South Yaamba Reef Water Quality Precinct Plan.

Addressing:

- Reef water quality report;
- Model for Practice Change;
- South Yaamba Precinct Water Quality Model.

Achieving Reef Water Quality in Agricultural Developments.

Prepared for Rockhampton Regional Council

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Glossary

A	Average annual soil loss (t/ha)
C	Cover management (vegetation ground cover)
EM	Electromagnetic (soil surveying)
DRCM	Dynamic Reference Cover Modelling
DROVER	Dynamic Reference for Optimising Value and Erosion Reduction
EPBC	Environment Protection and Biodiversity Conservation Act 1999
ESG	Environment, social and governance
ISSB	International Sustainability Standards Board
JRSRP	Joint Remote Sensing Research Program
K	Soil erodibility
LS	Slope length
RF	Rock (armouring) factor
P	Practice control
PDST	Pesticide Decision Support Tool
P2R	Paddock to Reef
RR	Reef Regulations (The *Environmental Protection (Great Barrier Reef Protection Measures) and Other Legislation Amendment Act 2019)*
RWLMCoP	Rookwood Weir Land Management Code of Practice
RUSLE	Revised Universal Soil Loss Equation
S	Slope
SALF	Salt and Leaching Fraction (model)
SILO	Database of Australian climate data from 1889 to the present
TERN	Terrestrial Ecosystem Research Network
TNFD	Taskforce on Nature-related Financial Disclosures

Executive Summary

South Yaamba Reef Water Quality Precinct Plan

Objective

The South Yaamba Reef Water Quality Precinct Plan aims to support sustainable agricultural development in the South Yaamba area and the broader Fitzroy Food Bowl while also causing no net decline in reef water quality by quantifying and identifying cumulative requirements to reduce sediment, nutrient, and pesticide runoff. This initiative is aligned with the Rookwood Weir Land Management Code of Practice (RWLMCoP) and the Reef Regulations (RR) and supports the Reef 2050 Long-Term Sustainability Plan objectives.

The Precinct Plan complements individual irrigation farm plans prepared in compliance with the Reef Regulations and the RWLMCoP, that specify practices and offset requirements to generate no net increase in sediment, nutrient or pesticide run off from their agricultural developments.

Landholder practices and aspirations

Sunwater has received 21 applications for development of irrigation farm plans across the Fitzroy Food Bowl, including 8 within the precinct totalling 4950 ML/yr to be applied to 708 ha of new irrigation area, representing an average of 7ML/ha/yr. The proposed irrigation area per property ranges from a minimum of 20ha (for sorghum, Oats, Rhodes grass and Cotton) to 350ha (for Macadamias).

Skills and experience of landholders include farmers new to cropping, farmers new to irrigated cropping and experience irrigated croppers using the new water to substitute existing water sources or expand existing activities.

All landholders are seeking to improve productivity and/or value and are receptive to adopting practice change measures to meet RWLMCoP compliance requirements of no net impact on Reef water quality. Landholders also recognise, and are receptive to contributing to, Sunwater's EPBC-based weir approval conditions embodied in the RWLMCoP, to achieve an improvement in water quality in line with the Reef 2050 water quality targets, however capacity to meet this obligation requires practice change beyond the landholders undertaking new irrigation developments.

Sediment and erosion risk in South Yaamba

Scenario modelling was carried out to explore the cumulative effect of irrigated development for thirteen different cropping practices under four management scenarios compared to baseline conditions:

- ***Baseline:*** based on average sediment export over the past seven years;
- ***Scenario 1:*** Irrigated cropping *with no best practice mitigation measures applied*;
- ***Scenario 2:*** Irrigated cropping *with best practice mitigation measures applied*;
- ***Scenario 3:*** Irrigated cropping *with best practice mitigation measures applied*, and *management practice improvement on non-developed areas to achieve no net impact*; and
- ***Scenario 4:*** Irrigated cropping *with best practice mitigation measures applied*, and *management practice improvement on non-developed areas to meet the Reef 2050 WQIP anthropogenic sediment reduction target*.

Scenarios 1 to 4 all assume:

- Development to irrigated cropping of 5% of the potentially developable area (3,874ha);
- Effectiveness of best management interventions of 30% reduction in sediment export;

- Each crop type x management scenario assumes 100% of the area developed for irrigation is for the specified crop type (ie, multiple crops are not accommodated).

Modelled average baseline sediment export for the precinct to the Fitzroy River is estimated at 4166 tons/year. Assuming an average fine sediment proportion of 35%, fine sediment export to the river will be approximately 1458 tons/yr. Based on an average riverine sediment delivery ratio (RSDR) of 82%, fine sediment export to the Reef (assessed at the river mouth) is 1196 tons/yr.

The sediment modelling results are based on a combination of scenarios and assumptions, so should not be interpreted literally. However, they are useful for indicating trends in management requirements associated with irrigated development.

- Perennial fodder and pasture crops managed under best practice have the capacity to reduce precinct sediment export relative to the current baseline conditions.
- Double cropping is preferred relative to a single cropping-fallow cycles, as the higher level of cover results in less sediment export. Notwithstanding, even with best management practices, complementary grazing practice change is required on undeveloped land (on and potentially beyond the property) to achieve no net impact.
- Under any circumstances, best management practices on 100% of land developed to irrigated cropping plus complementary grazing practice change on a very large proportion of the undeveloped land (45% to 80%) is required to reduce sediment export across the precinct by 30%, the reduction required to meet the Reef 2050 anthropogenic sediment reduction target.

Limitations in achieving sediment offset targets include availability of land not currently employing best practice; variation in land capability to deliver sediment offsets; limited opportunities for alternative for sediment reduction options including streambank and gully restoration; capacity for the overall program to deliver on EPBC related conditions; capacity to directly undertake works on third party-owned land; the need for incentives to landholders to implement grazing BMP; and potential legislative instruments.

Nutrient runoff and leaching risk in South Yaamba

Modelling nutrient loss is specific to the soils, topography and management practices. Therefore, nutrient loss was only modelled at the property scale. None-the-less, the principles of minimising nutrient loss are relevant at the precinct scale. Modelling of nitrogen losses in runoff and drainage at the property scale identified a number of common themes:

- Nitrate nitrogen is not strongly retained in topsoils, hence, runoff and leaching is likely during the wet seasons under both dryland and irrigated conditions.
- Modelled runoff of nitrate in an average rainfall year was predicted to peak for irrigated Rhodes grass at 0.75 kg/ha during the December to February high rainfall period, but runoff nitrate loss was negligible across the remainder of the year.
- Leaching of nitrate followed a similar trend to runoff losses, with most nitrate leached in December and February.
- Nitrate leaching is a function of soil mineralogy, soil pH, root depth distribution and rainfall. Hence, the leaching losses in the field are difficult to predict accurately.
- Under irrigated conditions, runoff and drainage nitrate concentrations are elevated, but drainage nitrate can be managed by irrigation scheduling to minimise deep drainage.

Limitations in achieving nutrient offset targets include: limited opportunities for nutrient offsets given the relatively small area of cropping and grazing currently practiced in the catchment; possible integration of nutrient offsets with hyacinth harvesting; capacity for the overall program to deliver on EPBC related conditions; ability to offer incentives to landholders to implement nutrient BMP to deliver offsets; rights to nutrient offsets associated with hyacinth harvesting; and potential legislative instruments.

Pesticide leaching and runoff risk in South Yaamba

Pesticide management comprises several steps:

- Reducing pesticide runoff.
- Optimising pesticide use.
- Selecting pesticides that pose a lower risk to aquatic environments (i.e., have lower mobility, persistence and ecotoxicity).

Recommended management strategies to reduce pesticide runoff include:

- Erosion and sediment control measures (see Section 4).
- Application timing.
- Optimised application rates.
- Use of lower risk pesticides.

The above strategies, in combination with the recommended erosion and sediment control measures will ensure that the water quality impacts from pesticides will be minimised and ensure compliance with the Code and Reef Protection Regulations.

Rising groundwater and salinity risk in South Yaamba

Rising groundwater and associated salinity risk may be influenced by any change in the hydrology of the landscape, such as clearing native forest for grazing, or conversion of grazing land to irrigated agriculture.

Salinity risk due to excessive deep drainage and rising groundwater was assessed by mapping depth to bedrock acrosnd then carrying out a time to fill analysis.

The results indicate that salinity risk due to rising groundwater is very low to low across the South Yaamba precinct given the depth to regolith is generally greater than 20m. Notwithstanding, poor irrigation practices that resulted in excessive deep drainage above the rate assumed (50mm/yr) would be expected to increase the rate of groundwater rise and risk of locally perched water tables. When groundwater intercepts historical salt stores in the regolith or soil profile it will carry the stored salts, and rise to the surface when the groundwater rises within 2m of the surface.

Risk assessment and control measures

A detailed risk assessment consistent with AS/NZS ISO 31000 was carried out to evaluate key risks and mitigation measures.

Sediment, nutrient and pesticide risk were all considered extreme in the absence of control measures, and moderate with application of control measures articulated though the precinct plan and individual farm plans.

Salinity risk was assessed as high in the absence of control measures, and low with application of control measures.

Provision of analysis data to Paddock to Reef

Data analysis results will be provided to the Paddock to Reef modelling team recognising the assumptions behind the modelling approaches adopted:

- Sediment: Use of the DROVER mapping tool considered more appropriate than the P2R tool for application at the property and precinct scale.
- Nutrient: Use of the Nitrate-N sub-model of HowLeaky, applied to the property scale to illustrate the principles of minimising nutrient loss are applied at the precinct scale.
- Pesticides: Interpretation of the *Pesticide Decision Support Tool.*
- Salinity: Paddock-scale salinity modelling using SALF2 to estimate deep drainage rates, and incorporation in a spreadsheet-based Time-to-fill analysis, applied spatially based on publicly available data layers for the depth to regolith.

Reef Water Quality Report

Sediment export

The modelling carried out to inform this Precinct plan indicates that for all irrigated cropping types other than perennial fodder and pasture crops, and possibly tree crops, irrigated cropping development can be expected to have a net impact on:

- Sediment export to the reef;
- Nutrient export; and
- Pesticide export.

Rising groundwater and salinity is considered a lower risk provided irrigation is efficiently managed to avoid excessive deep drainage. Salinity risk is considered very low across the majority of the precinct, and low in the north-west and southern corners of the precinct (Figure 28).

Increased sediment export from irrigated cropping development can offset by:

- Adoption of best-practice irrigation management practices (including in-crop management and out-of-crop sediment retention structures as detailed in individual farm plants).
- Management of seasonal crops under a double cropping regime, with fallow periods outside the seasons of likely intense rainfall.
- For seasonal crops other than perennial pasture and fodder crops (Rhodes hay and Lucerne) implementation of complementary grazing management practice improvements (forage budgeting, matching stocking to feed production, rotational grazing, distributed water points, regenerative grazing planning), potentially over 4% to 20% of undeveloped land (i.e., 4,598 to 22,991 ha) dependent and crop mix.

Delivery of a proportional contribution to the Reef 2050 sediment reduction target for the Fitzroy of a 30% reduction in anthropogenic sediment export to the reef is a more challenging target. To achieve a 30% reduction in anthropogenic sediment will require:

- Adoption of best-practice irrigation management practices (including in-crop management and out-of-crop sediment retention structures as detailed in individual farm plans).
- Management of seasonal crops under a double cropping regime, with fallow periods outside the seasons of likely intense rainfall.
- Implementation of complementary grazing management practice improvements (forage budgeting, matching stocking to feed production, rotational grazing, distributed water points, regenerative grazing planning), potentially over 45% to 70% of undeveloped land (i.e.,

51,700 to 80,500 ha) dependent and crop mix. The scale of offset requirement in addition to best management practice within irrigation developments will necessitate complementary practice change on unirrigated land well-beyond individual properties implementing new irrigation development.

Nutrient export

Key messages from individual nutrient loss modelling are:

- Nitrogen losses in drainage will only occur during periods of high rainfall, which cannot be controlled by the landholder.
- Nitrogen losses via runoff under irrigation were not materially different to runoff under dryland conditions.
- Vegetated buffer strips can be established to intercept nitrogen in the runoff.
- Appropriate irrigation scheduling will lead to minimal deep drainage and thus minimal drainage N losses.
- Best-practice fertiliser management (4Rs) (e.g. deep placement of fertiliser, timing of application, split applications, application rates) will further minimise nitrogen losses and ensure compliance with the Code and Reef Protection Regulations.

Pesticide export

Recommended management strategies to reduce pesticide runoff include:

- Erosion and sediment control measures
- Application timing
- Optimised application rates
- Integrated pest management principles
- Lower risk pesticides

Salinity

Irrigation induced salinity risk is very low to low across the Yaamba precinct given the depth to regolith is generally greater than 20m. Notwithstanding, poor irrigation practices that resulted in excessive deep drainage above the rate assumed (50mm/yr) would be expected to increase the rate of groundwater rise and risk of locally perched water tables.

Implications

Management of sediment can be achieved through best management practice, out-of-crop sediment retention measures plus the introduction of best practice grazing management, on complementary lands.

Management of nutrient impacts, and in particular, nitrogen, is more problematic as the development of irrigated cropping involves the introduction of new nitrogen into the landscape through fertiliser application required to support the intensification of agriculture. As cropping development and use of fertilisers in grazing is relatively limited, the associated “levers” available to reduce nitrogen impacts to waterways are also limited. Phosphorus losses are less problematic due to the soil buffering capacity.

The main “lever” to minimise pesticide export to waterways is selection of low-mobility chemicals, in association with sediment management.

Salinity is not a risk provided irrigation practices are appropriately managed to avoid development of localised perched water tables

Barriers to achieve no net Reef water quality impact from new irrigation developments and contributing toward achieving the Reef 2050 anthropogenic reduction targets include:

- Capacity of landholders to fully and effectively implement farm plans; and
- Availability of and access to land to implement offsets.

Enterprise change for new and existing landholders will require getting extension and capacity building support right to ensure engaged farmer adoption.

In parallel, Precinct-scale monitoring is critical to establishing a baseline and tracking cumulative changes over time. This can be readily carried out by remote sensing analysis for sediments, but will require integration of specific management data from each individual farmer for nutrients and pesticides.

South Yaamba Precinct Water Quality Model

Management of:

- sediment export to the Reef from irrigated cropping development; and
- contribution of irrigation water application to deep drainage

are the two critical components of delivering on the South Yaamba Precinct Water Quality Plan given the pathways for nutrient and pesticide export are linked to sediment loss and deep drainage.

Recommendations are made in relation to the strategy for implementation of the precinct plan to:

- Provide support and capacity building for farmers;
- Assist farmers achieve optimum crop production; and
- Minimise environmental impacts and deliver environmental benefits.

Publicly available data sources to support the Water Quality Model include:

- Ground cover data: TERN: Monthly Blended Ground Cover version 3 - Landsat and Sentinel-2, JRSRP algorithm, Queensland coverage;
- Rainfall (R) calculated from SILO daily rainfall grids;
- Soil Erodibility (K) 2022 version supplied from Paddock to Reef team (https://dataportal.reefplan.qld.gov.au/);
- Slope length (L) 2022 version supplied from Paddock to Reef team (https://dataportal.reefplan.qld.gov.au/);
- Rock factor (RF) 2022 version supplied from Paddock to Reef team (https://dataportal.reefplan.qld.gov.au/);
- Slope (S) 2022 version supplied from Paddock to Reef team (https://dataportal.reefplan.qld.gov.au/),
- Required farm-level management data required to support the Water Quality Model includes:
- Farm level management records - Fertiliser and pesticide application records, irrigation application records
- Soil moisture, solute monitoring and deep drainage via soil moisture monitoring probes
- Rainfall and climate data via automated weather stations at representative locations within each irrigation development.

- Electromagnetic (EM) surveying to inform irrigation block design, placement of soil moisture probes and to spatially identify changes in soil properties over time.

Data gaps include:

- Calibration of modelled sediment loads to measured sediment loads from riverine monitoring and possibly remote sensing of riverine turbidity levels (potential linkage and collaboration with CSIRO's AquaWatch Australia program).

Recommended on-farm actions are to:

1. Encourage farmers to undertake a pre-development EM survey to characterise soil type variation and soil sampling to quantify variation in soil characteristics.
2. Encourage and support farmers to utilise the results of the EM survey to inform irrigation block design and/or variable rate irrigation.
3. Encourage farmers to further utilise the results of the EM survey to inform representative placement and installation of soil moisture monitoring probes.
4. Encourage farmers to install an on-site automated weather station linked to the soil moisture probes to enable moisture probe interpretation for optimal irrigation management.
5. Encourage farmers to install flow meters on irrigation equipment enable irrigation planning informed by soil moisture probes.
6. Require farmers to make records in relation to irrigation scheduling, fertiliser use and pesticide use, available to Sunwater/DES to enable identification of events impacting water quality.
7. Encourage and support farmers to undertake annual EM surveys, soil sampling and EM-soil correlation to track changes in soil properties over time and inform adaptive management.

Recommended precinct-scale actions are to:

8. Undertake regular, monthly precinct wide monitoring and modelling of sediment, nutrient and pesticide export from the range of data pools available (satellite vegetation, cover, soil moisture probe data, distributed weather stations, farmer records for irrigation scheduling, fertiliser use and pesticide applications).
9. Provide support and capacity building for farmers to interpret soil EM maps, interpret soil moisture probe data, interpret soil tests to optimise fertiliser application rates and select and use minimum impact pesticides.
10. Provide incentives for practice change on undeveloped land (within and beyond land developed for new irrigation irrigation) to offset impacts and contribute to Reef 2050 targets.

Model for Practice Change

Successful delivery of the South Yaamba Reef Water Quality Precinct Plan will require strong stakeholder engagement and capacity building across the board. In turn, this will require appropriate management practices and controls at both the farm scale for individual irrigators, and precinct scale to manage not only the cumulative effects and impacts of land use change to irrigated cropping development, but also the effects and impacts of past land use on anthropogenic fine sediment loads to the Reef.

The associated goals underlying a model for practice change should aim to:

- Maximise crop production and soil health at the farm scale;
- Minimise potential negative impacts on sediment, pesticide and nutrient export;

- Offset any residual impacts on sediment, pesticide and nutrient export that cannot be avoided;
- Avoid any risk of local or regional impacts on salinity, either though groundwater rise or rootzone accumulation; and
- Contribute to a net positive outcome for the Fitzroy River and Reef water quality through precinct-wide practice change that contributes to the reef 2050 water quality targets for a 30% reduction in anthropogenic fine sediment load to the reef.

Requirements include:

- ***Detailed planning and design:*** Implementation of a quantitative approach to planning and design (e.g., matching soil types to irrigation blocks, matching irrigation rates to soil types, erosion control structures etc) will require considerable landowner capacity building and support from specialist advisors. Similarly, for calculating practice change requirement to offset sediment export.
- ***Appropriate implementation of the proposed management practices:*** Capacity building, education and development of a collective approach to sustainable irrigation development of the precinct are all critical to deliver on the stated practice change goals. This will include: One-on-one support; Development of a Community of practice; and the novel concept of establishing a wider Precinct sustainable management forum.
- ***Monitoring and continuous improvement:*** At the farm scale, comprehensive record keeping of management activities, combined with monitoring of site conditions, inputs and outputs is critical to quantitatively evaluate performance. Monitoring at the precinct scale will require dedicated resources to regularly evaluate water quality changes in response to cumulative activities across the entire precinct.
- ***Incentives for precinct-wide practice improvement on non-irrigated lands:*** Given the scale of offset requirement in addition to best management practice within irrigation developments to achieve the Reef 2050 sediment reduction target, and in some cases to achieve no net impact relative to the current baseline, complementary practice change on unirrigated land well-beyond individual properties implementing new irrigation development will be required if Sunwater is to meet its EPBC compliance obligations. This may include grazing practice change; gully or streambank remediation; implementation of other erosion control measures; and potentially, establishment of a sediment and nutrient trading scheme.
- ***Verification of land stewardship and market access:*** It can be expected that most landholders will not fully appreciate the momentum in global trends towards the requirement for independent verification of responsible land stewardship and market access to supply chains. Farm management practices that contribute to achieving the Reef 2050 plan can be expected to be a baseline level of stewardship. Considerable landholder education and engagement will be required to help position farmers to be able to meet such obligations and retain their social and commercial licence to operate.
- ***Transition plans to go from current practices to best management practice:*** Successful implementation of transition plans has a psychological dimension in change management. An integrated approach to the collective actions discussed above, particularly in relation to support for appropriate implementation of the proposed management practices, and evidence-based feedback through monitoring and continuous improvement, will contribute toward this objective.

1. Introduction

1.1 Purpose

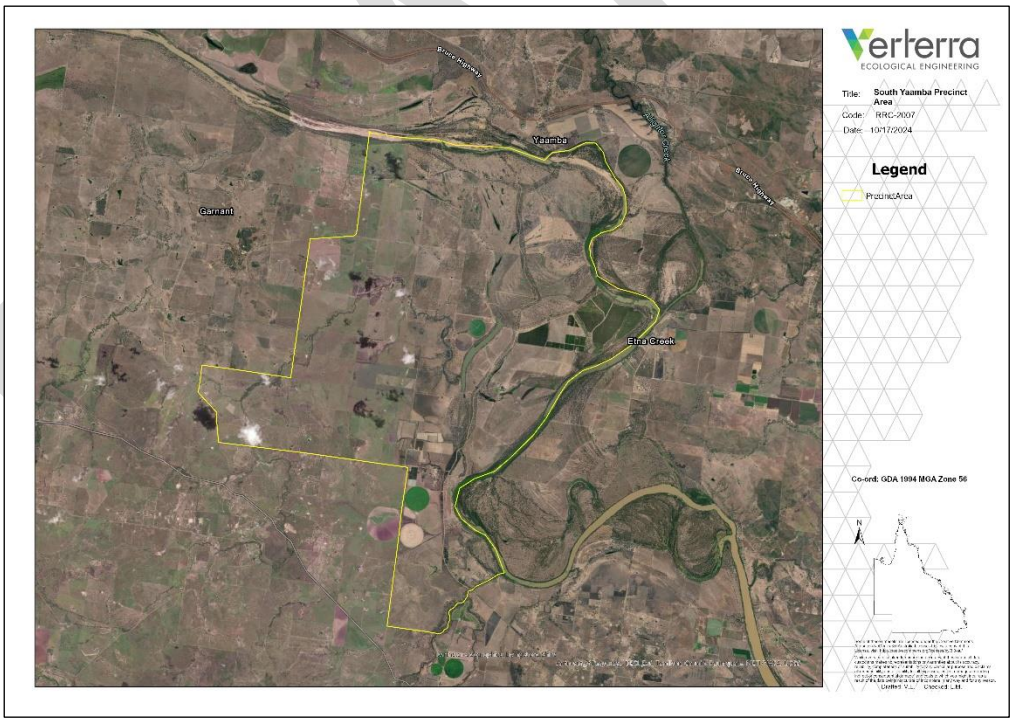
The purpose of the South Yaamba Reef Water Quality Precinct Plan is to provide support to the South Yaamba area and to selected landholders in the broader Fitzroy Food Bowl that will be progressing irrigation developments on their land to achieve reef water quality outcomes (reduce sediment, pesticide and nutrient export).

