheme are required to have a FWAP (Farm Water Access Plan). FWAP involves soil, water and biodiversity being mapped on farms. From this Best Management Practices (BMP) are identified and potentially damaging actions restricted. 15% of all FWAPs are audited each year with farms found not complying with their FWAP losing access to TI water. FWAPs are seen as a way of protecting current biodiversity values on farms but do not aim to create additional values (eg. through creation of corridors).

Stakeholder expressed that another driver that encourages best management practice for water quality and biodiversity are certification, accreditation and consumer demand.

APPENDIX 3. DESKTOP DATA ANALYSIS AND MAPS SHOWING POTENTIAL BIODIVERSITY VALUES

Priority actions for biodiversity management were developed using dektop data analysis, literature review and expert elicitation. Results of the data analysis, literature review and maps were used to facilitate discussions with ecological experts on the priorities for each subcatchment as well as from a regional perspective. For each subcatchment the process used with experts to develop these priorities:

1. Validate the values identified in the map and data table for the subcatchment. Are there any key values missing or should some of the identified values be removed?
2. Review the table of potential threats to these values and confirm which of these are relevant for the specified subcatchment. Identify any missing threats.
3. Review the table of potential actions to address these threats, identify any missing actions and provide feedback on their relative importance for addressing the threats to values in that subcatchment.

Maps and data used to underpin these discussions are presented in this section. A synthesis of outcomes from these discussions and priority values, threats and actions is presented in the main body of the Plan in Section 4. Table 7 to Table 9 summarise specific feedback received on key biodiversity values in each subcatchment as well as threats and actions to address these threats.

TABLE 7. EXPERT PANEL FEEDBACK ON KEY BIODIVERSITY VALUES (INDICATOR SPECIES AND COMMUNITIES) IN EACH SUBCATCHMENT

Subcatchment	Viminalis	Keeled snail	Orchids	Velvet Tussock	Devils & Quolls	Marrawah skipper	Saltmarsh & melaleuca	Limonium australe	Frogs	IBA	Azure Kingfisher	GFC	Whitebait	Dwarf Galaxid	Limefern	Goshawk
Duck River catchment																
Acton Bay foreshore							X		X							
Anthony beach							X			X						
Deep creek											X	X	X			
Duck river from Copper creek to Coventry creek										X	X	X				
Duck river from Roger river to Copper creek												X			X	
Fentons creek							X		X	X						
Geales creek												X				
Mill creek																X
Plains creek																X
Roger river												X				
Scopus creek												X				
Shipwreck point to Kingston point							X			X						
Upper Duck river to Roger river												X				
Montagu River catchment																
Barcoo creek							X	X		X						
Fixters creek							X				X	X				X
Montagu beach and Stony point							X			X						
Montagu Plains to Big Bay							X	X								
Montagu river Bond Tier to Montagu Plains									X			X		X		X
Montagu river Montagu Plains							X		X			X				
Robbins island							X			X						
Upper Montagu to Bond Tier												X				
West Montagu to Robbins passage							X			X						

Welcome River catchment																
North west corner		X		X	X	X	X						X			X
Swan river, Harcus creek and Dividing river							X									
Welcome river to Welcome inlet	X				X		X					X				
Western edge to Studland Bay			X	X	X	X										

TABLE 8. EXPERT PANEL FEEDBACK ON THREATS TO KEY BIODIVERSITY VALUES

Species/Community	Clearing and fragmentation of vegetation	Livestock	Poor water quality	Hydrology (flows and drainage)	Sedimentation	Weeds	Pests (& pets)	Disease	Recreation and tourism	Fishing/hunting	Poaching	Loss of interface between coast and marine - seascapes	Climate change – lack of retreat options	Forestry activities
Viminalis	X	X												
Keeled snail		X							X[5]					
Orchids		X							X[5]					
Velvet Tussock		X							X[5]					
Devils & Quolls	X	X[0]						X						
Marrawah skipper		X												
Saltmarsh	X	X	X	X[1]		X[2]						X		
Melaleuca	X	X				X						X		
Limonium australe														
Frogs	X	X	X	X[1]								X		
IBA	X	X	X	X[1]		X[2]	X[4]		X[5]			X		
Azure Kingfisher	X	X		X[1]										
GFC	X	X	X		X	X[3]				X	X			X[6]
Whitebait											X			
Dwarf Galaxid	X	X		X[1]										
Limefern		X												
Goshawk	X	X												

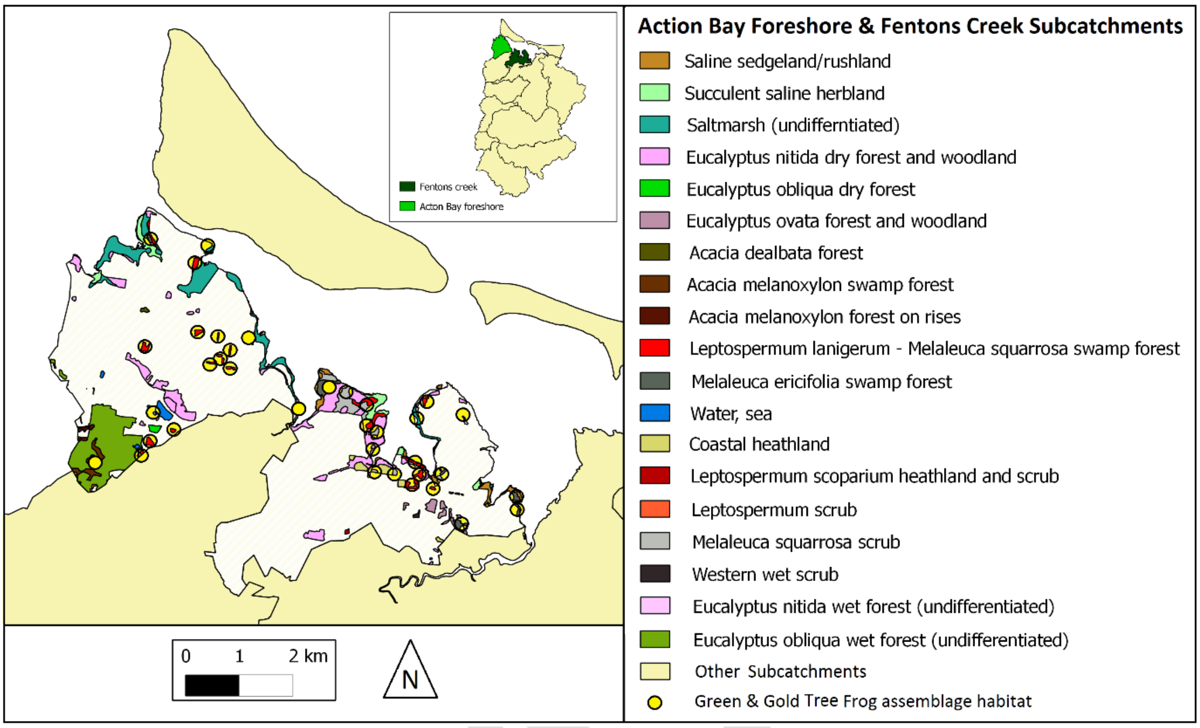
0 – impact on habitat; 1 – levees, loss of wetlands; 2 – ricegrass; 3 – willows; 4 – dogs; 5 – quad bikes and 4WD; 6 – in upper Montagu to Bond Tier

TABLE 9. EXPERT PANEL FEEDBACK ON ACTIONS TO ADDRESS THREATS

Threat	Actions to improve WQ	Fence stock out of vegetation	Create corridors between remnants	Exclude stock from streams	Protect and restore riparian buffers	Protect and restore remnants	Fence stock out of wetlands	Restore/protect wetlands	Remove levees	Pest and pet management	Weed management	Disease management	Restrict/manage tourist access	Good forest practices
Clearing and fragmentation of vegetation		X	X					X						
Livestock		X		X	X		X							
Poor water quality	X													
Hydrology (flows and drainage)								X	X					
Sedimentation	X			X			X	X						
Weeds											X			
Pests (& pets)												X		
Disease										X				
Recreation and tourism													X	
Fishing/hunting														
Poaching														
Loss of interface between coast and marine - seascapes						X	X							
Climate change – lack of retreat options			X			X								
Forestry activities														X

A3.1. Duck River Catchment

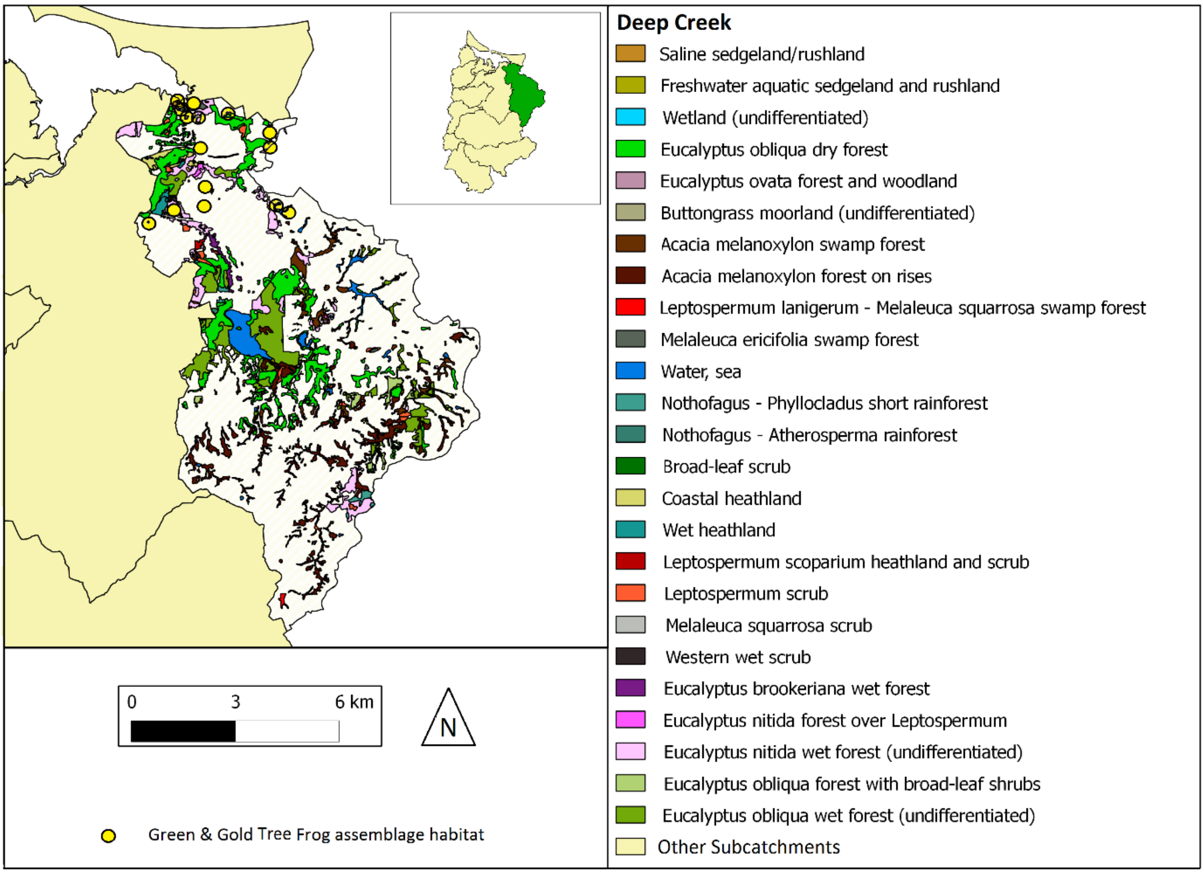
A3.1.1. Action Bay foreshore and Fentons Creek subcatchments



Duck Catchment - Action Bay Foreshore	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	1	0
Succulent saline herbland	2	12.1
Saltmarsh (undifferntiated)	9	71.3
Eucalyptus nitida dry forest and woodland	14	42.5
Eucalyptus obliqua dry forest	1	2.5
Acacia dealbata forest	1	1
Acacia melanoxylon swamp forest	1	10.8
Acacia melanoxylon forest on rises	3	2.6
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	15	12.4
Melaleuca ericifolia swamp forest	3	1.4
Water, sea	6	8
Leptospermum scrub	1	0.6
Melaleuca squarrosa scrub	2	1.5
Eucalyptus obliqua wet forest (undifferentiated)	10	119.6
Vegetation Patch Total	**69**	**286.3**
Green & Gold Tree Frog assemblage habitat	20	28.3
Giant Freshwater Crayfish known habitat	0	N/A

Duck Catchment - Fentons Creek Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	11	17.2
Succulent saline herbland	3	13.3
Saltmarsh (undifferntiated)	2	5.4
Eucalyptus nitida dry forest and woodland	16	64.5
Eucalyptus obliqua dry forest	4	0.6
Eucalyptus ovata forest and woodland	9	9.7
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	8	14.8
Melaleuca ericifolia swamp forest	8	12.2
Water, sea	1	0.1
Coastal heathland	7	12.4
Leptospermum scoparium heathland and scrub	1	0.6
Melaleuca squarrosa scrub	9	26.5
Western wet scrub	1	0.9
Eucalyptus nitida wet forest (undifferentiated)	1	0.4
Vegetation Patch Total	**81**	**178.6**
Green & Gold Tree Frog assemblage habitat	22	49.1
Giant Freshwater Crayfish known habitat	0	N/A

