Water Quality Improvement Plan for Floodplain Lower Ringarooma River Wetlands

isNRM Pty Ltd

May 2021

Citation: Kelly, R. (2021). Water Quality Improvement Plan for Floodplain Lower Ringarooma River Wetlands, Report to NRM North, isNRM Pty Ltd, May 2021.

Contents

Introduction

The Floodplain Lower Ringarooma Ramsar site is located in North-east Tasmania, adjacent to Bass Strait, as shown in Figure 1. This project focuses on the Ramsar site and activities in the Ringarooma river catchment which address threats to the Ramsar site identified in the Floodplain Lower Ringarooma Ramsar Site Ecological Character Description (ECD).

FIGURE 1. LOCATION OF THE FLOODPLAIN LOWER RINGAROOMA RAMSAR SITE AND THE RINGAROOMA RIVER CATCHMENT

The Ecological Character Description for the Flood Plain Lower Ringarooma River Ramsar site (Newall *et al.*, 2012) identifies 3 zones of the Ramsar - Freshwater, Floodplain and Wetland Zone; Estuary Zone; and Coastal Zone. Critical components, process and essential elements identified in the ECD include the presence of regionally rare flora and fauna as well as significant wetland types in the Freshwater, Floodplain and Wetland Zone. In the Estuary Zone these include significant wetland types as well as migratory and rare birds and fish and macroinvertebrates, while in the Coastal Zone water quality is also named in addition to these other critical components, processes and essential elements. The ECD identifies sedimentation, eutrophication and water quality decline from the catchment amongst the threats to critical components, processes and essential elements and to critical services.

In the ECD for the site it is stated that there is little water quality data available for the site. The ECD notes that there is water quality data available upstream of the site at on the Ringarooma river at Gladstone which is *'indicative of high-quality waters for a lowland river in south-eastern Australia. The water is high quality for an aquatic ecosystem with low electrical conductivity, turbidity and nutrients and high dissolved oxygen concentrations'*.

Data on nutrients and turbidity were collected as part of the TEFlows project in 2007 and 2008 for two sites – one in the catchment at the Moorina stream gauge (Ringarooma at Moorina, gauge number 30 - 10 observations) and the other within the Freshwater zone of the Ramsar site (5 observations). These data show that total nitrogen (TN) exceeds the low risk ANZECC guideline for 85% of observations. The site-specific trigger value is nearly 2 times higher than the ANZECC trigger value, with 15% of observations exceeding this higher threshold. Total phosphorus (TP) exceeded the ANZECC low risk threshold for 23% of observations or 8% of observations when compared to the site-specific value. 20% of observations exceed the site-specific turbidity threshold (which is within the broad range of ANZECC trigger values). The site within the wetland has turbidity measurements 4 times higher than the upstream site. TN measurements were on average lower than in the wetland than at the site in the catchment, while TP was higher in the wetland.

The latest publicly available data on water quality is available in the Water Management Plan (WMP), which contains data from 2013/14, collected after the ECD was written. Nutrients were not sampled but chlorophyll-a (Chl-A) was measured as part of condition. The WMP shows significantly elevated Chl-A measured in the upper Ringarooma River in high agriculture areas with high water allocations (that is, areas of intensive agriculture). This report noted that riparian vegetation cover appears to be impacted by agricultural land use in the upper catchment and that algal biomass (measured though Chl-A) was *'greater at sites with high levels of upstream agricultural land and water use compared to sites with low levels of agricultural land use*.' They also noted *that 'between spring 1994 and autumn 2013, there has been a significant decline in the health of macroinvertebrate communities in the Ringarooma River at Branxholm, and similar trends were also evident at other long-term monitoring sites in the upper Ringarooma catchment which are subject to effects of upstream agricultural land use and water use*.'

Over recent years agricultural land use in the Ringarooma catchment and the grazed areas in and around the Ramsar site have intensified. The WMP provides clear evidence that this intensification is placing pressures on water quality, particularly through increased eutrophication, as evidenced by increasing algal biomass in the Ringarooma river. This decline in water quality is a clear threat to the ecological condition of the Ramsar site.

This Water Quality Improvement Plan (WQIP) has been developed for the catchment of the Lower Ringarooma Floodplain Wetlands to:

- Provide a comprehensive whole-of-catchment picture of water quality contributed to the wetlands.
- 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.

The WQIP provides a snapshot of the sources of pollutants at a catchment scale, with the leverage of potential catchment management actions considered before developing a detailed investment plan for two properties immediately surrounding the wetlands. These investment plans are developed to inform actions to the funded through a Regional Land Program grant which is currently underway to improve the ecological character of the Ramsar site.

While it is recognised that the broader WQIP will need to be implemented by a range of key stakeholders in order to improve water quality, the focus of engagement in this plan has been on landholders immediately adjacent to the Ramsar site whose actions will potentially be funded through the RLP grant. It is recommended that further engagement with the broader catchment stakeholders be taken in the future to refine recommendations and build ownership of the Plan actions and outcomes.

WQIP development process

The WQIP has been developed through a combination of desktop analysis of existing data sets 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 potential management actions on water quality

The potential impacts of effluent management on nutrient and pathogen export to the wetlands have been estimated using a modified version of the effluent tool developed to inform the Tamar Action Grants (Kelly, 2019). A small-scale monitoring program has also been used to supplement modelled information on the relative magnitude of different sources of pollutant loads to the Ramsar site and provide an estimate of dissolved rather than total nutrients from areas surrounding the Ramsar site.

This assessment has informed discussions with key stakeholders about priority actions to be undertaken on their properties and recommendations that appear in this WQIP. The role of key stakeholders in the development of the WQIP is crucial to ensuring recommendations are adopted.

The WQIP has been developed using the four steps shown in Figure 1.

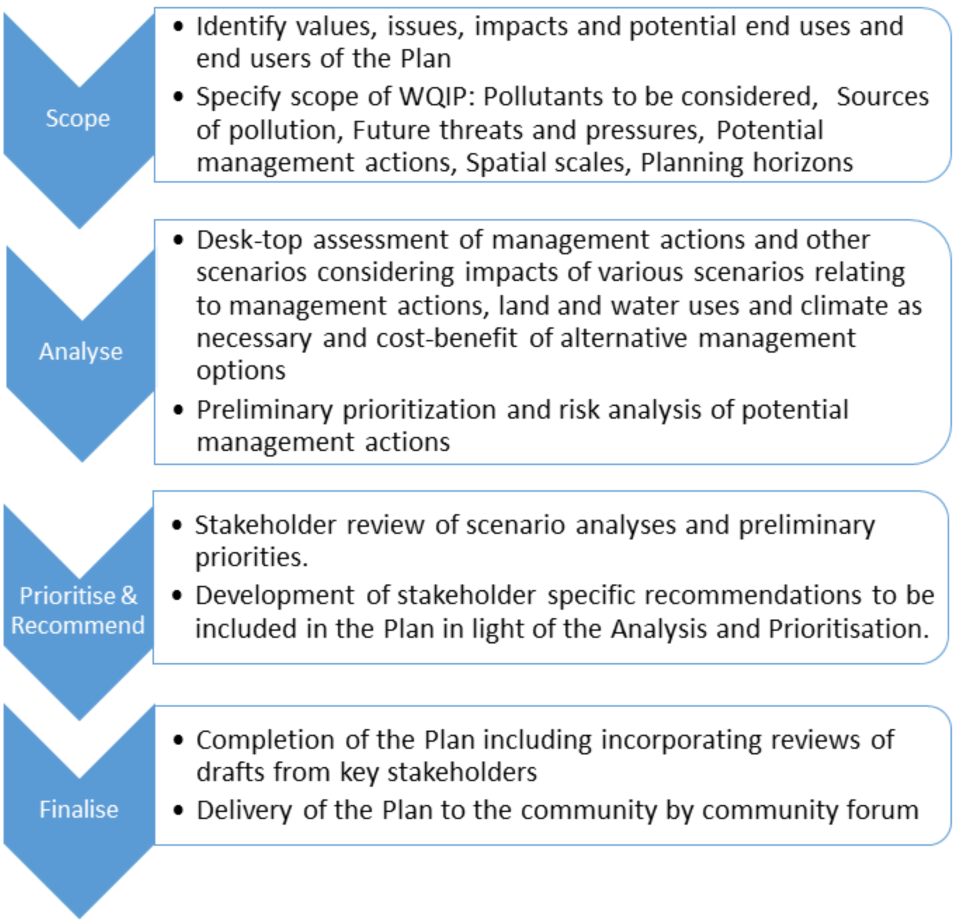


FIGURE 1. WQIP DEVELOPMENT PROCESS

An advisory committee for the RLP project has been used to review and refine potential actions and to prioritise recommendations for the property investment plans.

This document is split into several sections:

- A brief WQIP for the broader Ringarooma River catchment considering where pollutants come from and the leverage and approximate costs of potential management actions.
- Detailed investment plans for Rushy Lagoon and Boobyalla Park properties which are adjacent to the Ramsar site. These consider very specific actions to reduce nutrient exports from these properties to the Ramsar site.

The Floodplain Lower Ringarooma River wetland catchment - WQIP

Catchment description

The Floodplain Lower Ringarooma wetland catchment covers over 97,000ha. Figure 2 shows the distribution of land use types in the catchment. Areas and the proportion of the catchment covered by each land use type are given in Table 1 (note this data was produced in 2015). The map shows that grazing and dairy areas are largely in the upper to mid catchment except for the few properties immediately adjacent to the Ramsar site in the lower catchment. Approximately 17% of the catchment is grazing or dairy land. Green space covers over 50% of the catchment, with large areas of native forest between the grazed areas in the upper catchment and those immediately adjacent to the Ramsar site. Plantations cover approximately 12% of the catchment with native production forest covering a further 13%. Forestry activities are generally confined to the upper and mid catchment. There are mine sites scattered through the catchment with small areas of cropping, horticulture, rural residential and urban land uses in the upper to mid catchment.

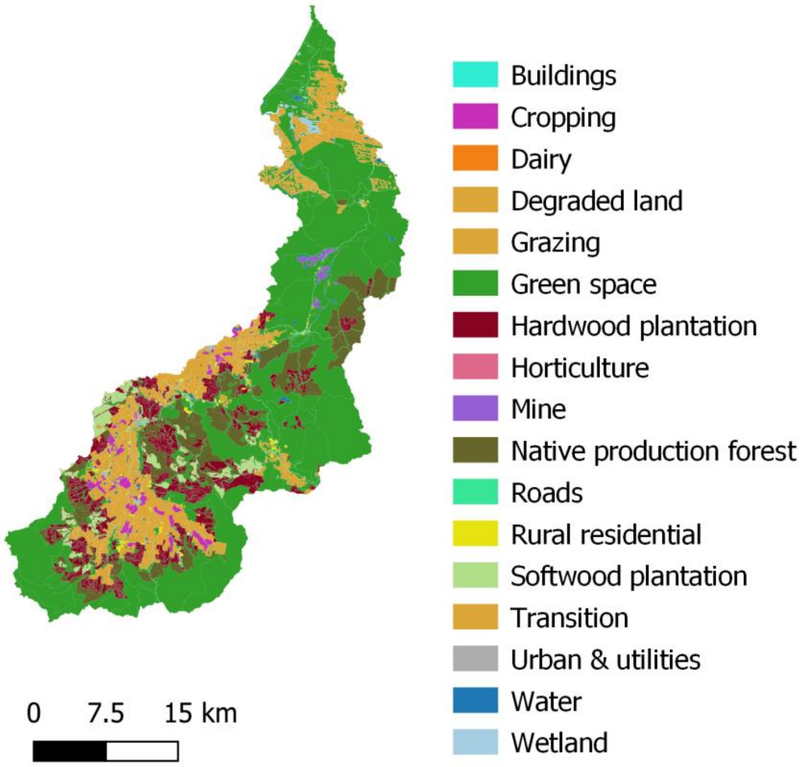


Figure 2. Land use in the Ringarooma River catchment (DPIPWE, 2015 land use layer)

TABLE 1. AREA AND PERCENTAGE OF CATCHMENT COVERED BY DIFFERENT LAND USE TYPES

Land use type	Area (ha)	% catchment
Cropping	1,295	1%
Dairy	9,102	9%
Grazing	8,019	8%
Green space	52,166	54%
Hardwood plantation	8,572	9%
Horticulture	64	0%
Mine	392	0%
Native production forest	12,884	13%
Roads	651	1%
Rural residential	482	0%
Softwood plantation	2,557	3%
Urban & utilities	212	0%
Water	735	1%
Wetland	298	0%
Total	97,430	100%

An analysis of woody vegetation in riparian zones in the catchment shows that two-thirds of streams in dairy areas and over 50% of streams in grazing have little to no vegetation in their riparian zone. Figure 3 shows the distribution of woody vegetation, grass and bare soil in streamside zones across the catchment. This figure shows substantial areas of poor riparian vegetation cover in grazing and dairy areas in the catchment.

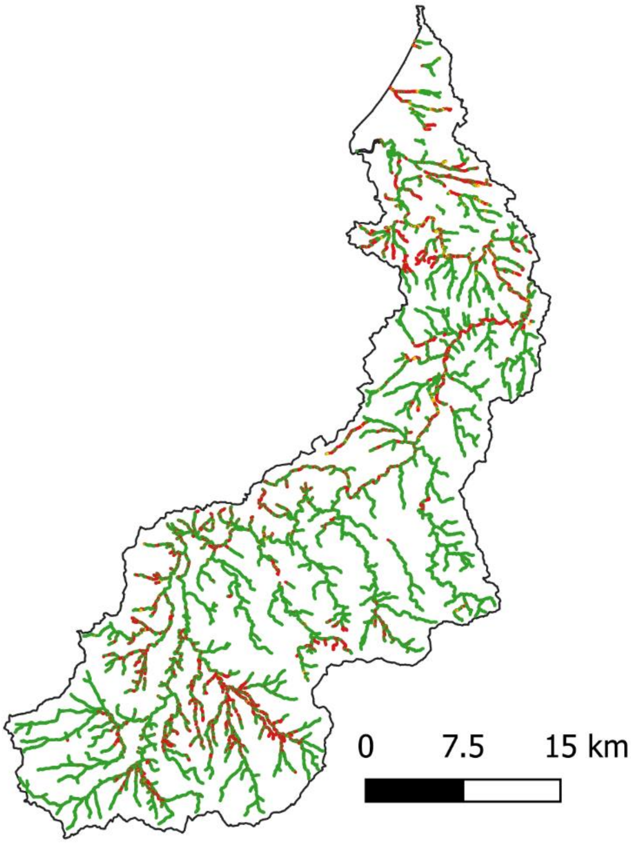


FIGURE 3. WOODY VEGETATION IN STREAMSIDE ZONES OF THE RINGAROOMA RIVER CATCHMENT

Figure 4 shows average monthly rainfall from 2010 to 2020 for 3 sites in the catchment – Rushy on the Ramsar site, Moorina in the mid catchment and Ringarooma in the upper catchment. This figure shows that rainfall is substantially higher in the mid and upper catchment than in the lower catchment, with annual rainfall of 765mm at Rushy, 1189mm at Moorina and 1127mm at Ringarooma.

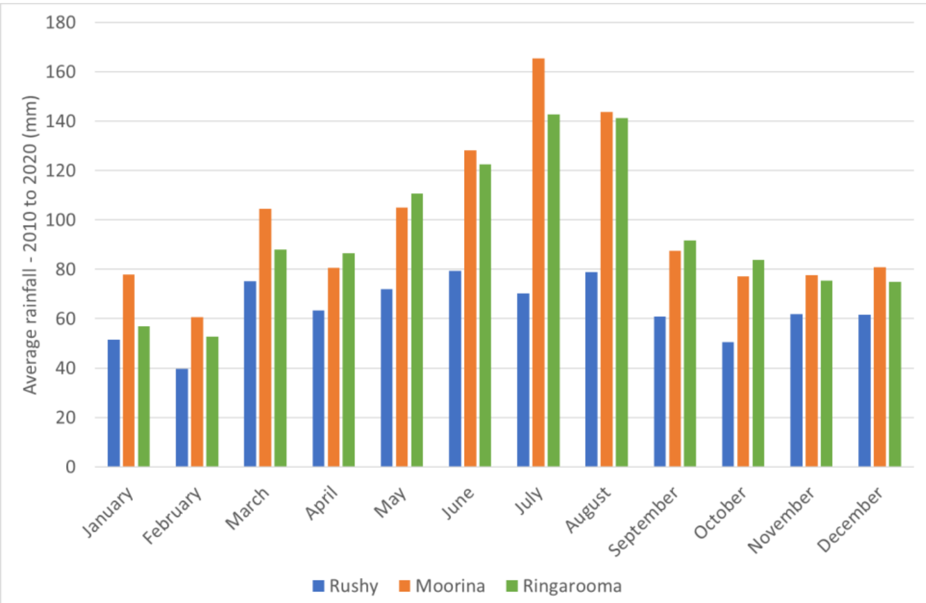


FIGURE 4. AVERAGE MONTHLY RAINFALL FROM 2010 TO 2020 AT SITES IN THE RINGAROOMA RIVER CATCHMENT, FROM SILO DATA BASE (JEFFREY ET AL., 2001)

Figure 5 shows the hillside water erosion hazard for areas of the Ringarooma river catchment. This shows areas where a water erosion hazard might exist if sufficient groundcover is not maintained, which could lead to soil resource degradation through soil, organic matter and nutrient loss, resulting in sedimentation and contamination of drainage lines and waterways after significant rainfall and runoff events. This shows that hillslope water erosion hazard is highest in areas in the upper catchment where slopes and rainfall are highest. Hillslope water erosion hazard is generally relatively low in the lower catchment around the Ramsar site.