1.2 Scope

The plan accounts for new and expanding agriculture in the region. The plan takes into account the Rookwood Weir Land Management Code of Practice (RWLMCoP) and the Reef Regulations (RR).

Development of the Precinct Plan (covering the area illustrated in Figure 1) encompassing an area of approximately 10,100ha and spanning approximately 15km north to south and 10km east to west, requires a region-wide assessment of the potential risks to water quality. The area has a range of irrigated and non-irrigated agricultural businesses including macadamias, lychees, cropping (both irrigated and dryland) and grazing.

Figure 1: South Yaamba precinct



1.3 Precinct plan overview

The South Yaamba Precinct Reef Water Quality Plan provides an overarching plan incorporating upwards of eight (8) individual Farm Plans and sub-catchment scale actions that deliver complementary cross-farm or catchment scale nutrient, pesticide and sediment control measures.

The South Yaamba Precinct Plan considers:

- landholders' growth aspirations in line with agricultural irrigation (including cropping, horticulture and intensive livestock operations); and
- current landholder practices to reduce sediment, pesticide and nutrient runoff.

The South Yaamba Reef Water Quality precinct plan:

- Includes an analysis of the South Yaamba area, including a description of natural features, contours, agricultural developments and infrastructure.
- Reviews previous investigations completed such as Agronomic Assessments, Agricultural Development Reports or Business Plans.
- Reviews soil type/s of the landholders' land including reviewing the Rookwood Weir Soil Suitability Tool, relevant maps, previous soil tests etc…
- Includes nutrient and sediment control measures, drainage structures and measures in place to minimise loss of irrigation water in line with the RWLMCoP and the RR.
- Includes potential sediment and nutrients reduced or nullified if practices are implemented.
- Provides a guide of record keeping requirements in line with the RWLMCoP and the RR.

The South Yaamba Reef Water Quality Precinct Plan incorporates:

1. A ***Reef Water Quality report*** outlining
    a. Land management change requirements.
    b. Barriers.
    c. Relative implications.
    d. Current monitoring.
    e. Evaluation of enterprise-wide change required.
    f. Pilot precinct base change mapping and impact review.
2. ***A Model for Practice Change*** forming a conceptual model of the pilot precinct which has:
    a. Strong partner engagement / ownership.
    b. Clear capacity building framework and implementation strategy for the precinct and broader farm planning.
3. ***The South Yaamba Precinct Water Quality Model*** that includes:
    a. Evaluation of existing data sources and gap analysis.
    b. Collective monitoring plan objectives.
    c. Collaborative monitoring data sources.
    d. Strategy for implementation of the precinct plan.

The plan is intended to be consistent with the Rookwood Weir Land Management Code of Practice (RWLMCoP) (Appendix 5) and the Reef Regulations (RR) (Appendix 6) by applying quantitative modelling to:

- Establish standard Land Management Practices for a range of crop types.
- Meet the sediment, nutrient and pesticide targets of the Reef 2050 Long-Term Sustainability Plan ("Reef 2050 Plan") and the Reef WQIP.
- Ensure water quality objectives are achieved through the implementation of land and water management practices such as fertiliser application rates based on soil testing.
- Establish mechanisms for ongoing compliance with the Code by water purchasers.
- Establish mechanisms for the effectiveness of the Code with respect to achieving and maintaining water quality objectives.

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- Mitigate of any risks that may lead to either export of nutrients (especially N &P) or fine sediment to the Great Barrier Reef.

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2. Overview of the South Yaamba Precinct

2.1 Natural features

The precinct is crossed by numerous paleochannels that today support high ecological significance wetlands. The location of these wetlands, concentrated in the north-east quarter of the precinct, is illustrated in Figure 2. Irrigated cropping development should not adversely impact these wetlands, either directly or indirectly. In general, any cropping development should not occur within 100m of a wetland.

Figure 2: MSES high ecological significance wetlands



2.2 Soil types

Soil type distribution is illustrated in Figure 3.

The north-east corner within a large bend in the Fitzroy River and a small area in the north-west is comprised of Tenosols, and described as Deep sandy soils overlying recent alluvium.

A band of soils running north-west to south-east adjoin the Tenosols is comprised of a mixture of Chromosomes, descried as sand or loam over friable or earthy clay; and Dermosols, descried as friable non-cracking clay or clay loam soils.

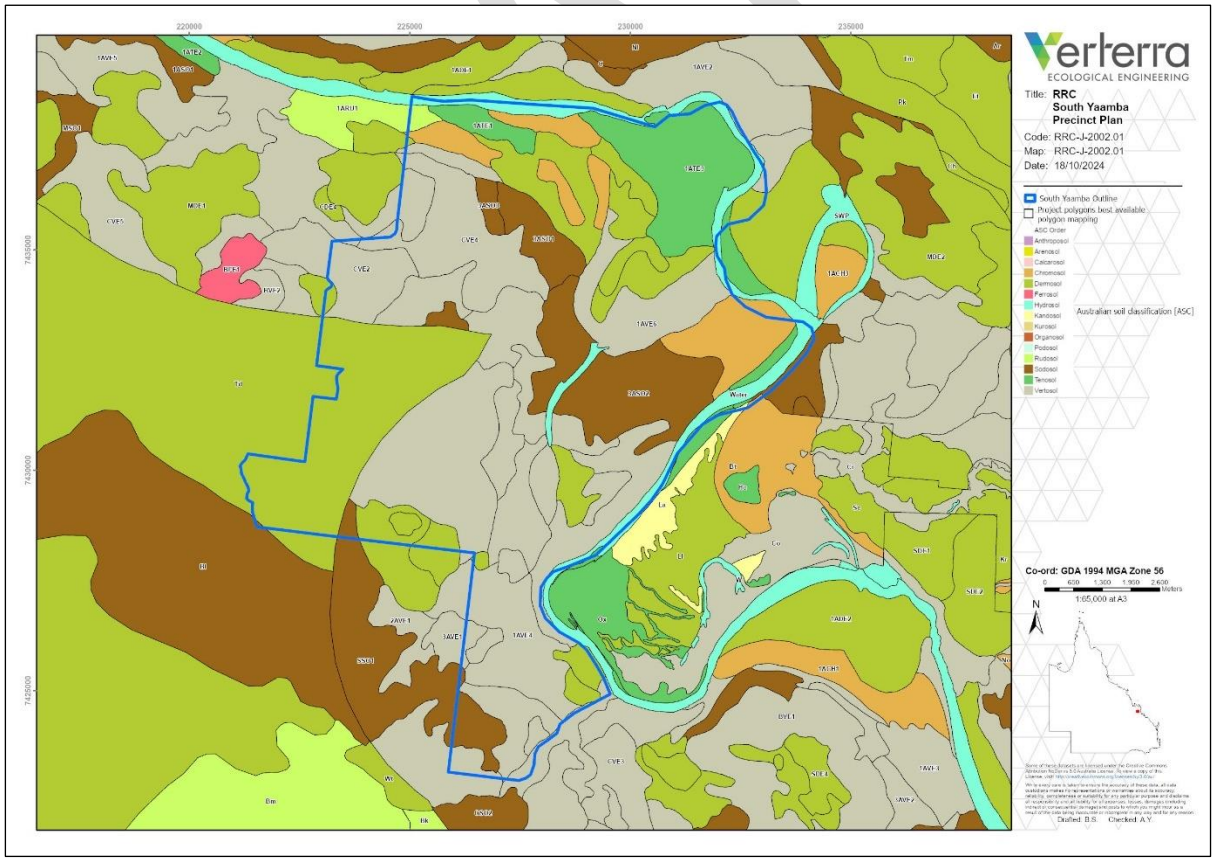
Generally, further from the river, the majority of the precinct is comprised of Sodosols, described as sand or loam over sodic clay; and Vertosols, described as cracking clay soils.

A significant area on the central west boundary of the precinct Is again comprised of Dermosols.

Of these soil types:

- The Vertosols are potentially the favoured soils for cropping where well drained, but unsuitable where they are subject to waterlogging, or for horticultural tree crops where shrink-swell cracking clay characteristics, potentially leading to root shear, are excessive;
- The Dermosols and Chromosols will likely be better drained than the Vertosols, and have lower water holding capacity, but are likely to be suitable for both cropping and horticultural tree crops subject to depth and chemical characteristics.
- The Tenosols are deep sandy soils overlying recent alluvium. These will likely be highly influenced by flood and deposition events. They can be expected to have lower water and nutrient holding capacity than the Vertosols, Dermosols and Chromosols, but are potentially suitable for a wide range of crops subject to flooding. They may require careful irrigation management to maintain soil moisture and prevent nutrient leaching.
- The Sodosols are likely the poorest soils in the precinct and will require careful management to avoid exposure of the sodic subsoil to erosion. Some areas of these soils are presently cultivated, indicating they can be cropped with careful management, but may require additional inputs to compensate for the poor sub-soil conditions.

Figure 3: Soil type distribution



2.3 Land Capability

Land suitability maps for a range of crops are illustrated in the following diagrams. Only a relatively small proportion of the precinct is classified under the "Land suitability for irrigated agriculture along the Fitzroy River" mapping (Queensland Government, 2020) as suitable for cropping development. The primary limitations are listed below with reference to soil types:

Tenosols:

- Classed as unsuitable for most crops due to frequently flooding (>1 in 5 years).

Chromosols:

- Suitable for crops such as:
    - Class 3: Citrus, grapes, lychee, macadamia, mango, pecan and vegetables;
- Unsuitable for a range of crops such as:
    - Chickpea, cotton, sorghum, lucerne, mungbean, navy bean, peanut, sesame, soybean and wheat, generally due to topographic complexity, undulating and dissected alluvial land.

Dermosols:

- Suitable for a wide range of spray irrigated crops such as:
    - Class 2: Citrus, grapes, lychee, macadamia, mango, pecan
    - Class 3: Chickpea, sorghum, lucerne, mungbean, navy bean, peanut, sesame, soybean, vegetables and wheat
- Unsuitable for furrow irrigated crops Topographic complexity, undulating and dissected alluvial land

Vertosols:

- In most locations, unsuitable for all crops due to wetness
- In the central western region of the precinct, suitable for all crops other than peanuts due to soil adhesiveness.

Figure 4, Figure 5 and Figure 6 are examples of irrigated cropping and horticultural mapping undertaken to indicate the suitability of land in the South Yaamba precinct for potential agricultural development. Note that examples are taken for sorghum, wheat and macadamias which have been selected as respective indicators for irrigated cropping and horticultural mapping.

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Figure 4: Land suitability for Sorghum under spray irrigation

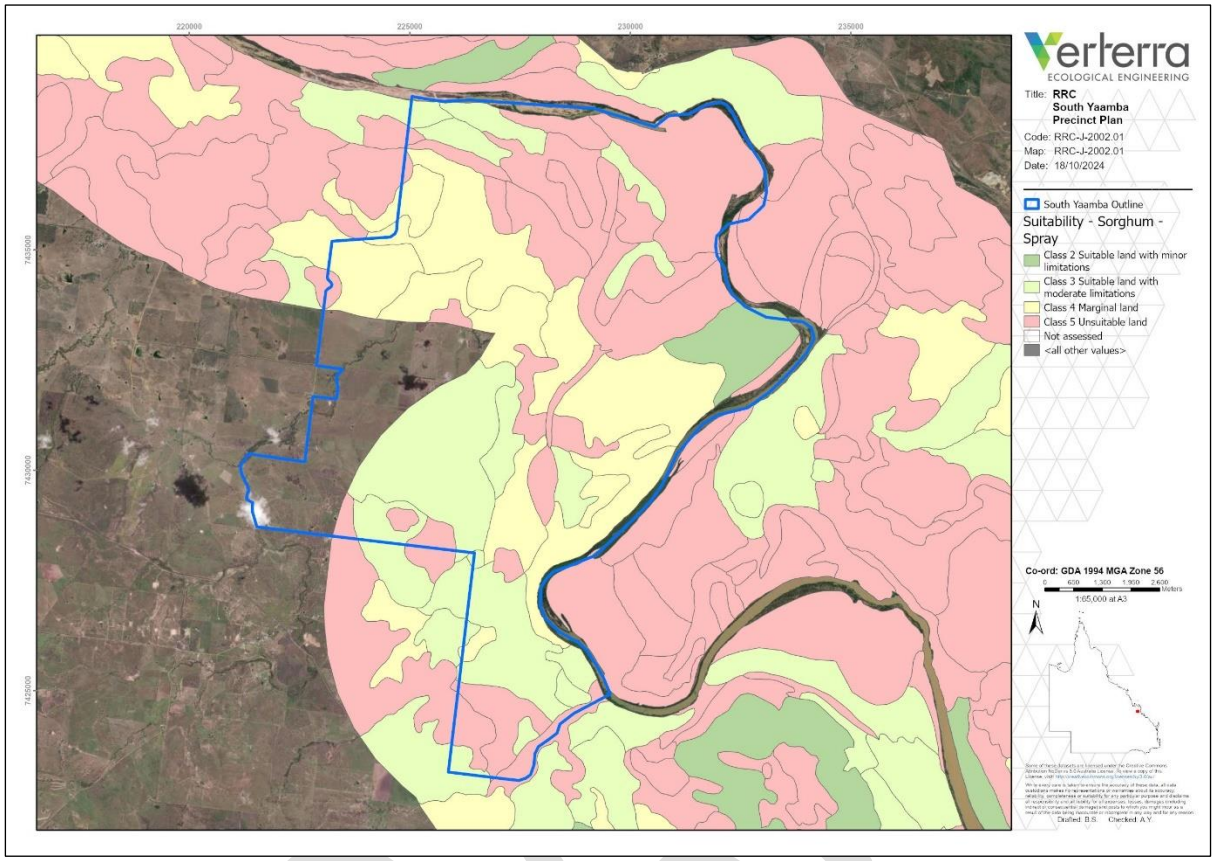


Figure 5: Land suitability for Wheat under spray irrigation

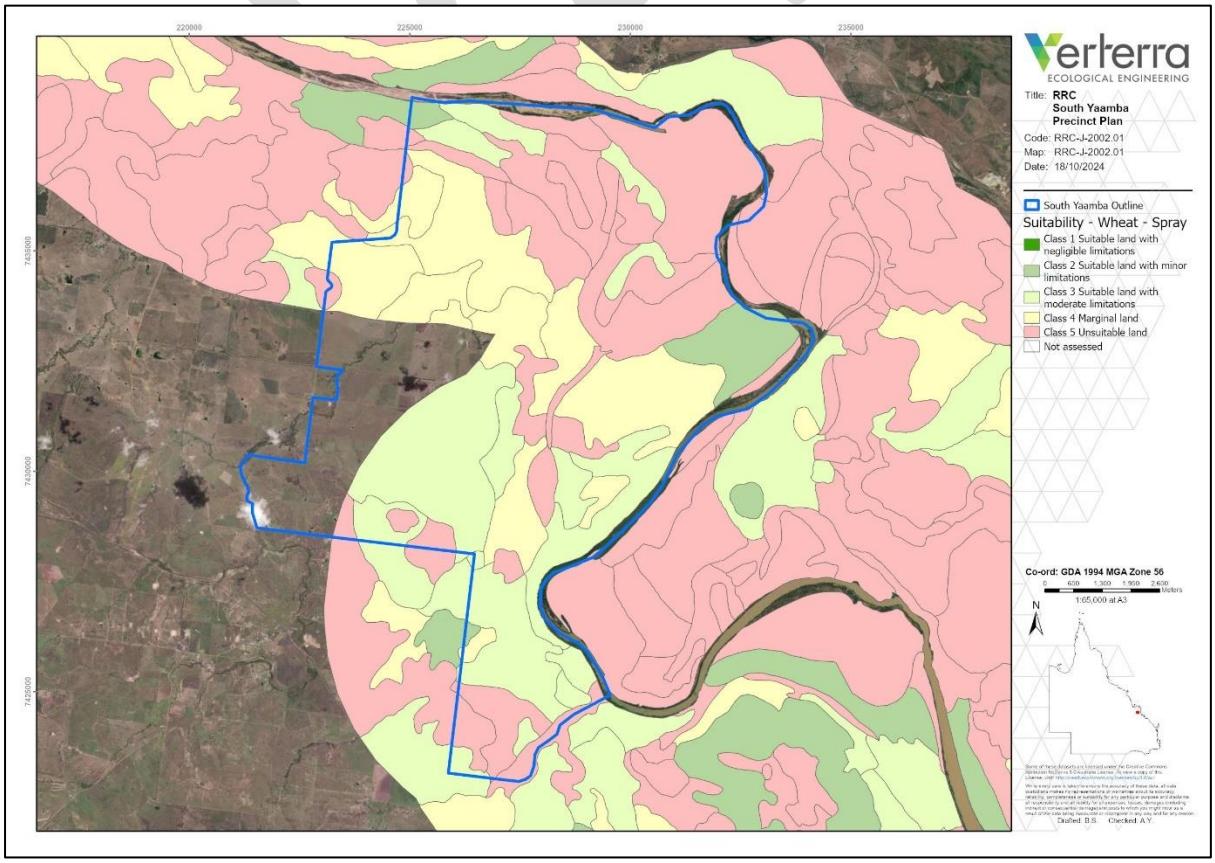
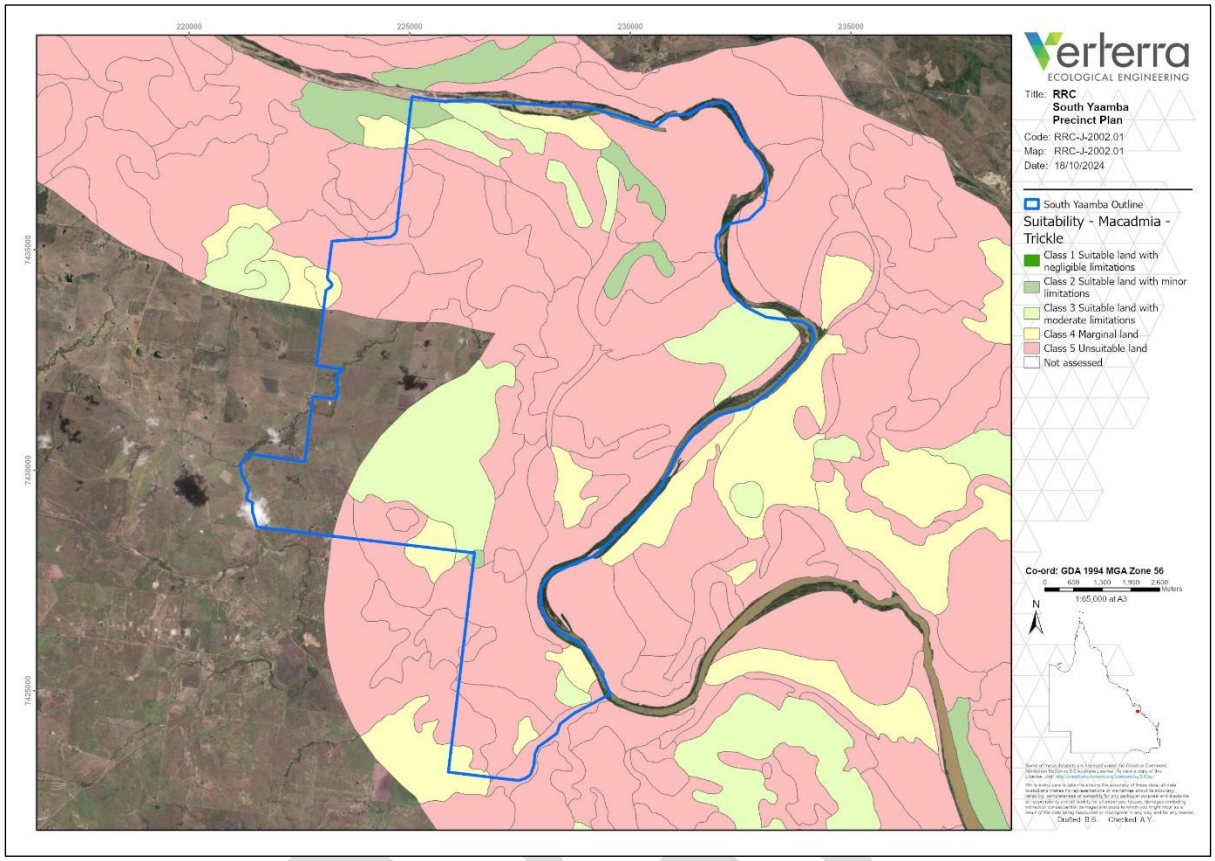


Figure 6: Land suitability for Macadamia under trickle irrigation



2.4 Topography

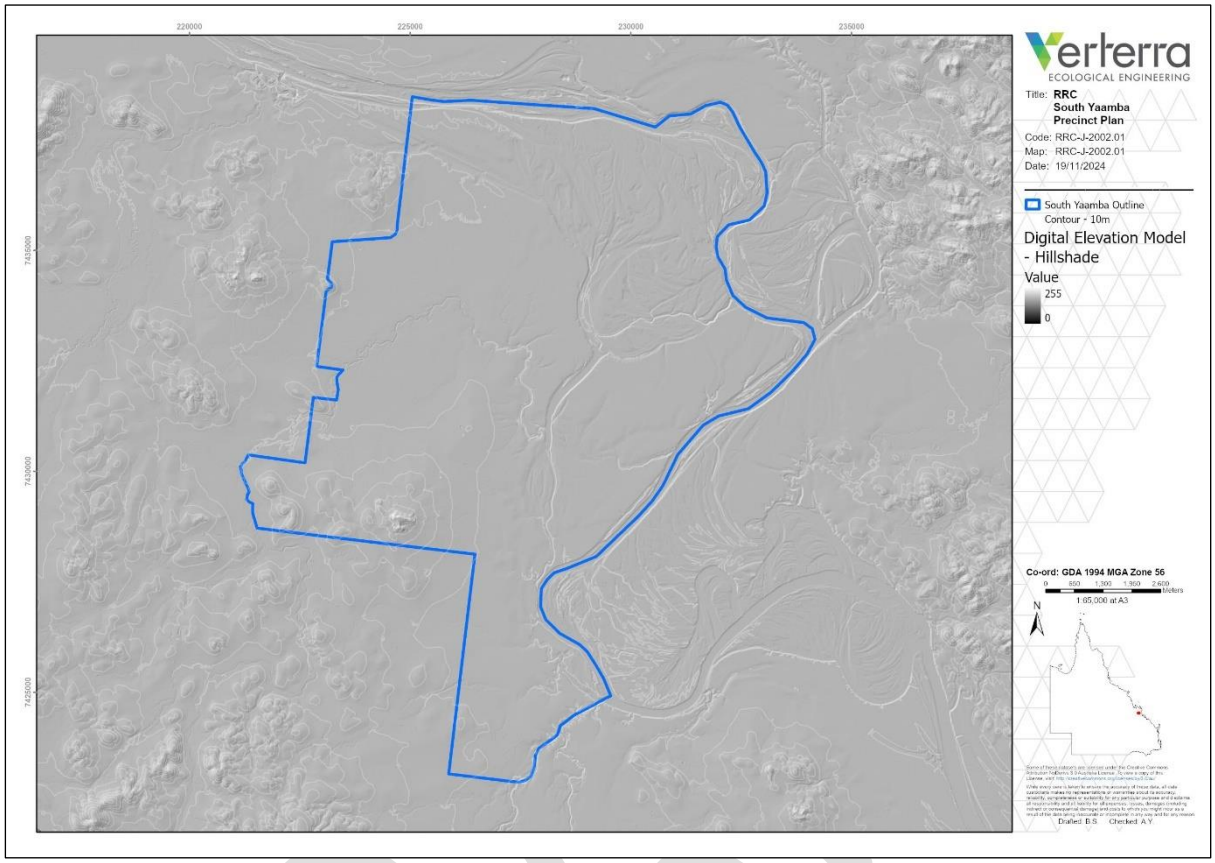
The precinct is generally level, falling from an average elevation of around 20m near the western boundary to around 14m elevation along the upper bank of the Fitzroy River on its northern and eastern boundary. This fall over an approximate distance of 5.3km equates to less the 0.12%. the only exception is a series of small peaks in the south-west corner of the precinct, the steepest of which rises in a conical peak to an elevation of 107m.