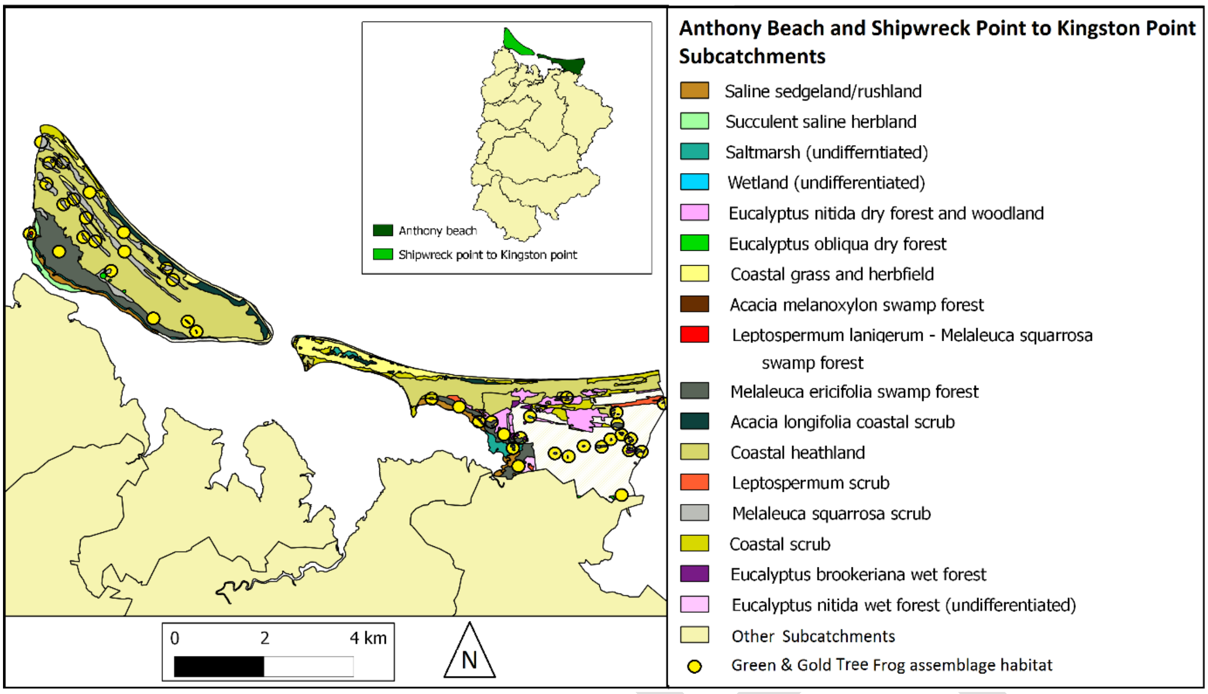
A3.1.2. Deep Creek



Duck Catchment - Deep Creek Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	8	5.9
Freshwater aquatic sedgeland and rushland	1	1.4
Wetland (undifferentiated)	3	0.7
Eucalyptus obliqua dry forest	115	609.7
Eucalyptus ovata forest and woodland	2	1.3
Buttongrass moorland (undifferentiated)	1	1.5
Acacia melanoxylon swamp forest	51	104.4
Acacia melanoxylon forest on rises	189	328.5
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	1	4.8
Melaleuca ericifolia swamp forest	15	20.6
Water, sea	62	152.7
Nothofagus - Phyllocladus short rainforest	4	19.7
Nothofagus - Atherosperma rainforest	1	2.2
Broad-leaf scrub	22	5.3
Coastal heathland	13	35.3
Wet heathland	5	20.7
Leptospermum scoparium heathland and scrub	2	5.6
Leptospermum scrub	48	62
Melaleuca squarrosa scrub	4	2.7
Western wet scrub	10	14.2

Eucalyptus brookeriana wet forest	2	20.8
Eucalyptus nitida forest over Leptospermum	3	6.1
Eucalyptus nitida wet forest (undifferentiated)	57	262.6
Eucalyptus obliqua forest with broad-leaf shrubs	34	53.9
Eucalyptus obliqua wet forest (undifferentiated)	103	433.1
Vegetation Patch Total	**756**	**2175.7**
Green & Gold Tree Frog assemblage habitat	18	108.3
Giant Freshwater Crayfish known habitat	0	N/A

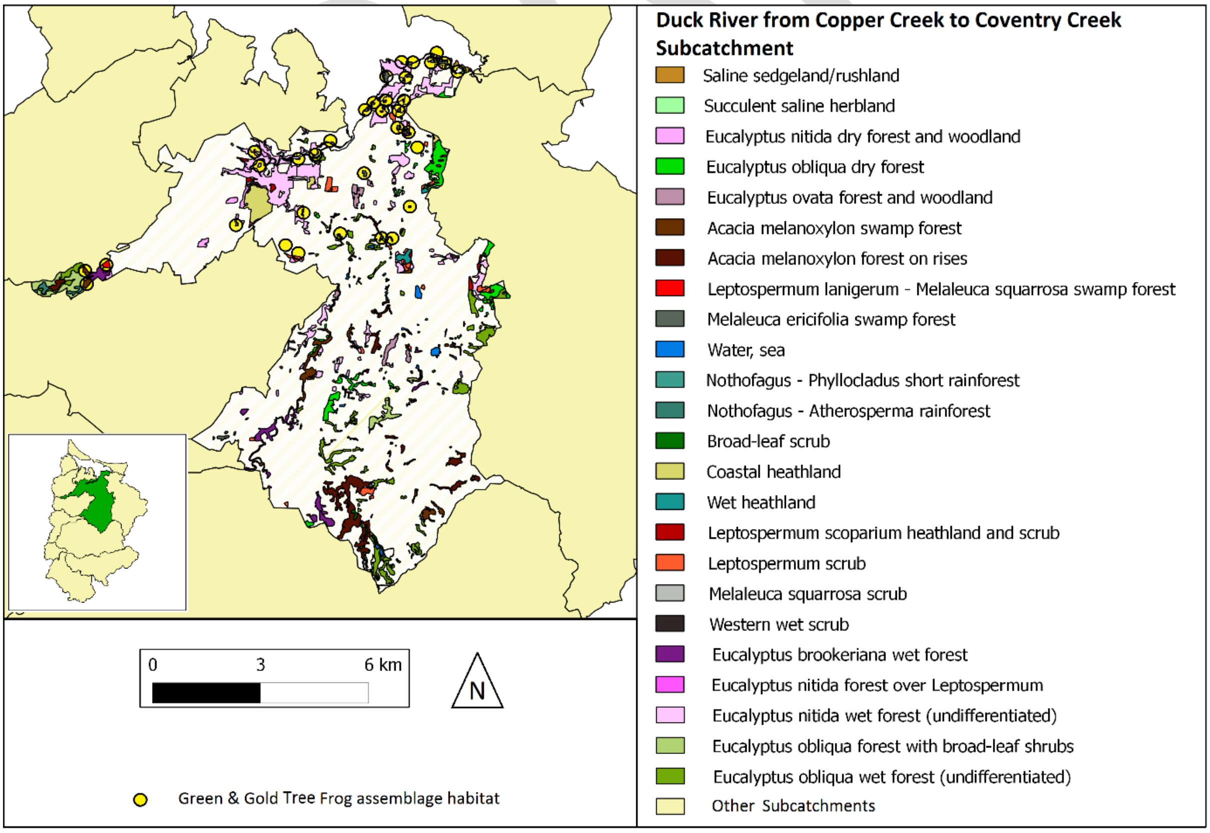
A3.1.3. Anthony Beach and Shipwreck Point to Kingston Point



Duck Catchment - Anthony Beach Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	6	29.4
Saltmarsh (undifferntiated)	4	26.6
Wetland (undifferentiated)	1	0.5
Eucalyptus nitida dry forest and woodland	17	91.3
Eucalyptus obliqua dry forest	3	1
Coastal grass and herbfield	2	91.9
Acacia melanoxylon swamp forest	1	0.3
Melaleuca ericifolia swamp forest	26	58.8
Sand, mud	5	8.3
Acacia longifolia coastal scrub	16	14.5
Coastal heathland	14	234.8
Leptospermum scrub	5	17.4
Melaleuca squarrosa scrub	1	1.9
Coastal scrub	27	79.1
Eucalyptus brookeriana wet forest	10	7.5
Eucalyptus nitida wet forest (undifferentiated)	2	7.5
Vegetation Patch Total	**140**	**670.8**
Green & Gold Tree Frog assemblage habitat	29	58.1
Giant Freshwater Crayfish known habitat	0	N/A

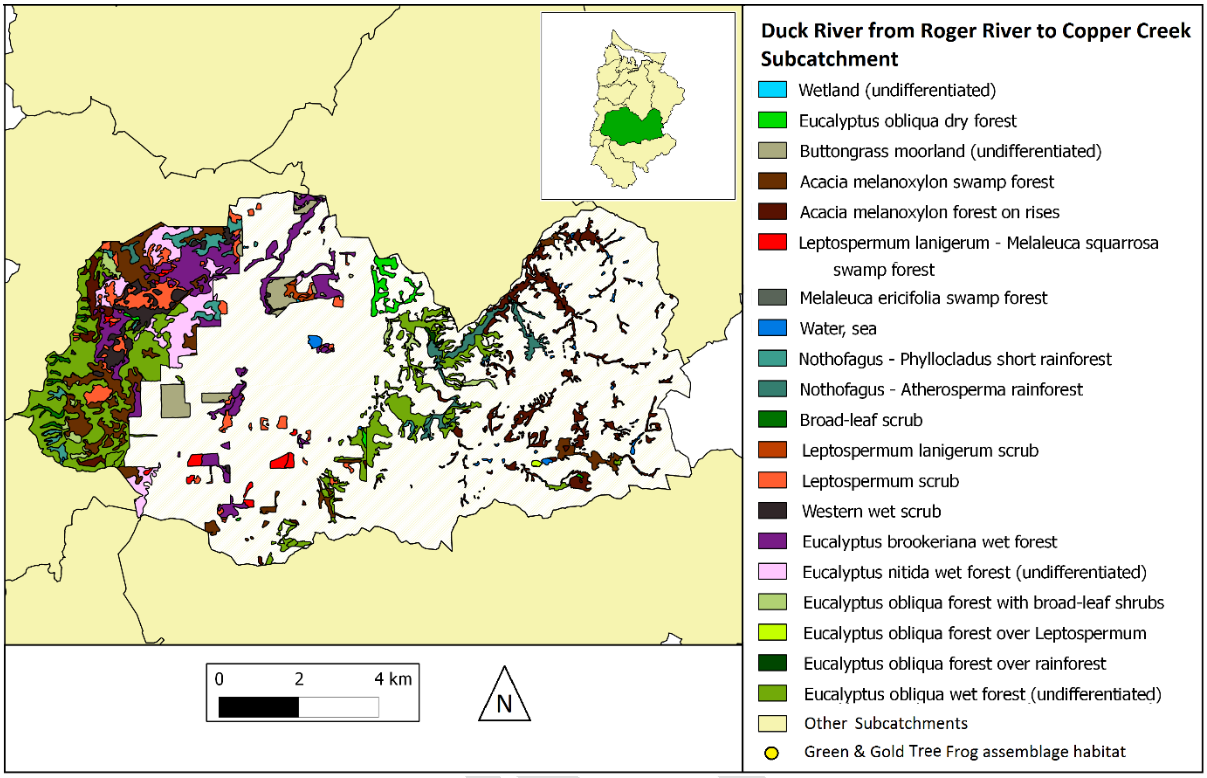
Duck Catchment - Shipwreck Point to Kingston Point Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	1	26.8
Succulent saline herbland	2	21.3
Saltmarsh (undifferntiated)	7	15.4
Wetland (undifferentiated)	2	0.4
Eucalyptus obliqua dry forest	3	2.2
Coastal grass and herbfield	5	19.4
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	1	0.4
Melaleuca ericifolia swamp forest	1	147
Sand, mud	1	40.1
Acacia longifolia coastal scrub	3	43.7
Coastal heathland	1	599.7
Melaleuca squarrosa scrub	18	106.3
Coastal scrub	3	18.5
Vegetation Patch Total	**48**	**1041.2**
Green & Gold Tree Frog assemblage habitat	20	252.7
Giant Freshwater Crayfish known habitat	0	N/A

A3.1.4. Duck River from Copper Creek to Coventry Creek



Duck Catchment - Duck River from Copper Creek to Covenrtry Creek Subcatchment	**Count of Area (ha)**	**Sum of Area (ha)**
Saline sedgeland/rushland	2	6
Succulent saline herbland	3	3
Eucalyptus nitida dry forest and woodland	28	39.7
Eucalyptus obliqua dry forest	35	113.4
Eucalyptus ovata forest and woodland	11	34.4
Acacia melanoxylon swamp forest	24	65.9
Acacia melanoxylon forest on rises	64	147.7
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	3	3.8
Melaleuca ericifolia swamp forest	54	35.1
Water, sea	34	27.6
Nothofagus - Phyllocladus short rainforest	2	5.4
Nothofagus - Atherosperma rainforest	5	7.1
Broad-leaf scrub	5	6.6
Coastal heathland	7	63
Wet heathland	3	11.1
Leptospermum scoparium heathland and scrub	10	13.3
Leptospermum scrub	53	56.3
Melaleuca squarrosa scrub	4	1.6
Western wet scrub	16	11.1
Eucalyptus brookeriana wet forest	16	61.8
Eucalyptus nitida forest over Leptospermum	1	0.9
Eucalyptus nitida wet forest (undifferentiated)	72	397.8
Eucalyptus obliqua forest with broad-leaf shrubs	8	71
Eucalyptus obliqua wet forest (undifferentiated)	118	203.8
Vegetation Patch Total	**578**	**1387.4**
Green & Gold Tree Frog assemblage habitat	58	68.3
Giant Freshwater Crayfish known habitat	0	N/A