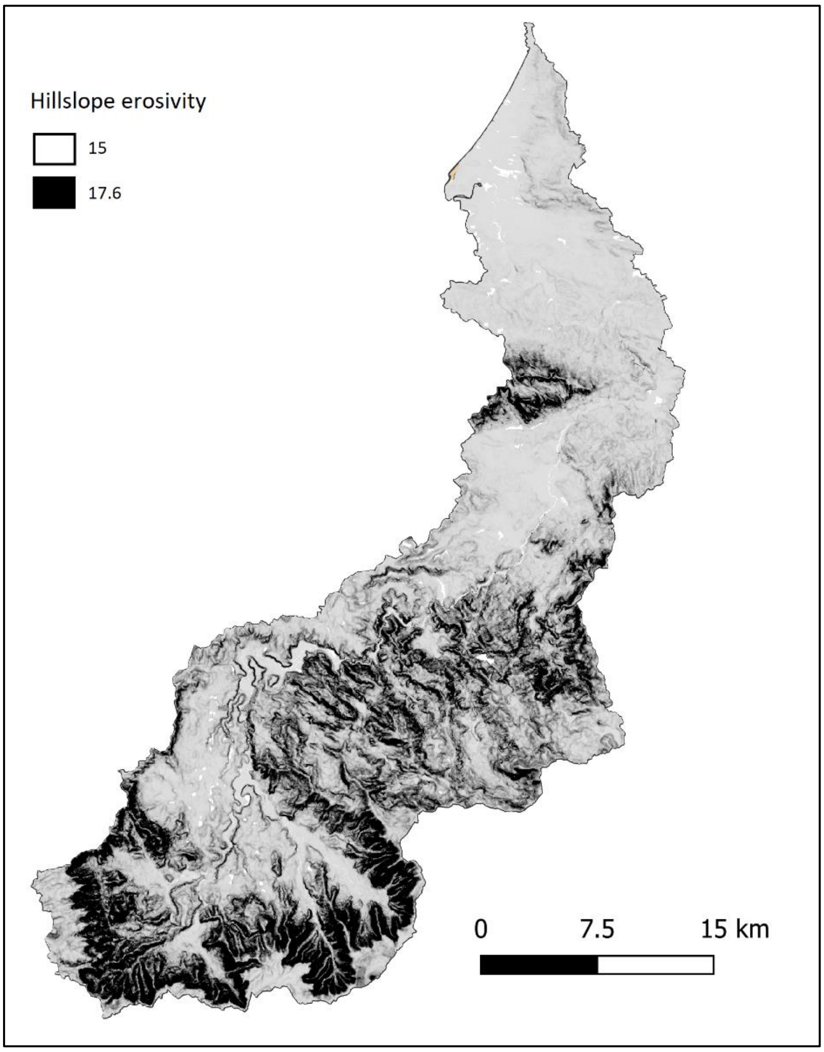


FIGURE 5. HILLSLOPE EROSION HAZARD IN THE RINGAROOMA RIVER CATCHMENT

Where do pollutants come from?

The sources of nutrient and sediment exports to the Ramsar site have been estimated using a combination of monitoring and modelling. This section first describes data collected as part of a spatial snapshot monitoring regime before providing an estimate of the land use sources of key pollutants to the Ramsar site.

Spatial snapshot monitoring

A spatial snapshot sampling regime has been used to provide an initial picture of where pollutants are coming from to the Ramsar site. This sampling has focused on identifying spatial differences between concentrations of runoff from different waterways as they enter the wetlands. Figure 6 shows the location of sampling points. Site locations and their characteristics are summarised in Table 2. To date grab sampling has occurred on 5 dates for all sites – 3 April 2020, 30 April 2020, 24 June 2020, 3

December 2020 and 25 March 2021. Samples were also collected at RR8, RR9 and RR10 on 22 October 2020.

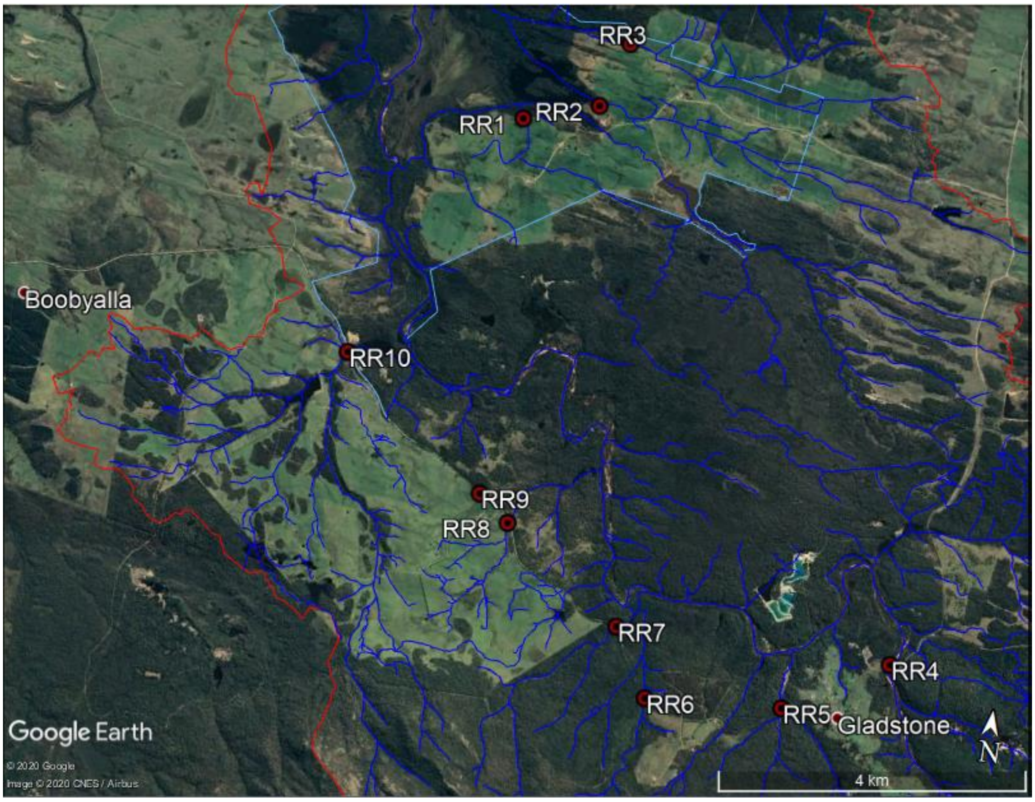


FIGURE 6. MONITORING SITES USED TO COLLECT WATER QUALITY SAMPLES

TABLE 2. CHARACTERISTICS OF THE MONITORING SITES USED FOR SPATIAL SNAPSHOT MONITORING

Site	Water course	Stream order	Land use
RR1	Cygnus (unnamed)	2	Dairy
RR2	Centre view (unnamed)	3	Dairy
RR3	Mayfield creek	3	Dairy
RR4	Ringarooma River	6	Mixed - upstream catchment
RR5	Mt Cameron Creek	4	Forest
RR6	Sextus Creek	3	Forest
RR7	Galloway Creek	3	Forest
RR8	Gincase Creek	4	Grazing
RR9	Echo Creek	1	Grazing
RR10	Hardwickes Creek	5	Grazing

Samples have been analysed for nutrients, sediments and chlorophyll-a. Monitored data is compared to the Slight to Moderately Disturbed (SMD) default guideline value (DGV) for the Ringarooma where possible. Note that data are generally presented on a log-scale due to the very large differences between values at different sites to allow low values to be better visualised.

Phosphorus

Figure 7 shows the log of total phosphorus concentrations at he 10 monitoring sites versus the slight to moderately disturbed default guideline value. This figure shows that concentrations in the Ringarooma river (RR4) are below the limit (0.03 mg/L) for 3 out of 5 samples and 2 to 3 times over the limit for the other two samples. Concentrations coming out of forested areas (RR5, RR6, RR7) are well below the guideline value for almost all samples (at the DGV for one observation at RR7). Concentrations from dairy areas (RR1, RR2, RR3) are generally higher than those off grazing (RR8, RR9, RR10) but both land uses are associated with concentrations of TP well above DGVs.

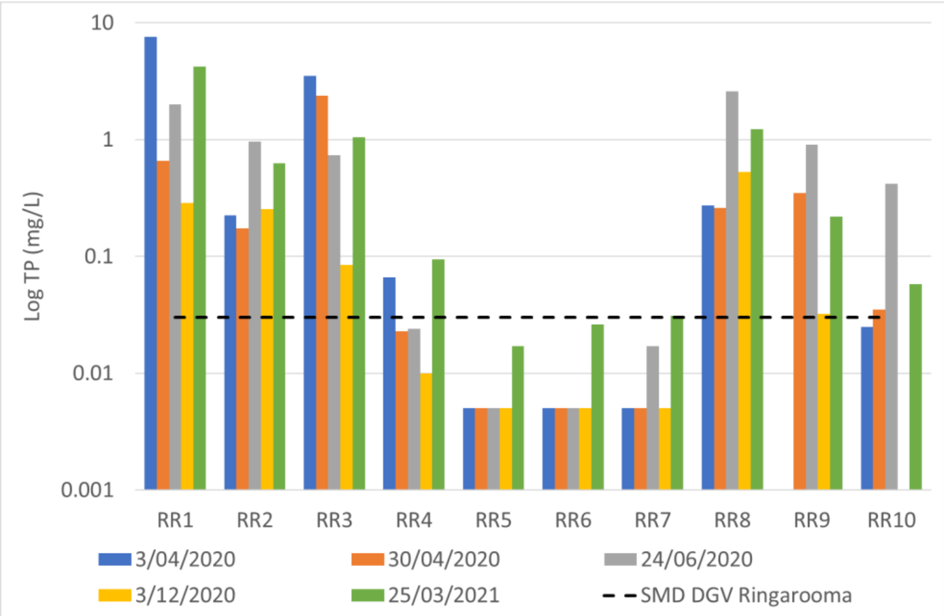


FIGURE 7. LOG TP (MG/L) AT MONITORING SITES VERSUS THE SLIGHT TO MODERATELY DISTURBED DEFAULT GUIDELINE VALUE FOR THE RINGAROOMA RIVER

Figure 8 shows the log of dissolved reactive phosphorus (DRP) concentrations versus the slight to moderately disturbed default guideline value. As was the case with TP, concentrations in the Ringarooma river (RR4) and from forested areas (RR5, RR6, RR7) are at or below the guideline value. Concentrations from dairy (RR1 RR2, RR3) and grazing (RR8, RR9, RR10) areas are well above the DGV. Concentrations of DRP from dairy sites are 2 to 3 orders of magnitude greater than the DGV, while grazing areas are 1 to 2 orders of magnitude greater.

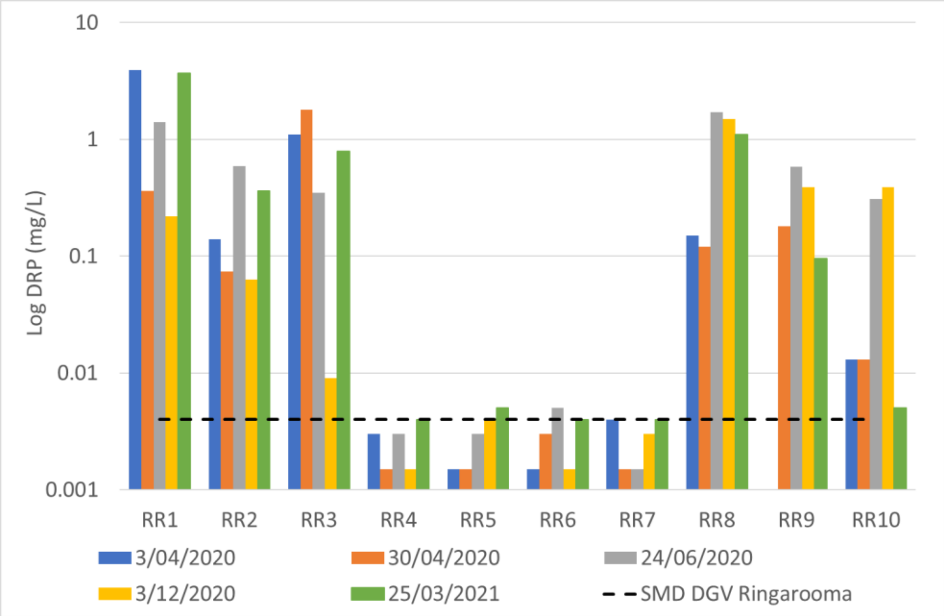


FIGURE 8. LOG DRP (MG/L) AT MONITORING SITES VERSUS THE SLIGHT TO MODERATELY DISTURBED DEFAULT GUIDELINE VALUE FOR THE RINGAROOMA RIVER

Nitrogen

Figure 9 shows the observed values of total nitrogen (TN) at the 10 monitoring sites versus the slight to moderately disturbed default guideline value (SMD DGV). This shows that dairy sites tend to substantially exceed the DGV, in some cases by more than an order of magnitude. Sites RR1 and RR3 drain subcatchments containing dairy effluent systems and have the highest concentrations of TN. The Ringarooma River (RR4) slightly exceeds the DGV on 3 of the 5 days monitored, but generally sites close to that level. Similarly runoff from forested areas (RR5, RR6, RR7) are at or below SMD DGV for most observations. TN concerns from grazing areas (RR8, RR9, RR10) often exceed the DGV but peak values are significantly lower than those off dairy areas. Concentrations at RR2, a dairy site not draining a catchment with a dairy effluent system, are relatively similar to grazing sites RR8 and RR9. TN concentrations at RR10 are generally lower than at other grazing sites. The stream draining to this site is extensively fenced to exclude stock with very wide vegetated riparian corridors.

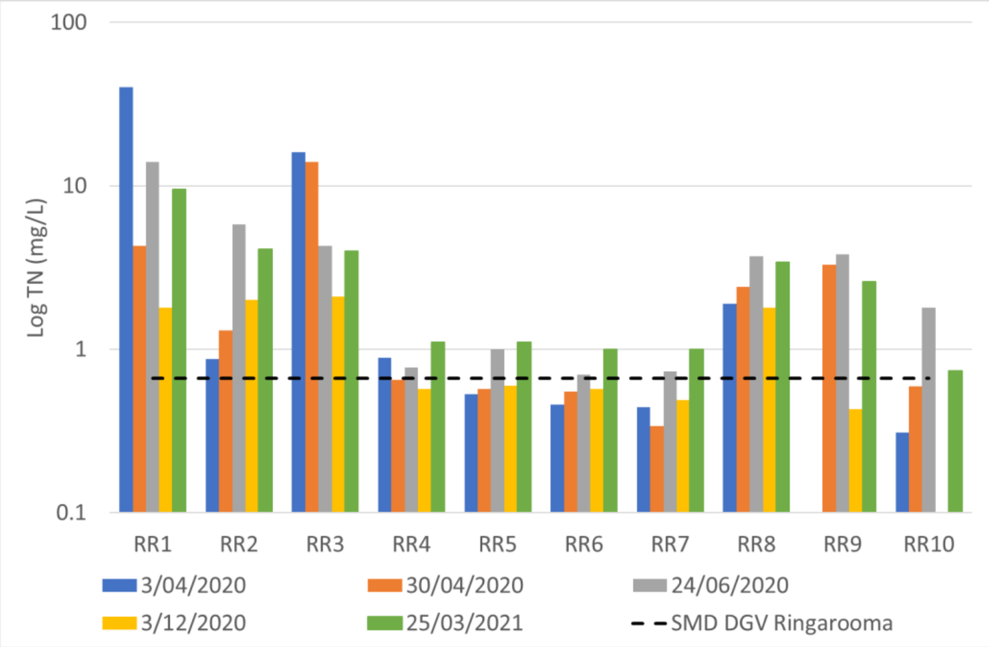


FIGURE 9. LOG TN (MG/L) AT MONITORING SITES VERSUS THE SLIGHT TO MODERATELY DISTURBED DEFAULT GUIDELINE VALUE FOR THE RINGAROOMA RIVER

Figure 10 shows the observed values of nitrate + nitrite (NOx) at the 10 monitoring sites. NOx concentrations at forested sites (RR5, RR6, RR7) are an order of magnitude lower than the SMD DGV. Concentrations from grazing areas (RR8, RR9, RR10) are also generally lower than the DGV with the exception of two observations (one at RR8 in March 2021, and the second in June 2020 at RR10). Observations in the Ringarooma river (RR4) all exceed the DGV but are of the same order of magnitude. NOx from dairy areas (RR1, RR2, RR3) are mixed, with some falling well below the DGV and others well above.

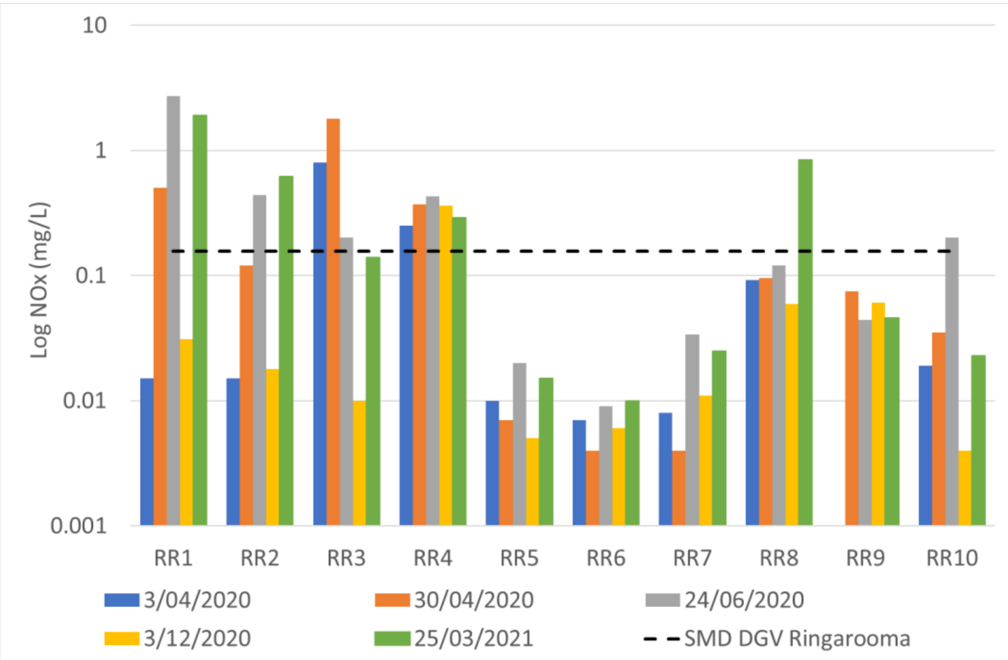


FIGURE 10. LOG NOX (MG/L) AT MONITORING SITES VERSUS THE SLIGHT TO MODERATELY DISTURBED DEFAULT GUIDELINE VALUE FOR THE RINGAROOMA RIVER

Figure 11 shows the ammonia concentration measured at the 10 monitoring sites. Note that ammonia was only measured for 3 of the 5 monitoring events. Concentrations from dairy areas exceed the DGV by 2 orders of magnitude on 3 occasions (measurements of 4.3mg/L, 2.6mg/L and 1.2mg/L versus the default guideline value of 0.021mg/L). All concentrations from dairy exceed the DGV. Measurements of ammonia in the Ringarooma river (RR4) fall below the DGV, while those from forested areas (RR5, RR6, RR7) are mixed between falling below and just above the threshold (the exception being a measurement at RR7 in December 2020 where the concentration was 0.064mg/L – 3 times the DGV). Concentrations off grazing areas (RR8, RR9, RR10) vary between sites. As was the case for other measures of nitrogen, concentrations at RR10 are generally lower, most probably due to stock exclusion and extensive riparian vegetation in the catchment to this site. Concentrations are greatest at RR8, with the peak value over 7 times the DGV.