Figure 7: Precinct topography



Despite the relatively flat terrain, the hillshade image for the precinct (Figure 8) indicates significant topographic complexity in the north-east corner and eastern side consistent with river meanders and paleochannels. These paleochannels may represent areas of preferential recharge from irrigated agriculture, potentially increasing local salinity risk (refer Section 7), but they may also provide preferential flow paths for drainage, increasing the rate of discharge and reducing salinity risk. The high level topographic complexity can be expected to be reflected in soil type variability, which in turn, may be reflected in agronomic variability. Accordingly, irrigated agriculture would be best to avoid these areas, or at least ensure detailed soil characterisation.

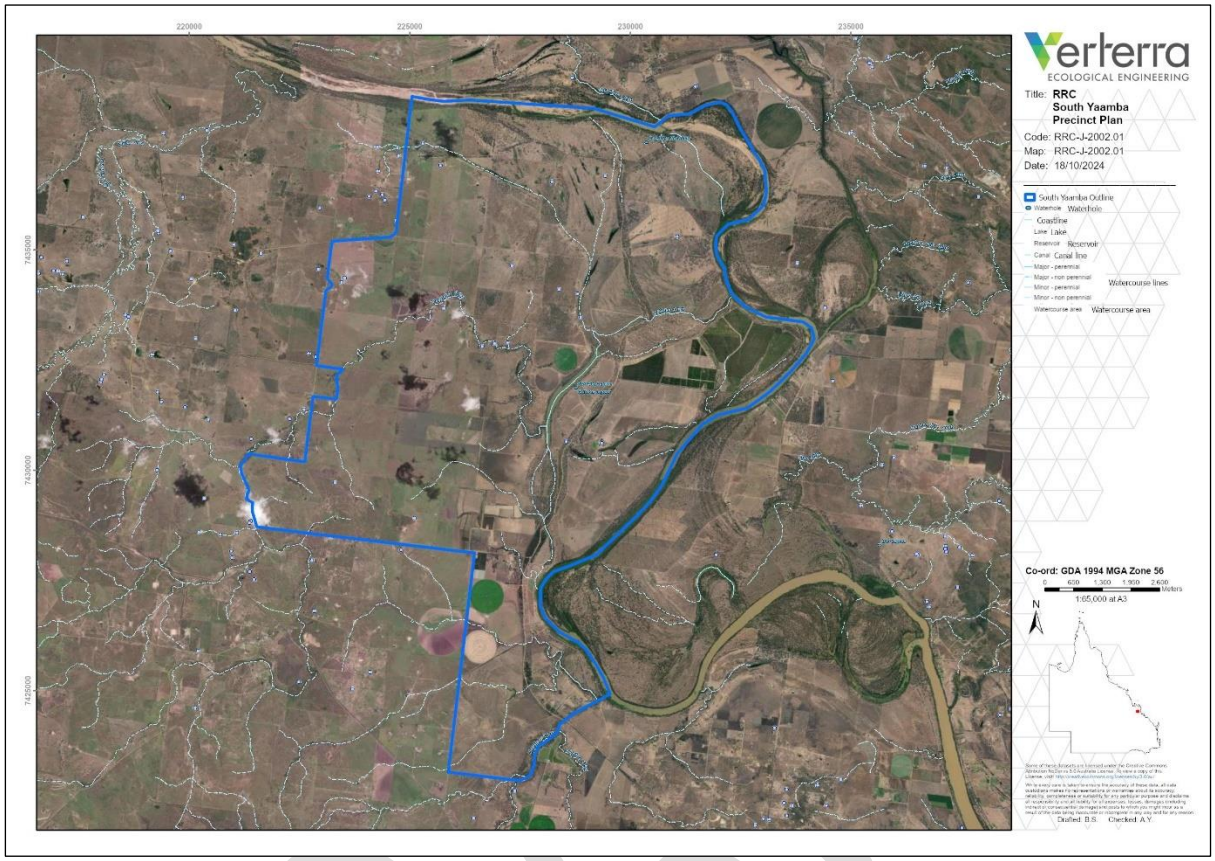
Figure 8: Topographic complexity



2.5 Drainage

Drainage lines across the Precinct are illustrated in Figure 9. Reflecting the flat topography, the watercourse are largely minor perennial streams. Ridgeands Creek drains a large area to the south-west of the precinct into a series of interconnected streams within the precinct, including De Burgh Creek, which drains between two points of the Fitzroy River via a 2.5km section of perennial watercourse. A buffer of at least 50m should be maintained around watercourses to prevent offsite movement of sediment, nutrients and pesticides.

Figure 9: Drainage



2.6 Flood risk

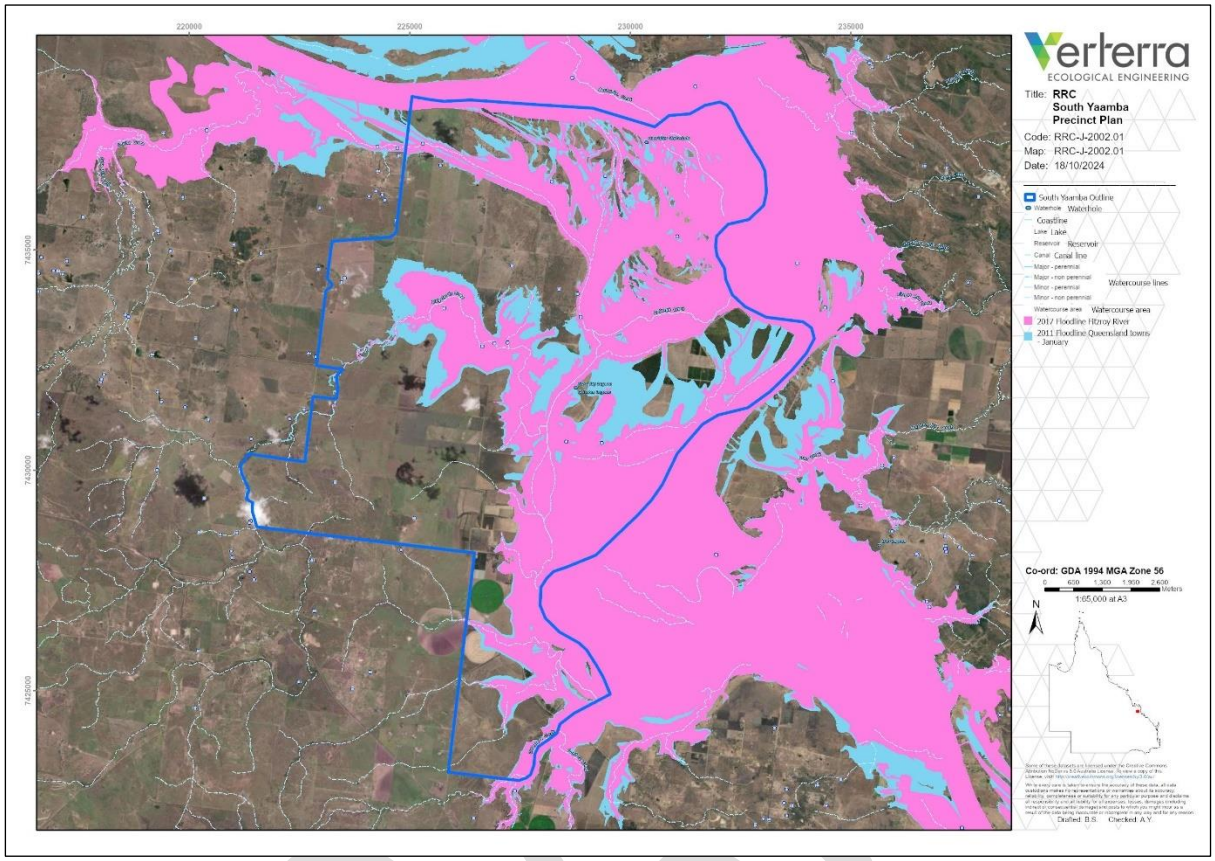
Flood levels from historic floods are illustrated in Figure 10. This indicates that the majority of the eastern half of the precinct is at risk of flooding.

Floods pose a number of risks:

- Loss of production, particularly if crops are damaged by fast flowing waters, or soils remain waterlogged for an extended period
- Pollution of surface waters with sediment, nutrients and pesticides lost by erosion and overland flow
- The risk of damage to physical irrigation infrastructure including pumps and centre pivots.

Flood risk should be fully reviewed prior to investment in any irrigation development, the risks fully considered and the appropriate steps taken to mitigates risks for both the cropping enterprise and the environment.

Figure 10: Historic flood risk



2.7 Existing agricultural developments

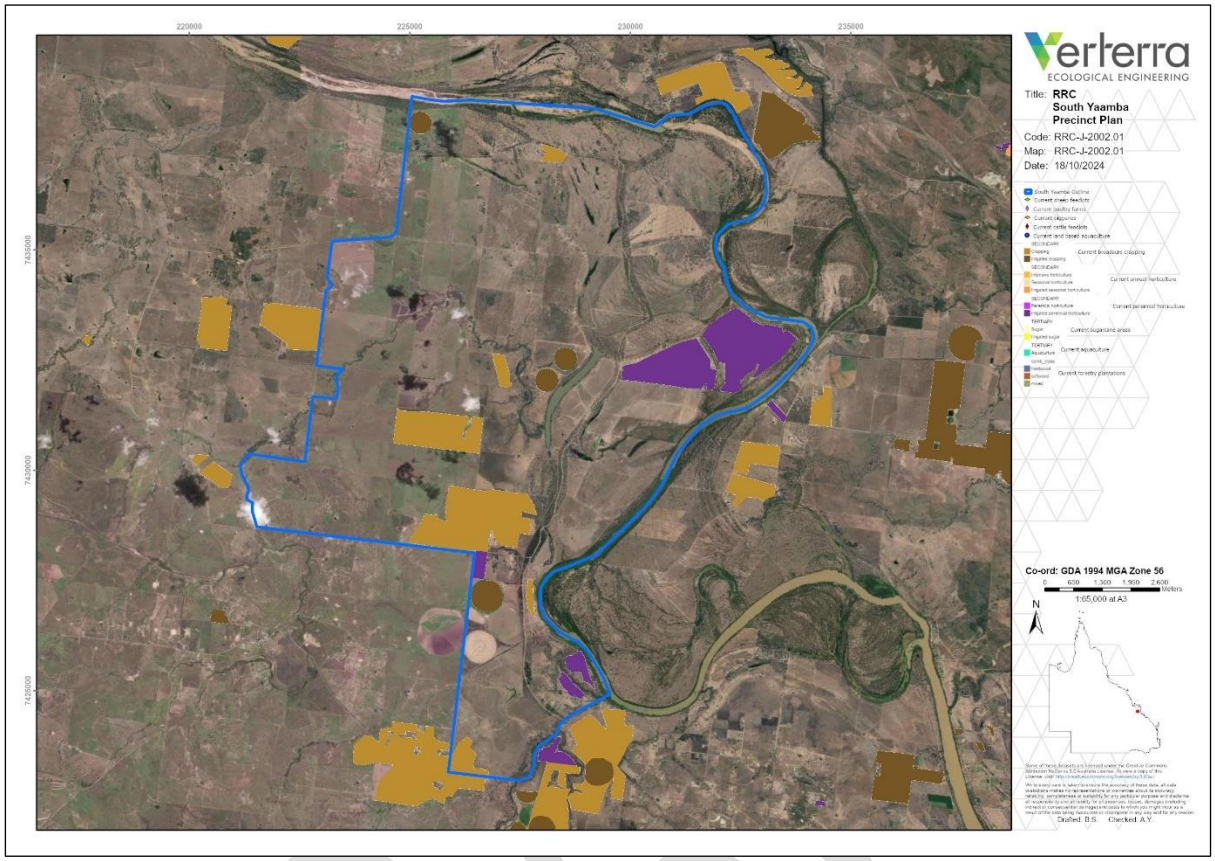
The majority of the precinct is presently grazing land with limited areas developed for:

- dryland broadacre farming (light brown);
- irrigated cropping, principally using centre pivot irrigators (dark brown); and
- intensive tree crop horticulture (purple area).

The most intensively developed areas are in the central and south-east adjacent the Fitzroy River, with a small area of pivot irrigated cropping in the north-west, also adjacent the river (Figure 3).

Conversion from predominantly grazing land to irrigated cropping and horticulture is expected to have a net impact on water quality as permanent pasture cover is periodically disturbed for initial (tree crops) or annual cultivation and is managed under a more intensive fertiliser regime. Impacts from cropping and horticultural development are discussed in more detail in Section 4, 5 and 7. These impacts will need to be offset by a combination of best practice management, direct mitigation measures and offsets by improved grazing practice on undeveloped lands. Control measures are discussed in more detail in Section 8.

Figure 11: Current agricultural activity



2.8 Protected vegetation

2.8.1 Remnant vegetation

The Precinct incorporates a relatively small area of protected vegetation, located principally along the Fitzroy River, drainage lines and anabranches. The dominant vegetation type is a mixture of the following communities:

- 11.3.3 - *Eucalyptus coolabah* woodland on alluvial plains
- 11.3.4 - *Eucalyptus tereticornis* and/or Eucalyptus spp. woodland on alluvial plains
- 11.3.2 - *Eucalyptus populnea* woodland on alluvial plains

These communities are classified as “Of concern”, representing medium protection status.

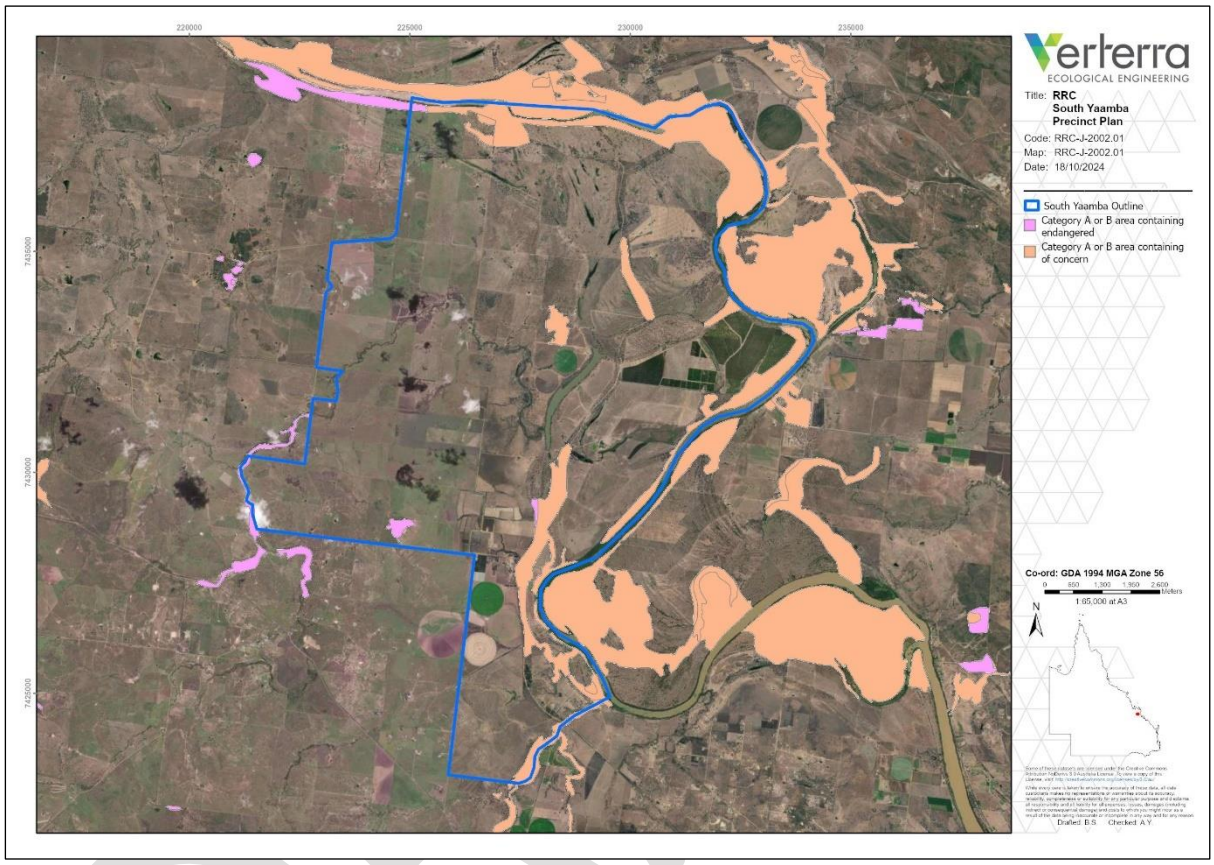
Smaller remnants of the following remnant vegetation also occur throughout the precinct:

- 11.3.1- *Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains
- 11.12.3 - *Eucalyptus crebra*, *E. tereticornis*, *Angophora leiocarpa* woodland on igneous rocks especially granite
- 11.12.21 - *Acacia harpophylla* open forest on igneous rocks. Colluvial lower slopes

The *Eucalyptus crebra* community is classified as “Of concern”.

The *Acacia harpophylla* communities, one occurring on alluvial plans in the south-east of the precinct, and the other on hilltops in the south-west, are both classified as "Endangered" representing the highest level of protection status.

Figure 12: Protected vegetation



2.8.2 Regulated vegetation

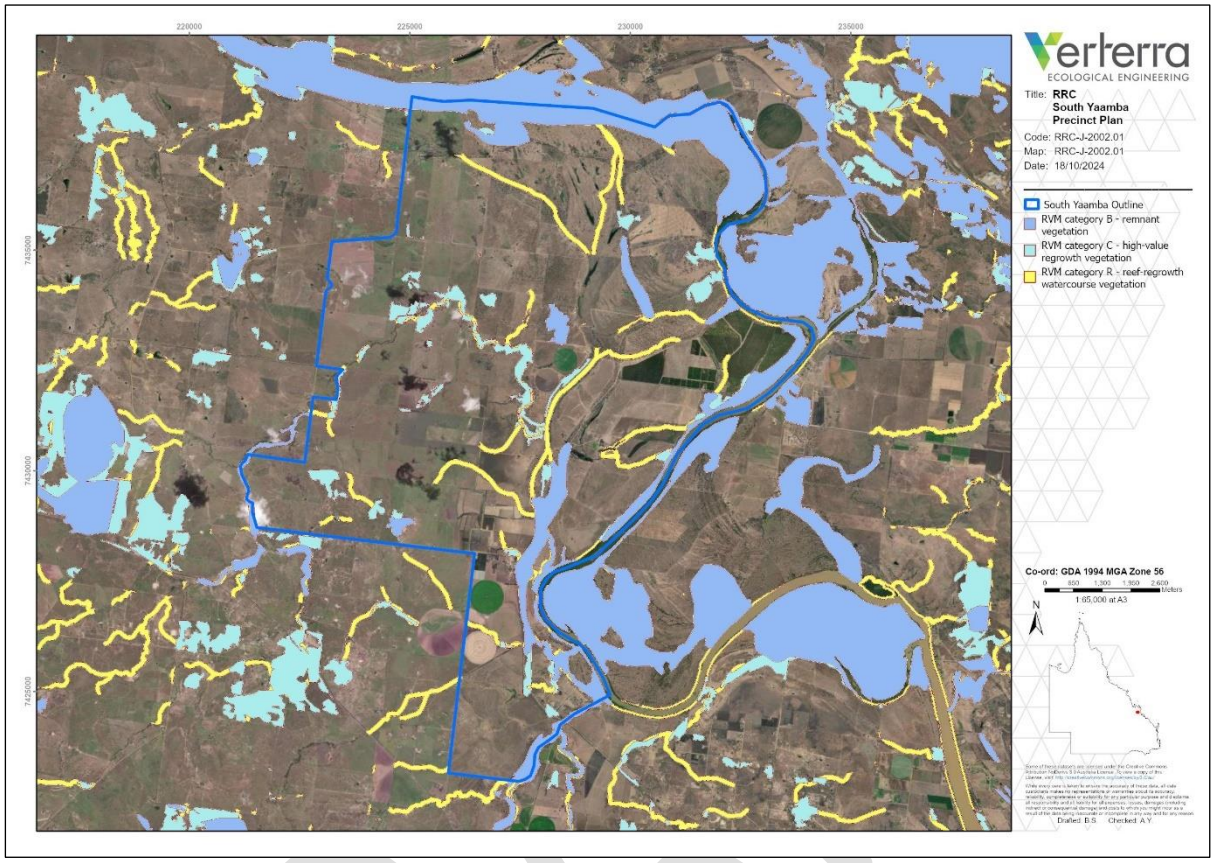
Regulated vegetation differs significantly to remnant vegetation and is illustrated in Figure 13.