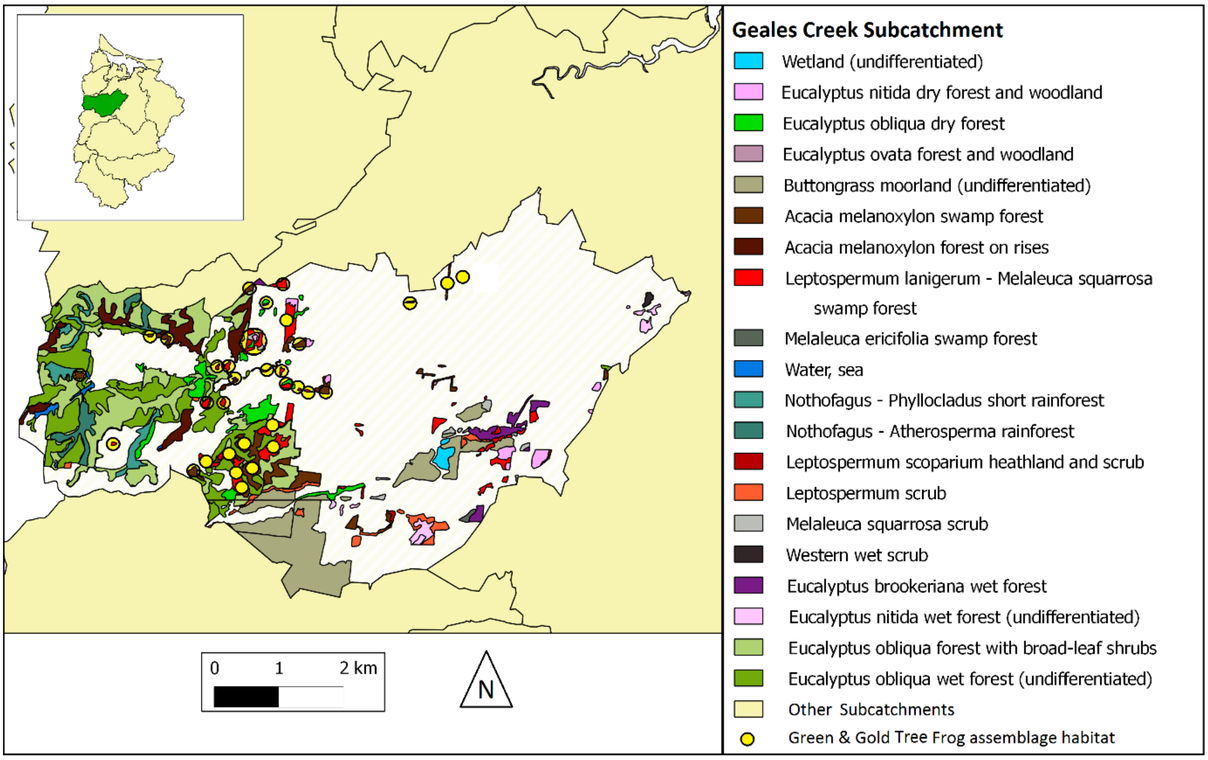
A3.1.5. Duck River from Roger River to Copper Creek



Duck Catchment - Duck River from Roger River to Copper Creek	**Count of Area (ha)**	**Sum of Area (ha)**
Wetland (undifferentiated)	2	1
Eucalyptus obliqua dry forest	8	65.3
Buttongrass moorland (undifferentiated)	14	136.1
Acacia melanoxylon swamp forest	26	387.1
Acacia melanoxylon forest on rises	142	380
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	14	49.3
Melaleuca ericifolia swamp forest	1	0.2
Water, sea	47	36.3
Nothofagus - Phyllocladus short rainforest	12	100.3
Nothofagus - Atherosperma rainforest	11	112.9
Broad-leaf scrub	10	27.8
Leptospermum lanigerum scrub	5	15.9
Leptospermum scrub	55	215.3
Western wet scrub	17	120.6
Eucalyptus brookeriana wet forest	41	410.7
Eucalyptus nitida wet forest (undifferentiated)	9	248.5
Eucalyptus obliqua forest with broad-leaf shrubs	53	65.2
Eucalyptus obliqua forest over Leptospermum	1	3
Eucalyptus obliqua forest over rainforest	8	8.1
Eucalyptus obliqua wet forest (undifferentiated)	106	926.9
Vegetation Patch Total	**582**	**3310.5**

Green & Gold Tree Frog assemblage habitat	0	0
Giant Freshwater Crayfish known habitat	24	N/A

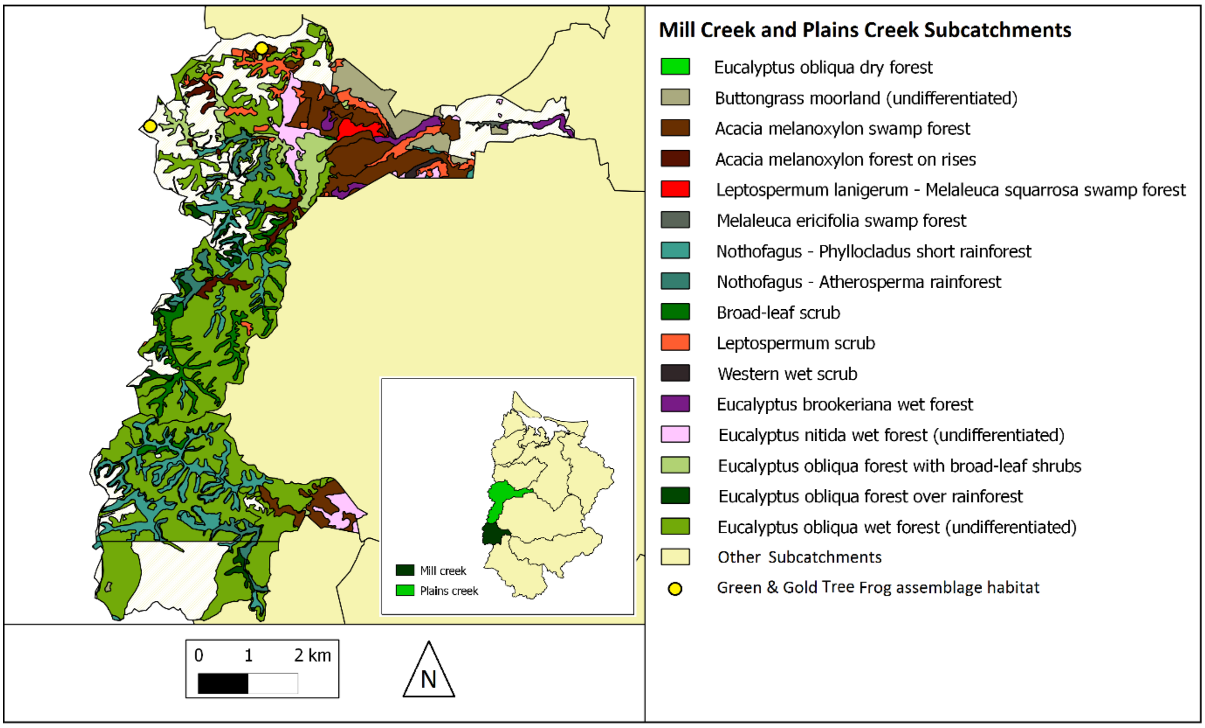
A3.1.6. Geales Creek



Duck Catchment - Geales Creek Subcatchment	Count of Area (ha)	Sum of Area (ha)
Wetland (undifferentiated)	2	8.3
Eucalyptus nitida dry forest and woodland	12	16.6
Eucalyptus obliqua dry forest	18	45.1
Eucalyptus ovata forest and woodland	1	0.4
Buttongrass moorland (undifferentiated)	11	200.3
Acacia melanoxylon swamp forest	27	65.5
Acacia melanoxylon forest on rises	10	64.2
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	38	59.5
Melaleuca ericifolia swamp forest	1	2
Water, sea	6	7.1
Nothofagus - Phyllocladus short rainforest	5	31
Nothofagus - Atherosperma rainforest	3	29.6
Leptospermum scoparium heathland and scrub	1	1.1
Leptospermum scrub	17	25.1
Melaleuca squarrosa scrub	11	9.1
Western wet scrub	1	2.1
Eucalyptus brookeriana wet forest	7	22.9
Eucalyptus nitida wet forest (undifferentiated)	9	16.4
Eucalyptus obliqua forest with broad-leaf shrubs	45	258.4

Eucalyptus obliqua wet forest (undifferentiated)	81	233.5
Vegetation Patch Total	**306**	**1098.2**
Green & Gold Tree Frog assemblage habitat	28	89.1
Giant Freshwater Crayfish known habitat	0	N/A

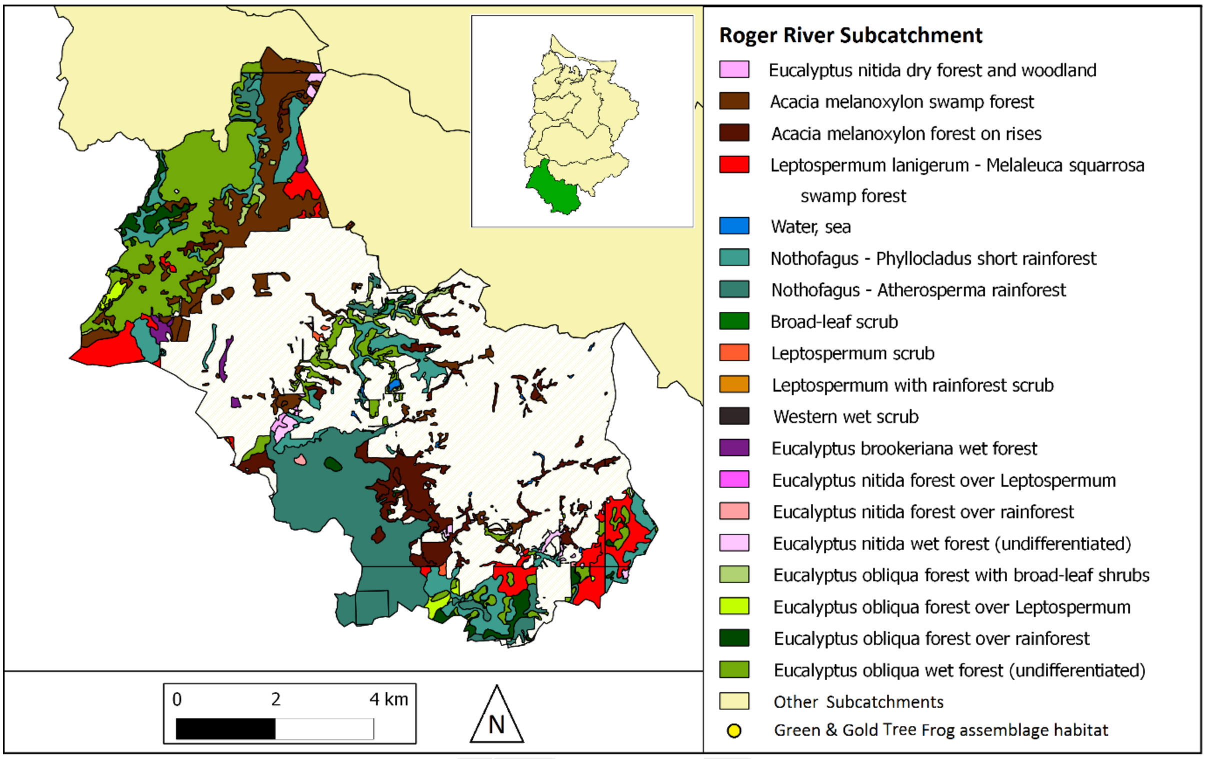
A3.1.7. Mill Creek and Plains Creek



Duck Catchment - Mill Creek	Count of Area (ha)	Sum of Area (ha)
Eucalyptus obliqua dry forest	2	1.2
Buttongrass moorland (undifferentiated)	1	1.6
Acacia melanoxylon swamp forest	1	63.5
Nothofagus - Phyllocladus short rainforest	23	226.8
Nothofagus - Atherosperma rainforest	10	37.5
Broad-leaf scrub	3	11.1
Eucalyptus nitida wet forest (undifferentiated)	1	34.4
Eucalyptus obliqua forest with broad-leaf shrubs	4	2
Eucalyptus obliqua forest over rainforest	60	33.8
Eucalyptus obliqua wet forest (undifferentiated)	25	691.8
Vegetation Patch Total	**130**	**1103.7**
Green & Gold Tree Frog assemblage habitat	0	0
Giant Freshwater Crayfish known habitat	0	N/A