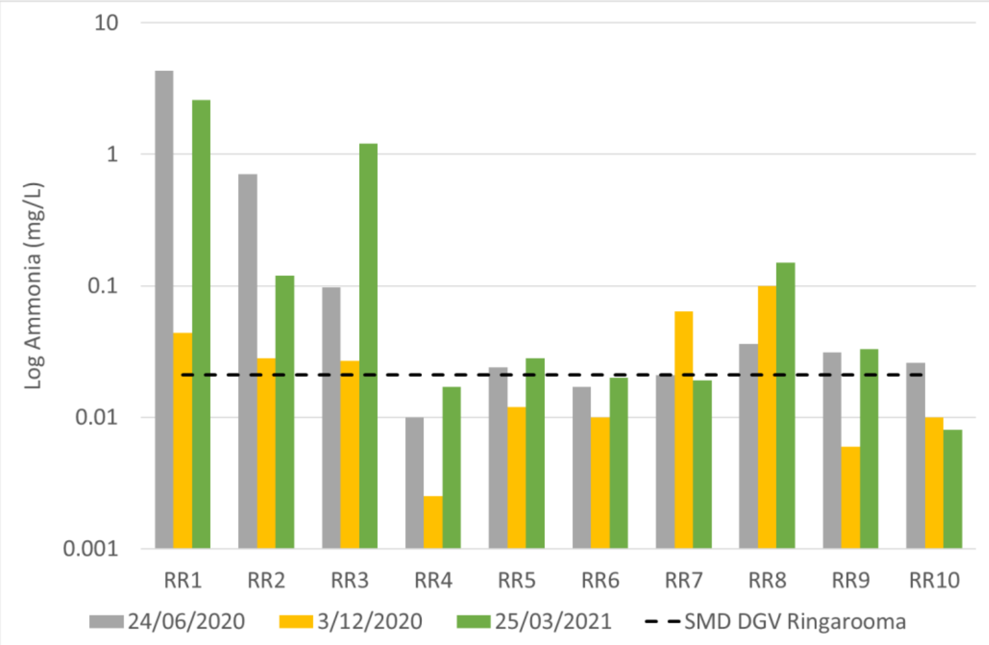


FIGURE 11. LOG AMMONIA (MG/L) AT MONITORING SITES VERSUS THE SLIGHT TO MODERATELY DISTURBED DEFAULT GUIDELINE VALUE FOR THE RINGAROOMA RIVER

Sediments and turbidity

Total suspended sediments (TSS) and turbidity were not measured on all days. Figures 12 and 13 show observed data versus slight to moderately disturbed default guideline values (SMD DGV) for TSS and turbidity respectively. These figures show that the differences in concentration of TSS and turbidity between sites is less pronounced than was the case for nutrient concentrations. More than half of the observed TSS values on dairy sites (RR1, RR2, RR3) exceed the DGV while only ¼ of observations from forested areas (RR5, RR6, RR7) exceed this level. Similarly only ¼ of observations from grazing areas (RR8, RR9, RR10) exceed the DGV, with these observations lower than peak values off forested areas. Only two measurements of TSS are available in the Ringarooma river (RR4) with one observation below the DGV and the other well above.

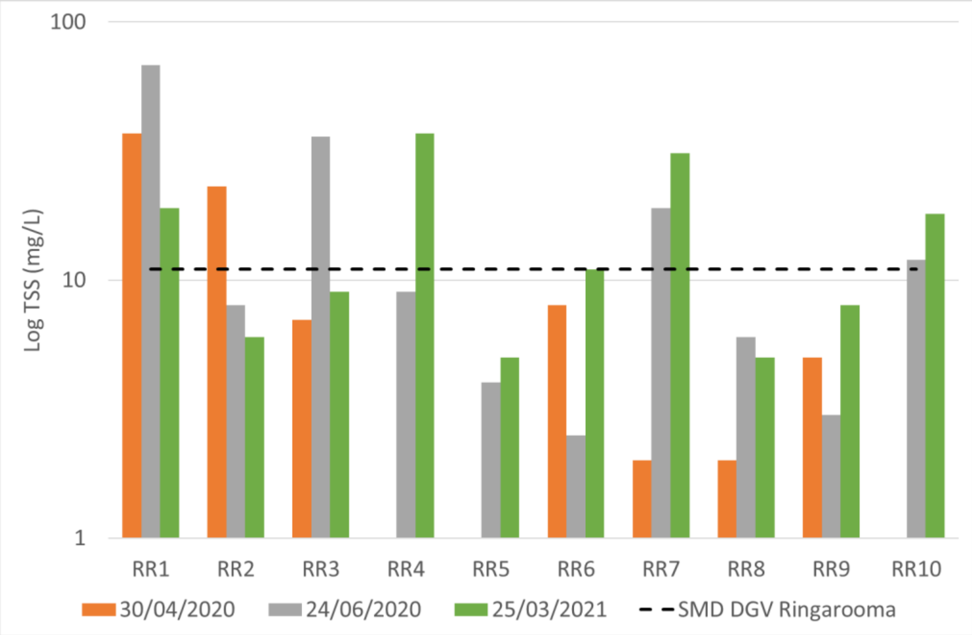


Figure 12. Log TSS (mg/L) at monitoring sites versus the slight to moderately disturbed default guideline value for the Ringarooma River

Figure 13 shows that almost all observations of turbidity exceed the SMD DGV. Observed turbidity from dairy areas (RR1, RR2, RR3) and in the Ringarooma river (RR4) all exceed the DGV, with peak levels nearly 8 times greater than the DGV. Turbidity levels from forested areas (RR5, RR6, RR7) are more mixed with measured levels both well below and well in excess of the DGV. Turbidity from grazing areas (RR8, RR9, RR10) is generally in excess of the SMD DGV with measurements at RR10 similar or higher than those at other grazing sites. This is unlike nutrients, where observed values were much lower at RR10 than at other sites.

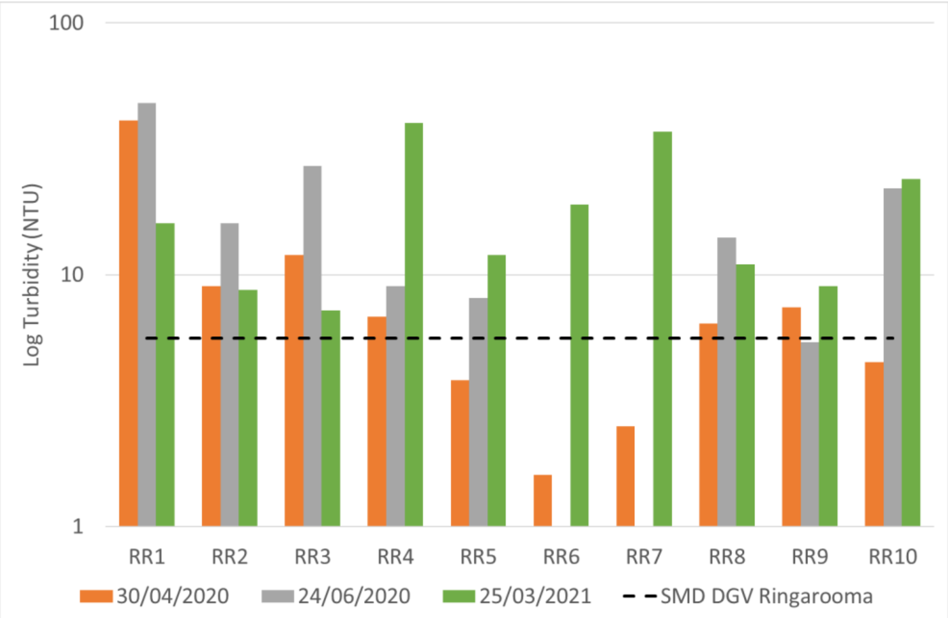


Figure 13. Log Turbidity (NTU) at monitoring sites versus the slight to moderately disturbed default guideline value for the Ringarooma River

ChlA

Figure 14 shows the concentration of ChlA at each of the 10 monitoring sites. Concentrations n the Ringarooma river (RR4) are all below the SMD DGV. Observations from forested areas (RR5, RR6, RR7) are also below the DGV with the exception of a single observation at RR7 in June 2020. ChlA at dairy sites differs between sites, with the highest concentrations, well above the DGV, at RR1, lower but still in excess of DGV concentrations at RR2 and levels generally at or below the DGV at RR3. ChlA from grazing areas is greatest at RR10, the site with the lowest nutrient levels, while RR8 is almost always within the DGV and site RR9 a mix of well below and above. The high concentrations of ChlA at RR10 may indicate that lower nutrient concentrations at this site are a result of nutrient uptake by ChlA rather than upstream management practices.

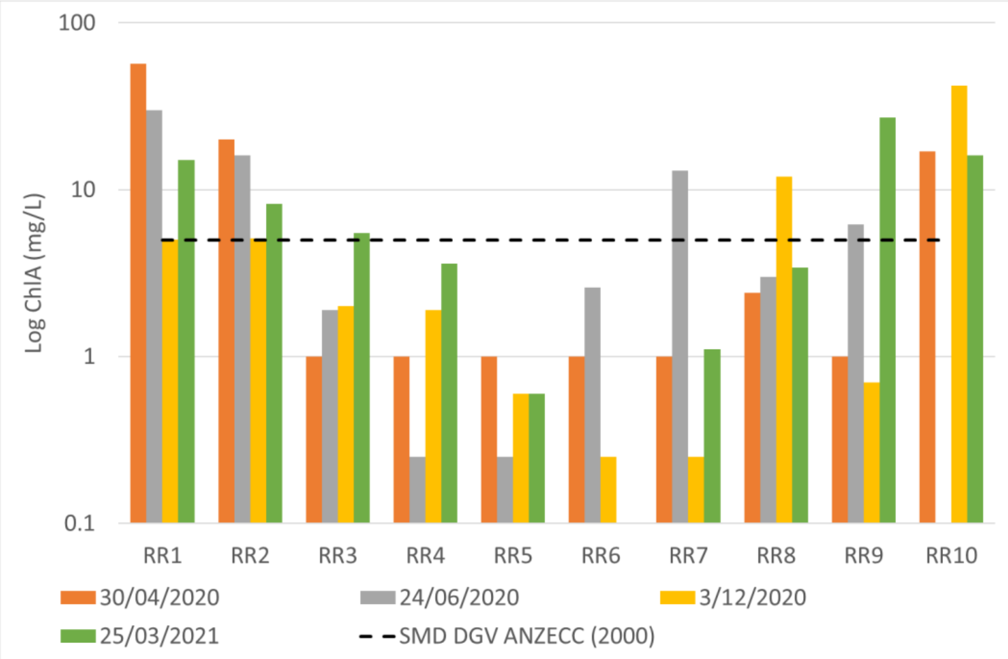


FIGURE 14. LOG CHL-A (MG/M3) AT MONITORING SITES VERSUS THE SLIGHT TO MODERATELY DISTURBED DEFAULT GUIDELINE VALUE FOR THE RINGAROOMA RIVER

Modelled Catchment Loads

The MiniCAPER DSS has been set up and used to simulate pollutant loads and flows in the Ringarooma catchment in response to land use and land management scenarios. Figure 15 shows the modelled relative contribution of land uses to different pollutant loads in contrast to their contribution to both area and flow.

Key drivers of pollutant export are climate, slope, groundcover, and land management. The relative contribution of land uses to flows relative to area shows that grazing and dairy areas produce less flow than would be expected per unit area due to their position in drier areas of the catchment (compared to native forest). Both dairy and grazing areas contribute substantially more load of nutrients and to a lesser extent TSS than would be otherwise expected based on their contribution to flow or area. Production forests make contributions to nutrients that are smaller than their relative contribution to area and flow, with sediment contributions comparative. Green space areas make their largest relative contribution to TSS but this is still below their relative contribution to either area or flow. Cropping is a small land use (~1% of area) but contributes TN and TSS at rates 2-3 times above this level.

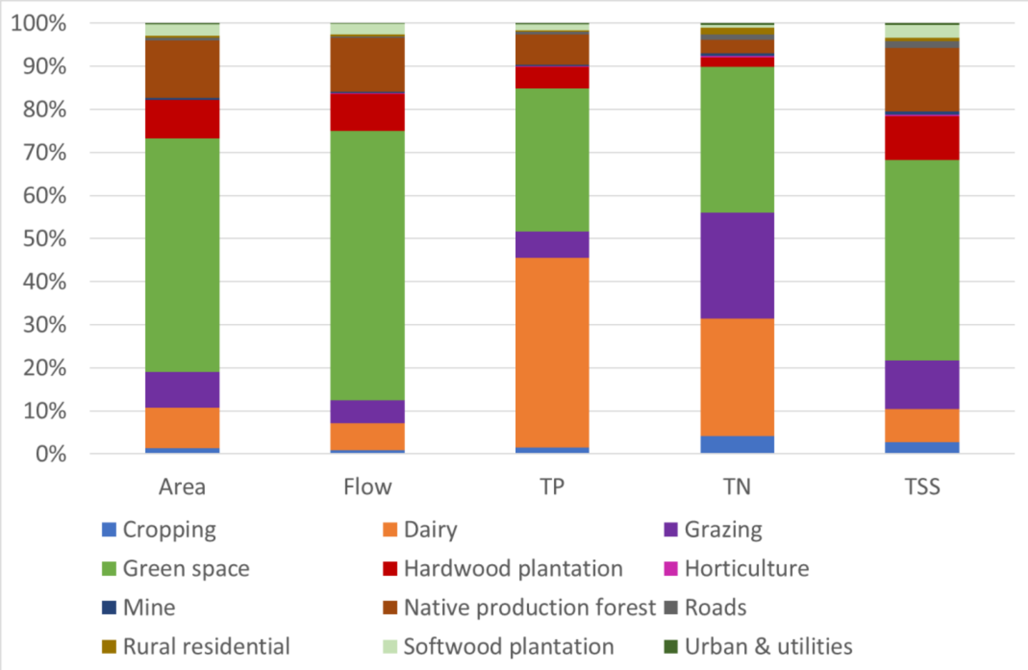


FIGURE 15. MODELLED RELATIVE CONTRIBUTION OF LAND USES TO AREA, FLOW AND POLLUTANT LOADS

Figure 16 shows the load per hectare of each of the pollutants (TP, TN and TSS) for different subcatchments. Red areas are those with the highest loads per unit area while blue areas produce the lowest loads. This figure shows that intensive agricultural subcatchments with limited green space in the upper catchment are associated with the highest nutrient loads per hectare. TSS loads per hectare are also relatively high in these subcatchments, but other upper subcatchments in the upper catchment with a large proportion of grazing and hardwood plantation also have high TSS loads per hectare. The mid-catchment which is primarily green space (ie native non-production forest) is generally associated with low loads of nutrients and sediments per hectare. Loads per hectare from land holdings around the Ramsar site are high, but somewhat lower than intensive areas in the upper catchment due to the area devoted to water and native vegetation in and around the wetlands.

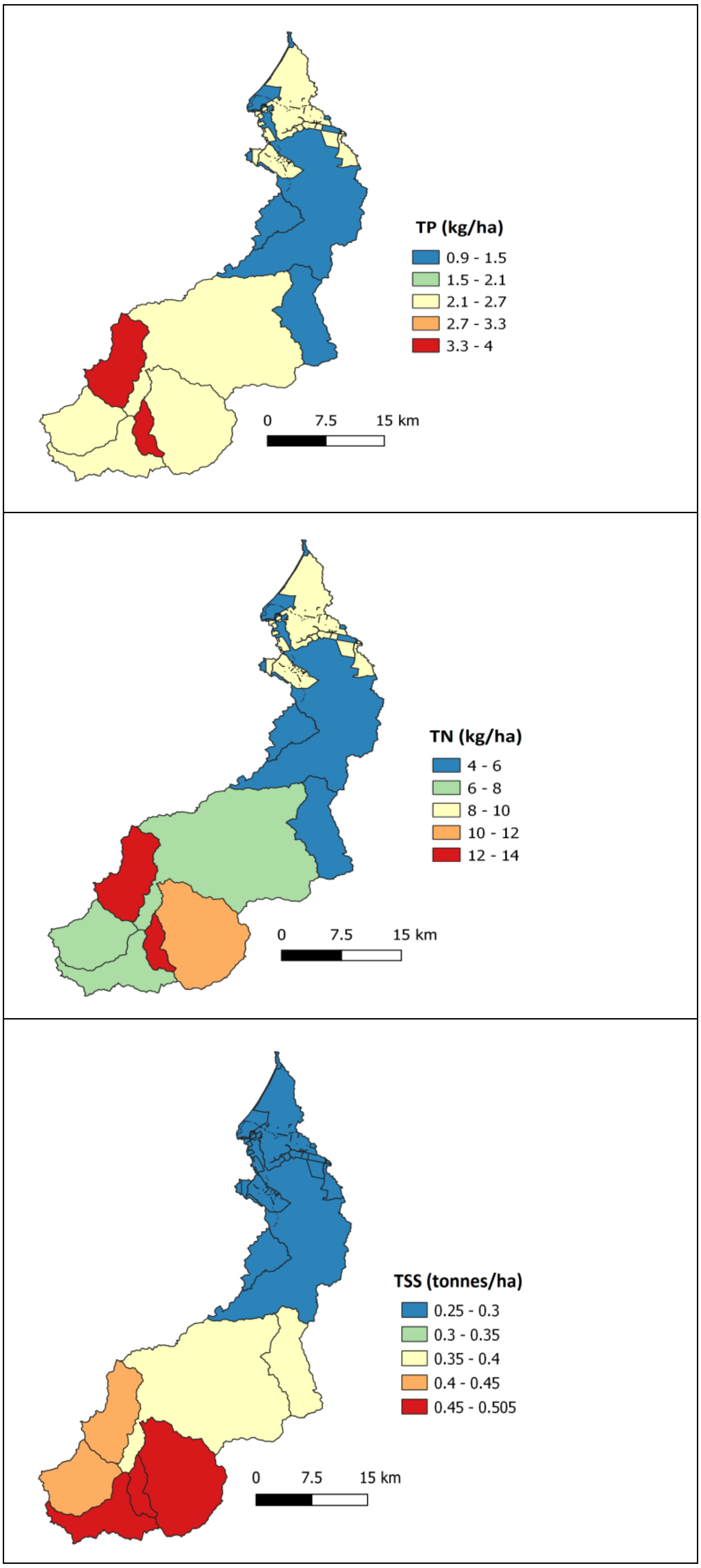


FIGURE 16. SPATIAL DISTRIBUTION OF MODELLED POLLUTANT LOADS PER HECTARE

Leverage of potential management actions in the broader catchment

Results from water quality monitoring and the modelling show that nutrient runoff from properties surrounding the Ramsar site are high relative to those from the rest of the catchment. Given that these areas also drain directly to the Ramsar site it is reasonable that investments funded through the RLP project to reduce nutrient loads delivered to the wetlands are focused on these properties. There are however other actions at a broader catchment scale that would have water quality benefits, both for the freshwater river system as well as the wetlands. This section explores the leverage of such catchment actions. The leverage and cost of specific actions on adjacent properties is considered separately in the next sections, both the allow for the privacy of specific information pertaining to these properties to be maintained as well as to allow more detailed analysis of very specific actions to inform investment decisions. Note that scenarios presented here do not include any actions on adjacent properties considered later in this plan.