Much of the remnant Eucalypt forests on alluvial plains are Category B protected vegetation (dark blue). A number of drainage lines internal to the precinct and at a distance from the river are Category C high value regrowth (light blue), and other drainage lines are Category R (reef-regrowth watercourse vegetation).

It should be noted that nil or light vegetation may occur in areas mapped as regulated vegetation, and that clearing of these vegetation categories other than for essential fixed infrastructure will require development approval.

Notwithstanding, there is limited overlap between areas suitable for cropping development and vegetated areas of any category, so this should not present a constraint, other than ensuring irrigated areas do not adversely impact protected vegetation directly or indirectly.

Figure 13: Regulated vegetation



2.9 Wildlife habitat

2.9.1 Essential habitat

Areas of State defined essential habitat within the precinct are illustrated in Figure 14. All essential habitat areas are located along the Fitzroy River. These areas all correspond to areas of riverine vegetation, or vegetation along waterways and do not overlap with areas suitable for irrigated crop development. Notwithstanding, cropping development should not adversely impact essential habitat areas, either directly or indirectly.

Figure 14: Essential habitat

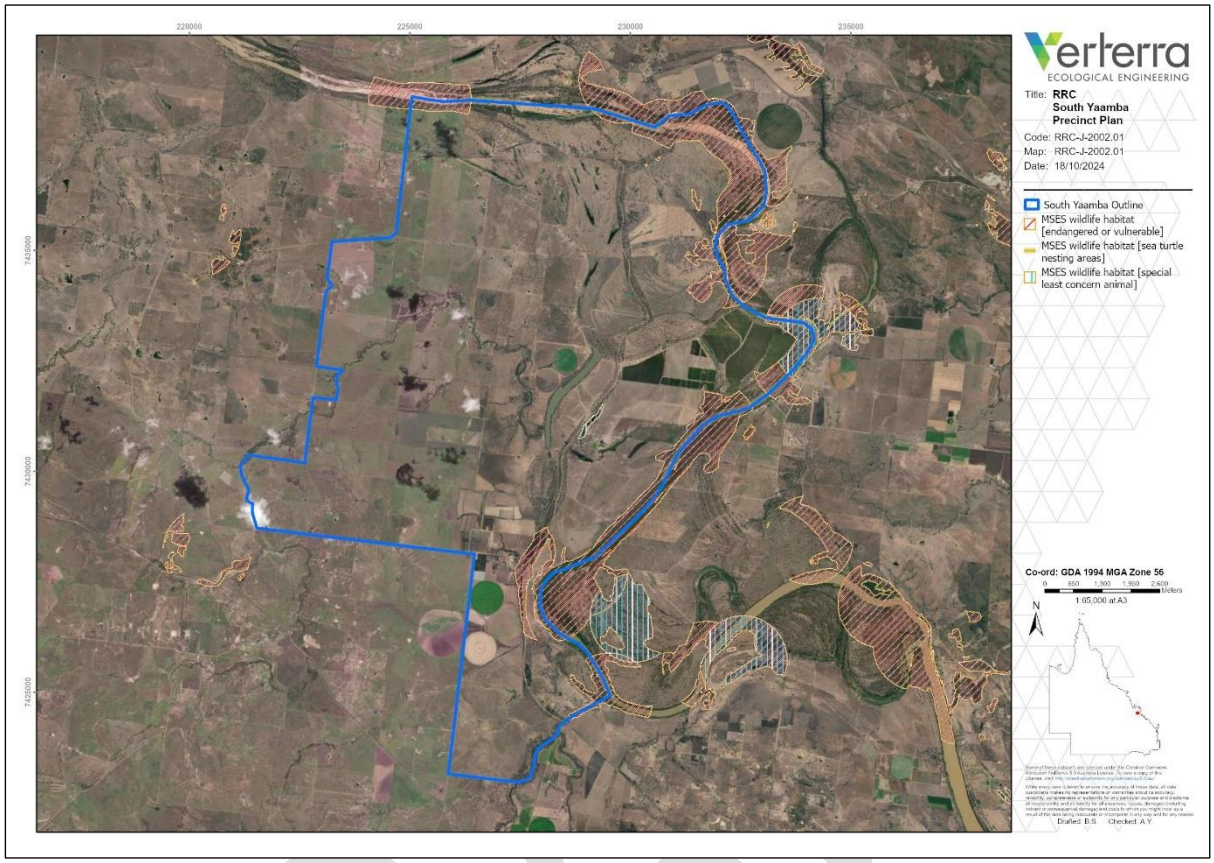


2.9.2 MSES wildlife habitat

Areas of Federally defined MSES wildlife habitat within the precinct are illustrated in Figure 15 Essential habitat. Areas of MSES wildlife habitat correlate closely with areas of essential habitat, but vary in some details, including an area of least concern in the central east of the precinct.

MSES wildlife habitat fall into two categories: “endangered or vulnerable”; and “special least concern animal”. The majority is “endangered of vulnerable”. As for essential habitat, new cropping developments should not adversely impact MSES wildlife habitat areas, either directly or indirectly.

Figure 15: MSES wildlife habitat

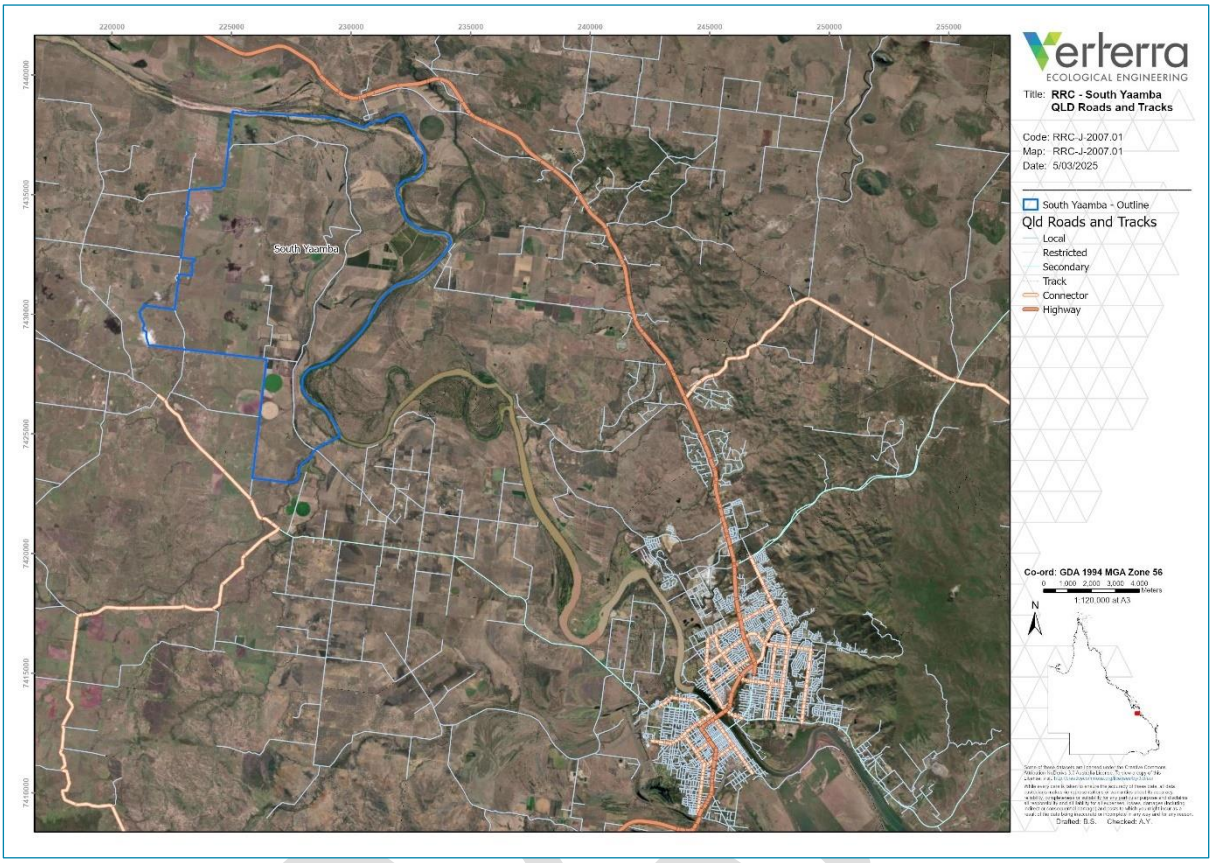


2.10 Infrastructure

Ridgelands Road, a State controlled road provides access from the city of Rockhampton, and passes to the south of the precinct (Figure 16).

Access within the precinct is serviced by unsealed roads. South Yaamba Road provides the major access into the precinct after leaving Ridgelands Road, and joins on the western boundary with Calmorin Road which loops back Ridgelands Road. The centre of the precinct is around 30km by road from the centre of Rockhampton.

Figure 16: Infrastructure



2.11 Potentially developable area

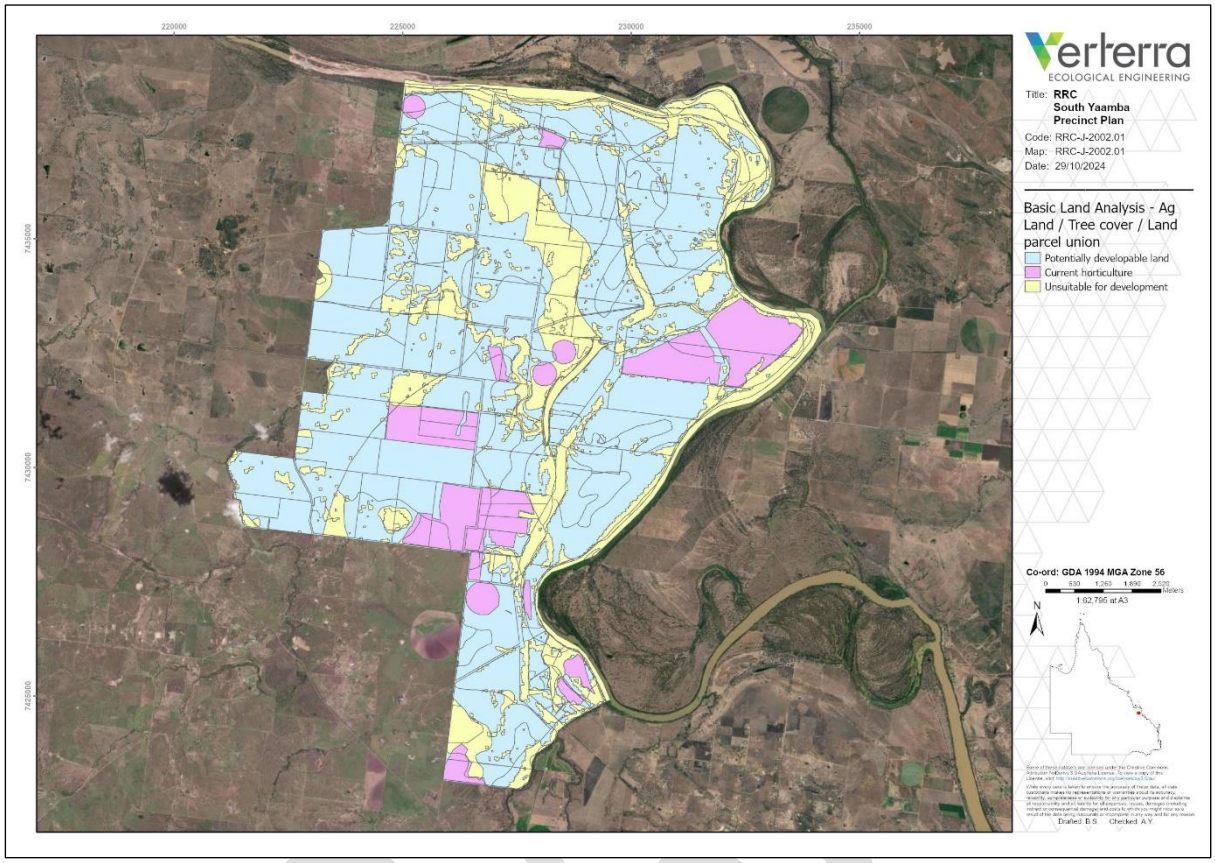
Notwithstanding the limited areas identified for as suitable for specific crops illustrated in 2.3, Figure 4 (Sorghum); Figure 5 (Wheat) and Figure 6 (Macadamia), the potentially developable area based on agricultural land classification is illustrated in Figure 17.

Areas identified in Figure 17 as potentially developable aggregate:

- Class A agricultural land;
- Class B agricultural land; and
- Class C1 grazing land.

Land identified as Class C2 or C3 grazing land have been considered as not suitable for potential irrigation development.

Figure 17: Potentially developable area based on agricultural land classification



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3. Landholder practices and aspirations

3.1 Landholders' growth aspirations in line with agricultural irrigation

Sunwater has received 21 applications for development of irrigation farm plans across the Fitzroy Food Bowl, including 8 within the precinct, totalling 4950 ML/yr to be applied to 708 ha of new irrigation area, representing an average of 7ML/ha/yr. The proposed irrigation area per property ranges from a minimum of 20ha (for sorghum, Oats, Rhodes grass and Cotton) to 350ha (for Macadamias).

The purposes for new irrigation include:

- New irrigated cropping on previously uncropped land.
- New irrigated cropping to augment existing dryland cropping.
- New irrigated cropping to substitute water sources for existing irrigated cropping.
- New irrigated cropping to expand existing irrigated cropping

Proposed crop types vary significantly and include:

- Sorghum
- Rhodes
- Wheat
- Mung bean
- Lychees
- Oats
- Cotton
- Macadamia
- Chickpeas
- Lucerne
- Rye
- Sesame
- Kalongi

Farmers new to cropping are typically aiming to produce irrigated pasture and forage crops such as rhodes grass, sorghum, lucerne and pulses to supplement livestock operations.

Existing dryland cropping farmers are generally planning to continue production of the same crops under irrigation, generally pasture and forage crops, with one exception aiming to produce a high-value seed crop.

Existing irrigation farmers substituting the new water for existing allocations on the same crops, are producing a mix of hay, cotton and intensive horticultural tree crops.

Farmers expanding the area under irrigation are irrigating more of the same crop and, in some cases producing new crops. These includes pasture, forage, cotton, intensive seasonal and perennial (tree) horticultural crops.

3.2 Current and proposed agricultural management practices and opportunities / constraints

All farmers were surveyed to understand management practices related to:

- Soil Management.
- Nutrient Management.

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- Chemical Management.
- Irrigation scheduling.

The list of survey questions and their alignment to the Rookwood Weir Land Management Code of Practice is presented in Appendix 1.

Responses varied greatly across landholders based on both variation between crop management requirements and experience with cropping.

At one end of the scale, landowners new to irrigated cropping required new equipment, had no historic soil or fertiliser use data, were receptive to use of monitoring equipment such as soil moisture probes and expressed the need to engage an agronomist to help with all aspects of cropping and irrigation management

At the other end are landowners highly experienced with irrigated cropping who manage their production in a nuanced way, with detailed soil testing matching nutrients to requirements, judicious use of fertiliser, an integrated approach to pest management, and active use of monitoring equipment such as soil moisture sensors with remote automation.

In between, landowners used prescriptive practices and relied heavily on agronomist advice.

Responses to management practices are summarised below. All landholders expressed an intent to comply with the Rookwood Weir Land Management Code of Practice, or at least, to transition to compliance within three years.

Soil management

- Tillage practices varied, and ranged from nil for tree crops, minimal till for cereal crops and infrequent periodic till at the time of refurbishment for pasture crops.
- Landholders generally recognised the need to manage compaction, with many landholders already equipped with GPS guidance, and others utilising wheel tracks with a plan to transition to GPS guidance.
- Erosion control requirements varied by property. A number of landholders have flat, laser levelled paddocks with contours and grassed waterways. Others plant tree crops on rows along the contour. Others have plans to begin installation of erosion controls with the aim of competing these within three years.

Nutrient management

- Most landowners undertook some level of soil sampling and analysis, though the comprehensiveness and frequency of this varied significantly.
- Many landowners relied on the advice of agronomists to determine fertiliser requirements.
- Some landowners used the same prescription each application (dominated by NPK), others tailored the prescription to soil results and considered micronutrients.
- At least one landowner included an organic fertiliser (poultry manure) in their mix, and another was engaged in nutrient management trials with Central Queensland University.
- Attitudes to the influence of stored soil moisture on yield and nitrogen fertiliser decisions varied significantly. Some farmers used precision tools and drip irrigation to get the most from their fertiliser. Some monitored soil moisture status visually. A number commented that they used to use soil moisture probes, but don't use them anymore. Other landowners expressed interest in investing in soil moisture probes.

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- Timing and practice of fertiliser applications varied in line with crop types. Applications ranged from small regular applications (up to 8 times per year) after cutting Rhodes hay, to GPS application to achieve precise fertiliser application rates.

Chemical Management

- Approach to chemical management varied widely from use of residual herbicides applied by boom spray to limited use of non-residual herbicides, to hand spaying with non-residuals only when necessary.
- To some extent, the range in herbicide use reflected different crop types, with more conservative herbicide use on tree and seed crops than cereal crops and pastures.
- Some landowners expressed a reluctance to use residual herbicides due to concerns with movement and soil health.
- Landowners generally had a conservative approach to pesticide management that included:
    - No use of pesticides (particularly for Rhodes hay crops).
    - Uses sacrificial (trap crop) of pigeon pea.
    - Integrated pest management approaches.
    - Use of natural pesticides (pyrethrum).
    - Targeted use of registered pesticides based on prevalent pests.
    - Selective use of pesticides based on pest occurrence thresholds.
    - Consideration given to efficacy and environmental risk, lower toxicity products selected when feasible.
    - Use per agronomist recommendations.

Irrigation scheduling

- Most landholders plan to use centre pivots for the ease of use, efficiency and ability to minimise runoff. Some landholders plan to use drip irrigation to achieve even greater efficiency and eliminate runoff.
- Landowners using pivots considered that runoff would be nil to minimal, and therefore no need to consider tailwater capture and reuse. Those using drip considered that there would be no runoff.
- Some landowners specifically expressed the need to efficiently manage irrigation practices to avoiding generation of run-off.
- Use and capacity of interpret soil moisture probes varied from farmers who have not used them, farmers who have probes but don't use them, to farmers that constantly monitor probes and use them to adjust watering.

3.3 Current landholder practices to reduce sediment, pesticide and nutrient runoff

In addition to the survey of management practices, landholders were also surveyed in relation to their current or proposed erosion and sediment control practices. The list of survey questions is presented in Appendix 2.

Similarly to the responses to agricultural management practices, responses to erosion and sediment control practices varied widely.

Responses to management practices are summarised below.

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Controlling runoff

- Erosion control structures in place across properties ranged from contour banks reporting to drains; whoa boys on tracks; to fully surveyed drainage designs incorporating contours, grassed waterways, grassed sediment basins, tree planning and clean and dirty water diversions.

Fallow management

- Fallow management included mulching the old crop and retaining it on top of the soil after harvest; avoiding bare paddocks during period of high rainfall risk, and leaving paddocks bare one month of the year at the point where the stubble breaks down and a new crop is planted.

In-field erosion control

- Landowners viewed contour banks as the primary in-field erosion control.

Roadway and headland maintenance

- Comments on roadway and headland maintenance were limited other than slopes are generally very low, and cattle are used for maintenance.

Flow concentration

- Comments on flow concentration are limited, other than diversion of overland flow into a lagoon that is used to then irrigate crops via pivots.

Sediment control

- Buffer zones for sediment control were the main control measure mentioned.

Drainage controls

- Most landowners failed to comment on drainage controls, however, one landowner in particular, has established grass swales and diversion banks. There is significant room for improvement in drainage control measures.

All landholders were receptive to establishing a range of erosion and sediment control practices, establish vegetated buffers, etc to meet code of practice and meet compliance requirements.

3.4 Landholder receptiveness to practice change aimed at improving productivity and environmental sustainability

All landholders are seeking to improve productivity and/or value, and recognise the requirements under the Code of Practice to improve environmental sustainability. All landholders that have water entitlements from Rookwood Weir will need to abide by the Rookwood Weir Land Management Code of Practice.

By definition, landholders new to cropping and or irrigated cropping are introducing new practices to their properties.

Landholders new to irrigated cropping expressed a strong willingness to learn more from others, and to seek support in all aspects of their proposed operations from suitably qualified agronomists.

Irrigated croppers using the new water to substitute for existing water sources are not changing their operation significantly. These croppers, and those using the new water to expand their irrigation

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operation, were receptive to adopting practice change measures to meet Code compliance requirements.

During site visits Verterra staff explained in detail the requirement to implement measures to improve productivity and sustainability and worked with croppers to understand their willingness and capability to implement such measures. After clear explanations and discussions about implementation, all croppers showed a willingness to adopt such measures to comply with requirements.

3.5 Compliance with the RWLMCoP

The Precinct Plan complements individual irrigation farm plans prepared in compliance with the Reef Regulations and the RWLMCoP, that specify practices and offset requirements to generate no net increase in sediment, nutrient or pesticide run off from their agricultural developments.

While the plans provide a solid foundation to meet compliance against the Code, achievement of the Code objectives will require implementation of new and expanded irrigation developments in accordance with farm plans; monitoring actual performance against forecast outcomes; and adaptive management for continuous improvement. In association, the capacity to successfully implement, monitor and adapt plans will require a considerable effort in capacity building among landholders. This will include, but is not restricted to:

- Development planning:
    - Characterisation of soil type variation to quantify variation in soil characteristics;
    - Use of soil maps to inform irrigation block design and/or variable rate irrigation;
    - Use of soil maps and paddock design to inform representative placement and installation of soil moisture monitoring probes.
- Irrigation monitoring infrastructure:
    - Selection and installation of soil moisture monitoring probes;
    - Selection and installation of weather stations linked to soil moisture probes to enable moisture probe interpretation for optimal irrigation management;
    - Selection and installation of flow meters on irrigation equipment enable irrigation planning informed by soil moisture probes.
- Agronomic practices:
    - Soil cultivation;
    - Sowing;
    - Weed and pest control;
    - Irrigation scheduling;
    - Harvesting;
    - Fallow management.
- Record keeping:
    - Irrigation applications;
    - Fertiliser use;
    - Pesticide use.
- Capacity building:
    - Interpretation of soil EM maps;
    - Interpretation of soil moisture probe data;
    - Interpretation of soil tests to optimise fertiliser application rates;

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    - Selection and use of minimum impact pesticides.
- Adaptative management
    - Annual EM surveys;
    - Soil sampling;
    - EM-soil correlation;
    - Capacity to interpret and integrate soil mounting data to track changes in soil properties over time and inform adaptive management.
- Offsets
    - Recognition of the need to adopt BMP on dryland outside irrigation development to offset residual impacts not addressed through irrigation BMP, and contribute to Reef 2050 targets.