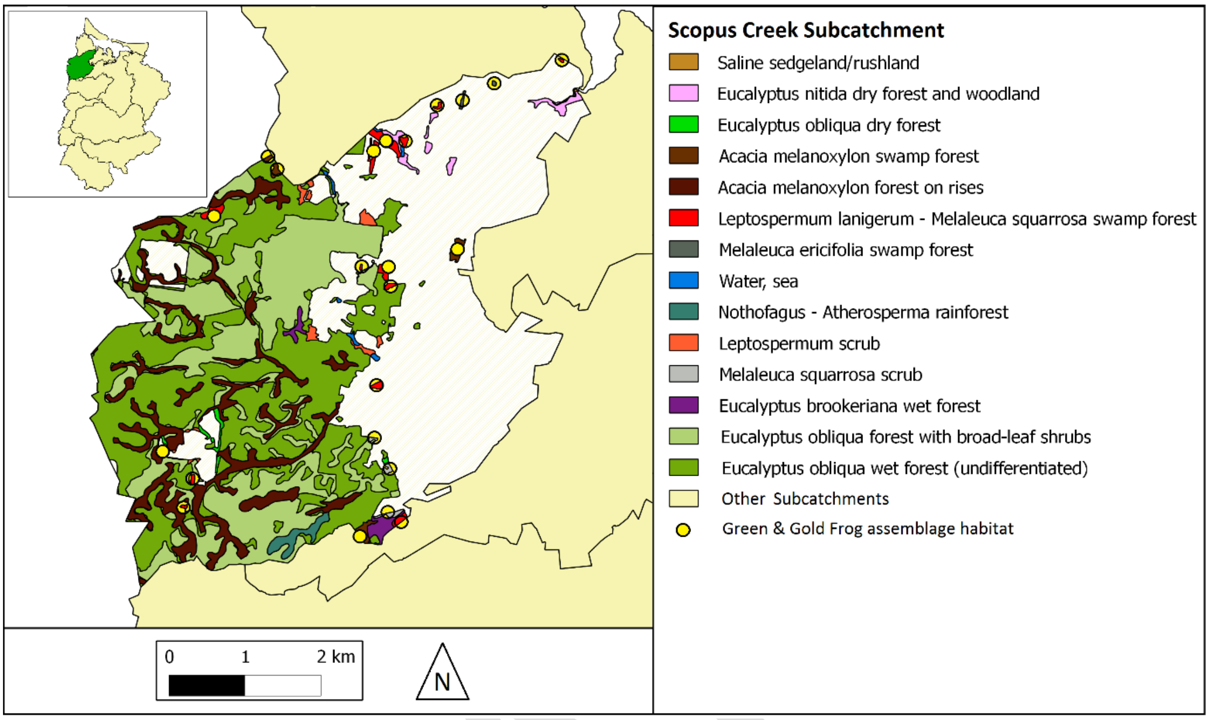
Duck Catchment - Plains Creek	Count of Area (ha)	Sum of Area (ha)
Eucalyptus obliqua dry forest	1	0.2
Buttongrass moorland (undifferentiated)	7	120.6
Acacia melanoxylon swamp forest	10	270.9
Acacia melanoxylon forest on rises	10	56.2
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	1	20.7
Melaleuca ericifolia swamp forest	2	10.5
Nothofagus - Phyllocladus short rainforest	18	107.6
Nothofagus - Atherosperma rainforest	7	67
Broad-leaf scrub	20	127.7
Leptospermum scrub	23	125.5
Western wet scrub	2	10
Eucalyptus brookeriana wet forest	6	47.1
Eucalyptus nitida wet forest (undifferentiated)	9	70.8
Eucalyptus obliqua forest with broad-leaf shrubs	47	137.3
Eucalyptus obliqua forest over rainforest	45	52.7
Eucalyptus obliqua wet forest (undifferentiated)	65	789.5
Vegetation Patch Total	**273**	**2014.3**
Green & Gold Tree Frog assemblage habitat	2	12.8
Giant Freshwater Crayfish known habitat	0	N/A

A3.1.8. Roger River



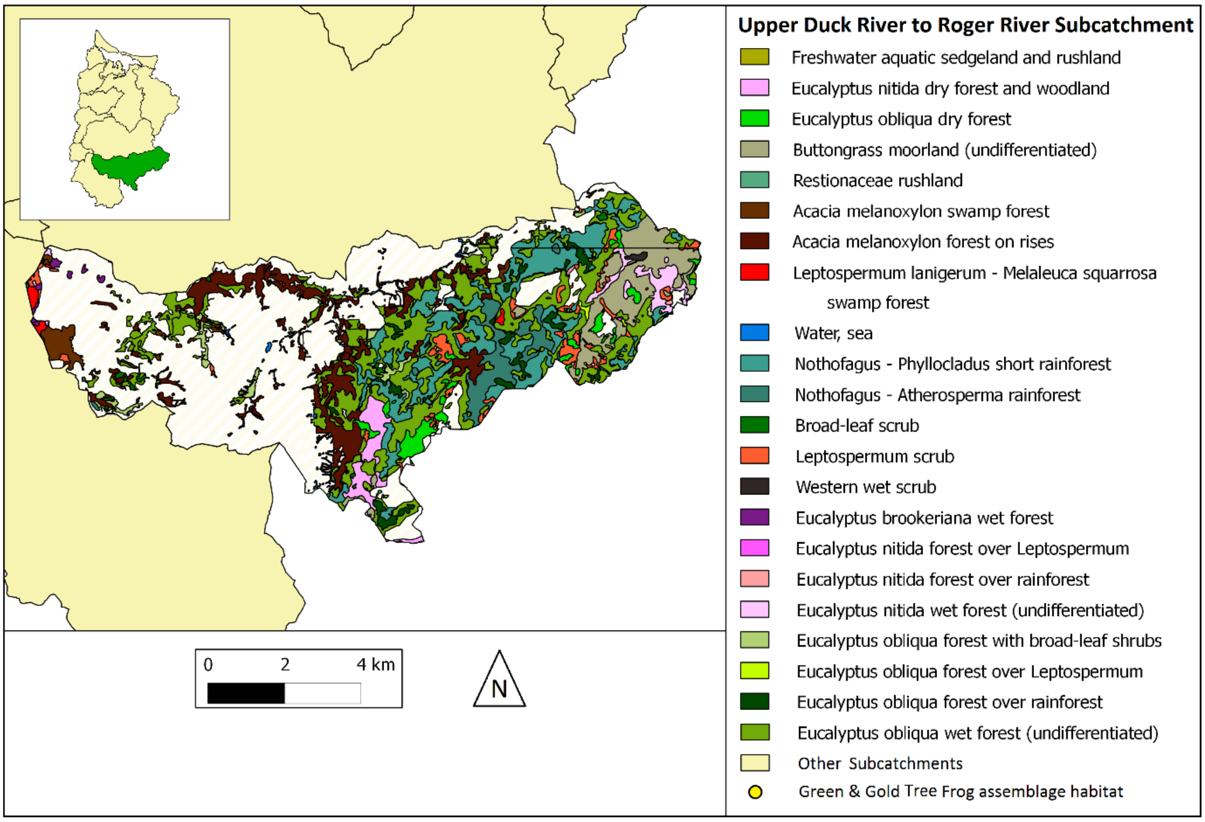
Duck Catchment - Roger River Subcatchment	Count of Area (ha)	Sum of Area (ha)2
Eucalyptus nitida dry forest and woodland	3	7
Acacia melanoxylon swamp forest	66	527
Acacia melanoxylon forest on rises	57	309.4
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	19	288.6
Water, sea	12	11
Nothofagus - Phyllocladus short rainforest	36	433.2
Nothofagus - Atherosperma rainforest	20	727.6
Broad-leaf scrub	8	6.4
Leptospermum scrub	10	12.5
Leptospermum with rainforest scrub	2	1.3
Western wet scrub	3	1.7
Eucalyptus brookeriana wet forest	10	32.6
Eucalyptus nitida forest over Leptospermum	1	0
Eucalyptus nitida forest over rainforest	5	4.8
Eucalyptus nitida wet forest (undifferentiated)	21	42.8
Eucalyptus obliqua forest with broad-leaf shrubs	63	66.9
Eucalyptus obliqua forest over Leptospermum	12	26.8
Eucalyptus obliqua forest over rainforest	43	107.6
Eucalyptus obliqua wet forest (undifferentiated)	128	730.8
Vegetation Patch Total	**519**	**3338**
Green & Gold Tree Frog assemblage habitat	0	0
Giant Freshwater Crayfish known habitat	1	N/A

A3.1.9. Scopus Creek



Duck Catchment - Scopus Creek Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	1	0.2
Eucalyptus nitida dry forest and woodland	7	15
Eucalyptus obliqua dry forest	5	5.4
Acacia melanoxylon swamp forest	3	9.1
Acacia melanoxylon forest on rises	21	210.8
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	14	18.9
Melaleuca ericifolia swamp forest	2	1
Water, sea	6	4
Nothofagus - Atherosperma rainforest	1	12.7
Leptospermum scrub	12	12.2
Melaleuca squarrosa scrub	4	3.2
Eucalyptus brookeriana wet forest	2	12.3
Eucalyptus obliqua forest with broad-leaf shrubs	71	531.7
Eucalyptus obliqua wet forest (undifferentiated)	74	695.9
Vegetation Patch Total	**223**	**1532.4**
Green & Gold Tree Frog assemblage habitat	23	32.9
Giant Freshwater Crayfish Known Habitat	0	N/A

A3.1.10. Upper Duck River to Roger River

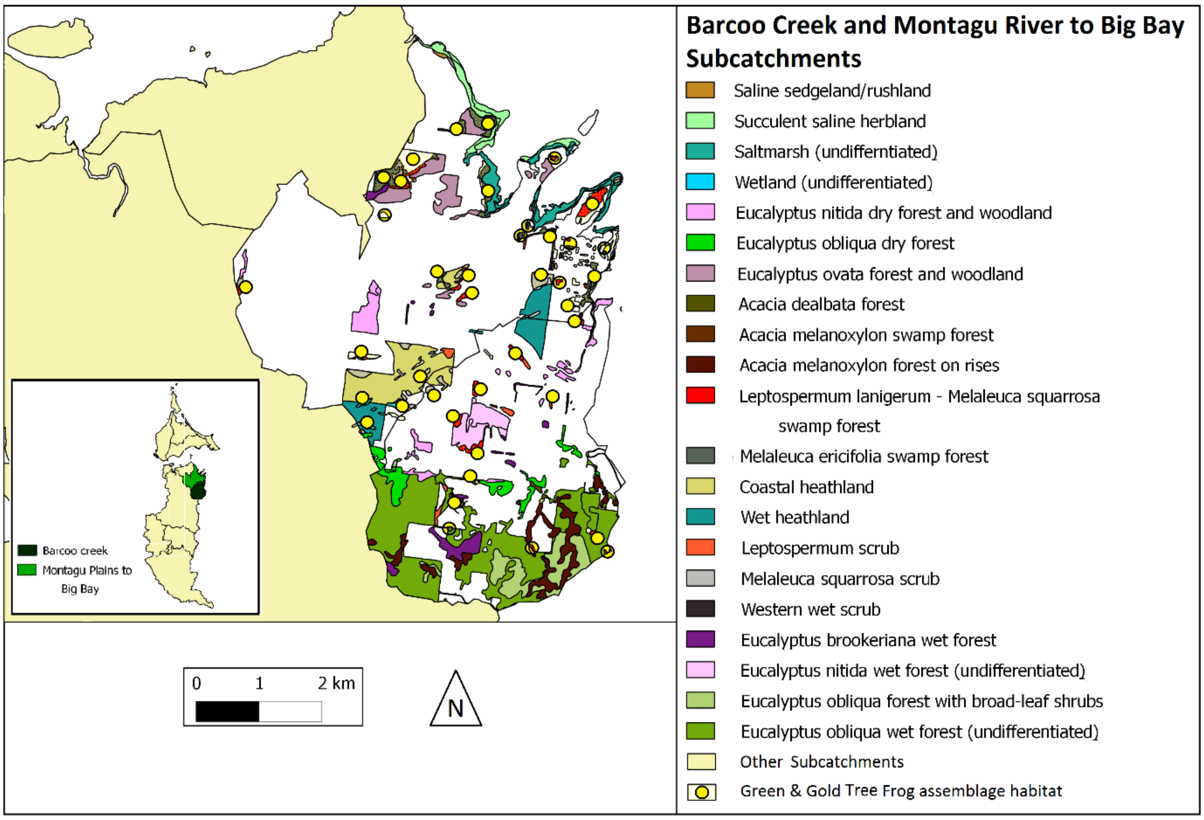


Duck Catchment - Upper Duck River to Roger River Subcatchment	Count of Area (ha)	Sum of Area (ha)
Freshwater aquatic sedgeland and rushland	2	1.1
Eucalyptus nitida dry forest and woodland	3	128.4
Eucalyptus obliqua dry forest	25	138.8
Buttongrass moorland (undifferentiated)	12	430.4
Restionaceae rushland	1	0.2
Acacia melanoxylon swamp forest	15	95.4
Acacia melanoxylon forest on rises	128	622.5
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	4	26.2
Water, sea	25	13.3
Nothofagus - Phyllocladus short rainforest	36	737.9
Nothofagus - Atherosperma rainforest	8	215.6
Broad-leaf scrub	16	25.6
Leptospermum scrub	48	168
Western wet scrub	2	12
Eucalyptus brookeriana wet forest	7	19.1
Eucalyptus nitida forest over Leptospermum	1	0.8
Eucalyptus nitida forest over rainforest	3	4
Eucalyptus nitida wet forest (undifferentiated)	18	103.1
Eucalyptus obliqua forest with broad-leaf shrubs	124	125.1
Eucalyptus obliqua forest over Leptospermum	4	8