Actions explored in this section relate to grazing and dairy land uses given their role in pollutant exports and the relative controllability of pollutant exports in these landscapes. Scenarios tested are:

- Dairy –
    - Stock exclusion from dairy streams and drains;
    - 5m to 20m buffers of dairy streams;
    - Vegetating drains.
- Grazing –
    - Stock exclusion from grazing streams and drains;
    - 5m to 20m buffers of grazing streams.

Scenarios are considered with 100% adoption of each action in the catchment. This is the leverage of the option – that is, the potential impact it could have on loads without considering available funding or other feasibility constraints. This bounds the benefits of each action and provides a basis for comparing their relative effectiveness.

Dairy management

Catchment scale dairy management options considered include riparian buffers and excluding stock from streams. No effluent management options are considered for the broader catchment given the relatively small number of dairy farms and the specific nature of effluent management issues on different properties which make broad averages that are suitable in larger catchments with more landholders a less reliable estimate of impact. Figure 17 shows the change in total catchment loads if these actions are applied to 100% of dairy areas in the catchment outside properties adjacent to the Ramsar site.

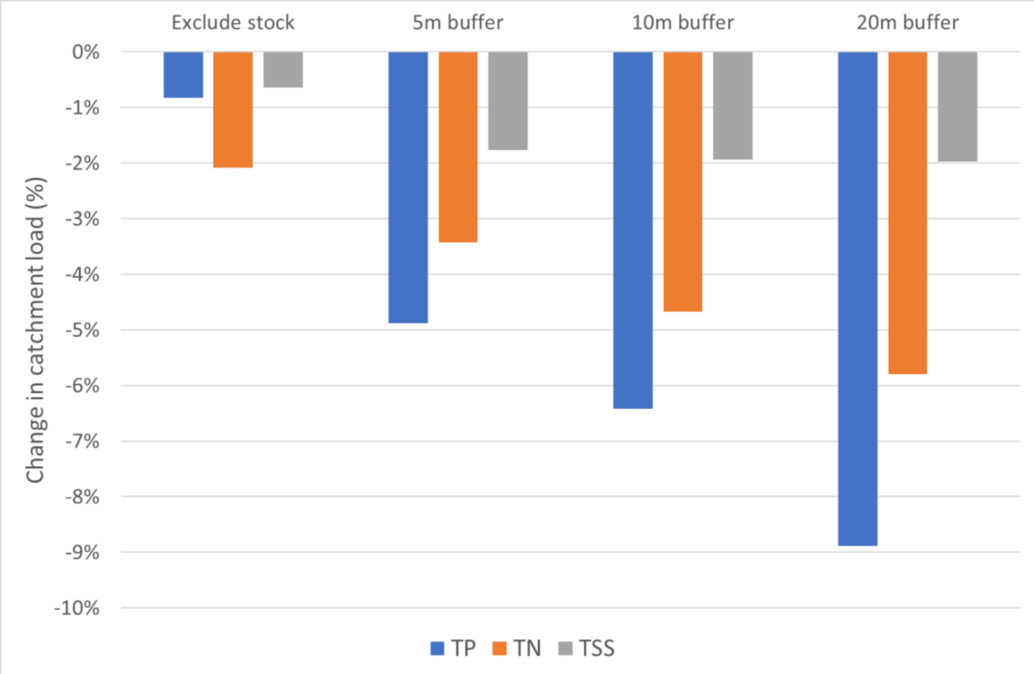


FIGURE 17. LEVERAGE OF DAIRY MANAGEMENT ACTIONS ON DRAINS AND STREAMS

This figure shows that vegetated buffers have the greatest leverage for decreasing nutrient and sediment loads from dairy areas. Increasing buffer width increases the leverage of the action, though this increase is not proportional, for example doubling the buffer width has a much small impact on load reductions. Impacts of all riparian buffers are greatest for TP (5% to 9%), with changes in TSS less than for nutrients (~2%). Note that the model does not consider changes in streambank erosion, a significant source of sediment loads associated with both stock access and removal of riparian vegetation. Riparian buffers also have the greatest impact on TN, though the effectiveness is smaller than was the case for TP. Decreases in TN range from 2% to nearly 6% of catchment loads depending on the action. Excluding stock has a greater impact on TN than the other pollutants. Fencing and revegetating the riparian zone would generally involve limiting stock access so benefits of this action are likely to be cumulative.

There are approximately 97km of streams in dairy areas estimated to have poor vegetation and stock access. At a cost of $10,000 per km, fencing and revegetating both sides of these streams would cost nearly $2,000,000 to implement, assuming 100% adoption was feasible. Lower levels of adoption would be associated with reduced costs and benefits. Costs would differ if fencing and off-stream water were placed without any active revegetation of the riparian zone. It is likely that the feasibility of broadscale adoption of wide buffers (eg. 20m) is low and that greater adoption of narrow buffers with stock exclusion would be the most effective feasible management option.

Grazing management

Actions in grazing areas considered at the catchment scale outside neighbouring properties are creating vegetated riparian buffers of different widths and excluding stock from streams. Figure 18 shows the change in catchment loads resulting from these actions.

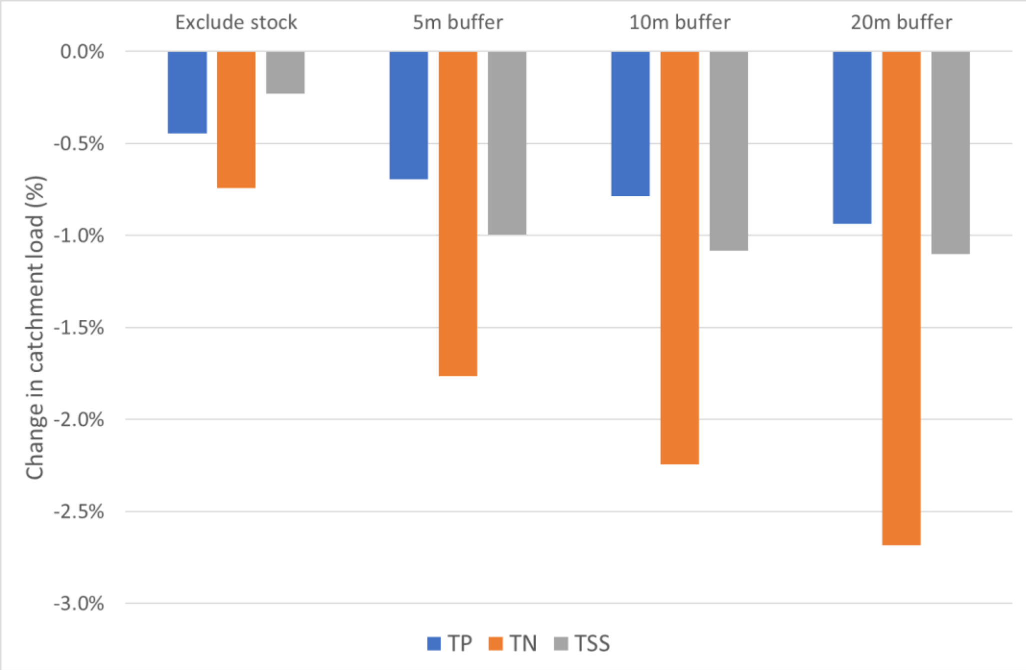


FIGURE 18. IMPACT OF VEGETATED BUFFERS AND STOCK EXCLUSION ON 100% OF GRAZING STREAMS OUTSIDE ADJACENT PROPERTIES

This figure shows these actions having the greatest impacts on TN, which sees approximately 2.5% decrease in load for 20m riparian buffers and a 0.7% decrease for stock exclusion along (note actions which exclude stock and create riparian buffers simultaneously would experience these reductions cumulatively). Riparian buffers reduce TP loads by between 0.7% and 0.9% with stock exclusion leading to a 0.4% reduction in TP loads. Decreases in TSS loads vary between 0.2% for stock exclusion to 1.1% for 20m buffers, though this is a likely to be an underestimate of the impact on loads given the benefits of reduced streambank erosion are not accounted for in the modelling. Impacts on TP and TSS are relatively stable across different buffer widths compared to TN where buffer width has a more significant impact on the magnitude of loads reduced.

There are approximately 53km of streams with poor riparian vegetation and stock access to stream in grazing areas. Fencing and revegetation of both sides of these streams would cost approximately $1.6m to implement at a catchment scale at $10,000 per km. As was the case with dairy, it is likely that adoption of very wide riparian buffers (eg. 20m) would be low and narrower buffers are more likely to be adopted more broadly.

Rushy Lagoon – Water Quality Improvement Investment Plan

Rushy Lagoon is a large landholding compromising over 20,000ha of sheep and cattle grazing and 4 dairies. The property extends outside the catchment of the Floodplain Lower Ringarooma River Wetlands. The property boundary and catchment boundary are shown as orange and red lines respectively in Figure 19. The boundary of the Ramsar site is shown in the blue line.

FIGURE 19. RUSHY LAGOON PROPERTY BOUNDARY (ORANGE) WITH CATCHMENT (RED) AN RAMSAR SITE (BLUE) BOUNDARIES MARKED

Within the catchment, Rushy Lagoon consists of over 6500 ha of native vegetation, 1900 ha of intensive dairy production, 1500ha of grazing on modified and native pastures. Nearly 360ha of the property are wetland and water. Figure 20 provides a closer view of this area within the catchment. As seen in this figure irrigation pivots and dairy production areas lie within the Ramsar site boundary.

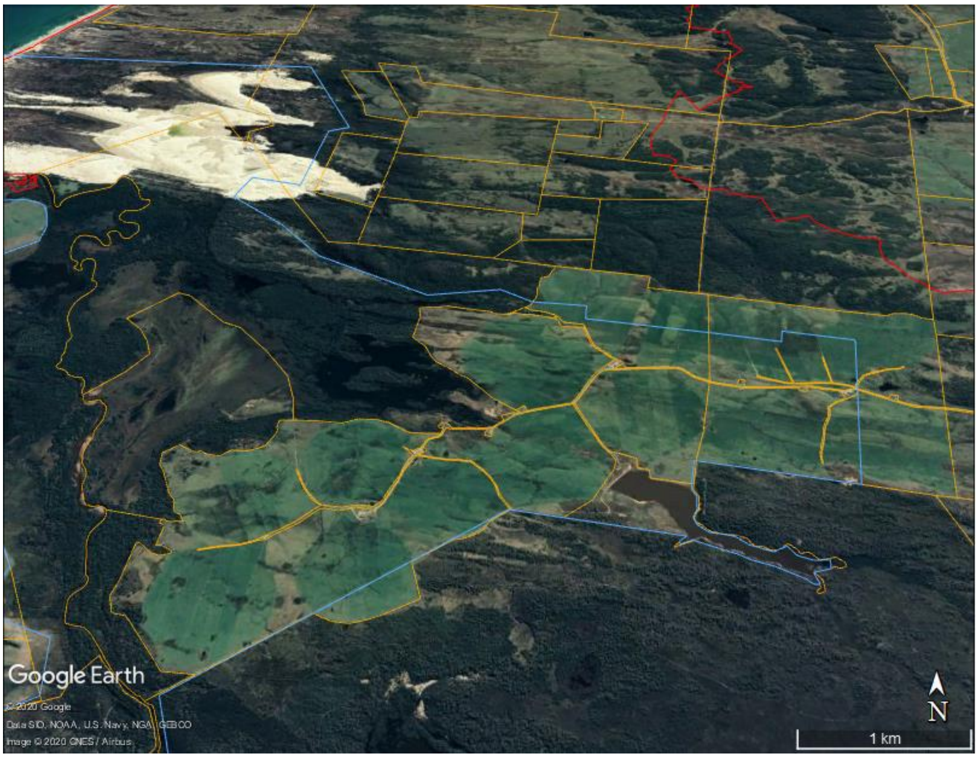


FIGURE 20. INTENSIVE AGRICULTURAL ACTIVITIES ON RUSHY LAGOON WITHIN AND DIRECTLY ADJACENT TO RAMSAR SITE BOUNDARY

Three dairies operated on Rushy Lagoon within the catchment – Cygnus, Quinfields and Centre View. In early 2020 Quinfields and Centre View dairies were decommissioned and replaced with a new dairy, as shown in Figure 21.

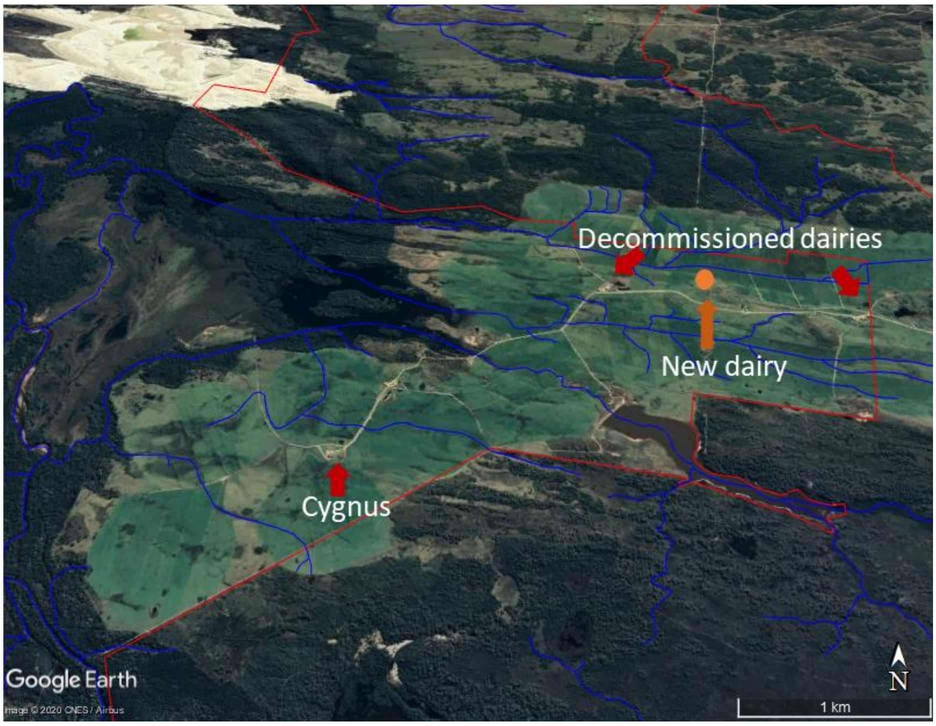


FIGURE 21. DAIRIES ON RUSHY LAGOON – CYGNUS IS EXISTING, THE TWO DAIRIES (QUINFIELDS AND CENTRE VIEW) WERE DECOMMISSIONED IN 2020 AND REPLACED WITH A NEW DAIRY AS MARKED

Effluent management

Until recently 3 dairies were located on Rushy Lagoon – Cygnus, Quinfields and Centre view. Quinfields and Centre view were decommissioned in early 2020 and replaced by a single new dairy. As part of this upgrade, effluent irrigation areas for this new dairy have also been moved and expanded such that dairy effluent is applied to a larger area. Armstrong and Badcock (2007) describe these 3 dairies as:

- Spring calving with generally no milking from mid-June to the end of July (approx. 7 weeks).
- Cow numbers of 700, 600 and 600 for the 3 systems respectively.
- At that time, the system at Quinfields consisted of a concrete sump connected by a pump to a static sprinkler.
- Centre view consisted of a sump with effluent passed through two ponds with effluent from the second pond pumped to pasture.
- Cygnus also consisted of two ponds with effluent pumped to an effluent irrigator.

This report identified several issues with effluent management at that time:

- Large amounts of sand were being tracked into the dairy which extended yard washing time and added to sand in the trafficable sand and gravel traps. It was also suggested that this sand was responsible for rapid wearing of effluent pumps, which had a life of a year or less with frequent pump breakdowns resulting in overflows of effluent to natural drainage lines.
- Longer than average time spent in milking yards was resulting in large amounts of manure which are difficult to handle and require extra washdown water and more frequent clearing of traps and pumping sumps with an excavator.
- While effluent irrigation areas were considered large enough, manual moving of sprinklers was considered to be unreliable and likely to lead to excessive applications of effluent if a sprinkler isn't moved regularly particularly when soils are wet from either rainfall or irrigation. This meant that risks to surface water of nutrient runoff and of inefficient utilisation of effluent were high.
- Effluent was being applied through winter which increases risks of surface water pollution.

This report suggested numerous improvements to effluent management:

- 'Installation of a footbath to remove sand before cows enter the yard.
- Roof water should be diverted from the effluent stream.
- Plate cooler and vacuum pump water should be diverted from the effluent stream (usually to a tank for yard washing).
- Divert runoff from the yards during the non-milking period.
- Scrape the yard to remove solids, using a rubber blade mounted on a 4-wheel bike.'

Two possible options for solids removal were also proposed: a settlement trench; or mechanical removal of solids using a static screen. A green water storage pond of 6.5ML was also recommended for each dairy designed to contain all but the wettest 10% of years within the top water level and an additional with 0.7m freeboard. The report then proposed green water be applied to paddocks through the existing centre pivot irrigation facilities. They recommend green water being diluted 20:1 with irrigation water.