Monitoring for Code compliance at the Precinct level will complement monitoring and compliance at the farm level, and will provide an integrated picture of performance across the entire precinct. The proposed approach will involve:

- Precinct wide monitoring and modelling of sediment export using satellite data and spatial analysis and modelling;
- Utilisation of a range of data pools available (satellite vegetation, cover, soil moisture probe data, distributed weather stations, farmer records for irrigation scheduling, fertiliser use and pesticide applications) to assess nutrient and pesticide compliance.

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4. Sediment and erosion risk modelling

4.1 Quantitative approach to erosion modelling

The RUSLE (Renard *et al*, 1991) provides a well-established method for estimating erosion form cropping land. Erosion was calculated using a modified form of the Revised Universal Soil Loss Equation (RUSLE) as:

$$A = R \times K \times RF \times LS \times C \times P$$

Where:

- A = Average annual soil loss (t/ha)
- R = Rainfall-runoff erosivity
- K = Soil erodibility
- RF = Rock (armouring) factor
- LS = Slope length and slope steepness (topographic factor)
- C = Cover management
- P = Practice control.

Verterra's, DROVER tool, incorporated in the application of the peer reviewed and approved Grazing Land Management Reef Credit method, provides an approach to spatial application of the RUSLE that enables:

- quantification of erosion and sediment loss under existing land management (both grazing and cropping);
- the change in erosion and sediment loss under changed practice (either changes to grazing practice or changed land use such as grazing to irrigated cropping); and
- scenario modelling of potential changes in erosion and sediment loss under changed practices and practice control measures.

DROVER uses the same rainfall (R), soil erodibility (K) and topographic data as the Queensland Government's *Source Catchment* modelling (Reefplan, 2023).

DROVER varies from the *Source Catchment* modelling by using a procedure known as Dynamic Reference Cover Modelling (DRCM) (Bastin *et al*, 2012) to adjust ground cover changes for seasonal influences. This enables a more accurate estimate of the change in erosion and sediment loss when land is converted from grazing to irrigated cropping by enabling seasonal variation in erosion and sediment loss to be removed from erosion and sediment loss attributed to the land use or practice change.

Applying DRCM using DROVER, minimally disturbed areas termed 'reference areas' are used to benchmark changes in groundcover through time. These areas can be thought of as a 'control' that are compared against areas where management changes have been implemented. The method assumes that within reference areas, changes in groundcover result predominately from the influence of weather and climate conditions rather than management activities or other disturbances. Calculating the difference in groundcover between the reference and project areas is therefore a measure of management impact on groundcover. In this way, the method is able to establish a baseline for business as usual, and measure (using Sentinel 2 satellite imagery) changes in erosion relative to this baseline resulting from changes in land management practices and activities.

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The final factor in the RUSLE, Practice control (P), relates to farm-scale works to reduce erosion (contour banks, strip cropping, sediment basins etc). These interventions are not addressed in the *Source Catchment* modelling (Reefplan, 2023) but can be included in DROVER modelling.

4.2 Approach to application of erosion modelling

Application of DROVER to the South Yaamba Precinct, has been used to determine the baseline erosion for each drainage sub-catchment (ensuring full coverage of the precinct) in order to:

1. Identify risk areas where baseline erosion and sediment export is highest;
2. Enable scenario analysis to investigate the potential effects of farm-scale management changes on erosion and sediment export; and
3. Provide a baseline to monitor and measure actual changes in erosion and sediment export.

Scenario modelling has been used to inform individual farm planning by providing guidance on management practices and regimes that meet the objectives of no-net increase (and ideally a net decrease) in sediment export from new or expanded irrigation developments by:

1. Varying the nature and timing of management practices to minimise increases in erosion and sediment loss from conversion of grazing or dryland cropping land to irrigated cropping;
2. Varying the nature and timing of management practices on existing irrigated land to minimise erosion and sediment loss from irrigated cropping activities;
3. Mitigating any net increases in erosion and sediment loss through the application of practice control measures such as sediment retention basins; and
4. For residual increases in erosion and sediment loss that cannot be reduced or mitigated, offsetting by changes in grazing practice on non-cropped land within the properties on which irrigation is practiced.

The capacity to apply the method to monitor and measure actual changes in erosion and sediment export over time will ensure powerful, quantitative feedback on the effectiveness of irrigation and cropping practices in achieving the objectives of Reef Regulations and the RWLMCoP and assist with ongoing stewardship to ensure the health of waterways and the Reef.

4.3 Procedure for estimation of erosion and sediment loss

To estimate precinct level erosion and sediment loss under varying scenarios, the following procedure was implemented:

1. The precinct was spatially stratified into “blocks” with each block representing a unique combination of:
    a. agricultural land classification (incorporating soil type and topography).
    b. current development status:
        i. developable (open grazing (C1), other);
        ii. developed (dryland cropping, horticulture, irrigated cropping);
        iii. non-agricultural (forest grazing, open grazing (C2 & C3), urban, water).

    The size of blocks varied greatly depending on the uniformity or variability at any particular location. A total of 19,884 blocks were delineated in this manner.

2. The RUSLE was applied using the DROVER tool to estimate the average baseline sediment export for each block over a period of seven years (2017 to 2024), and to aggregate this over the whole precinct, to explore five scenarios (detailed in Table 1) in relation to the effect of:
    a. Irrigation development for a specified crop;
    b. Over a specified proportion of the total precinct area;
    c. With a specified application of best management practice over the new irrigated crop area; and
    d. With management practice improvement over the balance of the precinct (including grazing land, cropping land and newly developed irrigation land if not already implementing best management practice).

The crop type, proportion of area developed to irrigation and proportion of developed area with best management practice applied, and proportion of the remaining area with management practice improvement are all definable values in the scenario analysis.

The assumed baseline vegetation cover achieved by each crop type (or double crop combination) without best management practice or management practice improvement, and change in cover with season is presented graphically in Appendix 4.

Sediment abatement relative to no best management practice or management practice improvement is also a definable value, but to reduce complexity in the scenario analysis, was assumed to be 30% for all scenarios.

Each scenario tested assumed all newly developed land was used to irrigate a single crop type. Different scenarios were run for different crop types. Again, this simplifying assumption was made to reduce the complexity and infinite number of combinations for multiple crop types. Notwithstanding, the analysis could be run to explore the effect of a set of specific planned crop types at specific locations throughout the precinct.

For each set of conditions within each scenario, a Monte-Carlo analysis was carried out using 100 random selections of the 1668 delineated blocks to meet the specified combination of criteria for each scenario. The results are presented in Section 4.4.

Table 1: Precinct erosion modelling scenarios (incremental changes each scenario shown in bold)

No.	Scenario
1	Baseline sediment export.
2	New development over: • a specified proportion of the precinct; • for a specified crop; with • **No best management practice on the newly developed areas.**
3	New development over: • a specified proportion of the precinct; • for a specified crop; with • **Best management practice on the newly developed areas.**

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No.	Scenario
4	New development over: • a specified proportion of the precinct; • for a specified crop; with • Best management practice on the newly developed areas; plus • **Practice change improvement on non-developed areas to achieve no net impact.**
5	New development over: • a specified proportion of the precinct; • for a specified crop; with • Best management practice on the newly developed areas; plus • Practice change improvement on non-developed areas to achieve no net impact; and • **Meet Reef 2050 WQIP anthropogenic sediment reduction target (30%).**

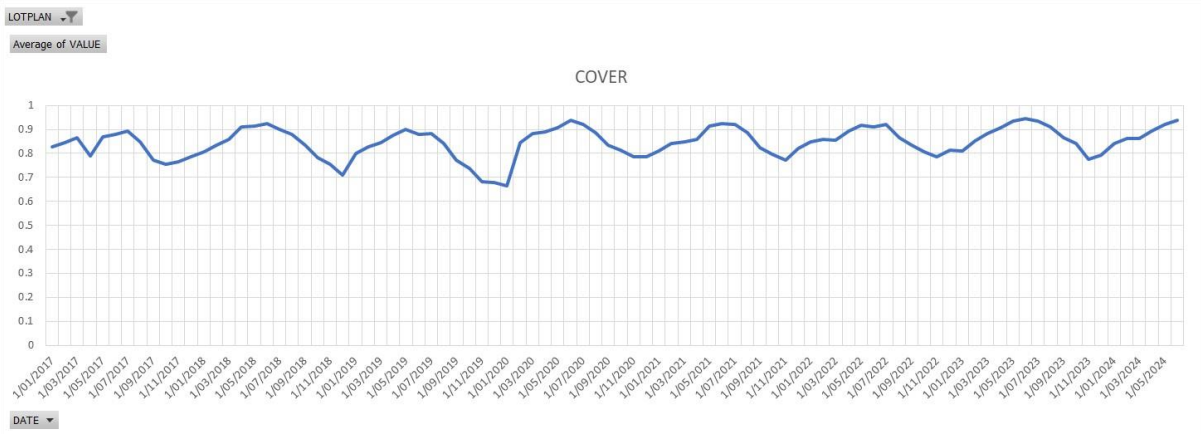
4.4 Erosion and sediment loss from irrigated development

4.4.1 Baseline fine sediment export

The baseline average monthly vegetation cover across the entire precinct is illustrated in Figure 18. The variation in rainfall intensity and monthly sediment export is illustrated in Figure 19.

It can be seen from Figure 18 that maximum average vegetation cover occurs each year in winter (May to June) and minimum vegetation cover occurs in late spring-early summer (October to December).

Figure 18: Seasonal baseline variation in average monthly vegetation cover for the precinct



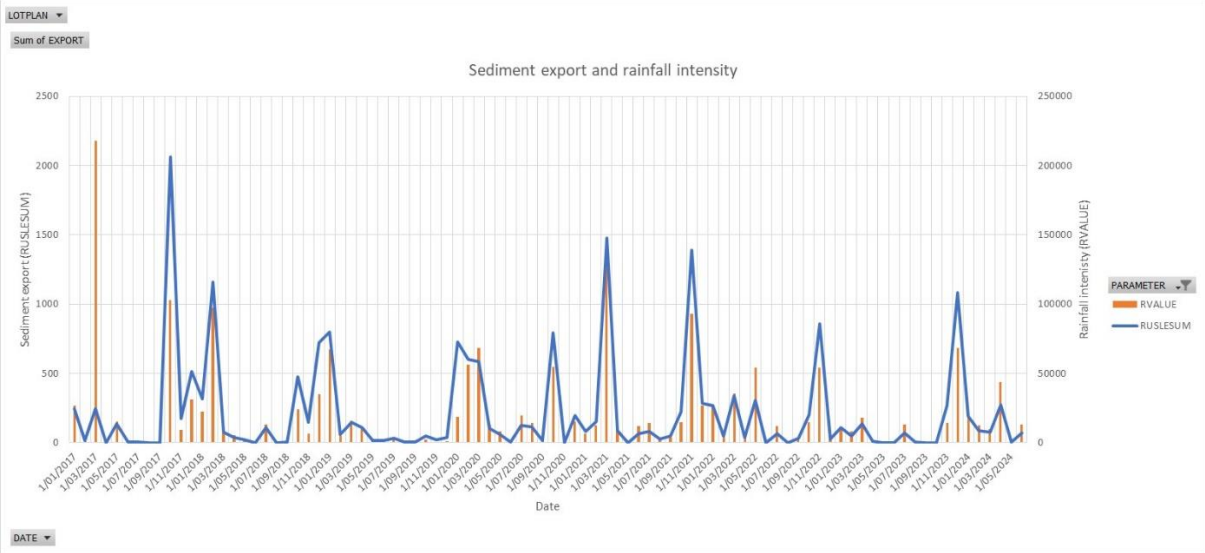
It can be seen from Figure 19 that sediment export events occur episodically and are generally associated with high rainfall events and low cover.

All sediment export events exceeding a total of 200 tons/month generally occur in the period October to March when rainfall intensity is high and cover is recovering from the annual low in October to

December. For the 7-year reference period, one high sediment export event in May 2022 is the exception, associated with a reasonably intense rainfall event.

Conversely, an extremely intense rainfall event in March 2017 did not result in a correspondingly high sediment loss, as cover was relatively high at the time.

Figure 19: Seasonal variation in baseline sediment export and rainfall intensity for the precinct



Presently, a large proportion of the precinct is grazing pastures, and the seasonal variation in cover and fine sediment export largely reflects the changes in pasture cover and grazing land vulnerability. An implication of changes in land use to seasonally irrigated crops will result in periods of the year when soil is bare and vulnerability to erosion is high. Management practices for irrigated crops, particularly seasonal crops, will need to aim to match fallow periods to periods of lower rainfall intensity to avoid significant increases in sediment export potential.

4.4.2 Scenario modelling for erosion impact of irrigated crop development

4.4.2.1 Scenario modelling assumptions

Modelling of sediment export to the Fitzroy River from the precinct was carried out for the baseline (existing) condition, plus irrigated development to thirteen different cropping practices under four management scenarios Table 1 as follows:

- ***Baseline:*** *Baseline sediment export* based on average sediment export over the past seven years;
- ***Scenario 1:*** Irrigated cropping *with no best practice mitigation measures applied*;
- ***Scenario 2:*** Irrigated cropping *with best practice mitigation measures applied*;
- ***Scenario 3:*** Irrigated cropping *with best practice mitigation measures applied*, and *management practice improvement on non-developed areas to achieve no net impact*; and
- ***Scenario 4:*** Irrigated cropping *with best practice mitigation measures applied*, and *management practice improvement on non-developed areas to meet the Reef 2050 WQIP anthropogenic sediment reduction target*.

Scenarios 1 to 4 all assume:

- Development to irrigated cropping of 5% of the potentially developable area (3,874ha);
- Effectiveness of best management interventions of 30% reduction in sediment export;
- Each crop type x management scenario assumes 100% of the area developed to irrigation is for the specified crop type (ie, multiple crops are not accommodated).

4.4.2.2 Baseline sediment export results

Modelled average baseline sediment export for the precinct to the Fitzroy River is estimated at 4166 tons/year. Assuming an average fine sediment proportion of 35%, fine sediment export to the river will be approximately 1458 tons/yr. Based on an average riverine sediment delivery ratio (RSDR) of 82%, fine sediment export to the Reef (assessed at the river mouth) is 1196 tons/yr.

The distribution of baseline sediment loss intensity is illustrated in

Figure 20. The results indicated that baseline sediment loss is generally low across most of the catchment, but is relatively higher in areas corresponding to:

- Steeper land in the south-west and wet of the precinct.
- Drainage lines in the central north of the precinct and some areas along the Fitzroy River in the east.
- Areas within an intensively developed horticultural tree crop farm in the central east of the precinct.

Figure 20: Scenario 1 - Baseline sediment export

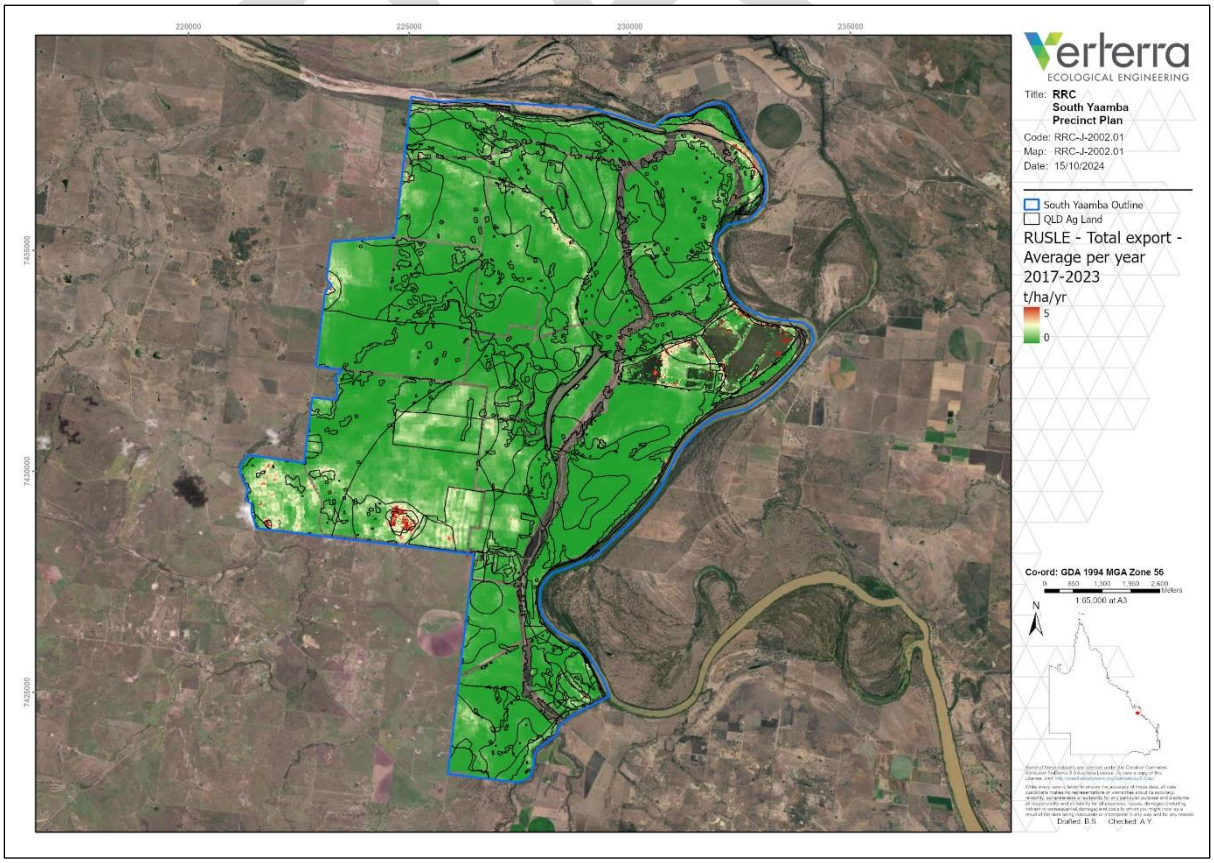


Table 2: Precinct sediment export under a range of scenarios

Cropping scenario	Total Area	Developable land	Development assumption		Scenario 1		Scenario 2		Scenario 3			Scenario 4			
			Proportion of potentially developable land converted to irrigated cropping (%)	Area of potentially developable land	Sediment export with no best management practice (tons/yr)	Sediment export relative to baseline with no BMP	Sediment export with best management practice (tons/yr)	Sediment export relative to baseline with BMP	Proportion of undeveloped land improved (%)	Sediment export with best management practice and complementary land improvement to achieve no net impact (tons/yr)	Sediment export relative to baseline with complementary land improvement to achieve no net impact	Proportion of undeveloped land improved (%)	Sediment export with best management practice and complementary land improvement to meet catchment target (tons/yr)	Sediment export relative to baseline with complementary land improvement to meet catchment target	Sediment export relative to baseline with complementary land improvement to meet catchment target
Baseline	121,004	77,487	0%	0	4166	100%	4165.8	100%	0%	4166	100%	0.0%	4166	100%	100%
Perennial pasture/fodder crops															
Rhodes grass hay	121,004	77,487	5%	3,874	4173	100%	4136.6	99%	0%	4142	99%	46.0%	2934	70%	30%
Lucerne	121,004	77,487	5%	3,874	4147	100%	4113.2	99%	0%	4120	99%	45.0%	2927	70%	30%
Double cropping															
Sorghum-Oats	121,004	77,487	5%	3,874	4506	108%	4365.6	105%	20%	4159	100%	70.0%	2906	70%	30%
Sorghum-Chickpea	121,004	77,487	5%	3,874	4555	109%	4380.1	105%	18%	4153	100%	71.0%	2910	70%	30%
Cotton-Mungbean	121,004	77,487	5%	3,874	4357	105%	4245.6	102%	10%	4155	100%	58.0%	2905	70%	30%
Cotton-Chickpea	121,004	77,487	5%	3,874	4312	104%	4241.3	102%	7%	4161	100%	58.0%	2901	70%	30%
Cotton-Wheat	121,004	77,487	5%	3,874	4328	104%	4235.4	102%	7%	4166	100%	58.0%	2904	70%	30%
Cotton-Barley	121,004	77,487	5%	3,874	4258	102%	4200.7	101%	4%	4160	100%	53.0%	2922	70%	30%
Single cropping - fallow															
Sorghum-Fallow	121,004	77,487	5%	3,874	4541	109%	4413.0	106%	20%	4155	100%	72.0%	2902	70%	30%
Wheat-Fallow	121,004	77,487	5%	3,874	4732	114%	4523.8	109%	32%	4185	100%	80.0%	2902	70%	30%
Chickpea-Fallow	121,004	77,487	5%	3,874	4785	115%	4555.8	109%	32%	4174	100%	80.0%	2933	70%	30%
Mungbean-Fallow	121,004	77,487	5%	3,874	4739	114%	4557.8	109%	33%	4174	100%	80.0%	2920	70%	30%
Cotton-Fallow	121,004	77,487	5%	3,874	4372	105%	4265.4	102%	10%	4168	100%	60.0%	2906	70%	30%

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4.4.2.3 Irrigation development scenarios

The results of modelling for these four irrigation development scenarios are presented in Table 2 and illustrated in Figure 20. Modelling results indicate the following:

Scenario 1: Irrigated development with no best practice and mitigation measures applied

- No net sediment impact for irrigated perennial pasture/fodder crops.
- An increase in sediment export of 2% to 9% for irrigated development to seasonal crops managed under a double cropping regime.
- An increase in sediment export of 5% to 15% for irrigated development to seasonal crops managed under a single cropping – fallow regime.

Scenario 2: Irrigated cropping with best practice mitigation measures applied

- A reduction in sediment export for irrigated perennial pasture/fodder crops of 1%.
- An increase in sediment export of 1% to 5% for irrigated development to seasonal crops managed under a double cropping regime.
- An increase in sediment export of 2% to 9% for irrigated development to seasonal crops managed under a single cropping – fallow regime.