Eucalyptus obliqua forest over rainforest	178	161.7
Eucalyptus obliqua wet forest (undifferentiated)	193	1376.1
Vegetation Patch Total	**853**	**4413.3**
Green & Gold Tree Frog assemblage habitat	0	0
Giant Freshwater Crayfish known habitat	54	N/A

A3.2. Montagu Catchment

A3.2.1. Barcoo Creek and Montagu River to Big Bay



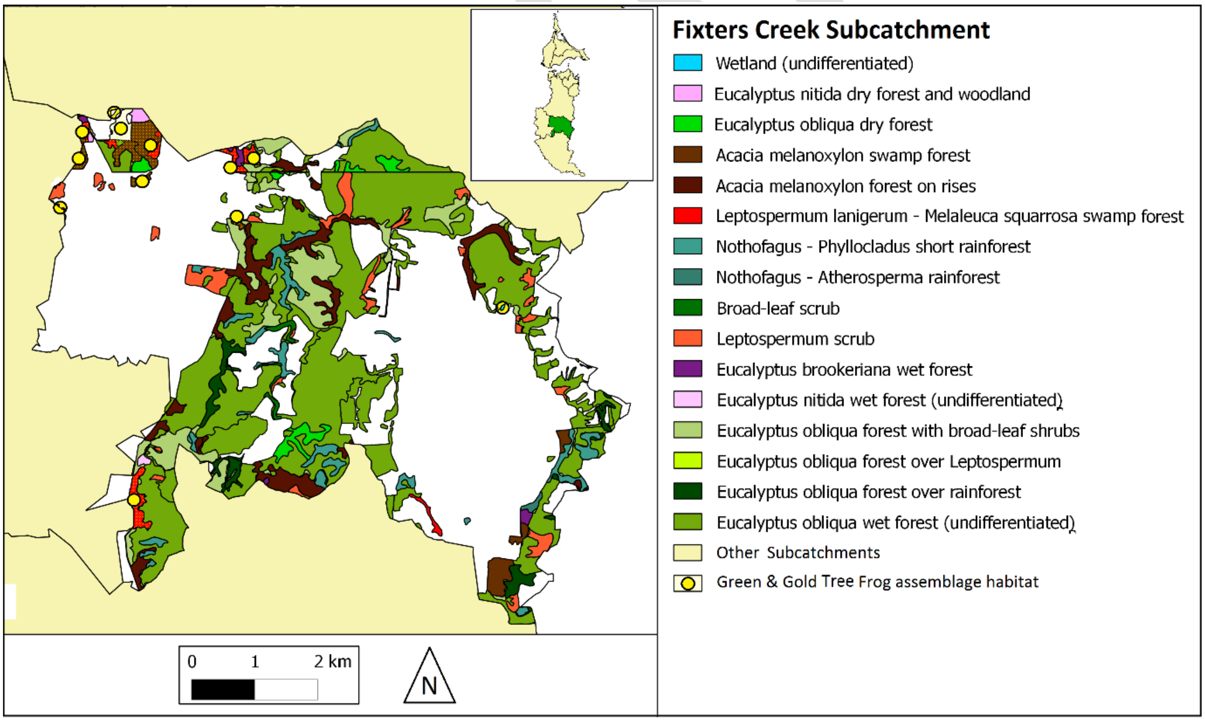
Below Table: Barcoo Creek includes one patch of Eucalyptus nitida dry forest and woodland (0.7 ha) along its coastline which was classified as belonging to Robbins Passage in the original data.

Montagu Catchment - Barcoo Creek Subcatchment	Count of Area (ha)	Sum of Area (ha)
Eucalyptus nitida dry forest and woodland	14	24.3
Eucalyptus obliqua dry forest	14	35.4
Acacia dealbata forest	2	1.8
Acacia melanoxylon swamp forest	3	3.6
Acacia melanoxylon forest on rises	14	58.9
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	9	12.5
Melaleuca ericifolia swamp forest	1	0.4
Coastal heathland	2	8.4
Wet heathland	2	19.2
Leptospermum scrub	5	5.1
Melaleuca squarrosa scrub	5	3.8
Western wet scrub	1	0.4
Eucalyptus brookeriana wet forest	13	25.2
Eucalyptus nitida wet forest (undifferentiated)	7	39.5
Eucalyptus obliqua forest with broad-leaf shrubs	9	63.7
Eucalyptus obliqua wet forest (undifferentiated)	21	296.1
Vegetation Patch Total	**122**	**598.3**
Green & Gold Tree Frog assemblage habitat	19	22.3
Giant Freshwater Crayfish known habitat	0	N/A

Below Table: Montagu Plains to Big Bay subcatchment includes one patch of Eucalyptus Brookeriana wet forest (0.0 ha) from the subcatchment known as Montagu Beach and Stony Point and 24 patches (43 ha) of various vegetation from the subcatchment known as Robbins passage in the original data. The most significant patches from Robbins Passage are 18 patches (26.1 ha) of undifferentiated saltmarsh and 2 patches (16.4 ha) of succulent saline herbland.

Montagu Catchment - Montagu Plains to Big Bay	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	1	1.2
Succulent saline herbland	4	34.6
Saltmarsh (undiffernetiated)	29	51.3
Wetland (undifferentiated)	3	4.5
Eucalyptus nitida dry forest and woodland	4	24.4
Eucalyptus obliqua dry forest	1	6
Eucalyptus ovata forest and woodland	17	58.8
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	16	20.3
Melaleuca ericifolia swamp forest	19	44.4
Coastal heathland	3	93.8
Wet heathland	4	42.4
Leptospermum scrub	2	3.2
Melaleuca squarrosa scrub	14	17.8
Eucalyptus brookeriana wet forest	8	5.8
Vegetation Patch Total	**125**	**408.5**
Green & Gold Tree Frog assemblage habitat	64	129.9
Giant Freshwater Crayfish known habitat	0	N/A

A3.2.2. Fixters Creek



Montagu Catchment - Fixters Creek Subcatchment	Count of Area (ha)	Sum of Area (ha)
Wetland (undifferentiated)	1	0.4
Eucalyptus nitida dry forest and woodland	2	6.4
Eucalyptus obliqua dry forest	8	37.6
Acacia melanoxylon swamp forest	9	70
Acacia melanoxylon forest on rises	20	153.8
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	10	39.6
Nothofagus - Phyllocladus short rainforest	25	97.8
Nothofagus - Atherosperma rainforest	2	4.4
Broad-leaf scrub	5	10.3
Leptospermum scrub	27	92.5
Eucalyptus brookeriana wet forest	6	9
Eucalyptus nitida wet forest (undifferentiated)	1	2.6
Eucalyptus obliqua forest with broad-leaf shrubs	76	215.6
Eucalyptus obliqua forest over Leptospermum	1	0.2
Eucalyptus obliqua forest over rainforest	30	55.9
Eucalyptus obliqua wet forest (undifferentiated)	124	1219.8
Vegetation Patch Total	**347**	**2015.9**
Green & Gold Tree Frog assemblage habitat	11	91.5
Giant Freshwater Crayfish known habitat	0	N/A

A3.2.3. Montagu Beach, Stony Point and West Montagu to Robbins Passage

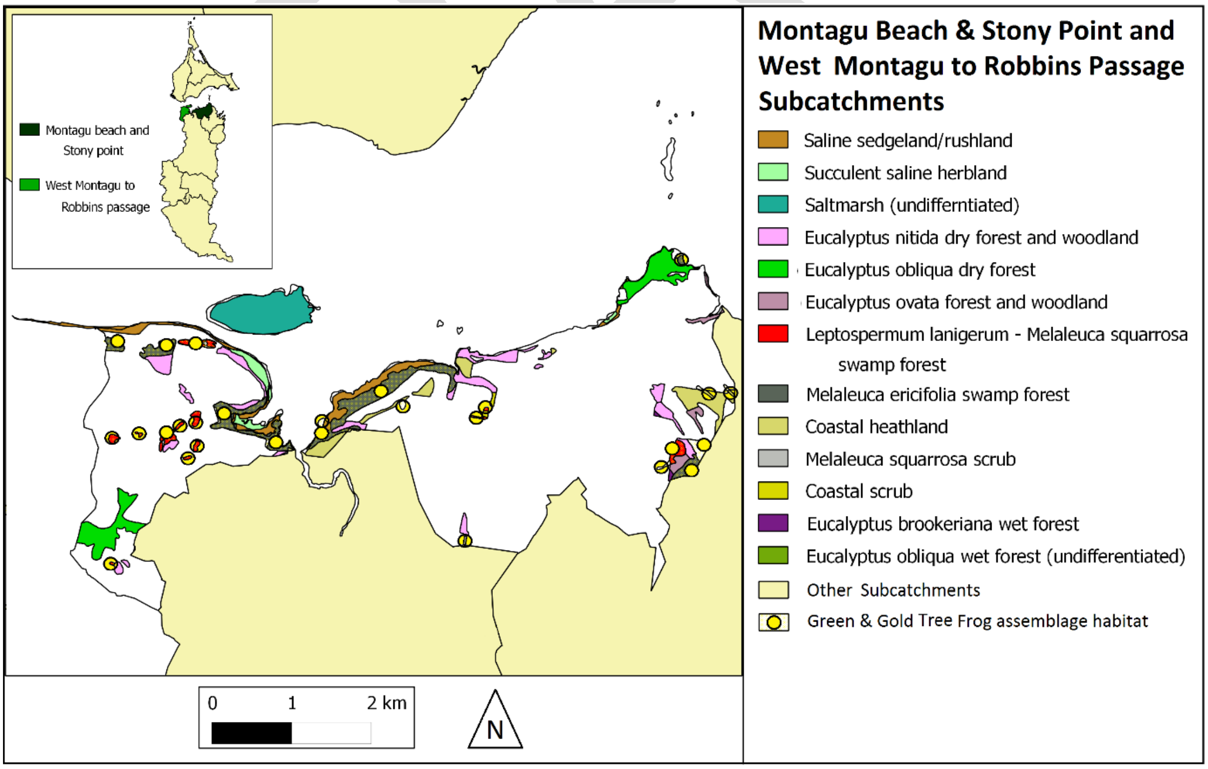


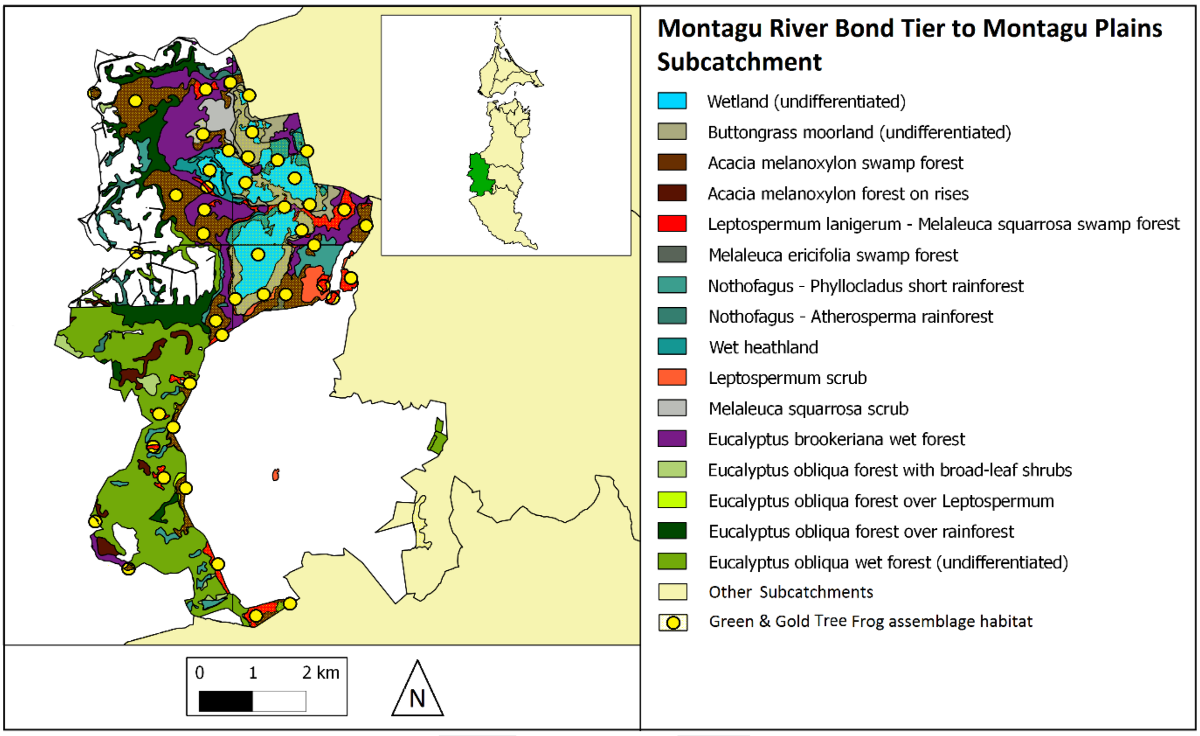
Table Below: Montagu Beach and Stony Point Subcatchment includes 13 patches of vegetation (0.7 ha in total) along its coastline made up of seven vegetation types that were part of Robbins Passage subcatchment in the original data.