The new dairy has been designed by Agritech and is described in Hooper (2019). This design is proposed for a combined herd of 850 cows. Solids are collected in a trafficable solids trap with weeping wall and then applied to paddocks by a mechanical spreader. This trap is designed to be emptied every 60 days. Effluent water is then gravity fed to an effluent storage pond with an effective capacity of 8.8ML and total capacity of 10.8ML. The design also consists of water saving devices designed to minimise the water used during yard wash and consumed in the dairy during milking. Effluent from the storage pond will then be applied to pasture through the irrigation system on two different pivots. Total effluent irrigation areas is nearly 120ha, split into two separate pivots on either side of the dairy. Figure 22 shows the location of new effluent irrigation areas as shown in Hooper (2019).

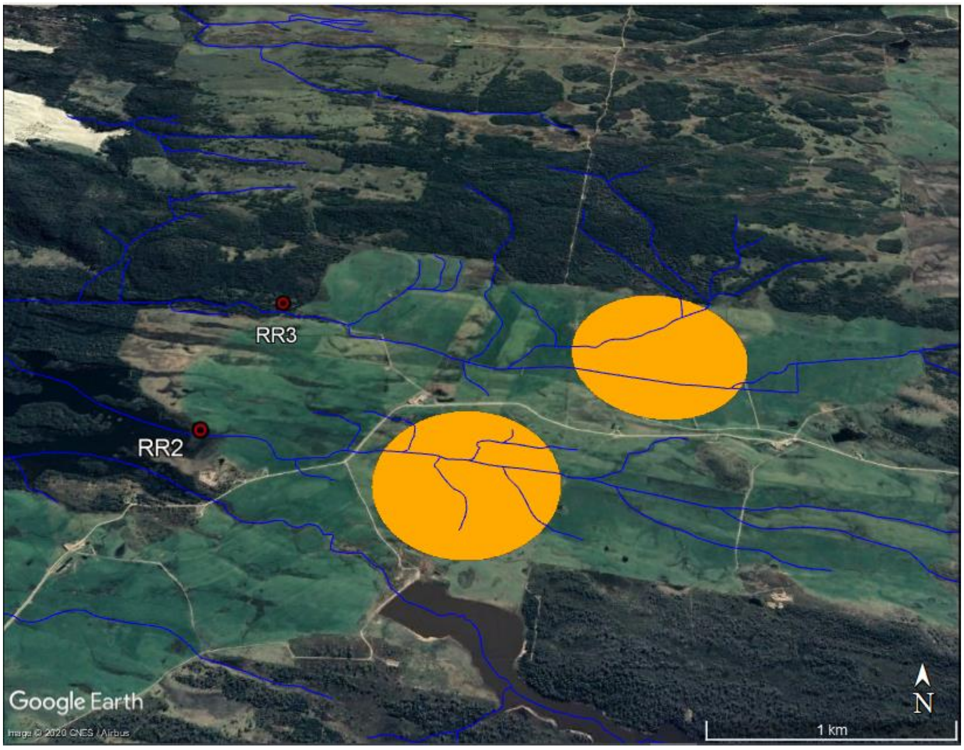


FIGURE 22. NEW EFFLUENT IRRIGATION AREAS FOR NEW DAIRY REPLACING QUINFIELDS AND CENTRE VIEW (ESTIMATED FROM HOOPER, 2019)

Cygnus dairy was upgraded in 2014. Hooper (2014) describes the upgraded effluent management plan for this dairy. This plan states the herd capacity is 750-800 cows for this dairy with total water use of 56,260 litres per day (approx. 70-75 litres per cow per day). The system consists of a solids trench and 2 ponds with 0.85ML and 7.8ML effective capacity respectively. Effluent irrigation and dry solids spreading areas as well as the location of pond and pit for the Cygnus dairy are shown in Figure 23. Effluent is irrigated on to 50 ha of paddock through a centre pivot with total solids spreading area equal to 9.87ha.

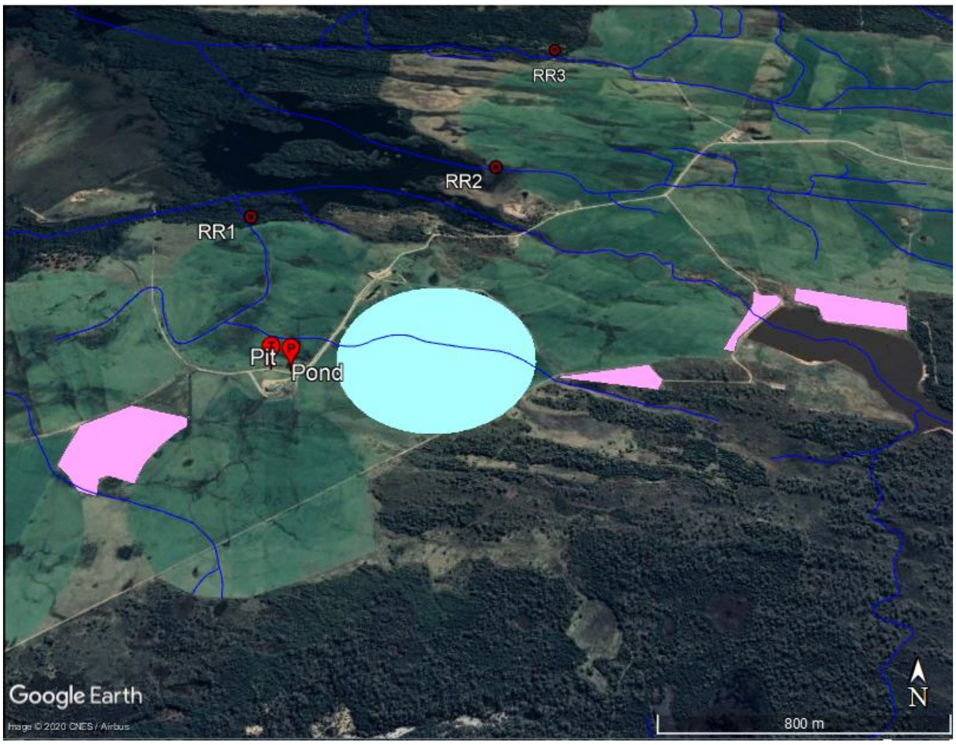


FIGURE 23. EFFLUENT IRRIGATION AND DRIED SOLIDS SPREADING AREAS FOR CYGNUS DAIRY

Soil moisture monitoring of irrigation paddocks is not currently used to time irrigation with land manager experience generally relied on for timing decisions. Soil nutrient testing is undertaken on some paddocks but has generally focused on areas with poorer fertility. Areas where solids are spread and effluent irrigated have not been subject to regular nutrient testing. FertSMART planning has not been undertaken for the property.

Fencing, drain vegetation and stock access to waterways

Comprehensive mapping of drains has not been conducted. A visit to Rushy Lagoon in January 2020 showed that many drains contained significant vegetation which could be expected to act to improve the quality of water leaving the property. In some cases these drains are also fenced to exclude stock as shown in Figure 24. Drains under pivots are generally unfenced due to the constraints of irrigation.

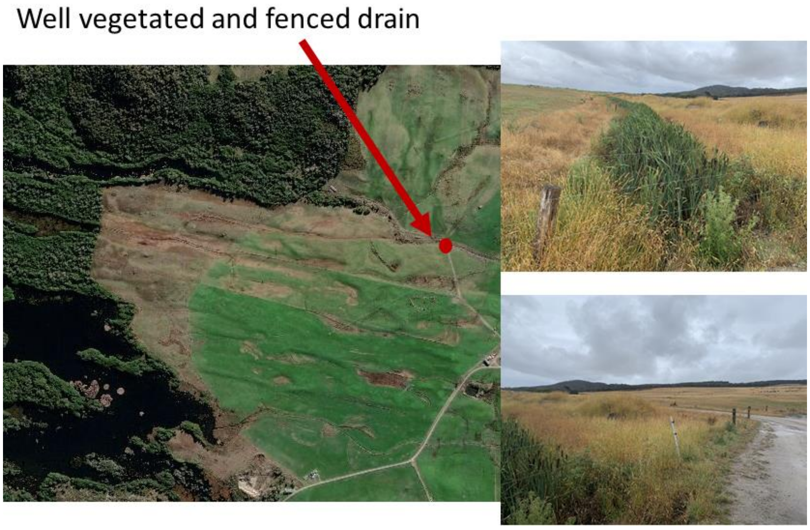


FIGURE 24. A WELL VEGETATED AND FENCED DRAINAGE LINE

Stock crossings were also seen during site visits to contribute to water quality issues. Figure 25 shows an example of a stock crossing with clear evidence of stock trampling and manure in the drainage line. Water quality upstream of this stock crossing was visibly high in nutrients (large quantities of green algal growth were visible). Downstream of this crossing the waterway was fenced and had a narrow strip of trees in the riparian zone.

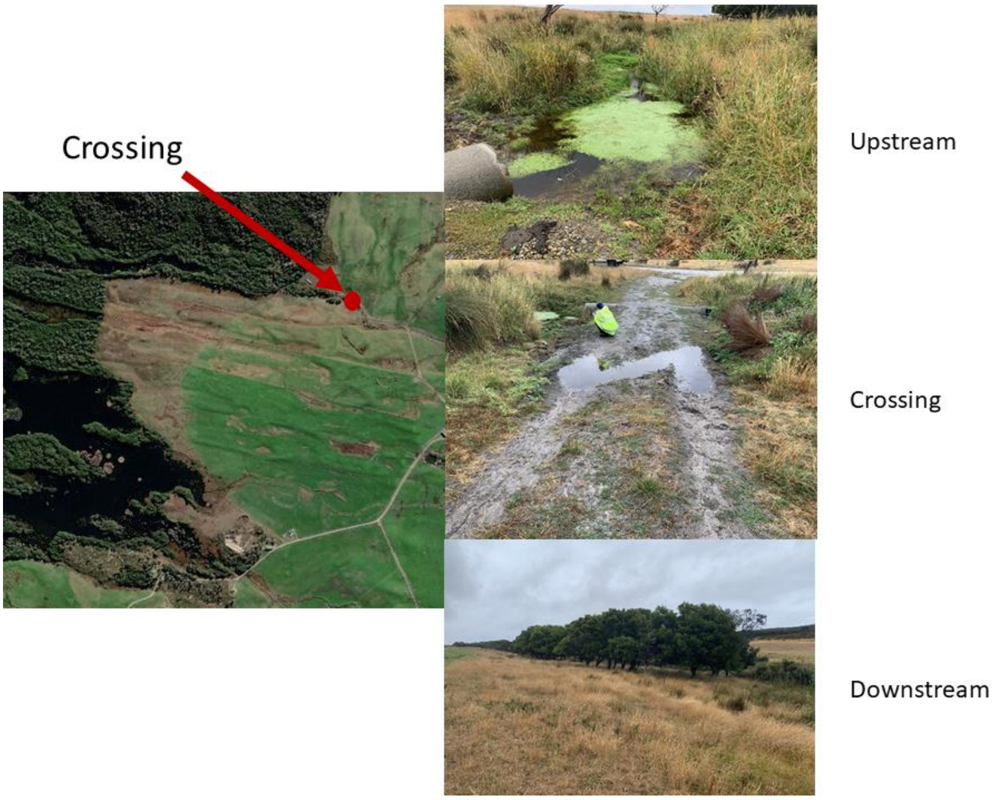


FIGURE 25. STOCK CROSSING AND WATERWAY IMMEDIATELY UP AND DOWNSTREAM

Staff at Enviro-dynamics undertook ground surveys of fencing adjacent to the wetland during site visits in early 2020. Figure 26 shows mapped fencing with fences labelled intact, unknown or disrepair. While the majority of fencing appears to be intact, there are some sections in disrepair that would allow stock to access areas of the wetland.

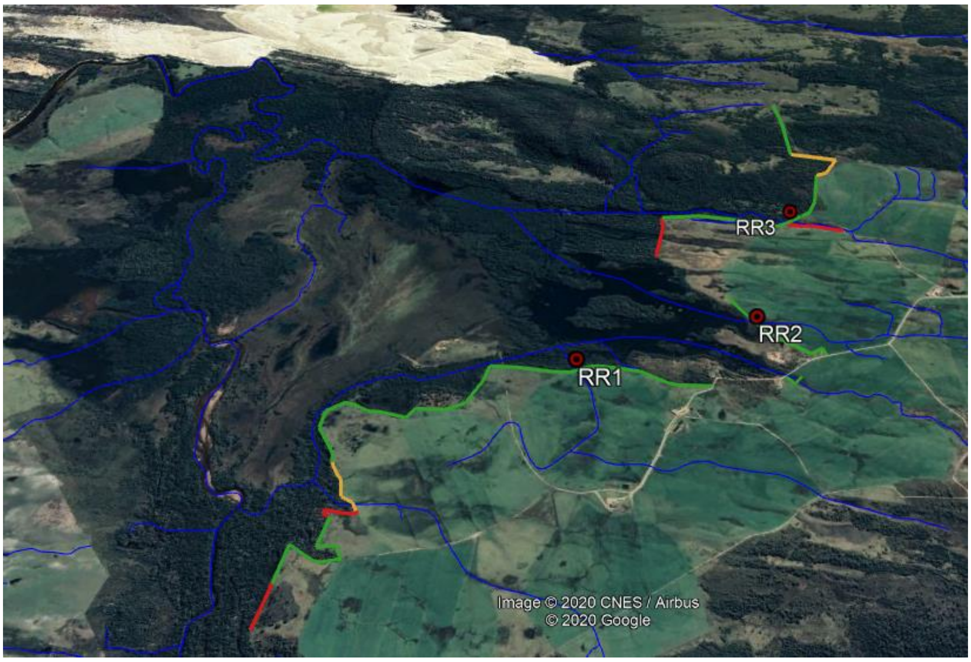


FIGURE 26. OBSERVED CONDITION OF FENCING ALONG WETLAND BOUNDARY 2020 (GREEN IS INTACT, ORANGE IS UNKNOWN, RED IS DISREPAIR)

Figure 27 shows a photo taken in January 2020 where there is evidence of stock access to the wetland (visible in the background of the image) behind a fence. Trampling and manure are both seen in close proximity to the wetland and in drainage lines entering the wetland.

FIGURE 27. PHOTO OF AREA ADJACENT TO WETLANDS WITH EVIDENCE OF STOCK ACCESS BEHIND A FENCELINE (TRAMPLING AND MANURE ON RIGHT HAND SIDE OF IMAGE)

An area of significant ecological values is the Fosters Marshes. This area is periodically grazed. The Marshes appear to be largely fenced but access is gained across a causeway. Access through this entry way is via a gate. A site visit during January 2020 showed evidence of significant stock access with large amounts of manure on the causeway entering the Marshes and on the cleared hillside within the

Marshes as shown in Figure 28. Stock trails and manure were also observed through wet areas of Ti Tree within the Marshes.

FIGURE 28. SIGNS OF STOCK ACCESS IN FOSTERS MARSHES – MANURE ON HILLSIDE, ON STOCK CROSSING INTO MARSHES AND THROUGH TI TREE AND WET AREAS

Where do pollutants come from?

Water Quality Monitoring

Snapshot water quality monitoring has been undertaken as part of this project to assist in identifying potential sources of nutrients to the wetlands. Water quality was sampled at 3 monitoring sites on Rushy Lagoon (Figure 29) following 5 rainfall events in 2020 and 2021 (3 April 2020, 30 April 2020, 24 June 2020, 3 December 2020, 25 March 2021).

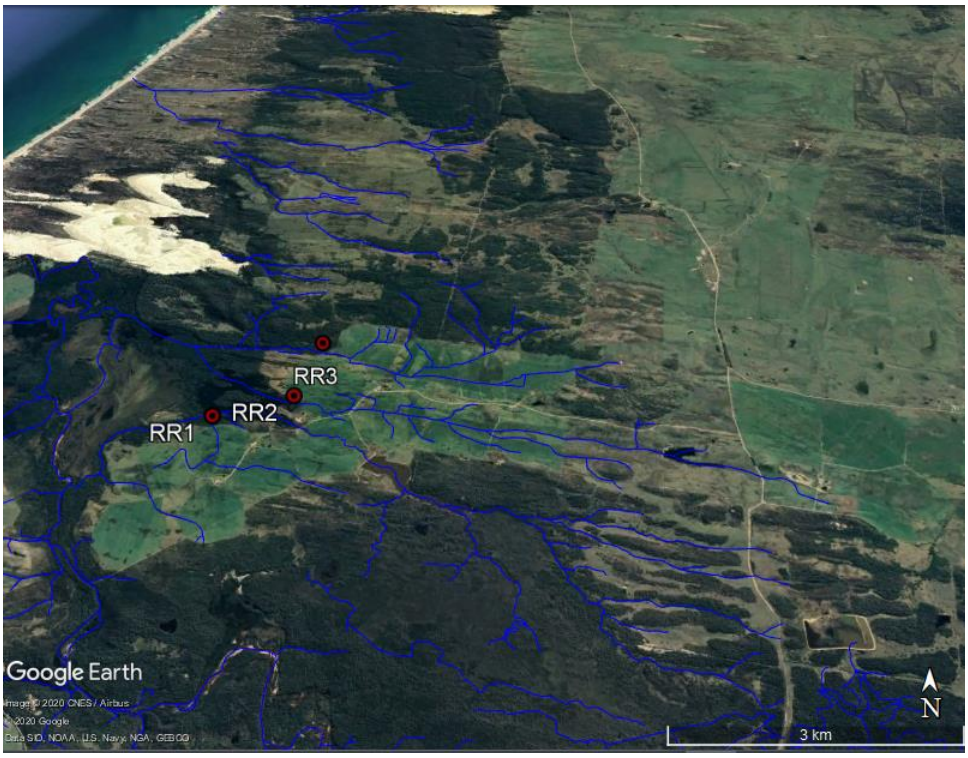
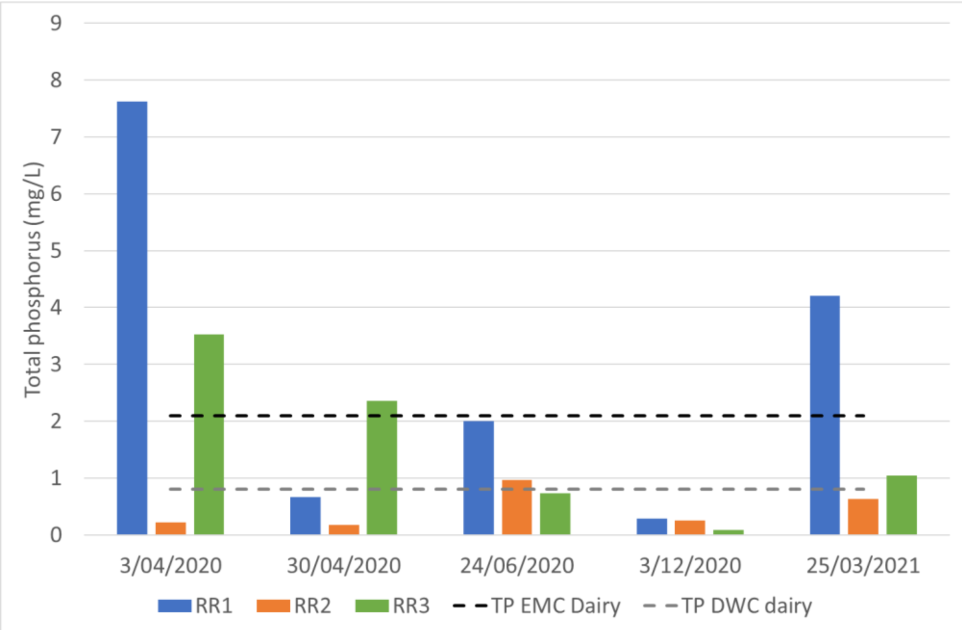


FIGURE 29. WATER QUALITY MONITORING LOCATIONS ON RUSHY LAGOON

Grab samples were taken at these sites and sent to AST laboratories for analysis of dissolved and total nutrients, Chlorophyll-a, turbidity and TSS. A hand-held meter was also used to measure pH, temperature, dissolved oxygen, EC and total dissolved solids.