Scenario 3: Irrigated cropping with best practice mitigation measures applied, and management practice improvement on non-developed areas to achieve no net impact

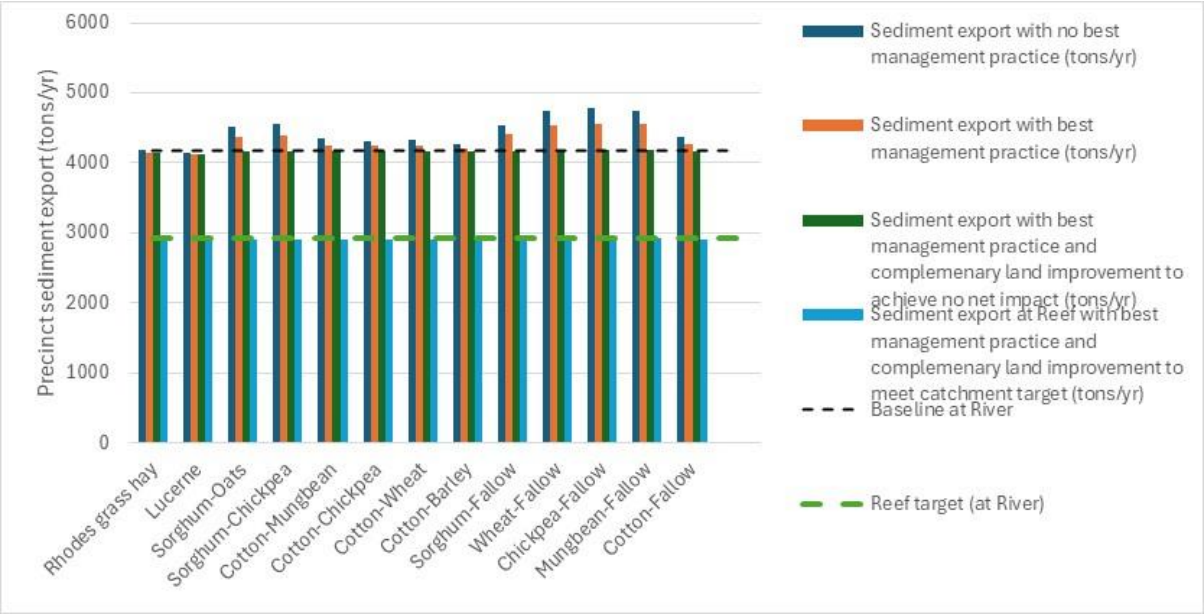
- No management practice improvement on non-developed areas required to achieve no net impact for irrigated perennial pasture/fodder crops.
- Management practice improvement on non-developed areas required over 4% to 20% of the undeveloped land (4,598 to 22,991ha) for irrigated development to seasonal crops managed under a double cropping regime to achieve no net impact.
- Management practice improvement on non-developed areas required over 10% to 33% of the undeveloped land (11,495 to 37,935ha) for irrigated development to seasonal crops managed under a single cropping – fallow regime to achieve no net impact.

Scenario 4: Irrigated cropping with best practice mitigation measures applied, and management practice improvement on non-developed areas to meet the Reef 2050 WQIP anthropogenic sediment reduction target.

- Management practice improvement over 45% to 46% of non-developed areas (51,729 to 52,879 ha) to meet the Reef 2050 water quality improvement target for irrigated perennial pasture/fodder crops.
- Management practice improvement over 53% to 71% of non-developed areas (60,925 ha to 80,467 ha) to meet the reef 2050 water quality improvement target for irrigated development to seasonal crops managed under a double cropping regime.
- Management practice improvement over 60% to 80% of non-developed areas (68,972 ha to 91,963 ha) to meet the reef 2050 water quality improvement target for irrigated development to seasonal crops managed under a single cropping – fallow regime.

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Figure 21: Sediment export modelling results for four irrigated cropping management scenarios



4.4.3 Implication of sediment modelling results

The sediment modelling results are based on a combination of scenarios and assumptions, so should not be interpreted literally. However, they are useful for indicating trends in management requirements associated with irrigated development.

- Perennial fodder and pasture crops managed under best practice have the capacity to reduce precinct sediment export relative to the current baseline conditions.
- Double cropping is preferred relative to a single cropping-fallow cycles, as the higher level of cover results in less sediment export. Notwithstanding, even with best management practices, complementary grazing practice change is required on undeveloped land to achieve no net impact.
- Under any circumstances, best management practices on 100% of land developed to irrigated cropping plus complementary grazing practice change on a very large proportion of the undeveloped land (45% to 80%) is required to reduce sediment export across the precinct by 30%, the reduction required to meet the Reef 2050 anthropogenic sediment reduction target.

Significant practical challenges to achieve the Reef 2050 targets, given the large area of grazing lands requiring practice change include:

- Availability of land not currently employing best practice grazing management that could be improved to deliver offsets;
- The sediment offsets that can be delivered from grazing land, which will vary with soil type, slope, landscape position and distance from the river mouth;
- Limited opportunities for other options of sediment reduction including streambank and gully restoration.

Significant governance challenges to achieve the Reef 2050 targets, given the large area of grazing lands requiring practice change include:

- Capacity for the overall program to deliver on EPBC related conditions (specifically, Condition 2c);
- Opportunity and capacity to directly undertake works such as streambank and gully restoration on third party-owned land;
- Ability to offer incentives to landholders to implement grazing BMP to deliver sediment offsets;
- Potential legislative instruments to require management practice change to support both the irrigation development and Reef 2050 targets.

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5. Nutrient runoff and leaching risk

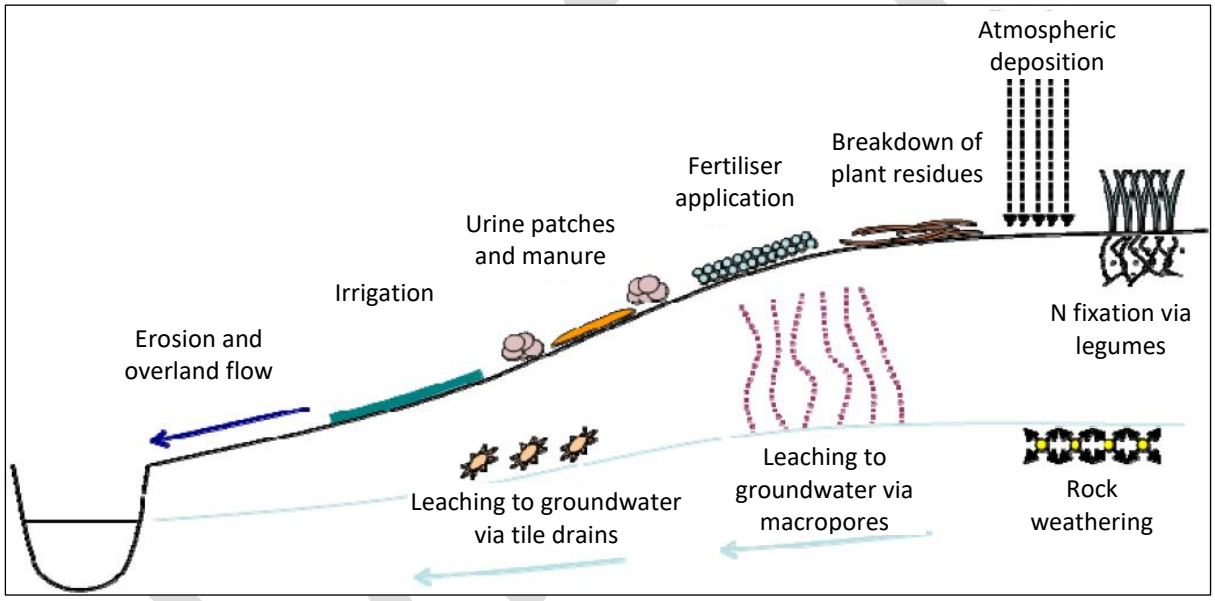
5.1 Conceptual model

The risk of nutrient movement to waterways is complex, being a function of, *inter alia*:

- Management practices (application rate relative to crop demand).
- Application method (banding, broadcast etc).
- Timing of application(s).
- Nutrient form (ammonium, nitrate, urea, nitrate, enhanced efficiency, organic, etc).
- Irrigation practices (influencing both runoff and deep drainage).

Dissolved nutrients may enter waterways by leaching and in overland flow, while particulate nutrients predominately enter waterways by overland flow. Both processes may be associated with sediment export. A conceptual model for nutrient transport pathways is illustrated in Figure 22.

Figure 22: Conceptual mode for N and P transport pathways (Newham and Drewry, 2006)



Modelling nutrient loss is specific to the soils, topography and management practices. Therefore, nutrient loss was only modelled at the property scale. None-the-less, the principles of minimising nutrient loss are relevant at the precinct scale.

To model nutrient export to waterways, we made the simplifying assumption that the predominant current land use is grazing. We then determined the average nutrient application rates to grazing land through a combination of literature search, interviews with relevant bodies (DAF, CSIRO, FBA) plus a survey of graziers throughout the region.

We undertook modelling using HowLeaky (DES, 2019) to determine a baseline for nutrient export to waterways (for each property assessed). As for sediment export, this identified risk areas where baseline export may be high; enabling scenario analysis; and provide the basis to model changes over time.

In addition to nutrient losses to waterways, significant losses of nitrogen may also occur via volatilisation of ammonia from surface applied urea, and denitrification of nitrate by anerobic soil bacteria. N_2O, an intermediate product of denitrification, is a potent greenhouse gas, so management practices to minimise anerobic soil conditions and denitrification are important from both a nutrient use efficiency and greenhouse gas abatement viewpoint.

5.2 Nutrient use rates

Through a combination of literature search, interviews with relevant bodies (DAF, CSIRO, FBA) plus a survey of landholders, we determined the average nutrient application rates to grazing land and cropping, summarised in Table 3. These rates were used in subsequent modelling.

Table 3: Nutrient use rates in grazing and cropping

Activity	Nutrient use rate range	Adopted average.
Dryland grazing	50–100kg N/ha/yr	75kg N/ha/yr
Annual crops (Sorghum)	50-150kg N/ha/yr	100kg N/ha/yr
Irrigated pasture (Rhodes)	150-250kg N/ha/yr	200kg N/ha/yr
Perennial crops (Macadamias)	200-300kg N/ha/yr	250kg N/ha/yr

5.3 Nutrient loss modelling

Modelling of nitrogen losses in runoff and drainage at the property scale identified a number of common themes:

- Nitrate nitrogen is not strongly retained in topsoils, hence, runoff and leaching is likely during the wet seasons under both dryland and irrigated conditions.
- Modelled runoff of nitrate in an average rainfall year was predicted to peak for irrigated Rhodes grass at 0.75 kg/ha during the December to February high rainfall period, but runoff nitrate loss was negligible across the remainder of the year.
- Leaching of nitrate followed a similar trend to runoff losses, with most nitrate leached in Dec and February.
- Nitrate leaching is a function of soil mineralogy, soil pH, root depth distribution and rainfall. Hence, the leaching losses in the field are difficult to predict accurately.
- Under irrigated conditions, runoff and drainage nitrate concentrations are elevated, but drainage nitrate can be managed by irrigation scheduling to minimise deep drainage.

The output of nitrogen loss modelling using Dunrobin (an irrigated cropping concern in South Yaamba) as an example is illustrated in Figure 23. Figure 23 figure illustrates modelled nitrate nitrogen losses under dryland Rhodes grass and average rainfall conditions for:

- runoff (a); and
- drainage (b) and

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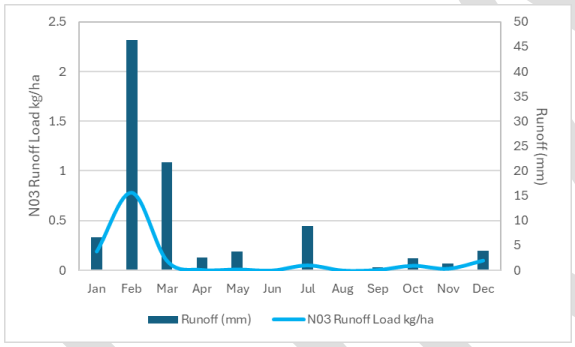
modelled nitrate nitrogen losses for irrigated Rhodes grass for:

- in runoff (c); and
- drainage (d).

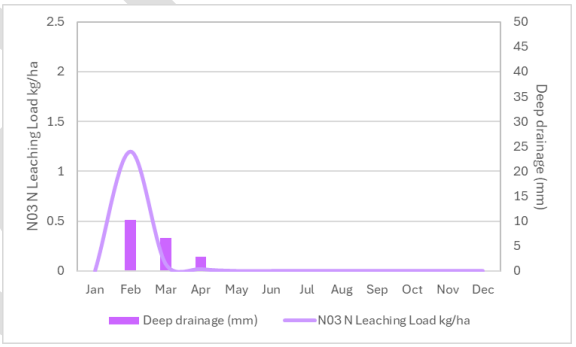
The runoff losses shown in Figure 23 refer to a land surface without erosion control practices. Key messages are:

- Nitrogen losses in drainage will only occur during periods of high rainfall, which cannot be controlled by the landholder.
- Nitrogen losses via runoff under irrigation were not materially different to runoff under dryland conditions.
- Vegetated buffer strips can be established to intercept nitrogen in the runoff.
- Appropriate irrigation scheduling will lead to minimal deep drainage and thus minimal drainage N losses.
- Best-practice fertiliser management (4Rs) (e.g. deep placement of fertiliser, timing of application, split applications, application rates) will further minimise nitrogen losses and ensure compliance with the Code and Reef Protection Regulations.

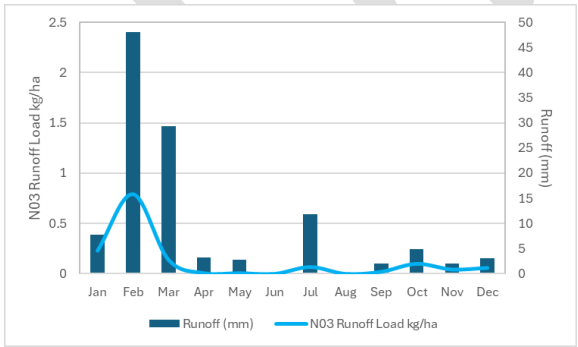
Figure 23: Modelled nitrate loads associated with both runoff and deep draining under current dryland and proposed irrigated conditions for Dunrobin



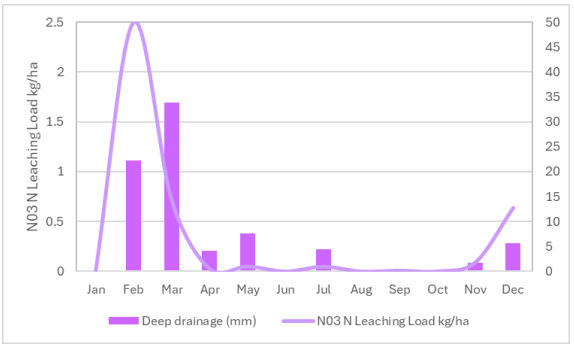
a) nitrate in runoff of dryland Rhodes grass



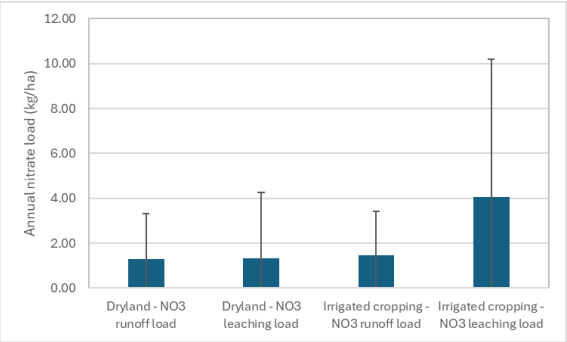
b) nitrate in drainage of dryland Rhodes grass



c) nitrate in runoff of irrigated sorghum-mungbean crop



d) nitrate in drainage of irrigated sorghum-mungbean crop



e) annual nitrate loads (10 year average)

5.3.1 Implication of nutrient modelling results

Significant practical challenges to achieve the Reef 2050 targets with respect to nutrient impacts include:

- Limited opportunities for nutrient offsets given the relatively small area of cropping and grazing currently practiced in the catchment.
- Possible integration of nutrient offsets with hyacinth harvesting.

Significant governance challenges to achieve the Reef 2050 targets, given the large area of grazing lands requiring practice change include:

- Capacity for the overall program to deliver on EPBC related conditions (specifically, Condition 2c);
- Ability to offer incentives to landholders to implement nutrient BMP to deliver offsets.
- Rights to nutrient offsets associated with hyacinth harvesting.
- Potential legislative instruments to require management practice change to support both the irrigation development and Reef 2050 targets.

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6. Pesticide leaching and runoff risk

6.1 Conceptual model

For the purposes of this discussion pesticides, herbicides, fungicides and nematicides are collectively referred to as “pesticides”.

As for nutrients, modelling of pesticide export to waterways and associated risk is a complex function of:

- Chemical concentration
- Application rate
- Application method (e.g., blanket or spot)
- Timing of application
- Ecotoxicity, mobility and persistence the chemical applied.

For a given pesticide regime, practices that minimise chemical toxicity, chemical persistence and application rate, plus sediment and nutrient export will contribute to minimising pesticide export.

Given the complexity of pesticide export and heavy dependence on farm-specific management factors, pesticide export has not been modelled at the precinct level.

Rather, we have used the *Pesticide Decision Support Tool* (PDST) (Warne *et al.*, 2023), to explore the relative aquatic risk of 47 chemicals potentially used across a range of crops, and used this inform and describe management practices that will contribute to reducing risk and provide guidelines for pesticide management.

6.2 Pesticide risk evaluation

The *Pesticide Decision Support Tool* (PDST) (Warne *et al.*, 2023), although developed with a focus on sugar cane, covers key pesticides used across most of Queensland’s crops.

The PDST calculates the aquatic risk of a chemical applied as a function of its:

- measure of effect, which is based on the application rate and ecotoxicity threshold value; and
- measure of mobility and persistence, which is a measure of the potential of active ingredients to move from farmland to waterways (or the change of the active ingredient being lost in runoff) and persist.

Overall aquatic risk is calculated by multiplying the measure of effect by the measure of mobility and persistence.

Table 4 presents a list of 47 pesticides that are included in the PDST ranked from lowest to highest aquatic risk x class. This table is expanded to show relevant crops in Appendix 3. The aquatic risk table presented in Table 4 and Appendix 3 assumes:

- The maximum permitted application rate (kg/ha) of each active ingredient; and
- Broadcast or blanket application (applied to 100% of the treated area).

The PDST can be used to estimate the relative reduction in aquatic risk by:

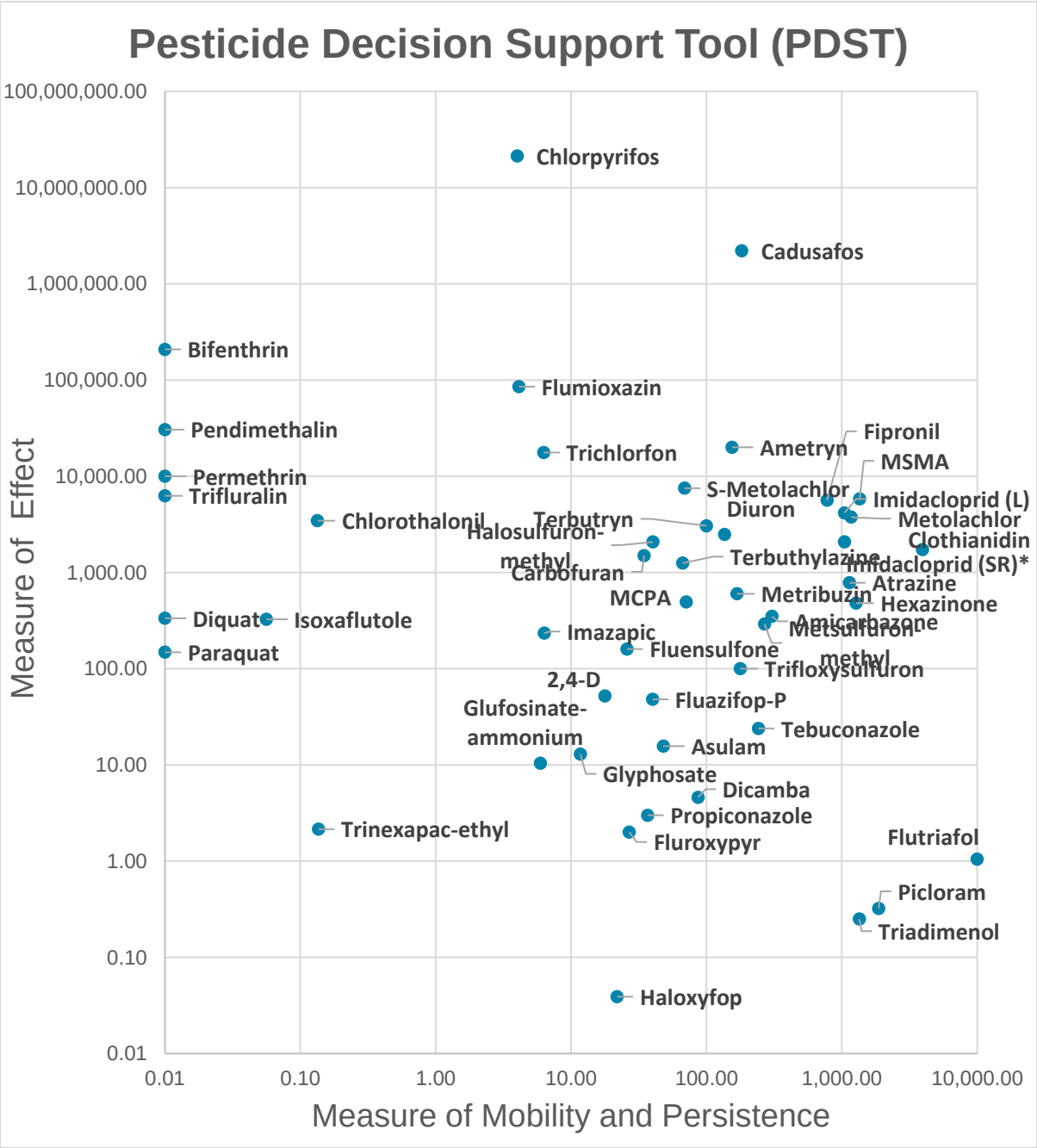
- Selecting an alternative pesticide;
- Reducing the application rate (concentration and/or volume applied per unit area); and
- Reducing the area to which chemical is applied within the treated area (e.g., by spot spray).