Montagu Catchment - Montagu Beach and Stony Point Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	5	16.4
Succulent saline herbland	2	0.8
Eucalyptus nitida dry forest and woodland	12	28.8
Eucalyptus obliqua dry forest	3	21.3
Eucalyptus ovata forest and woodland	6	8.5
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	3	4.2
Melaleuca ericifolia swamp forest	5	33.6
Coastal heathland	6	32.1
Melaleuca squarrosa scrub	1	0.3
Coastal scrub	6	1.5
Eucalyptus brookeriana wet forest	2	0.9
Vegetation Patch Total	**51**	**148.4**
Green & Gold Tree Frog assemblage habitat	10	45.9
Giant Freshwater Crayfish known habitat	0	N/A

Table Below: The West Montagu to Robbins Passage Subcatchment includes 7 patches (3.4 ha) of 4 different vegetation types along its coastline that were included in the Robbins Passage Subcatchment in the original data. The most common vegetation type from Robbins Passage subcatchment now included in West Montahe to Robbins Passage is 3 patches of Saline sedgeland/rushland accounting for 3.2 ha (of the total 3.4 ha).

Montagu Catchment - West Montagu to Robbins Passage Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	6	16.5
Succulent saline herbland	5	9.9
Saltmarsh (undifferntiated)	2	51.6
Eucalyptus nitida dry forest and woodland	8	18.5
Eucalyptus obliqua dry forest	1	23.3
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	12	10.1
Melaleuca ericifolia swamp forest	4	26.1
Eucalyptus obliqua wet forest (undifferentiated)	1	0
Vegetation Patch Total	**39**	**156**
Green & Gold Tree Frog assemblage habitat	14	36.6
Giant Freshwater Crayfish known habitat	0	N/A

A3.2.4. Montagu River Bond Tier to Montagu Plains



Montagu Catchment - Montagu River Bond Tier to Montagu Plains	Count of Area (ha)	Sum of Area (ha)
Wetland (undifferentiated)	15	242.6
Buttongrass moorland (undifferentiated)	7	176.3
Acacia melanoxylon swamp forest	17	306.9
Acacia melanoxylon forest on rises	9	44.7
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	22	102.4
Melaleuca ericifolia swamp forest	1	3.8
Nothofagus - Phyllocladus short rainforest	21	89.5
Nothofagus - Atherosperma rainforest	8	40.6
Wet heathland	9	83.4
Leptospermum scrub	9	37.9
Melaleuca squarrosa scrub	4	46.4
Eucalyptus brookeriana wet forest	23	284.9
Eucalyptus obliqua forest with broad-leaf shrubs	13	27.5
Eucalyptus obliqua forest over Leptospermum	5	5.3
Eucalyptus obliqua forest over rainforest	56	217.6
Eucalyptus obliqua wet forest (undifferentiated)	47	665.4
Vegetation Patch Total	**266**	**2375.2**
Green & Gold Tree Frog assemblage habitat	28	858.8
Giant Freshwater Crayfish known habitat	0	N/A

A3.2.5. Montagu River Montagu Plains

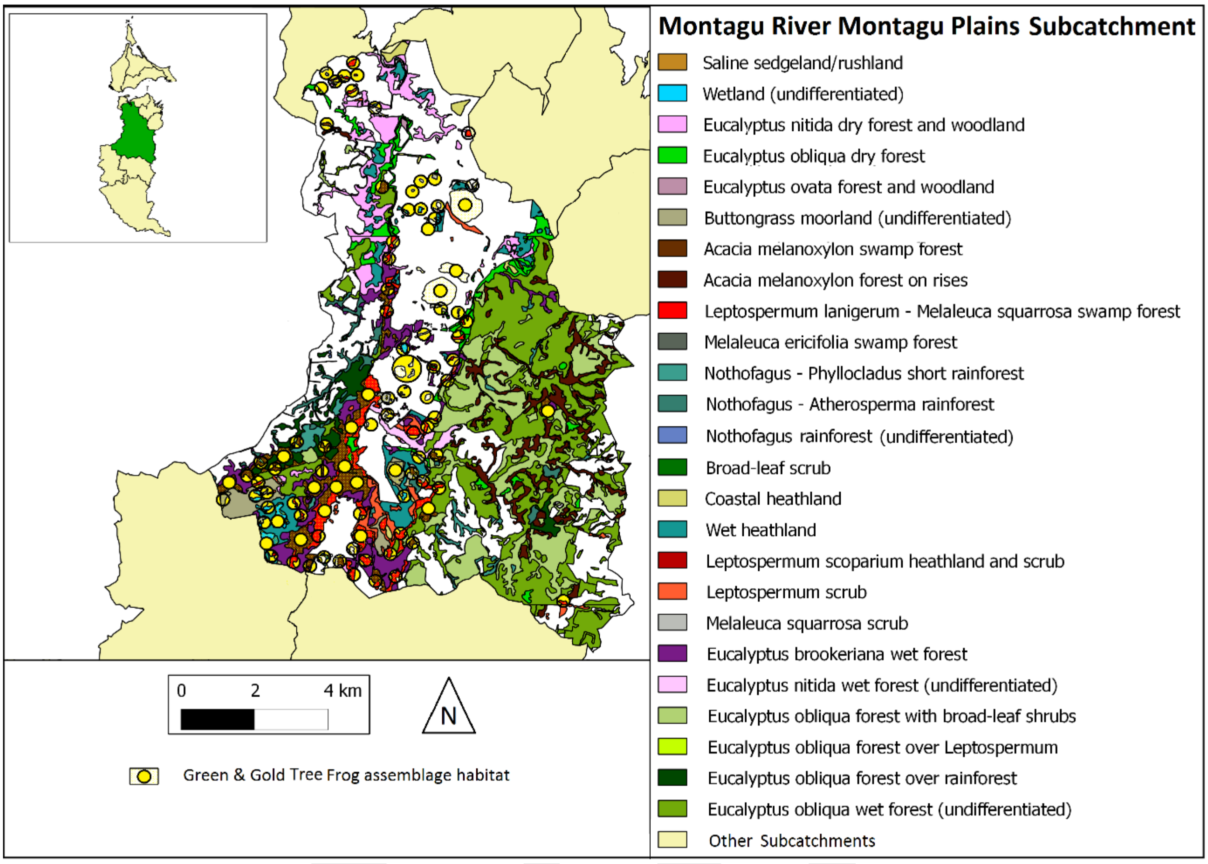


Table Below: Montagu River Montagu Plains subcatchment includes 3 different vegetation patches (1.8ha total) along the coastline from the Robbins Passage subcatchment in the original data set. The most significant vegetation patch is Eucalyptus nitida dry forest and woodland which is 1.6 ha.

Montagu Catchment - Montagu River Montagu Plains Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	3	0.7
Wetland (undifferentiated)	24	37.5
Eucalyptus nitida dry forest and woodland	59	403.1
Eucalyptus obliqua dry forest	57	253.3
Eucalyptus ovata forest and woodland	5	4.5
Buttongrass moorland (undifferentiated)	5	154.8
Acacia melanoxylon swamp forest	29	331.6
Acacia melanoxylon forest on rises	53	418.4
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	54	299.9
Melaleuca ericifolia swamp forest	2	0.5
Nothofagus - Phyllocladus short rainforest	20	115.3
Nothofagus - Atherosperma rainforest	20	122.4
Nothofagus rainforest (undifferentiated)	2	1.2
Broad-leaf scrub	1	0.5
Coastal heathland	12	47.4
Wet heathland	47	358.2
Leptospermum scoparium heathland and scrub	2	1

Leptospermum scrub	33	127.3
Melaleuca squarrosa scrub	30	41.9
Eucalyptus brookeriana wet forest	70	446.5
Eucalyptus nitida wet forest (undifferentiated)	10	85.7
Eucalyptus obliqua forest with broad-leaf shrubs	158	1059.1
Eucalyptus obliqua forest over Leptospermum	1	1.5
Eucalyptus obliqua forest over rainforest	20	202.7
Eucalyptus obliqua wet forest (undifferentiated)	145	1956.1
Vegetation Patch Total	**862**	**6471.1**
Green & Gold Tree Frog assemblage habitat	109	955.8
Giant Freshwater Crayfish known habitat	0	N/A

A3.2.6. Robbins Island

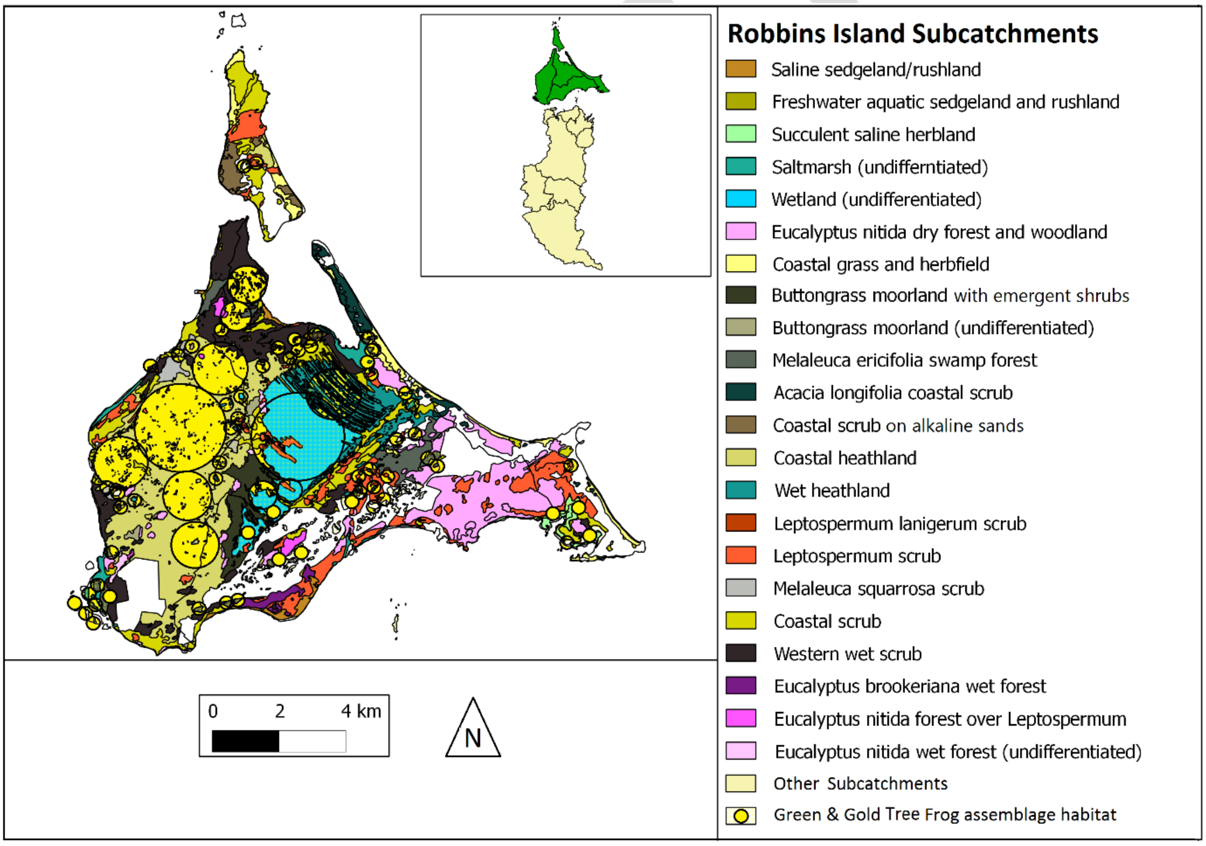
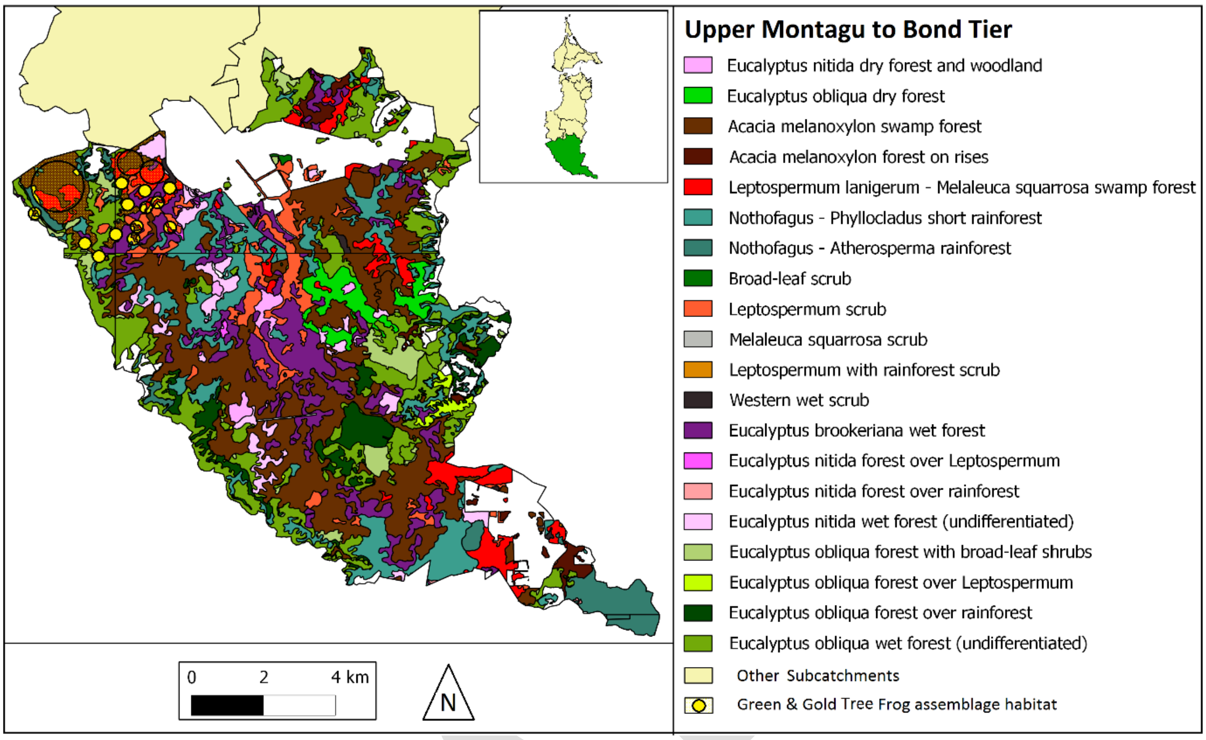


Table Below: Robbins Island subcatchments includes 22 patches of vegetation along the shoreline of Robbins Island that was included in the original data set as Robbins Passage. These 22 patches are made up of 11 different vegetation types which cover 2.6 ha. The most commonly occurring vegetation: Saltmarsh (undifferntiated) occurs 5 times accounting for 1 ha of land in total.