Figure 30 shows dissolved and total phosphorus concentrations at the 3 monitoring sites on Rushy Lagoon. These are compared with standard literature-based event mean and dry weather concentrations of TP for dairy runoff. This figure shows that samples at site RR2 were substantially lower than measurements at RR1 and RR3 on days sampled except June 2020 for both total and dissolved phosphorus. Dissolved and total phosphorus measurements were very high at RR1 in early April but fell substantially later that month before rising again in June 2020 and March 2021. Concentrations at RR2 were highest in June whereas other sites had higher concentrations in April. While the high concentrations at RR1 in early April were originally thought to have been caused by a break in effluent lines following vehicle damage to pipes, these high concentrations are again seen in March 2021.

TP



DRP

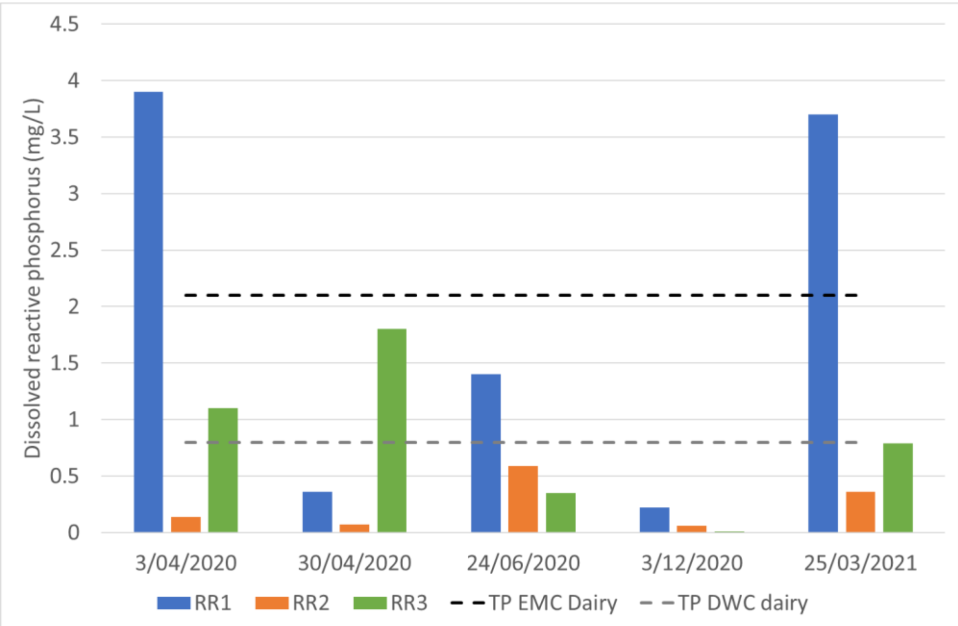


FIGURE 30. MEASURED PHOSPHORUS CONCENTRATIONS AT MONITORING SITES ON RUSHY LAGOON COMPARED TO DRY WEATHER AND EVENT MEAN CONCENTRATIONS FOR TP ON DAIRY AREAS

Figure 31 shows nitrogen concentrations from sites on Rushy Lagoon. Note that ammonia was only measured from the June 2020 sample onwards. This figure shows a similar pattern for TN as was the case for TP, with very high concentrations of TN at RR1 in first sample in April and June 2020 and March 2021, falling significantly for the second April and the December samples. Measurements of TN at RR2 are generally lower than RR1 and RR3 though the June 2020 and March 2021 samples are similar to RR3. TN at this site is more stable than at the other sites. The concentration of ammonia at RR1 in June 2020 and again in March 2021 are very high, well above expected background levels (4.3mg/L and 2.6mg/L respectively versus a slight to moderately disturbed default guideline values for the Ringarooma river of 0.021mg/L – 2 orders of magnitude greater). NOx concentrations are also significantly elevated at RR1 on these dates with peaks in NOx at RR3 coinciding with high values on the two dates sampled in April 2020.

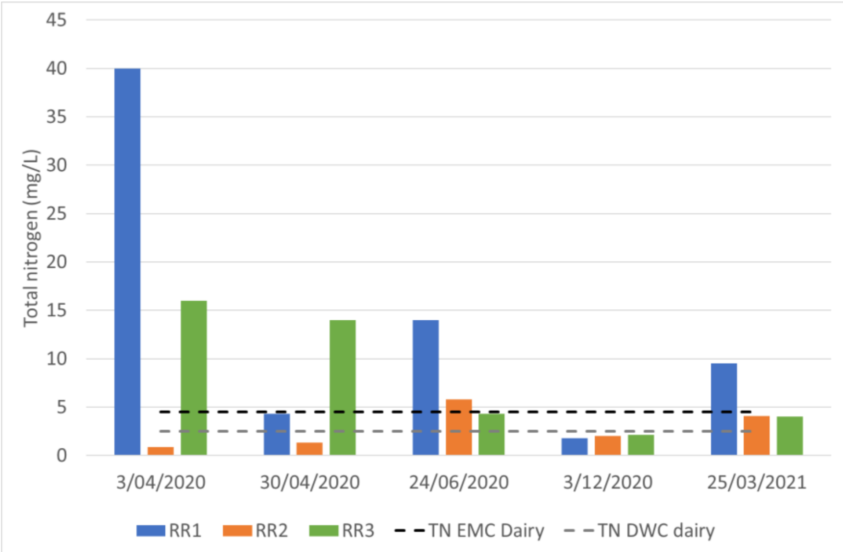
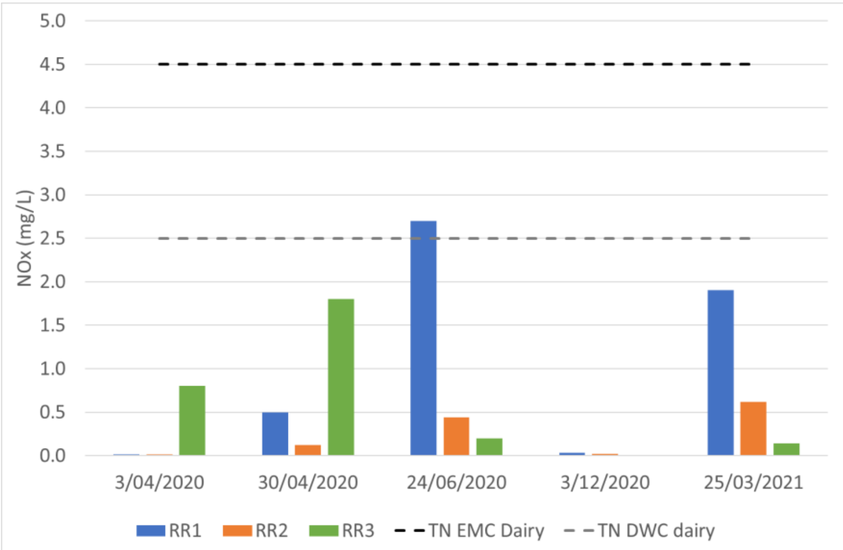
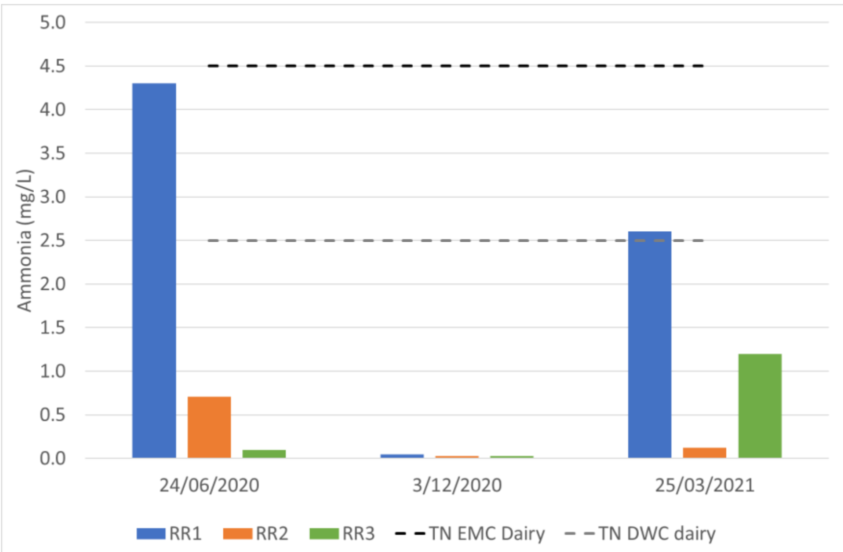
TN	
NOx	
Ammonia	

FIGURE 31. MEASURED NITROGEN CONCENTRATIONS AT MONITORING SITES ON RUSHY LAGOON COMPARED TO DRY WEATHER AND EVENT MEAN CONCENTRATIONS OF TN FOR DAIRY

Figure 32 shows TSS concentrations relative to literature-based event mean and dry weather concentrations for dairy. The pattern of TSS concentrations for the 3 sites for the 30/4 is very different than for either TP or TN with RR2 having higher concentrations than RR3. The pattern for the 24/6 is also different than what was seen for TN and TP with more pronounced peaks of TSS at RR1 and RR3 on this day. All concentrations are well below the event mean concentration and some are below the dry weather concentration.

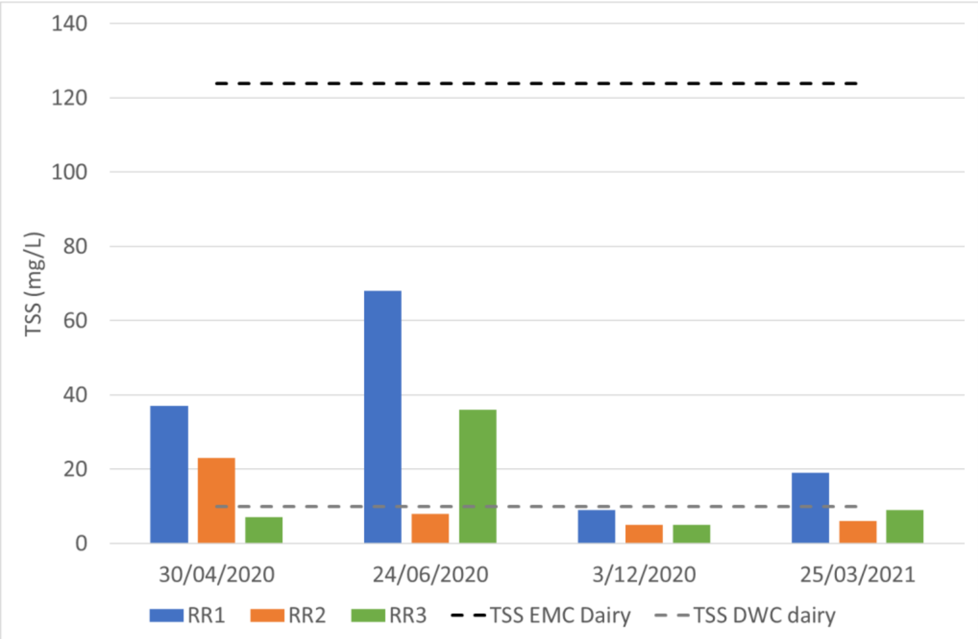


FIGURE 32. MEASURED SEDIMENT CONCENTRATIONS AT MONITORING SITES ON RUSHY LAGOON

These water quality results are consistent with effluent being the source of high nutrient levels at RR1 in April and June 2020 and March 2021. The high concentration of dissolved nutrients, in particular ammonia, indicated that effluent is a likely source. The balance between ammonia and NOx (ie concentrations of ammonia are greater than NOx) indicates that this source is relatively fresh, without having sufficient time to oxidise. Dairy Australia (2008) indicate that in warm conditions there is almost complete conversion of ammonia to nitrate within surface soils. This suggests that effluent is either directly spilling from pumps and ponds or that applied effluent is running directly to stream. Concentrations at RR3 were highest in April 2020 then dropped substantially. It is possible this might be due to decommissioning of Quinfields and Centre view and the move to new effluent irrigation paddocks that occurred around this time but there is insufficient data to say this with confidence.

Modelled loads

The relative contribution of potential sources of nutrients exported to the wetlands from Rushy Lagoon have been modelled using a simple conceptual model. This model consists of:

- Background diffuse loads calculated using background assumptions on flow and nutrient concentrations from the CAPER DSS.
- A model of nutrient loads from effluent irrigation and spread using a daily effluent model developed for the Tamar Action Grants (TAG) program run by NRM North which has been adapted to include nutrient removal through effluent storage and effluent runoff. This is used to estimate the benefits of the decommissioning and upgrade already undertaken as well as the loads expected to be delivered from the Cygnus dairy. Several management options are also modelled to consider their potential to reduce loads to the wetlands.

- Estimated direct loads from stock access to wetlands and drainage lines. Given the lack of definitive data on the extent of stock access (number of stock and time spent in or near waterways), these are scenario based and use an assumption around potential levels of stock access and the impact they would be expected to have on loads.

Flow modelling uses the models calibrated for the entire Ringarooma catchment with local rainfall obtained from the SILO database. Assumptions used in the effluent model for model for Cygnus, Quinfields, Centre View and the new dairy have been taken from:

- Armstrong and Babcock (2007) for the original Cygnus
- Hooper (2014) for the current Cygnus system
- Hooper (2019) for Quinfields, Centre View and the new dairy.

Values used within the effluent model are given in Table 3. Note that parameters for original systems have been used to estimate the benefits of investments already made on the property by the landowner.

TABLE 3. EFFLUENT MODEL INPUTS FOR CYGNUS, QUINFIELDS, CENTRE VIEW AND NEW DAIRY

Parameter	Quinfields – Old system	Centre View – Old system	New system	Cygnus – Old system	Cygnus – Current system
Dairy characteristics					
Milking herd size (number of cows)	600	600	850	700	800
Calving type	Spring	Spring	Spring	Spring	Spring
Milk shed water use per milking - L/cow/day	100	100	35	100	66.25
Area effluent irrigation (ha)	35	35	115	35	70
Catchment area of roofs and yard (m^2)	1330	1330	1035	1330	1330
Effluent irrigation depth (mm)	8	8	5	8	8
Average time spent on yards for per day/cow (min)	480	480	360	480	360
Type of effluent system	Direct application	Dual pond	Single pond	Dual pond	Single pond[1]
Area irrigated per day (ha)	10	10	115	10	70
Water: Effluent applied	1	1	20:1	1	20:1
Trafficable solids trap					
Is there a trafficable solids trap?	No	No	Yes	No	Yes
Period of accumulation before desludging (days)	NA	NA	60	NA	365
First month of clean out	NA	NA	January	NA	June
Is sludge composted after removal?	NA	NA	No	NA	Yes
Period of composting (days)	NA	NA	365	NA	180
Area spread over (ha)	NA	NA	20	NA	12
First/single pond					
Storage volume (ML)	NA	3	8.8	3	8.65
Pond catchment area (m^2)	NA	1800	4400	1800	3874
Storage area for evaporation (m^2)	NA	0	750	0	1000

[1] Cygnus has two ponds but the first pond is very small and is not sufficient volume for settling solids and provides very short term storage before passing to the second pond. For this reason the ponds are modelled as a single pond system.

Period of accumulation before desludging (days)	NA	365	730	365	365
First month of clean out	NA	June	June	June	January
Area of solids spread (ha)	NA	10	50	10	10
Second pond (if dual pond system)					
Storage volume (ML)	NA	3	NA	3	NA
Pond catchment area (m^2)	NA	1800	NA	1800	NA
Storage area for evaporation (m^2)	NA	900	NA	900	NA

Two areas of effluent irrigation management are also considered – the lack of soil moisture monitoring to time effluent irrigation to ensure effluent is only applied to soils where risks of runoff are minimal; and, irrigation of effluent directly over drainage lines which would be expected to see some irrigated effluent run directly to the waterway. The proportion of irrigated effluent assumed to runoff from irrigation over drains is assumed to be proportional to the relative area, calculated based on a 5m width of drain within the effluent area. Proportions of irrigated effluent which would runoff from poorly timed irrigation are harder to estimate. For the purposes of estimating relative benefits of this management action it is assumed that 10% of applied effluent runs off on 10 days over 9 months of potential irrigation (equating to 0.4% of total irrigated effluent).

For stock access to drains, creeks and wetlands nutrient inputs are assumed to be a point source of manure. In order to estimate the relative magnitude of nutrient load that could be sourced from stock access assumptions about the number of stock and length of time they access waterways are made. Base case assumptions are summarised in Table4.