Table 4: Aquatic risk of pesticides ranked lowest to highest risk x class based on default assumptions

Active Ingredient	Class	Measure of Mobility & Persistence	Measure of Effect	Aquatic risk value
Propiconazole	Fungicide	36.8	3.0	1.10
Triadimenol	Fungicide	1345.4	0.3	3.36
Chlorothalonil	Fungicide	0.134	3450.0	4.61
Tebuconazole	Fungicide	241.7	23.9	57.86
Flutriafol	Fungicide	9977.3	1.05	104.80
Diquat	Herbicide	0.0	334.5	0.0
Paraquat	Herbicide	0.01	148.1	0.0
Pendimethalin	Herbicide	0.01	30530.6	0.0
Trifluralin	Herbicide	0.01	6260.9	0.0
Trinexapac-ethyl	Herbicide	0.1	2.2	0.003
Haloxyfop	Herbicide	21.8	0.0390	0.009
Isoxaflutole	Herbicide	0.06	326.1	0.183
Fluroxypyr	Herbicide	26.9	2.0	0.538
Glufosinate-ammonium	Herbicide	5.93	10.4	0.618
Glyphosate	Herbicide	11.7	13.0	1.518
Dicamba	Herbicide	86.6	4.6	3.977
Picloram	Herbicide	1871.1	0.3	6.014
Asulam	Herbicide	48.0	15.7	7.525
2,4-D	Herbicide	18	52	9.271
Imazapic	Herbicide	6.33	234.1	14.83
Fluazifop-P	Herbicide	39.9	48.0	19.16
Trifloxysulfuron	Herbicide	177.4	100.0	177.37
MCPA	Herbicide	71.0	494.3	351.03
Metsulfuron-methyl	Herbicide	268.1	291.7	782.06
Terbuthylazine	Herbicide	66.5	1250.0	831.76
Halosulfuron-methyl	Herbicide	40.2	2074.5	834.21
Metribuzin	Herbicide	168.2	600.0	1009.0
Amicarbazone	Herbicide	305.4	350.0	1069.0
Terbutryn	Herbicide	100.0	3055.6	3056.2
Diuron	Herbicide	136.0	2478.3	3369.6
Flumioxazin	Herbicide	4.1	85365.9	3518.4
S-Metolachlor	Herbicide	68.9	7513.0	5174.3
Hexazinone	Herbicide	1274.0	480.0	6115.4
Atrazine	Herbicide	1138.3	781.6	8896.4
Ametryn	Herbicide	154.7	20000.0	30938.3
Metolachlor	Herbicide	1170.0	3756.5	43951.9
MSMA	Herbicide	1353.8	5830.7	78936.5
Bifenthrin	Insecticide	0.01	208333.3	0.0
Permethrin	Insecticide	0.01	10000.0	0.0
Carbofuran	Insecticide	34.6	1500.0	519.6
Trichlorfon	Insecticide	6.27	17647.1	1107.2
Imidacloprid	Insecticide	1045.5	4166.7	43564.0
Fipronil	Insecticide	776.8	5618.0	43641.3
Clothianidin	Insecticide	3938.2	1724.1	67899.9
Chlorpyrifos	Insecticide	4.00	21276595.7	850694.1
Cadusafos	Insecticide	182.1	2197802.2	4001266.9
Fluensulfone	Nematicide	25.8	160.0	41.3

The relative aquatic risk of pesticides listed in Table 4 is illustrated in Figure 24. Chemicals with a higher measure of effect and measure of mobility and persistence (top right) pose a greater risk than chemicals in the bottom left. Note, the diagram axes are presented in log scale. Also note, Figure 24 is based on sugarcane application rates. The label for these chemicals will have different maximum allowed applications rates for the mix of proposed crops for South Yaamba. The aquatic risks need to be reassessed for crop-specific applications and label rates.

Figure 24: Aquatic risk of pesticides based on default rate and method



6.3 Pesticide management practices

Pesticide management comprises several steps:

- reducing pesticide runoff,
- optimising pesticide use, and
- selecting pesticides that pose a lower risk to aquatic environments (i.e., have lower mobility, persistence and ecotoxicity).

Recommended management strategies to reduce pesticide runoff include:

- Erosion and sediment control measures (see Section 4):
    - Establishing buffer zones between treated areas and flow paths that will trap sediment (including adsorbed pesticides) and increase runoff time of concentration, reducing the likelihood that pesticides will reach aquatic environments before degrading.
- Application timing:
    - Applying pesticides during dry periods or before the onset of the wet season will minimize the runoff risk and the chance of pesticide loss through deep drainage.
- Optimised application rates:
    - Reducing overall pesticide usage, through using spot or band spraying to target specific areas, will reduce the risk of pesticide loss through runoff.
    - Integrated pest management principles (i.e., monitoring, intervention thresholds, biological controls, crop rotation and maintaining good soil health) can help to minimise reliance on pesticides and reduce usage.
- Use lower risk pesticides:
    - It is recommended to select pesticide products containing pesticides with lower aquatic risk values (see Table 4), noting that pesticide products that contain pesticides with low aquatic risk values but high measure of effect values (i.e., low aquatic risk due to low mobility and/or persistence) should be stored, handled and applied with care to avoid direct contamination of waterways.

The above strategies, in combination with the recommended erosion and sediment control measures in Section 4, will ensure that the water quality impacts from pesticides will be minimised and ensure compliance with the Code and Reef Protection Regulations.

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7. Rising groundwater and salinity risk

7.1 Salinity overview

Salinity due to introduction of irrigation may occur in two general forms:

1. Salinity due to rising ground water (accompanied by waterlogging risk); and
2. Salinisation of the crop rootzone due to insufficient leaching of applied salts.

In the context of irrigation using water from Rookwood Weir, the former presents the greater risk, but both will be discussed below. Sustainable irrigation requires a balance between ensuring sufficient deep drainage to prevent accumulation of salt in the rootzone while avoiding excessive deep drainage that may lead to groundwater rise.

7.1.1 Salinity due to rising groundwater

Rising groundwater and associated salinity risk may be influenced by any change in the hydrology of the landscape, such as clearing native forest for grazing or conversion of grazing land to irrigated agriculture, and must be considered to ensure sustainable agricultural development for the Rockhampton Region.

Conversion of grazing land to irrigation is likely to increase deep drainage into the soil and regolith below the rootzone contributing to rising groundwater. Where rising groundwater intercepts salt stored in the soil, and comes within 2m of the surface, salt is likely to rise to the surface by capillary action, resulting in irrigation induced salinity and potentially, waterlogging.

As a rule-of-thumb, a change in land management from forest to pasture may increase deep drainage from 5mm/yr to 50mm/yr. Given a regolith porosity of 20%, this may change the effective depth of annual groundwater increase, ignoring groundwater discharge or lateral flows, from 25mm to 250mm/year.

Salinity may occur at local or regional scale, and may take years to decades to be expressed. Rising groundwater and salinity is emerging as a serious issue in irrigated regions of the Burdekin, 30 years after construction of the Burdekin Falls Dam.

7.1.2 Salinity due to insufficient leaching

All irrigation waters contain some concentration of salts. It can be expected that Fitzroy River water will have a salinity in the order of 300µS/cm. Sustainable irrigation requires that a small proportion of applied water moves below the rootzone as deep drainage in order to remove some of the applied salts from the rootzone. This is referred to as the leaching fraction. In the absence of a leaching fraction, applied salts will progressively accumulate in the rootzone, even with low salinity water, ultimately resulting in crop death.

7.2 Risk assessment framework

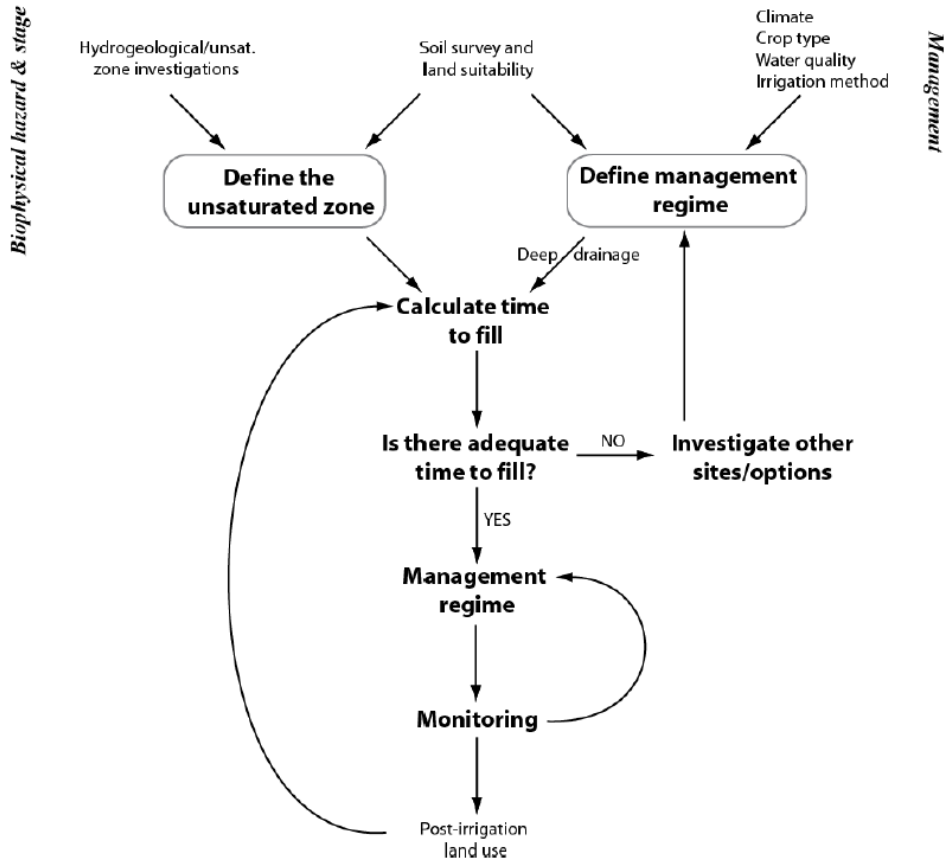
7.2.1 Salinity due to rising groundwater

A salinity risk assessment framework (DES, 2021) for assessment of salinity due to groundwater rise is presented in Figure 25. Under this framework, the potential water storage capacity of the soil plus regolith is determined from the depth to bedrock x the average porosity, less the extent to which groundwater storage capacity is reduced by increased deep drainage since the time of clearing. The

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time to fill is then calculated as the available groundwater storage capacity divided by the expected deep drainage from irrigation. As a rule of thumb, a time to fill of greater than 100 years is generally considered to be acceptable (DES, 2021; Biggs et al., 2013).

Figure 25: Salinity risk assessment framework (DES, 2021)

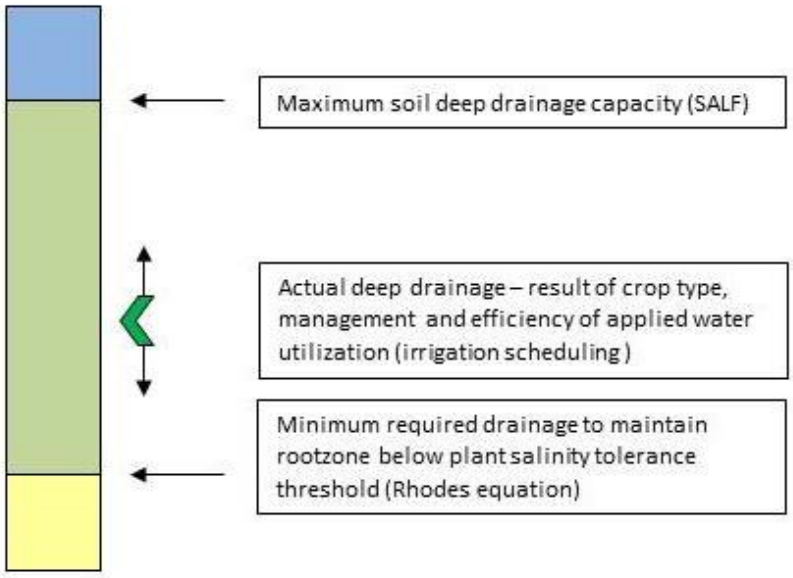


7.2.2 Salinity due to insufficient leaching

Assessment of the risk of salinity due to insufficient leaching is based on determination of the maximum deep drainage capacity of the soil and the minimum deep drainage required to prevent salt accumulation. This framework is illustrated in Figure 26. Provided the maximum deep drainage capacity exceeds the minimum deep drainage requirement, irrigation management practices can be managed to maintain deep drainage within this range.

As salinity due to insufficient leaching is generally only an issue on either very poorly drained soils, or due to use of saline irrigation water, it is more appropriately considered on a paddock rather than a precinct scale.

Figure 26: Diagrammatic illustration of approach to deep drainage estimation



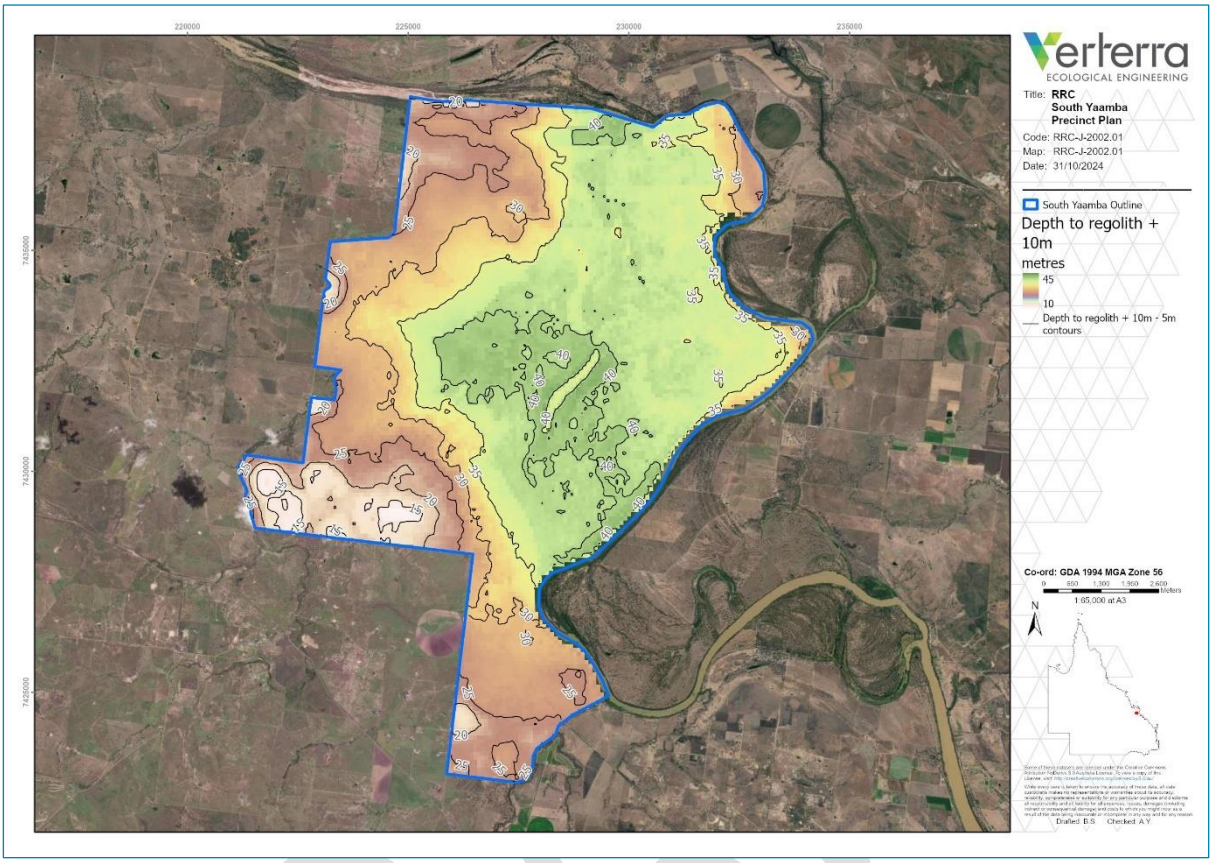
7.3 Salinity risk

7.3.1 Salinity due to rising groundwater

Salinity risk due to excessive deep drainage and rising groundwater was assessed by first mapping depth to bedrock across the precinct (Figure 27) and then carrying out a time to fill analysis (Biggs et al, 2013) using approximate values for regolith porosity, post clearing deep drainage. The results of this analysis (Table 5) are presented in Figure 28.

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Figure 27: Depth to regolith



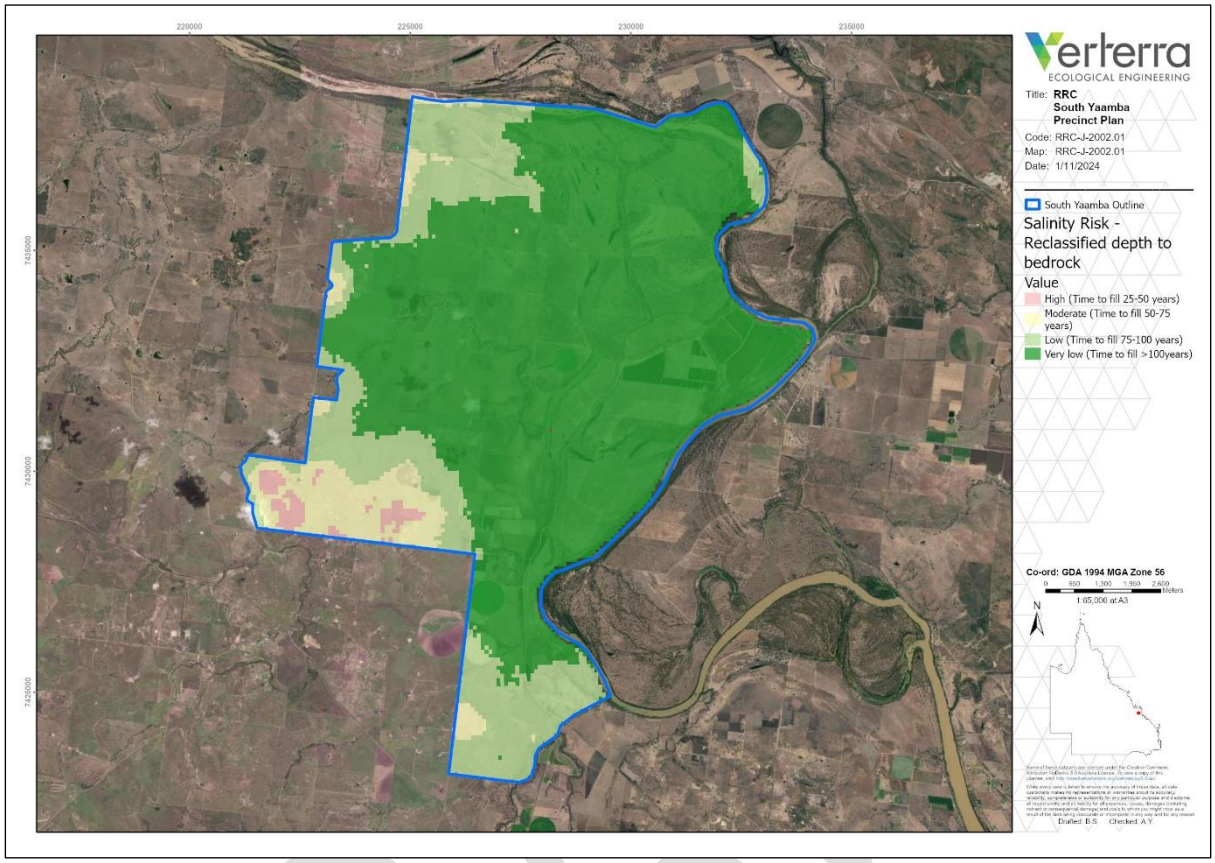
Time to fill analysis results are shown in Table 5, and salinity risk is illustrated in Figure 28. Salinity risk is categorised as follows:

- Very high 0-25 years to fill
- High 25-50 years to fill
- Moderate 50-75 years to fill
- Low 75-100 years to fill
- Very Low > 100 years to fill

Table 5: Time to fill analysis for a range of regolith depths

Unsat. Zone thickness (m)	Porosity (%)	Starting Porosity (mm)	Post clearing deep drainage (mm/yr)	Years since clearing (years)	Wate added in years since clearing (mm)	Starting storage (mm)	Estimated Irrigation deep drainage (mm/yr)	Time to fill (years)
8.75	20%	1750	10	50	500	1250	50	25
15.00	20%	3000	10	50	500	2500	50	50
21.25	20%	4250	10	50	500	3750	50	75
27.50	20%	5500	10	50	500	5000	50	100

Figure 28: Salinity risk



The results shown in Figure 28 indicate that salinity risk due to rising groundwater is very low to low across the South Yaamba precinct given the depth to regolith is generally greater than 20m. Notwithstanding, poor irrigation practices that resulted in excessive deep drainage above the rate assumed (50mm/yr) would be expected to increase the rate of groundwater rise and risk of locally perched water tables. When groundwater intercepts historical salt stores in the regolith or soil profile it will carry the stored salts, and rise to the surface when the groundwater rises within 2m of the surface.

The time to fill analysis makes the simplifying assumption that water added to the soil profile and regolith through deep drainage accumulates. In practice, water will gradually move vertically to groundwater aquifers, or laterally to stream. Examination of Figure 7 indicates that the South Yaamba precinct area is generally 8 to 15m above the Fitzroy River level, providing the capacity for water to move laterally to stream. The topography in the north-east corner of the precinct shows a level of complexity consistent with stream meanders and paleochannels, also enabling lateral groundwater movement preventing the risk of groundwater rise to near the surface.