Montagu Catchment - Robbins Island Subcatchments	**Count of Area (ha)**	**Sum of Area (ha)**
Saline sedgeland/rushland	7	62.6
Freshwater aquatic sedgeland and rushland	10	13.8
Succulent saline herbland	7	69
Saltmarsh (undifferntiated)	16	142.7
Wetland (undifferentiated)	21	661.2
Eucalyptus nitida dry forest and woodland	39	838.5
Coastal grass and herbfield	21	217.8
Buttongrass moorland with emergent shrubs	2	260.8
Buttongrass moorland (undifferentiated)	5	29.7
Melaleuca ericifolia swamp forest	26	253.3
Acacia longifolia coastal scrub	20	130.7
Coastal scrub on alkaline sands	18	113.9
Coastal heathland	15	2486.5
Wet heathland	12	557.2
Leptospermum lanigerum scrub	1	0.8
Leptospermum scrub	68	771.6
Melaleuca squarrosa scrub	15	93.3
Coastal scrub	86	779.2
Western wet scrub	41	983.4
Eucalyptus brookeriana wet forest	6	67
Eucalyptus nitida forest over Leptospermum	5	46.6
Eucalyptus nitida wet forest (undifferentiated)	10	39.1
Vegetation Patch Total	**451**	**8618.7**
Green & Gold Tree Frog assemblage habitat	1143	1360.2
Giant Freshwater Crayfish known habitat	0	N/A

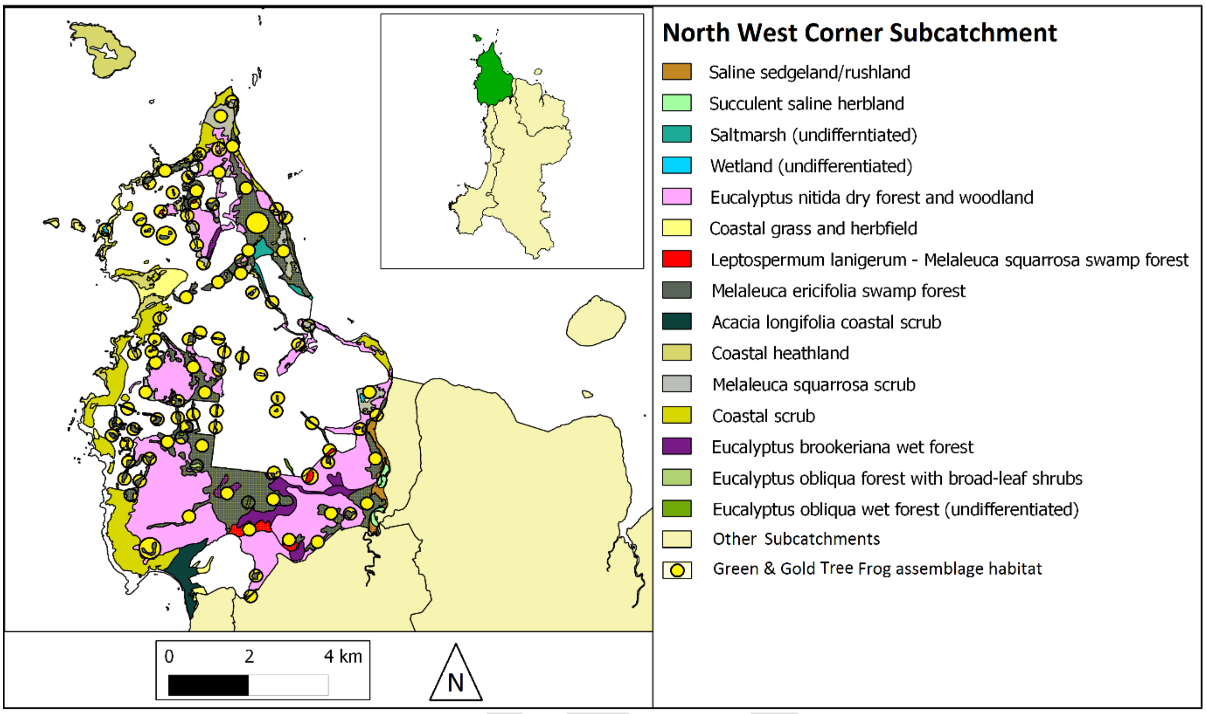
A3.2.7. Upper Montagu to Bond Tier



Montagu Catchment - Upper Montagu to Bond Tier Subcatchment	Count of Area (ha)	Sum of Area (ha)
Eucalyptus nitida dry forest and woodland	4	93.1
Eucalyptus obliqua dry forest	6	286.9
Acacia melanoxylon swamp forest	46	3058.4
Acacia melanoxylon forest on rises	14	170.7
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	36	611.6
Nothofagus - Phyllocladus short rainforest	73	1352.9
Nothofagus - Atherosperma rainforest	25	418.9
Broad-leaf scrub	10	18.5
Leptospermum scrub	60	549.5
Melaleuca squarrosa scrub	1	0.2
Leptospermum with rainforest scrub	1	0.7
Western wet scrub	10	31.6
Eucalyptus brookeriana wet forest	71	1216.4
Eucalyptus nitida forest over Leptospermum	14	17.6
Eucalyptus nitida forest over rainforest	11	4.9
Eucalyptus nitida wet forest (undifferentiated)	37	374
Eucalyptus obliqua forest with broad-leaf shrubs	159	347.9
Eucalyptus obliqua forest over Leptospermum	9	61.3
Eucalyptus obliqua forest over rainforest	169	507
Eucalyptus obliqua wet forest (undifferentiated)	176	1888.4
Vegetation Patch Total	**932**	**11010.5**
Green & Gold Tree Frog assemblage habitat	8	492.4
Giant Freshwater Crayfish known habitat	0	N/A

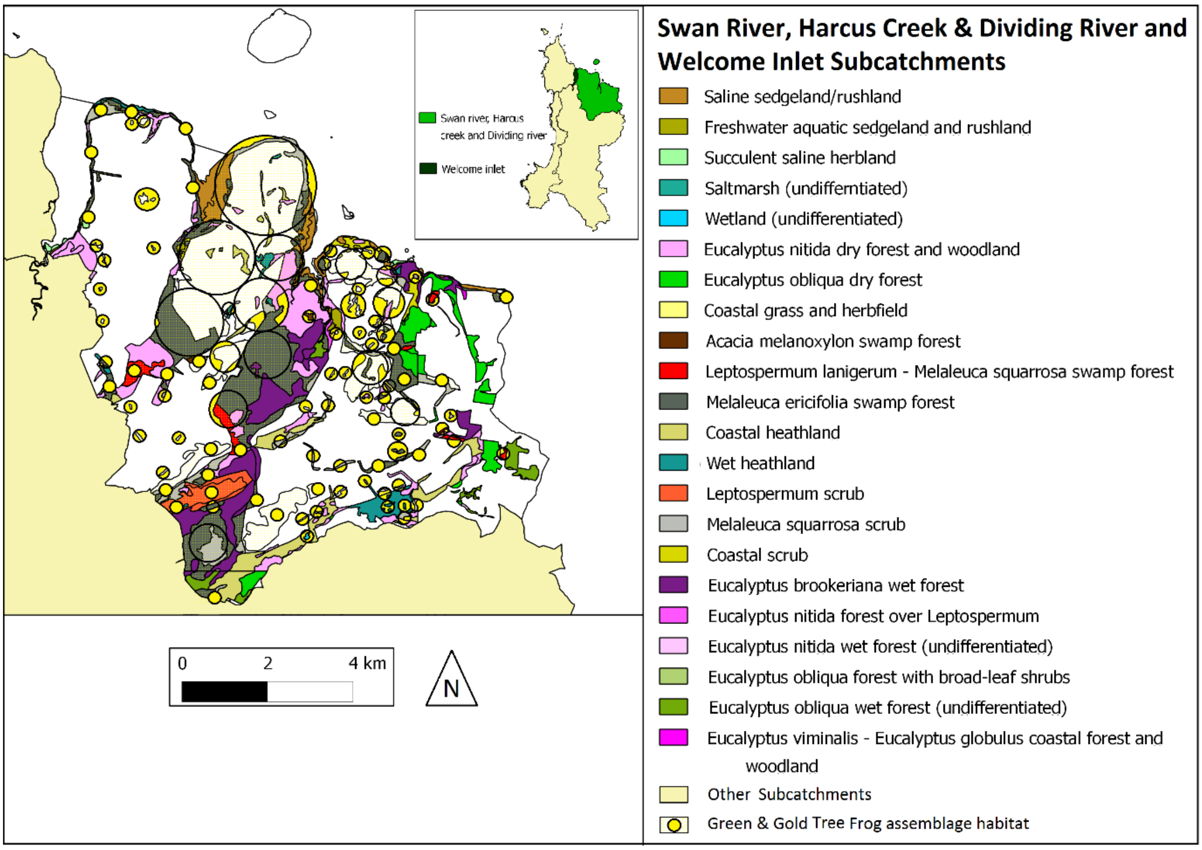
A3.3. Welcome Catchment

A3.3.1. North West Corner



Welcome Catchment - North West Corner Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	2	35.7
Succulent saline herbland	5	15.2
Saltmarsh (undifferntiated)	5	28.4
Wetland (undifferentiated)	2	4.3
Eucalyptus nitida dry forest and woodland	30	1297.3
Coastal grass and herbfield	19	114.6
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	11	40.8
Melaleuca ericifolia swamp forest	73	811.3
Acacia longifolia coastal scrub	3	72.5
Coastal heathland	20	177.1
Melaleuca squarrosa scrub	40	169.1
Coastal scrub	29	389.5
Eucalyptus brookeriana wet forest	6	119.7
Eucalyptus obliqua forest with broad-leaf shrubs	1	2.2
Eucalyptus obliqua wet forest (undifferentiated)	3	4.9
Vegetation Patch Total	**249**	**3282.6**
Green & Gold Tree Frog assemblage habitat	99	1079
Giant Freshwater Crayfish known habitat	0	N/A