TABLE 4. ASSUMPTIONS UNDERPINNING CALCULATIONS OF IMPACTS OF LOADS FROM STOCK ACCESS TO WATERWAYS

Waterway	Number of cows	Days per year with access	Proportion of time in or near waterway
Fosters Marshes	800	42	100%
Mayfield creek	200	150	6%
Marsh creek	200	150	6%
Unnamed creek	200	150	6%
Foreshore - fences breached	10	100	6%

The modelled base case loads (using current effluent systems) from Rushy Lagoon calculated using these assumptions are given in Table 5.

TABLE 5. BASE CASE MODELLED NUTRIENT LOADS FROM RUSHY LAGOON (KG)

Pollutant source	TN	TP	% TN	% TP
Paddock runoff	28,849	6,332	81%	73%
Stock access to waterways				
Fosters Marshes	3,662	594	10%	7%
Mayfield creek	147	24	0%	0%
Marsh creek	147	24	0%	0%
Unnamed creek	147	24	0%	0%
Foreshore - fences breached	597	97	2%	1%
Effluent				
Cygnus	959	687	3%	8%
New dairy	949	847	3%	10%

Table 6 shows the base case loads from Rushy Lagoon relative to total loads from the catchment (including Rushy Lagoon). This table shows that Rushy Lagoon is estimated to currently produce approximately 10% of catchment TN exports and 8% of catchment TP loads to the Ramsar site.

TABLE 6. RELATIVE MODELLED LOADS FROM RUSHY LAGOON AND THE RINGAROOMA RIVER CATCHMENT. NOTE RUSHY LOADS INCLUDE ALL LAND USES INCLUDING GREEN SPACE, GRAZING AND DAIRY

Nutrient	Rushy Lagoon	Catchment loads	% of catchment
TP (kg)	21,386	179,473	12%
TN (kg)	92,870	664,450	14%
TSS (tonnes)	3,371	34,737	10%

The benefits of investments Rushy Lagoon has already taken in decommissioning Quinfields and Centre View dairies and developing a new dairy have also been estimated. This action is estimated to have reduced TN and TP export from Rushy Lagoon substantially, reducing total catchment loads to the Ramsar site by 34% and 32% respectively.

Leverage of potential management actions

The potential leverage of management actions in reducing pollutant exports from Rushy Lagoon are summarised in Table 7.

TABLE 7. LEVERAGE OF POTENTIAL MANAGEMENT ACTIONS IN REDUCING NUTRIENT EXPORTS FROM RUSHY LAGOON – DECREASE IN POLLUTANT LOADS FROM DAIRY AREAS ON RUSHY LAGOON

Action	TN	TP
Remove stock from Fosters Marshes	8.9%	5.8%
Remove stock from Mayfield creek	0.4%	0.2%
Remove stock from Marsh creek	0.4%	0.2%
Remove stock from Unnamed creek	0.4%	0.2%
Foreshore – repairing fences in disrepair	1.5%	1.0%
Cygnus move effluent irrigation area	1.9%	3.5%
FertSMART	1.8%	11.3%
Soil Moisture monitoring on effluent irrigation areas	0.6%	0.2%

Feasibility and barriers to implementation on Rushy Lagoon

The actions outlined above differ substantially in their feasibility and cost. In the case of some actions, funding could be used to overcome some of the barriers to action. For other actions production impacts associated with the action make them unlikely to be adopted even if costs were able to be funded. Table 8 summarises costs and the acceptability of each of the actions. Information on feasibility and barriers to adoption has been summarised based on discussions with the land manager.

TABLE 8. COSTS AND FEASIBILITY OF POTENTIAL MANAGEMENT ACTIONS

Action	Feasibility	Cost
Remove stock from Fosters Marshes	Removing stock from Fosters Marshes would require this section of the property to be purchased and added to the reserve system.	The most recent valuation suggested this would cost approx. $1.5 million. The high cost of this action would make it infeasible in this project but it may be worth agencies pursuing this in the future given the additional benefits to reduced weed incursion and other stock related threats to the Marshes.
Remove stock - Mayfield creek	Fencing would need to go through areas with pivots making this option infeasible.	Infeasible
Remove stock - Marsh creek	Fencing would need to go through areas with pivots making this option infeasible.	Infeasible
Remove stock - Unnamed creek	Fencing would need to go through areas with pivots making this option infeasible.	Infeasible
Move Cyngus effluent paddocks	This option requires purchase of a new pump and pipe to the new area. The landholder has identified a new irrigation area which meets their needs which is further from the wetlands, larger area and doesn't involve irrigation over a drain.	To be costed
Soil moisture monitoring	This option requires purchase of 6 soil moisture probes (2 each for effluent irrigation paddocks). These must be able to cope with high salinity and should be able to connect remotely to phone/tablet to enable irrigation scheduling.	To be costed
FertSMART	This action is highly adoptable and likely to lead to production improvements if improvements in nutrient application are identified and carried out.	To be costed
Foreshore fencing	Estimate less than 2km of fencing in disrepair or unknown state. This action is easily implemented and adoptable.	< $20,000

Recommendations for action and achievable targets for Rushy Lagoon

Based on discussions with the landholder, costs and the leverage of actions it is recommended that 4 key actions on Rushy Lagoon should be pursued in this project to improve water quality entering the wetlands:

- Move Cyngus effluent paddocks
- Soil moisture monitoring on effluent irrigation paddocks

- FertSMART and implementation of recommended changes in nutrient management
- Foreshore fencing

If these 4 actions are implemented in full and maintained it is expected that TN exports from Rushy Lagoon would decrease TN by over 5% and TP by over 15%. Purchasing Foster's Marshes and removing stock from this area is beyond the scope of this project but may be a high benefit option if funds become available in the future (approx. 9% and 6% decrease in TN and TP loads respectively in addition to direct benefits on vegetation of reduced stock trampling and introduction of weeds via stock).

The high concentrations of dissolved nutrients especially ammonia at RR3 may be due to irrigation of effluent over drains but may also be caused by pump or pond failures. Given the uncertainty about the cause of these elevated concentrations, water quality monitoring at RR3 should be continued to ensure further spikes in dissolved nutrient concentrations do not occur. The cause of such spikes should be further investigated if they were to occur.

If these four recommended actions on Rushy Lagoon were to be implemented catchment loads of TN and TP would be reduced by 0.9% and 0.4% respectively.

Boobyalla Park

Boobyalla Park is a 1780ha sheep grazing property carrying 15 DSE per ha. Outside of lambing periods when a set stock management approach is used, grazing is conducted on a rotational basis with stock moved every 7 days. Grazing is on permanent pasture. Nearly 23ha of the property is protected by a Conservation covenant. Soil testing is conducted regularly at fixed locations. The current owners acquired the property in 2006 and found very low fertility levels at that time. Since then there has been a focus on application of phosphorus and lime to improve fertility.

Where do pollutants come from?

Water Quality Monitoring

Water quality monitoring was undertaken at 3 sites on Boobyalla Park to inform this project as shown in Figure 33. Grab samples from these sites were collected on 6 occasions in 2020 and 2021 – 3 April 2020, 30 April 2020, 24 June 2020, 22 October 2020, 3 December 2020 and 25 March 2021. Data for observed phosphorus, nitrogen and suspended sediments at these sites are given in Figures 34 to 36.

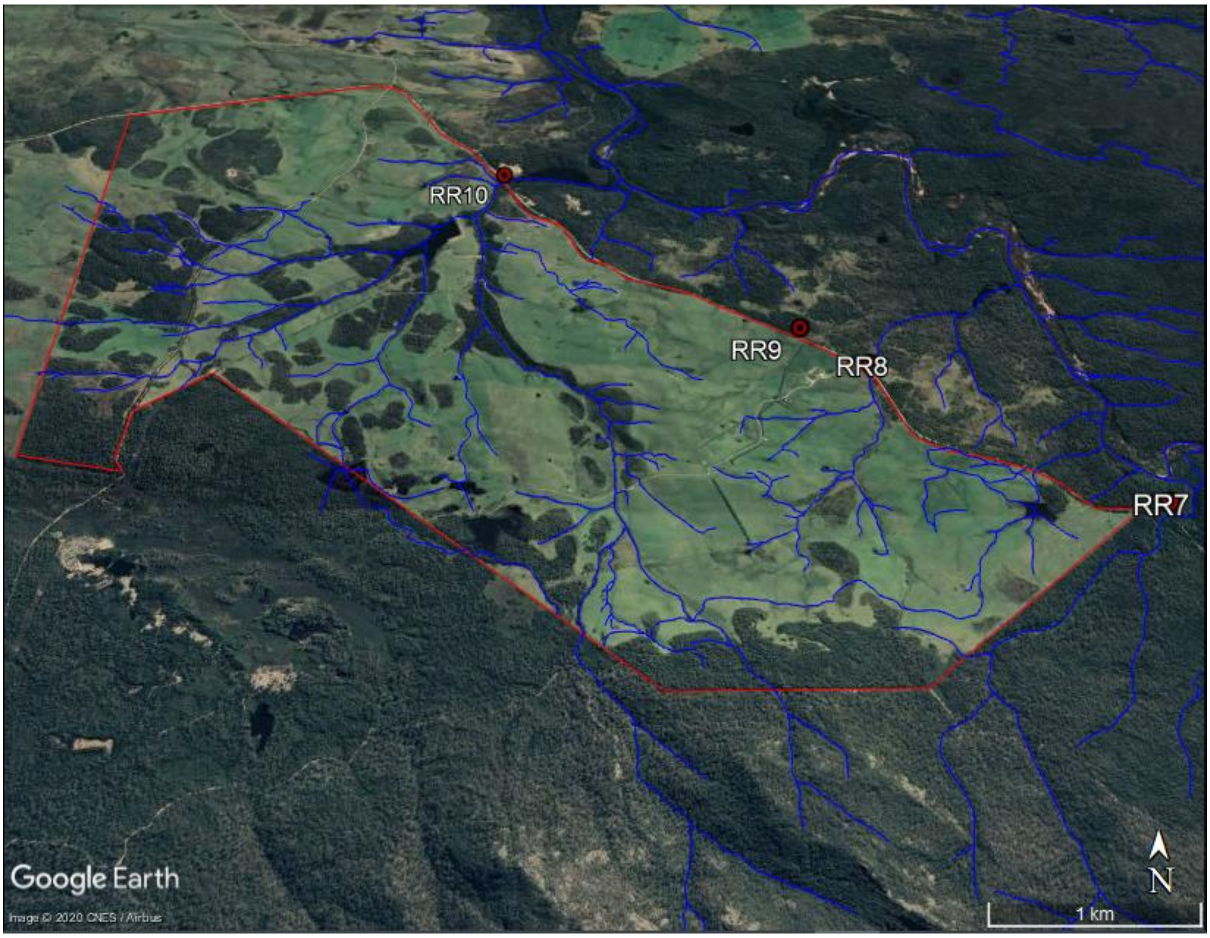


FIGURE 33. MONITORING SITES ON BOOBYALLA PARK – NOTE RR7 FALLS OUTSIDE THE PROPERTY BOUNDARY AND REFLECTS FORESTED AREA CONTRIBUTIONS TO WATER QUALITY

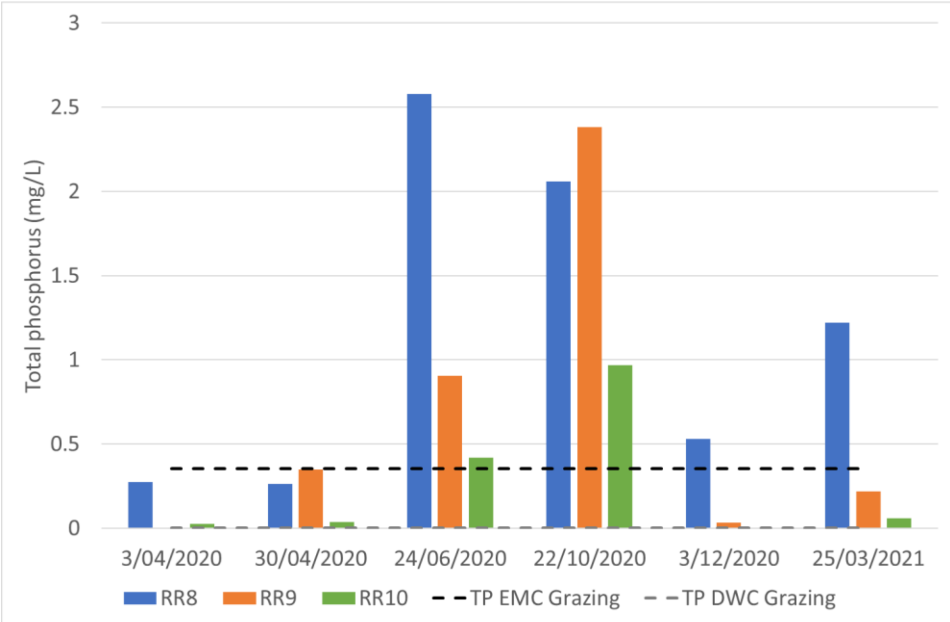
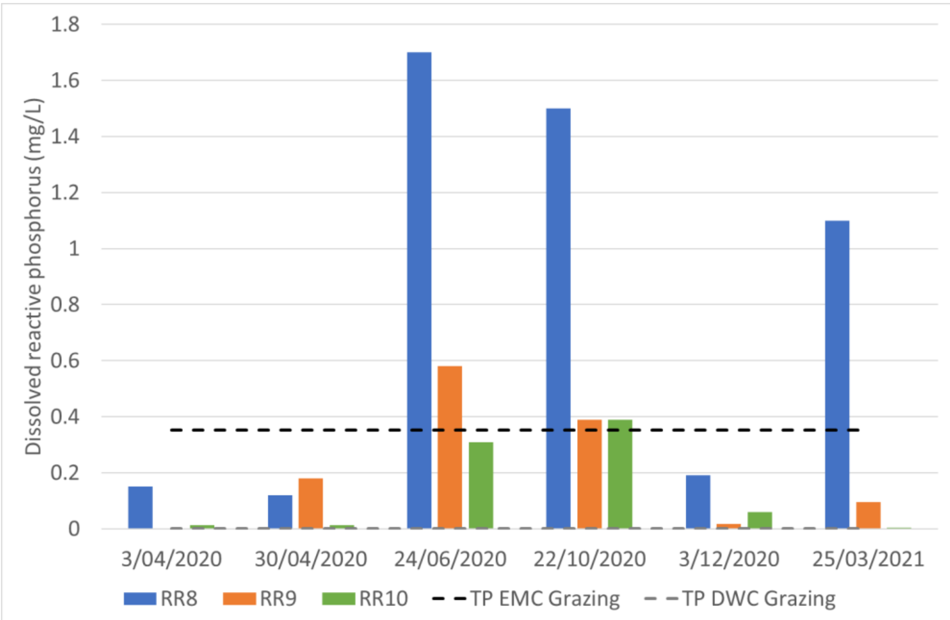
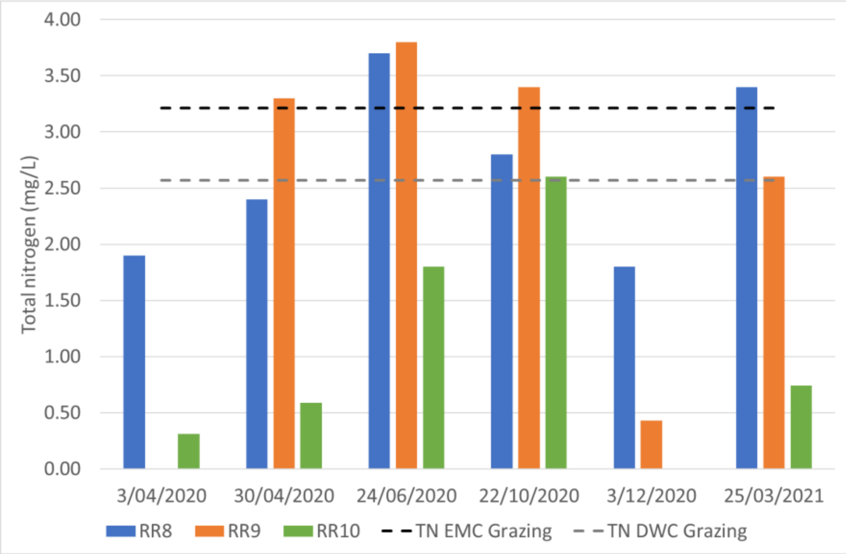
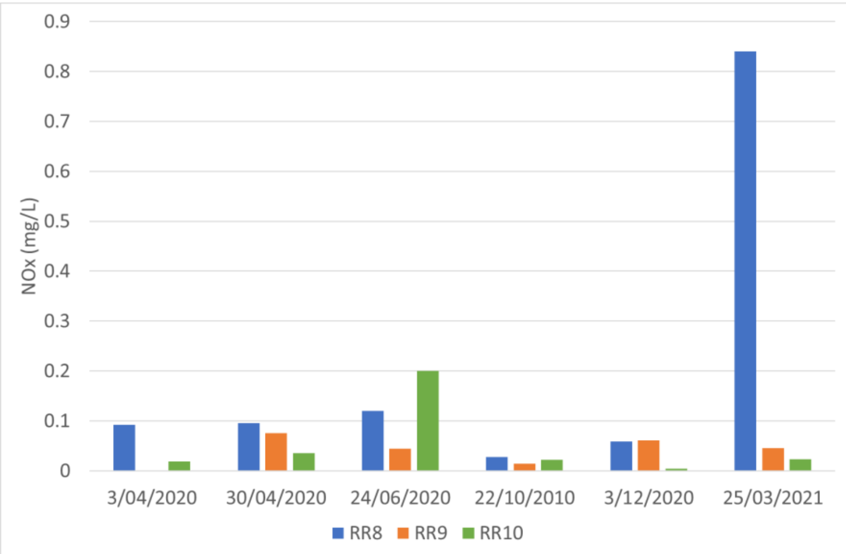
TP	
DRP	

FIGURE 34. MEASURED PHOSPHORUS CONCENTRATIONS AT MONITORING SITES ON BOOBYALLA PARK COMPARED TO DRY WEATHER AND EVENT MEAN CONCENTRATIONS FOR TP ON GRAZING AREAS

TN



NOx



Ammonia

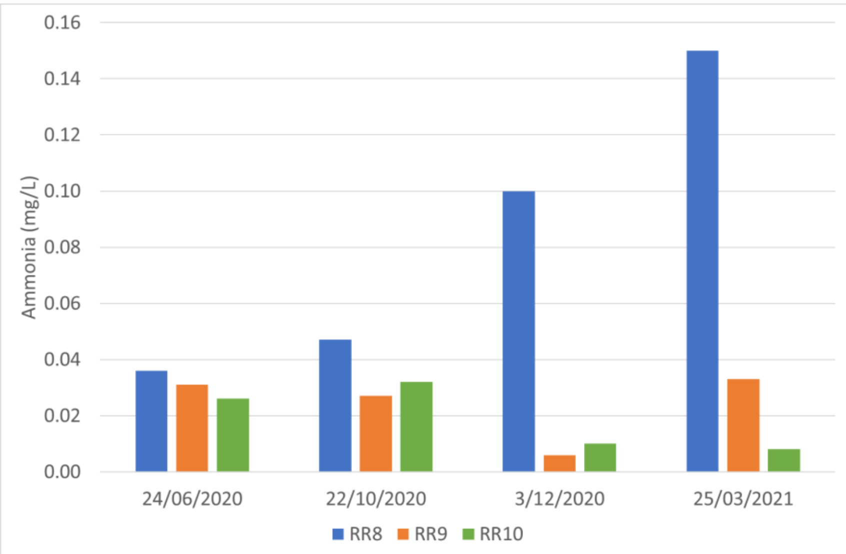


Figure 35. Measured Nitrogen concentrations at monitoring sites on Boobyalla Park compared to dry weather and event mean concentrations for TN on Grazing areas (TN only)

These figures show:

- Dissolved nutrients are higher at RR8 than other sites with very high concentrations of dissolved reactive phosphorus in June and October 2020 and March 2021. Peak concentrations of ammonia occur in December 2020 and March 2021 at this site with a very large spike in NOx in March 2021. Ammonia is an order of magnitude lower than NOx concentrations.
- Total nutrient concentrations are at or below literature-based event mean concentrations for grazing. Dissolved nutrients at this site are generally low. The RR10 site drains a larger catchment with extensive stock fencing and riparian vegetation for most of the stream sections. The unfenced areas with minimal riparian vegetation are primarily at the top of this catchment. This is a likely reason for these low nutrient concentrations.
- RR9 does not experience the peaks in dissolved nutrients that RR8 does though total nutrients are not dissimilar at the two sites. Concentrations of total nutrients are always higher at this site than RR10. Both RR8 and RR9 are smaller catchments with less riparian vegetation and where stock are still able to access the stream. Dead stock were observed in the stream and against the fence in a tributary to RR8 which may be a driver for higher dissolved nutrients at this site.