A3.3.2. Swan River, Harcus Creek, Dividing River and Welcome Inlet

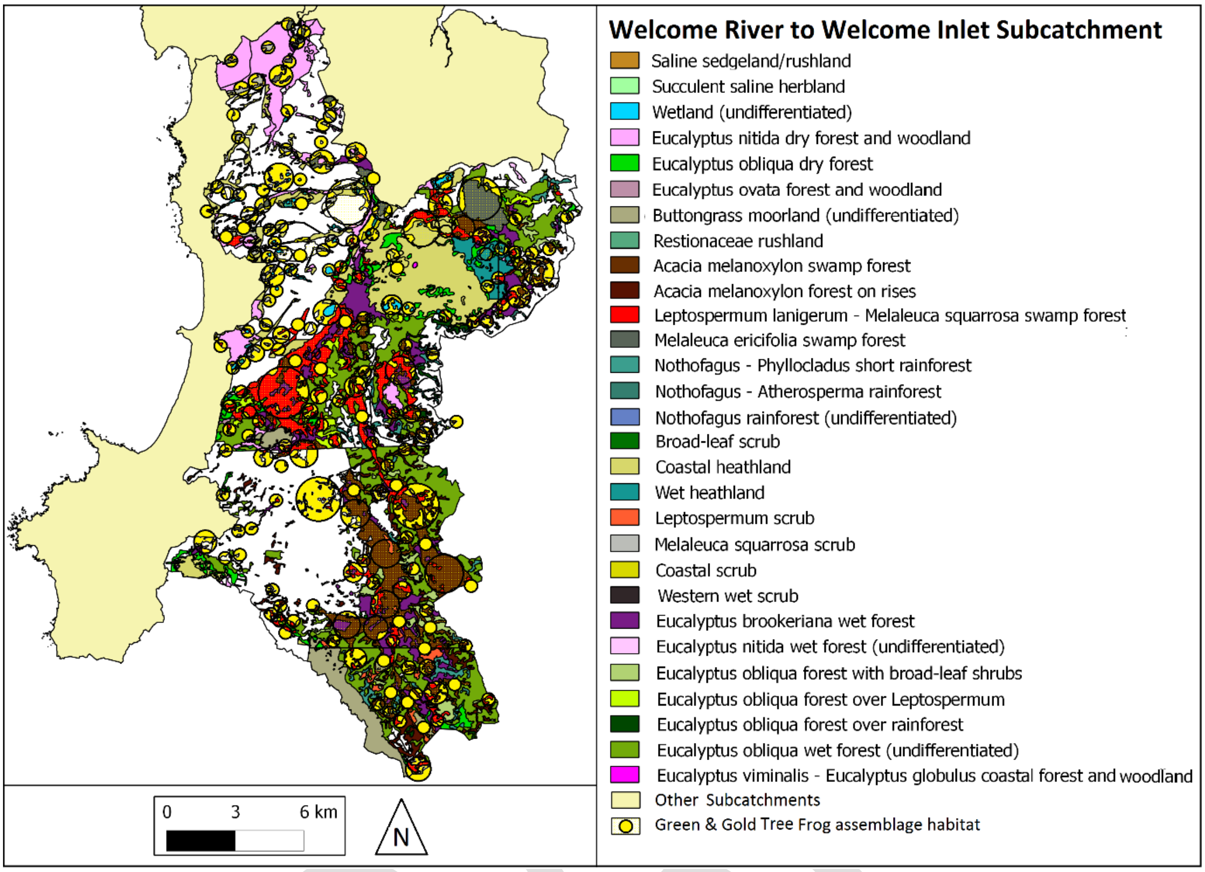


Welcome Catchment - Swan River, Harcus Creek and Dividing River Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	16	160.1
Freshwater aquatic sedgeland and rushland	2	14.9
Succulent saline herbland	3	8.5
Saltmarsh (undifferntiated)	2	8.3
Wetland (undifferentiated)	1	1.3
Eucalyptus nitida dry forest and woodland	62	454.4
Eucalyptus obliqua dry forest	19	180.6
Eucalyptus viminalis - Eucalyptus globulus coastal forest and woodland	1	2.5
Coastal grass and herbfield	1	0.3
Acacia melanoxylon swamp forest	2	4.6
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	8	62.8
Melaleuca ericifolia swamp forest	44	756.5
Coastal heathland	15	215.6
Wet heathland	11	85.5
Leptospermum scrub	1	96.2
Melaleuca squarrosa scrub	27	192.9
Coastal scrub	3	31.3
Eucalyptus brookeriana wet forest	18	331.5
Eucalyptus nitida forest over Leptospermum	1	6.9
Eucalyptus nitida wet forest (undifferentiated)	3	1.2

Eucalyptus obliqua forest with broad-leaf shrubs	2	0.6
Eucalyptus obliqua wet forest (undifferentiated)	16	74.2
Vegetation Patch Total	**258**	**2690.7**
Green & Gold Tree Frog assemblage habitat	92	2507.9
Giant Freshwater Crayfish known habitat	0	N/A

Welcome Catchment - Welcome Inlet Subcatchment	**Count of Area (ha)**	**Sum of Area (ha)**
Saline sedgeland/rushland	5	0.7
Succulent saline herbland	5	2
Saltmarsh (undifferntiated)	1	0
Eucalyptus nitida dry forest and woodland	4	0
Melaleuca ericifolia swamp forest	8	0
Melaleuca squarrosa scrub	1	0
Eucalyptus brookeriana wet forest	1	0
Vegetation Patch Total	**25**	**2.7**
Green & Gold Tree Frog assemblage habitat	5	2.6
Giant Freshwater Crayfish known habitat	0	N/A

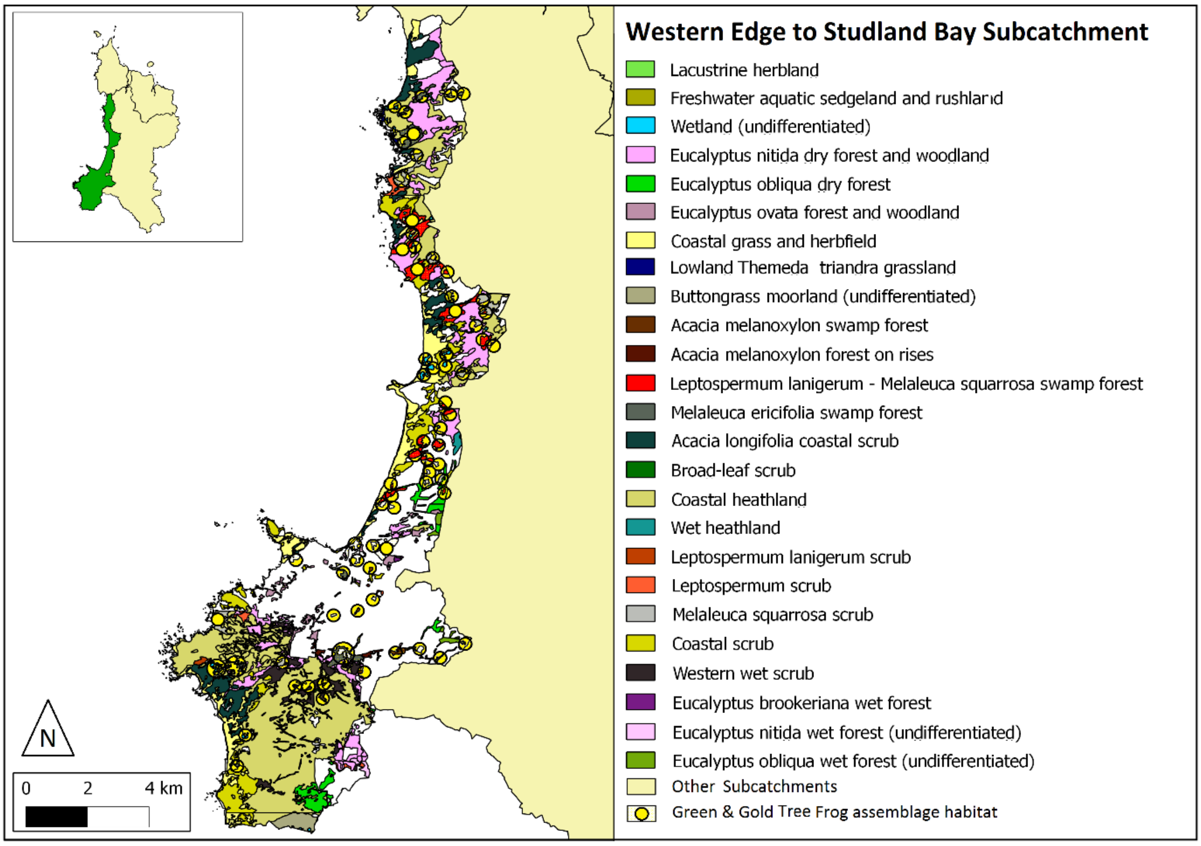
A3.3.3. Welcome River to Welcome Inlet



Welcome Catchment - Welcome River to Welcome Inlet Subcatchment	Count of Area (ha)	Sum of Area (ha)
Saline sedgeland/rushland	2	2.2
Succulent saline herbland	1	0.6
Wetland (undifferentiated)	70	127.8
Eucalyptus nitida dry forest and woodland	78	1545.4
Eucalyptus obliqua dry forest	102	650
Eucalyptus ovata forest and woodland	2	9.3
Eucalyptus viminalis - Eucalyptus globulus coastal forest and woodland	1	3.9
Buttongrass moorland (undifferentiated)	12	673.7
Restionaceae rushland	2	0.3
Acacia melanoxylon swamp forest	105	2220.6
Acacia melanoxylon forest on rises	71	405.8
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	116	1919.9
Melaleuca ericifolia swamp forest	57	485.7
Nothofagus - Phyllocladus short rainforest	43	331.9
Nothofagus - Atherosperma rainforest	21	60.5
Nothofagus rainforest (undifferentiated)	1	0.4
Broad-leaf scrub	3	4.5
Coastal heathland	96	2536.2
Wet heathland	30	458.9
Leptospermum scrub	41	181.2

Melaleuca squarrosa scrub	83	248.8
Coastal scrub	8	54.1
Western wet scrub	22	14.1
Eucalyptus brookeriana wet forest	129	1520
Eucalyptus nitida wet forest (undifferentiated)	3	15.8
Eucalyptus obliqua forest with broad-leaf shrubs	247	558.5
Eucalyptus obliqua forest over Leptospermum	43	270.4
Eucalyptus obliqua forest over rainforest	90	154.3
Eucalyptus obliqua wet forest (undifferentiated)	298	4019.4
Vegetation Patch Total	**1777**	**18474.2**
Green & Gold Tree Frog assemblage habitat	346	6215.1
Giant Freshwater Crayfish known habitat	0	N/A

A3.3.4. Western Edge to Studland Bay



Welcome Catchment - Western Edge to Studland Bay Subcatchment	Count of Area (ha)	Sum of Area (ha)
Lacustrine herbland	1	0.2
Freshwater aquatic sedgeland and rushland	2	5.7
Wetland (undifferentiated)	41	33.3
Eucalyptus nitida dry forest and woodland	72	776.5
Eucalyptus obliqua dry forest	20	151.5
Eucalyptus ovata forest and woodland	47	82.8
Coastal grass and herbfield	53	503.5
Lowland Themeda triandra grassland	4	9.2
Buttongrass moorland (undifferentiated)	2	59.1
Acacia melanoxylon swamp forest	4	11.9
Acacia melanoxylon forest on rises	6	14
Leptospermum lanigerum - Melaleuca squarrosa swamp forest	30	198.8
Melaleuca ericifolia swamp forest	38	105.4
Acacia longifolia coastal scrub	40	373.4
Broad-leaf scrub	1	1.2
Coastal heathland	118	2081.1
Wet heathland	10	19.4
Leptospermum lanigerum scrub	1	6.9
Leptospermum scrub	11	39.1
Melaleuca squarrosa scrub	25	100.7
Coastal scrub	51	456.5
Western wet scrub	57	228.1
Eucalyptus brookeriana wet forest	1	2.9
Eucalyptus nitida wet forest (undifferentiated)	2	13.9
Eucalyptus obliqua wet forest (undifferentiated)	9	25.9
Vegetation Patch Total	**646**	**5301**
Green & Gold Tree Frog assemblage habitat	159	561.6
Giant Freshwater Crayfish known habitat	0	N/A

APPENDIX 4. ESTIMATES OF CURRENT AVERAGE ANNUAL POLLUTANT LOADS

Average annual pollutant loads for current land use and management have been estimated using the MiniCAPER DSS. Table 10 provides estimated average annual pollutant loads.

TABLE 10. AVERAGE ANNUAL POLLUTANT LOADS

Subcatchment	TN (kg/yr)	TP (kg/yr)	TSS (T/yr)	Faecal coliforms (cfu/yr)	Area (ha)
Duck River Catchment					
Acton Bay foreshore	15,958	5,689	287	5.1E+13	1351.6
Anthony beach	6,467	2,306	123	2.0E+13	475.3
Deep creek	95,587	32,752	1,824	2.8E+14	7696.5
Duck river from Copper creek to Coventry creek	103,838	36,037	1,933	3.5E+14	7742.1
Duck river from Roger river to Copper creek	100,804	35,892	1,855	3.3E+14	10668.9
Fentons creek	12,143	4,257	225	4.3E+13	1148.9
Geales creek	32,935	11,932	587	1.2E+14	3512.9
Mill creek	1,536	229	98	9.4E+11	1392.9
Plains creek	5,953	1,667	230	1.4E+13	2623.6
Roger river	26,867	9,029	674	8.1E+13	6635.9
Scopus creek	17,986	6,260	380	6.1E+13	2705.7
Shipwreck point to Kingston point	333	84	50	6.5E+11	1054.7
Upper Duck river to Roger river	44,146	14,519	999	1.2E+14	7796
Montagu River Catchment					
Barcoo creek	11,177	3,998	219	3.9E+13	1400.4
Fixters creek	32,879	11,626	663	1.1E+14	4449.1
Montagu beach and Stony point	10,404	3,740	188	3.4E+13	1050.2
Montagu Plains to Big Bay	18,927	6,932	322	6.7E+13	1836.6
Montagu river Bond Tier to Montagu Plains	23,975	8,716	518	8.8E+13	4725.3
Montagu river Montagu Plains	43,486	14,149	1,136	1.2E+14	10725.9
Robbins island	11,676	3,892	656	3.4E+13	10493.5
Upper Montagu to Bond Tier	28,492	8,127	1,072	6.7E+13	12962.1
West Montagu to Robbins passage	5,492	1,917	100	1.6E+13	562.1
Welcome River Catchment					
North west corner	34,191	12,393	706	1.2E+14	6102.4
Swan river; Harcus creek and Dividing river	60,330	21,977	1,099	2.2E+14	7874.4
Welcome river to Welcome inlet	122,036	40,929	2,999	3.8E+14	29144.1
Western edge to Studland Bay	49,657	17,665	1,131	1.6E+14	8433.1

Note that the model is a simple adaptation of the TEER CAPER DSS. Flow is modelled in the MiniCAPER DSS using an empirical model developed using data from the Circular Head catchments. Water quality parameters, event mean concentration and dry weather concentrations for each land use, have been modified from a WaterCAST (now Source Catchments) model, previously developed for the Montagu river catchment by Weber and Holz (2007). The modelling should be considered indicative of relative loads.