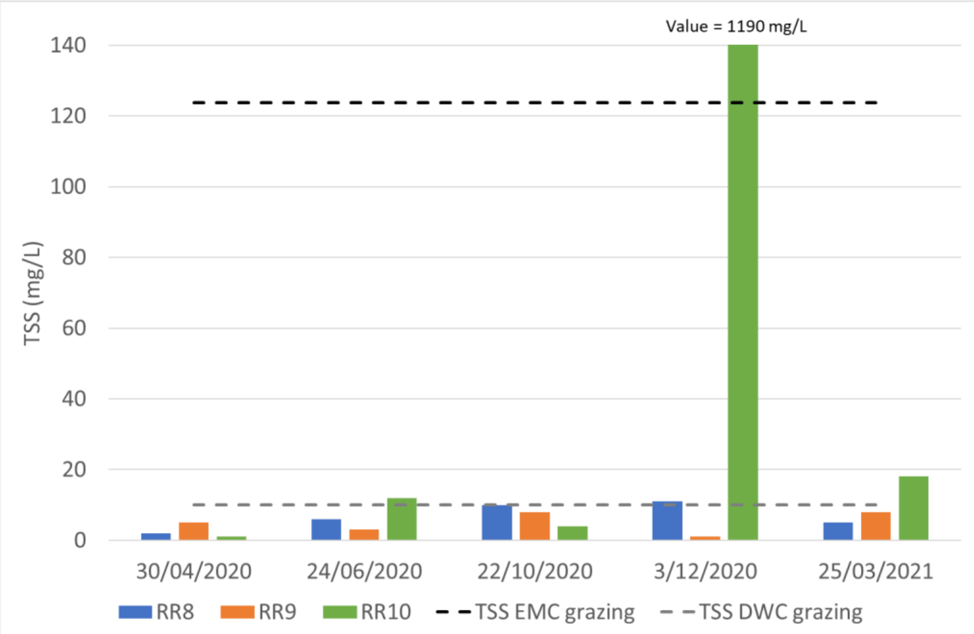


Figure 36. Measured suspended sediment concentrations at monitoring sites on Boobyalla Park compared to dry weather and event mean concentrations for TSS on grazing areas. Note the y-axis has been set to a maximum of 140 mg/L such that the peak value of 1190 mg/L experienced in December 2020 at RR10 does not display

Figure 36 shows the concentration of TSS at each of the 3 sites on Boobyalla Park. This shows that in general TSS concentrations are very low at all sites, with the exception of RR10 in December 2020, when a peak concentration of 1190mg/L was observed.

Modelled loads

Nutrient loads from Boobyalla Park to the Ramsar site have been estimated using the MiniCAPER DSS. Diffuse loads are estimated using event mean and dry weather concentrations for grazing areas combined with estimates of annual slow and quick flow volumes based on streamflow analysis and regionalisation. Point source loads from stock access to streams have then been estimated based on number of stock accessing the stream, the percentage of time they are estimated to be in and around the stream and literature based values for manure volumes and nutrient and sediment concentrations for sheep manure. A comprehensive audit of fences and stock access to streams has not been undertaken. A field visit in October 2020 was used to undertake a general assessment of fenced and unfenced areas. In general stock access to streams is well controlled on the property, with significant vegetated riparian buffers along most stream sections. The key areas identified without fencing where stock are accessing streams are shown in Figure 37. The contributing paddock area for each stream section with stock access is mapped. A fixed stocking rate of 15 DSE per hectare, based on results of the farm audit interview conducted with the land manager, is applied to these areas to create an assumption of the number of stock accessing the stream. The proportion of time stock spend in and around the stream is assumed to be 6% based on Wagner *et al.* (2008).

FIGURE 37. AREAS WHERE STOCK ARE CURRENTLY ACCESSING STREAMS ON BOOBYALLA PARK. MAPPED AREA IS ASSUMED CONTRIBUTING PADDOCK AREA WHERE STOCK ARE ABLE TO ACCESS RELEVANT STREAM SECTION

Estimated total loads from Boobyalla Park are summarised in Table 9 relative to total catchment loads.

TABLE 9. ESTIMATED BASE CASE LOADS FROM BOOBYALLA PARK RELATIVE TO CATCHMENT LOADS

Pollutant	Boobyalla	Catchment load	% contribution
TP (kg)	1,505	179,473	0.8%
TN (kg)	16,109	664,450	2.4%
TSS (tonnes)	0.5	34,737	<0.1%

This table shows that Boobyalla Park is estimated to contribute approximately 2.4% of the total nitrogen load, 0.8% of the total phosphorus and less than 0.1% of suspended sediment load to the Ramsar site.

Potential management actions

Overall Boobyalla Park has a high level of riparian protection and vegetation. As shown in Figure 38, four potential sites for excluding stock have been identified and assessed for their leverage, cost and feasibility.

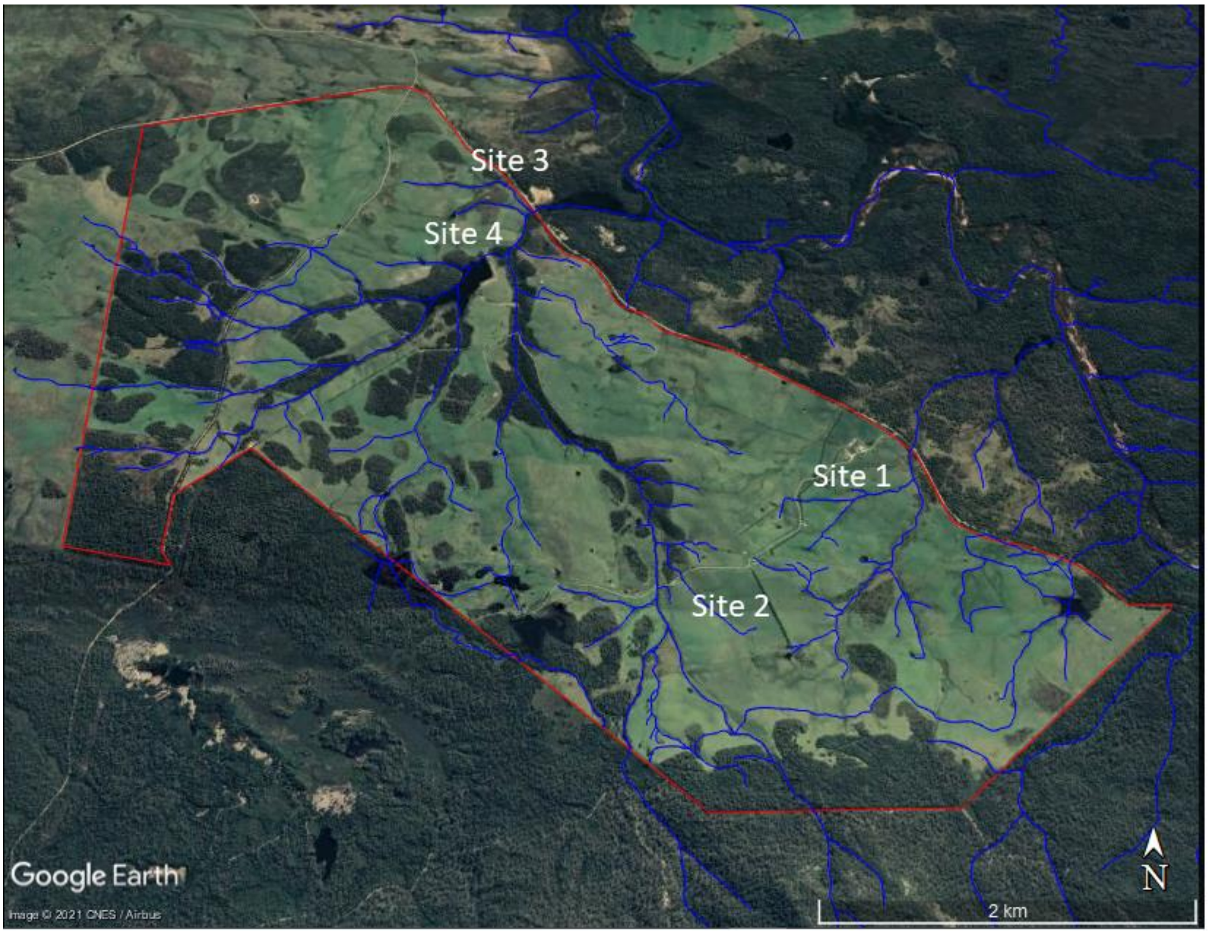


FIGURE 38. FOUR POSSIBLE MANAGEMENT ACTIONS SITES IDENTIFIED ON BOOBYALLA PARK

Site 1 – Unnamed tributary to Gincase creek – Fence waterway and targeted vegetation

Site 1 is an unnamed tributary to Gincase creek that drains to the wetlands past monitoring site RR8 (see Figure 39). Observations of this creek during the site visit in October 2020 showed that the creek was unfenced and had no riparian vegetation. There were several dead stock in the creek line indicating there may be production benefits to keeping stock out of this section of waterway. Significant levels of algal growth were observed immediately downstream of this tributary in Gincase creek. Observations at RR8 indicated elevated TN and TP at site RR8 in June 2020 with a very high concentration of TP observed. This action would require 1.5km of fencing, 1.5ha of riparian revegetation and gates to allow stock and vehicle crossing between paddocks.

FIGURE 39. SITE 1 – A). LOCATION OF STREAM SECTION B) VIEW LOOKING UPSTREAM ALONG STREAM SECTION C) LOWER SECTION WHERE EVIDENCE OF SEVERAL DEAD SHEEP WAS SEEN

Site 2 – Top of Hardwickes creek – broaden fencing and revegetation works to address channelised flow into the stream

The lower part of Hardwickes creek is fenced and has very substantial vegetated riparian buffers. Site 2 is the top part of Hardwickes creek (see Figure 40). This site is already fenced and has a narrow strip of riparian vegetation. Observations taken during a site visit in October 2020 indicated that despite this there was evidence of nutrient loads in the stream (elevated algal growth). Closer inspection of the site found that the hillside contributing to this stream drains into the corner of this paddock at a point where the riparian buffer is very narrow. There is a natural depression in the paddock at this point which is encouraging runoff to preferentially flow to this part of the paddock. There was evidence of rills where runoff from this hillside is channelising and passing directly through the riparian zone into the stream. A potential management action was identified to widen the riparian buffer to provide a natural filter for flows and nutrients running off at this point. This action would require 350m of fencing (current fences could potentially be repurposed with some new materials and labour required) and revegetation of the widened buffer.

Figure 40. Site 2 – a) Location of site works b) flow channel taking channelised flow from hillside c) flow channels formed through narrow riparian vegetation

Sites 3 and 4 – Hardwickes Lagoon direct tributaries

Sites 3 and 4 both drain almost directly into Hardwickes lagoon (see Figure 35). Both waterways show signs of erosion and with stock access and minimal riparian revegetation. It is considered that there are two potential options for improving water quality from these sites:

- Optimal option – fence off a corner of the property containing both sites and revegetate. This would provide a significant buffer for inflows into Hardwickes lagoon from the property.
- Alternative option – fence and vegetate a separate buffer on each of the waterways to reduce stock access and provide a filter for runoff from the surrounding paddocks.

It is also noted that opposite this site there is a significant quarry site within the National Park used to obtain gravel. This quarry is very close to the Lagoon and can be considered a risk to water quality. While this is not managed by Boobyalla park it is suggested that improved management of this site would be desirable, both for the environmental benefits as well as to help address any concerns by the landholder that they are taking significant actions on their own property while a Government managed piece of land poses a more immediate threat. At a minimum creating a wider buffer between the quarry and the lagoon should be considered.

FIGURE 35. LOCATION OF SITES 3 AND 4 – NOTE QUARRY OPPOSITE SITE ON NATIONAL PARK ADJACENT TO HARDWICKES LAGOON

Leverage of potential management actions

The potential impact of implementing each of these actions has been estimated using the MiniCAPER DSS. Load reductions are a combination of reduced point source pollutants from removing stock access to streams and increased vegetation riparian buffers trapping nutrients that runoff paddocks before they enter the stream. Table 10 shows the leverage of each of these actions in reducing nutrient loads from Boobyalla Park. In all cases the greatest benefit comes from the vegetated riparian buffer rather than reduced nutrient input from manure direct to the stream. The effect of dead stock in the stream on water quality is not estimated. This would be an additional benefit over and above these estimates. Note that the effects of site 3 and 4 are greater if implemented together due to the greater area of vegetated riparian zone that would be created by this combined action than the addition of areas from these sites implemented alone.

Table 10. Load reduction (kg) and as a percentage of loads from Boobyalla Park from potential management actions

	TP	TN	TSS	TP - % Boobyalla loads	TN - % Boobyalla loads	TSS - % Boobyalla loads
Site 1	23.7	573.8	37.8	2.6%	4.1%	10.3%
Site 2	8.1	157.5	2.7	0.9%	1.1%	0.7%
Site 3	1.5	36.2	2.4	0.2%	0.3%	0.7%
Site 4	1.4	33.5	2.2	0.2%	0.2%	0.6%
Site 3 & 4 combined	6.3	123.0	5.0	0.7%	0.9%	1.4%
Total	38.1	854.3	45.5	4.2%	6.1%	12.4%

Actions at Site 1 have the greatest impact on both all pollutants. The effects of actions at Site 3 or 4 are small if these areas are treated in isolation but if implemented as a combined action have an impact close to that of actions on Site 2 for nutrients and greater than Site 2 for TSS. If all actions were implemented nutrients loads from Boobyalla Park could be reduced by approximately 6% for TN, 4% for TP and 12% for TSS.

Feasibility and barriers to implementation on Boobyalla Park

The feasibility and potential barriers to implementation of these actions were identified through discussions with the landowner. These are summarised in Table 11.

TABLE 11. COSTS AND FEASIBILITY OF POTENTIAL MANAGEMENT ACTIONS

Action	Feasibility	Cost*
Site 1 – fence and vegetate both sides of creek, including gates to allow access through creek	1.5km fencing, 2 gates, 1.5ha of vegetation – ADD LANDHOLDER DISCUSSION	Fencing - $15,000 Revegetation - $15,000 TOTAL = $30,000
Site 2 – move 350m of fencing and vegetate to create a wider buffer to address channelised flows	1ha of vegetation, labour to move existing fencing – ADD LANDHOLDER DISCUSSION	Revegetation – $10,000 Labour costs for moving fence minimal TOTAL = $10,000
Sites 3 and 4 – Optimal option: fence and revegetate corner to remove stock and provide a buffer to Hardwickes Lagoon	200m fencing, 1ha vegetation – ADD LANDHOLDER DISCUSSION	Fencing - $2,000 Revegetation - $10,000 TOTAL = $12,000
Sites 3 and 4 – Alternative option: fence and revegetate one or both of the stream sections at Sites 3 and 4	Site 3 – 250m fencing, 0.5ha of vegetation Site 4 – 500m of fencing, 0.5ha of vegetation – ADD LANDHOLDER DISCUSSION	Site 3: Fencing - $2,500 Revegetation - $5,000 TOTAL = $7,500 Site 4: Fencing - $5,000 Revegetation - $5,000 TOTAL = $10,000

* costs are estimated total including labour. Project investment may be lower with landholder contribution to be negotiated.

Recommendations for action and achievable targets

Based on discussions with the landholder, costs and the leverage of actions it is recommended that 3 key actions on Boobyalla Park should be pursued in this project to improve water quality entering the wetlands:

- Fencing and revegetating Site 1 – unnamed tributary to Gincase creek.
- Broadening the fenced and vegetated area to improve buffer effectiveness at Site 2 at top of Hardwickes creek.
- Fence and vegetate tributaries to Harwickes lagoon as a single action (Site 3 and 4).

If these actions are implemented in full and maintained it is expected that TN exports from Boobyalla Park would decrease TN by 6%, TP by 4% and TSS by 12%. This equates to very small reductions in loads relative to total catchment loads (<0.15% for all pollutants). Despite their small relative magnitude, these loads reductions do impact directly on the wetland and can be expected to have localised benefits especially to Hardwickes Lagoon.

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