7.3.2 Salinity due to insufficient leaching

The maximum rootzone salinity was estimated at the paddock scale on a property x property level using the Salt and Leaching Fraction (SALF) model, in combination with application of the Rhoades equation, to calculate the leaching requirement for the soil and crop combination. Expected

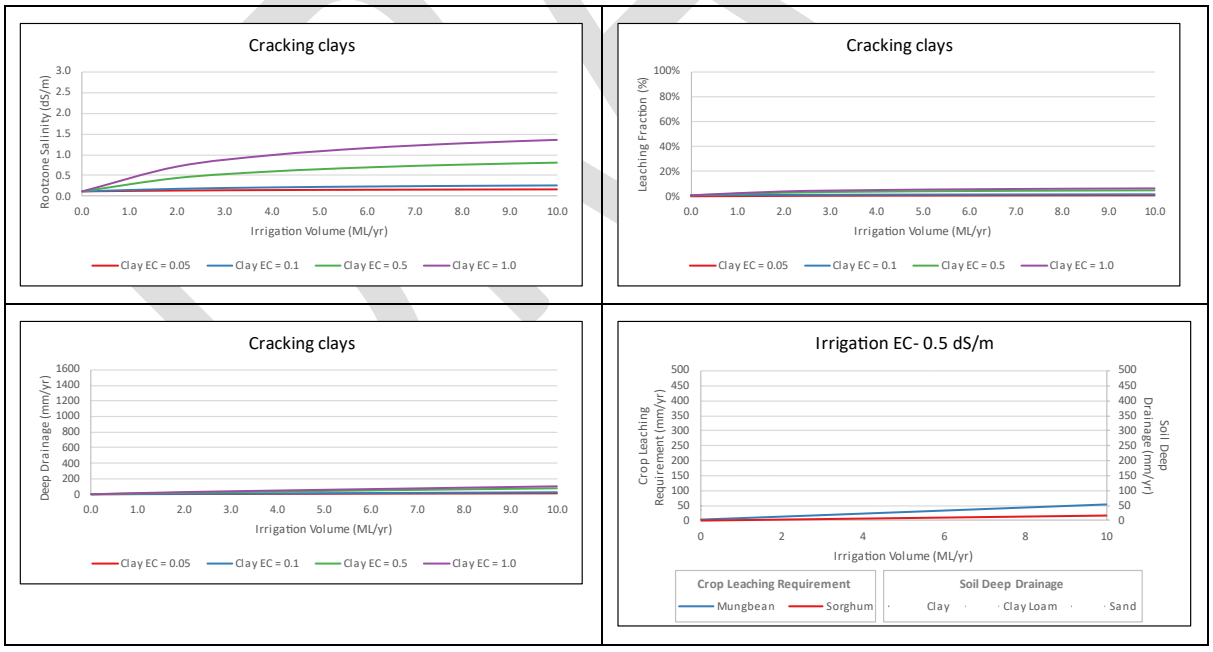
equilibrium root zone salinity for discreet soil types was then estimated from water balance modelling which took into account expected deep drainage volumes.

An example of the results of SALF modelling is presented in Figure 29 for heavy, cracking clay soils. Cracking clay soils have been used as an example given they display low permeability and are most at risk of salt accumulation in the rootzone.

The results illustrate the following:

- **Equilibrium rootzone salinity (TL):** increases with increasing volume and salinity (EC) of irrigation water but equilibrates at a maximum of 1.5dS/m at 10Ml/ha/yr and an irrigation water EC of 1.4dS. This indicates that rootzone salinity is a low risk;
- **Leaching fraction (TR):** The leaching fraction of the black cracking clays is very low regardless of irrigation water salinity, and is in the order of 5% to 7% of the applied water;
- **Deep drainage (BL):** increases with increasing volume and irrigation water salinity, but doesn't exceed a maximum of about 100mm/yr at an irrigation rate of 10ML/ha/yr.
- **Leaching requirement (BR):** (assuming irrigation with 0.5dS/m water): is around 100mm/yr for mungbean irrigated at 10ML/ha/yr and around 20 mm/yr for Sorghum. The leaching rate for clay only marginally exceed the leaching requirements for mungbean, but is just adequate to reach an acceptable soil salinity equilibrium.

Figure 29: SALF modelling results or *equilibrium rootzone salinity (TR); Leaching fraction (TR); Deep drainage (BL); and leaching requirement (assuming irrigation with 0.5dS/m water)*



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8. Risk assessment and control measures

Based on the modelling of environmental risks, a risk assessment was carried out to determine the appropriate management requirements. A standard approach to risk assessment consistent with AS/NZS ISO 31000 was adopted for evaluation of environmental risks associated with the activities proposed under this Precinct Plan. The approach involves an objective evaluation of risk likelihood and risk consequence (according to the criteria set out in the aspects and impacts risk matrix in Table 6), then evaluating a risk rating in accordance with this matrix, with rating categories as detailed in Table 7.

Table 6: Irrigated agriculture risk matrix

Consequence Category			Minor	Moderate	Severe	Major	Catastrophic
Likelihood			1	2	3	4	5
Almost Certain >90% probability	Expected in most circumstances	5	5	10	15	20	25
Likely 51-90% probability	Will probably occur in most circumstances	4	4	8	12	16	20
Possible 31-50% probability	Might occur at some time	3	3	6	9	12	15
Unlikely 10-30% probability	Could occur at some time	2	2	4	6	8	10
Rare <10% Probability	May occur only in exceptional circumstances	1	1	2	3	4	5

Table 7: Residual risk rating level

Risk rating code	Risk rating score	Risk rating description
E	15-25	Extreme Risk – Detailed action plan required
H	8-12	High Risk – Needs senior management attention
M	3-6	Moderate Risk – Specify management responsibilities
L	1-2	Low Risk – Manage by routine procedures

Likelihood and risk rating were evaluated:

a) Assuming no risk mitigation; and
b) Following implementation of routine risk mitigation practices.

The risk assessment is presented in Table 8.

Table 8: Environmental risk assessment

RISK	PREVENTION AND CONTROL MEASURES	CONSEQUENCE (independent of control measures)	LIKELIHOOD (*with control measures* / without control measures)	RISK RATING (*with control measures* / without control measures)
Sediment and Erosion Risk				
Erosion from runoff	**Design** • Plan crop types & harvesting to ensure fallow falls outside high rainfall seasons • Construction of contour banks • Incorporation of grassed waterways • GPS enabled guidance for controlled traffic farming • Design drip irrigation where possible, otherwise pivot irrigation with instantaneous precipitation rate matched to soil infiltration • Match paddocks and/or variable rate irrigation to soil types • Install soil moisture probes in representative soil types • Desing tailwater capture system **Management and maintenance** • Maintain a high level of cover during periods of high seasonal rainfall • Maintain trash in-paddock after harvest • Maintain contour banks to prevent blockages, overtopping and breakthrough • Maintain a high level of cover and roughness on grassed waterways • Ensure controlled traffic lanes used diligently • Maintain GPS equipment in good working order • Maintain irrigation system to prevent leaks and breakage • Repair incipient erosion as it appears • Apply irrigation at a rate to avoid runoff • Use soil moisture probes to inform irrigation timing and volume • Regularly maintain tailwater drains and test tailwater prior to reuse **Monitoring** • Monitor crop health (visually/drones) to ensure capacity to maintain high cover • Inspect contour banks regularly, especially prior to and during the wet season • Visually monitor grassed waterways to ensure high cover and no incipient erosion • Visually inspect irrigation infiltration/runoff during irrigation events • Regularly monitor soil moisture status to inform irrigation • Undertake analysis and testing of tailwater	*Major (4)*	*Almost certain (5)* *Rare (1)*	*Extreme (20)* *Moderate (4)*

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RISK	PREVENTION AND CONTROL MEASURES	CONSEQUENCE (independent of control measures)	LIKELIHOOD (*with control measures* / without control measures)	RISK RATING (*with control measures* / without control measures)
Erosion from roadway and headland	**Design** • Incorporate whoa boys into all roadways at appropriate spacing for the soil type and slope • Shed water from whoa boys onto well grassed areas • Design tracks to shed rather than concentrate water **Management and maintenance** • Maintain whoa boys to repair erosion, ensure free draining • Maintain a high level of grass cover on the watershed from whoa boys **Monitoring** • Inspect whoa boys regularly, especially prior to and during the wet season • Visually monitor grass cover on the watershed from whoa boys to ensure high cover and no incipient erosion	*Major (4)*	*Almost certain (5)* *Rare (1)*	*Extreme (20)* *Moderate (4)*
Sediment loss to waterways	**Design** • Incorporate grassed sediment basins or filter dams at the low point of concentrated overland flow paths • Incorporate vegetated buffer strips along waterways **Management** • Maintain sediment basins or filter dams to ensure capacity to capture concentrated flows for most storm events • Maintain vegetation in sediment basins to slow water, filter sediment and enhance evaporation • Remove sediment from sediment basins or filter dams to maintain capacity • Maintain a high level of groundcover in vegetation buffers and regularly manage weeds **Monitoring** • Inspect sediment basins or filter dams regularly, especially prior to and during the wet season • Visually inspect vegetated buffer strips for health and integrity of vegetation and soil	*Major (4)*	*Almost certain (5)* *Rare (1)*	*Extreme (20)* *Moderate (4)*

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RISK	PREVENTION AND CONTROL MEASURES	CONSEQUENCE (independent of control measures)	LIKELIHOOD (*with control measures* / without control measures)	RISK RATING (*with control measures* / without control measures)
Nutrient leaching and runoff risk				
Nutrient loss to waterways	**Design** • Selection of low leaching (ammonium), enhanced efficiency or organic fertilisers • Match paddocks and/or variable rate irrigation to soil types • Install soil moisture probes in representative soil types • Avoid irrigation of low clay/low cation exchange soils • Establish sediment basins and vegetated buffer strips **Management** • Soil testing to determine site-specific deficiencies • Apply nutrients in line with soil deficiencies and crop demand • Precision nutrient application and deep placement • Time fertiliser applications outside periods of heavy rainfall • Split fertiliser application to match uptake rate with crop demand • Use soil moisture probes to inform irrigation timing and volume to prevent runoff and deep drainage beyond minimum leaching fraction requirements • Training of irrigation staff to understand water application triggers • Maintain sediment basins and vegetated buffer strips **Monitoring** • Foliar and biomass monitoring to assess balance of nutrient mass applied V's incorporated in crop • Regularly monitor soil moisture status to inform irrigation • Visually inspect sediment basins and vegetated buffer strips for health and integrity of vegetation and soil	*Major (4)*	*Almost certain (5)* *Rare (1)*	*Extreme (20)* *Moderate (4)*

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RISK	PREVENTION AND CONTROL MEASURES	CONSEQUENCE (independent of control measures)	LIKELIHOOD (*with control measures* / without control measures)	RISK RATING (*with control measures* / without control measures)
Pesticide leaching and runoff risk				
Pesticide loss to waterways	**Design** • Selection of low effect, low persistence chemicals • Install soil moisture probes in representative soil types **Management** • Practice integrated pest management • Minimise chemical application rate • Use targeted pesticide applications to minimise chemical application quantity • Use soil moisture probes to inform irrigation timing and volume to prevent runoff and deep drainage beyond minimum leaching fraction requirements • Training of irrigation staff to understand water application triggers • Applying pesticides during dry periods or before the onset of the wet season **Monitoring** • Monitor inspect, and pest populations to inform early and targeted intervention	*Major (4)*	*Almost certain (5)* *Rare (1)*	*Extreme (20)* *Moderate (4)*
Groundwater rise and salinity risk				
Soil salinity and groundwater rise	**Design** • Install soil moisture probes in representative soil types • Design high efficiency drip irrigation where possible, otherwise variable rate pivot irrigation **Management** • Use soil moisture probes to inform irrigation timing and volume to prevent deep drainage beyond minimum leaching fraction requirements • Training of irrigation staff to understand water application triggers **Monitoring** • Regularly monitor soil moisture status to inform irrigation • Sampling of soil profile to assess changes in salinity • Periodic EM (electromagnetic survey)	*Moderate (2)*	*Almost certain (5)* *Rare (1)*	*High (10)* *Moderate (4)*

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RISK	PREVENTION AND CONTROL MEASURES	CONSEQUENCE (independent of control measures)	LIKELIHOOD (*with control measures* / without control measures)	RISK RATING (*with control measures* / without control measures)
(example) 1. Irrigation water salinity leads to salinisation of land, loss of soil productivity / yield capacity	**Monitoring** • Real-time, continuous monitoring of irrigation water pH, EC and volume to ensure quality remains within design limits and to identify changes • Fortnightly sampling for SAR, pH, EC and carbonates • Soil probe monitoring to determine real-time changes in soil profile salinity • Annual soil core sampling to validate changes in salinity • Annual EM surveying to map spatial changes in soil salinity and refine/revise soil probe locations **Management** • Reduce irrigation volume to reduce salt load and weighted average irrigation water application • Adaptive management of irrigation to ensure maintenance of a suitable leaching fraction to maintain an acceptable rootzone salinity • Cease or reduce irrigation in the event of an excessive change in water salinity outside design limits • Training of irrigation staff to understand water quality limits • Periodic, independent expert review of irrigation water quality parameters **Design** • Intensive mapping of soil types to and characterisation of soil management units. Modelling and assessment of forecast rootzone EC for each unit to ensure adequate drainage unlikely to accumulate salt in the rootzone, even with moderate to high salinity waters • Variable rate irrigation functionality in the pivots interfaced with mapped soil salinity variation to allow targeted leaching irrigations • Pivot control – soil EC interlock prevents EC over-load that might otherwise occur due to inappropriate manual irrigation operation	Severe	*Unlikely* / Possible	*Moderate (6)* / High (9)

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9. Provision of analysis data to Paddock to Reef

The modelling approach to sediment, nutrient and pesticides at precinct and paddock scale have been modelled in this report using the following tools:

Sediment:

- DROVER, a proprietary tool developed by Verterra to facilitate estimation of sediment export loads complaint with EcoMarkets Australia approved Grazing Land Management Method V1.0 (Silverwood and Yates, 2024). The tool has been modified slightly to accommodate irrigation and cropping. The approach to sediment export and contributing data layers are similar to Paddock to Reef, but are considered more appropriate at the farm and precinct scale.
- Paddock to Reef utilises qualitative data based on landholder responses to management questions to classify the quality of land management practice. Further, it assumes that once improved management practices have been implemented, the sediment savings occur instantaneously and continue indefinitely.
- The sediment modelling approach adopted in this plan is based on the observed outcome of changes in land management practice, quantified using satellite imagery. This overcomes the limitations of Paddock to Reef at the farm scale using an objective basis for quantifying the outcome of land management practices. Being based on satellite observations, it also responds to changes over time. Sediment export or savings and may increase or decrease in response to continuing practice change improvement, or failure to maintain practice standards.

Nutrient:

- The Nitrate-N sub-model of HowLeaky (DES, 2019). The model contains a subset of three separate models for calculating: dissolved Nitrate-N in runoff; dissolved Nitrate-N in leaching; and particulate Nitrate-N in runoff. These models do not employ a nitrate "Volume-Balance" and they do not "route" nitrate through the soil. Instead, they represent a simplified approach whereby (in most cases) a nitrate concentration profile in the soil through time is defined and responds to runoff and drainage events by estimating what nitrate would be removed during those events. The exception is in estimation of dissolved inorganic nitrogen in runoff which looks at runoff concentrations after fertiliser application.
- As nutrient export is highly specific to the soils, topography and management practices, nutrient loss was only modelled at the property scale. The principles of minimising nutrient loss are applied at the precinct scale.

Pesticides:

- The *Pesticide Decision Support Tool* (PDST) (Warne *et al.*, 2023) calculates the aquatic risk of a chemical applied as a function of its:
    - measure of effect, which is based on the application rate and ecotoxicity threshold value;
    - measure of mobility and persistence, which is a measure of the potential of active ingredients to move from farmland to waterways (or the change of the active ingredient being lost in runoff) and persist.

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- Overall aquatic risk is calculated by multiplying the measure of effect by the measure of mobility and persistence.
- As for nutrients, given the complexity of pesticide export and heavy dependence on farm-specific management factors, pesticide export has not been modelled at the precinct level. Rather, the principles of minimising pesticide export are applied at the precinct scale.

Salinity:

- Salinity risk at the paddock scale was assessed using a combination of SALF2 and the solute sub-model in HowLeaky (DES, 2019).
- SALF2 (Queensland Government, 2022) is a salinity, soil, water, irrigation suitability and plant salt tolerance calculator that provides an estimate for mixing of irrigation waters to manage salinity and sodicity.
- The solute submodel in HowLeaky is an experimental model to estimate solute leaching. It is loosely based on an older algorithm from the PERFECT model. The model works by providing an initial solute concentration across the soil layers (defined using a range of options) as well as rainfall and irrigation water solute concentrations. A mixing coefficient is also provided to then route the solute through the soil profile when rainfall or irrigation is sufficient to cause drainage.
- Salinity risk at the Precinct scale was assessed based on assessment of Time to Fill analysis (DES, 2021; Biggs et al., 2013). Time to fill is a simple calculation based on the available soil water storage capacity of the regolith assuming that no deep drainage leaves the regolith by lateral flow or drainage through the underlying bedrock. A spatial interpretation of regolith depth has been used as the basis for salinity risk assessment (Andrew Biggs pers. comm.).

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10. Reef water quality report

10.1 Overview

The modelling carried out to inform this Precinct plan indicates that for all irrigated cropping types other than perennial fodder and pasture crops, and possibly tree crops, irrigated cropping development can be expected to have a net impact on:

- Sediment export to the reef;
- Nutrient export; and
- Pesticide export.

Rising groundwater and salinity is considered a lower risk provided irrigation is efficiently managed to avoid excessive deep drainage. Salinity risk is considered very low across the majority of the precinct, and low in the north-west and southern corners of the precinct (Figure 28).

10.2 Irrigation development impacts

10.2.1 Sediment export

The baseline total sediment export to the Fitzroy River from existing agricultural and pastoral operations within the precinct is estimated at 4166 tons per year.

Assuming a fine sediment proportion of 35%, this equates to 1458 tons/yr of fine sediment.

Using an average riverine sediment delivery ratio for the precinct of 0.82, this equates to 1196 tons/yr of fine sediment export to the Reef.

Increased sediment export from irrigated cropping development can offset by:

- Adoption of best-practice irrigation management practices (including in-crop management and out-of-crop sediment retention structures as detailed in individual farm plants).
- Management of seasonal crops under a double cropping regime, with fallow periods outside the seasons of likely intense rainfall.
- For seasonal crops other than perennial pasture and fodder crops (Rhodes hay and Lucerne) implementation of complementary grazing management practice improvements (forage budgeting, matching stocking to feed production, rotational grazing, distributed water points, regenerative grazing planning), potentially over 4% to 20% of undeveloped land (i.e., 4,598 to 22,991 ha) dependent on crop mix.

Delivery of a proportional contribution to the Reef 2050 sediment reduction target for the Fitzroy of a 30% reduction in anthropogenic sediment export to the reef is a more challenging target. Being low in the catchment, sediment leaving the land and entering the river is more directly conveyed to the Reef. Accordingly, the required sediment reduction per unit area of land is greater than for the same area higher in the catchment. To achieve a 30% reduction in anthropogenic sediment will require:

- Adoption of best-practice irrigation management practices (including in-crop management and out-of-crop sediment retention structures as detailed in individual farm plants).
- Management of seasonal crops under a double cropping regime, with fallow periods outside the seasons of likely intense rainfall; and
- Implementation of complementary grazing management practice improvements (forage budgeting, matching stocking to feed production, rotational grazing, distributed water

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points, regenerative grazing planning), potentially over 45% to 70% of undeveloped land (i.e., 51,700 to 80,500 ha) dependent and crop mix.

10.2.2 Nutrient export

Modelling nutrient loss is specific to the soils, topography and management practices. Therefore, nutrient loss was only modelled at the property scale. None-the-less, the principles of minimising nutrient loss are relevant at the precinct scale.

Common themes from individual farm modelling are:

- Nitrate nitrogen is not strongly retained in topsoil, hence, runoff and leaching is likely during the wet seasons under both dryland and irrigated conditions.
- Modelled runoff of nitrate in an average rainfall year was predicted to peak for irrigated Rhodes grass at 0.75 kg/ha during the December to February high rainfall period, but runoff nitrate loss was negligible across the remainder of the year.
- Leaching of nitrate followed a similar trend to runoff losses, with most nitrate leached in December and February.
- Nitrate leaching is a function of soil mineralogy, soil pH, root depth distribution and rainfall. Hence, the leaching losses in the field are difficult to predict accurately.
- Under irrigated conditions, runoff and drainage nitrate concentrations are elevated, but drainage nitrate can be managed by irrigation scheduling to minimise deep drainage.

Key messages from individual farm modelling are:

- Nitrogen losses in drainage will only occur during periods of high rainfall, which cannot be controlled by the landholder.
- Nitrogen losses via runoff under irrigation were not materially different to runoff under dryland conditions.
- Vegetated buffer strips can be established to intercept nitrogen in the runoff.
- Appropriate irrigation scheduling will lead to minimal deep drainage and thus minimal drainage N losses.
- Best-practice fertiliser management (4Rs) (e.g. deep placement of fertiliser, timing of application, split applications, application rates) will further minimise nitrogen losses and ensure compliance with the Code and Reef Protection Regulations.

10.2.3 Pesticide export

As for nutrients, the complexity of pesticide export and heavy dependence on farm-specific management factors, renders pesticide export specific to the soils, topography and management.

Rather, pesticide risk was assessed using the *Pesticide Decision Support Tool* (PDST) (Warne *et al.*, 2023), which calculates the aquatic risk of a chemical applied as a function of its:

- measure of effect, which is based on the application rate and ecotoxicity threshold value; and
- measure of mobility and persistence, which is a measure of the potential of active ingredients to move from farmland to waterways (or the change of the active ingredient being lost in runoff) and persist.

Recommended management strategies to reduce pesticide runoff include:

- *Erosion and sediment control measures:* Establishing buffer zones between treated areas and flow paths to trap sediment (including adsorbed pesticides) and increase runoff time of concentration, reducing the likelihood that pesticides will reach aquatic environments before degrading.
- *Application timing:* Applying pesticides during dry periods or before the onset of the wet season will minimize the runoff risk and the chance of pesticide loss through deep drainage.
- *Optimised application rates:* Reducing overall pesticide usage, through using spot or band spraying to target specific areas, will reduce the risk of pesticide loss through runoff.
- *Integrated pest management principles:* monitoring, intervention thresholds, biological controls, crop rotation and maintaining good soil health can help to minimise reliance on pesticides and reduce usage.
- *Lower risk pesticides:* It is recommended to select pesticide products containing pesticides with lower aquatic risk values (see Table 4), noting that pesticide products that contain pesticides with low aquatic risk values but high measure of effect values (i.e., low aquatic risk due to low mobility and/or persistence) should be stored, handled and applied with care to avoid direct contamination of waterways.

10.2.4 Salinity

Irrigation induced salinity risk is very low to low across the South Yaamba precinct given the depth to regolith is generally greater than 20m. Notwithstanding, poor irrigation practices that resulted in excessive deep drainage above the rate assumed (50mm/yr) would be expected to increase the rate of groundwater rise and risk of locally perched water tables. When groundwater intercepts historical salt stores in the regolith or soil profile it will carry the stored salts, and rise to the surface when the groundwater rises within 2m of the surface. Areas at greatest risk occur in the north-west and southern corners of the precinct.

Insufficient leaching may also lead to a salinity risk though accumulation of salts in the rootzone. Cropping on low permeability cracking black clays in particularly is a risk due to a low inherent leaching fraction. These areas require careful management and regular monitoring of rootzone salinity either by direct soil sampling, electromagnetic surveying or both.

10.3 Implications of irrigation development impacts

10.3.1 Land management change requirements

10.3.1.1 Sediment

Direct irrigation development impacts on sediment can largely be met through implementation of best management practices in-crop and implementation of out-of-crop sediment retention measures, with some requirement for introduction of best practice grazing management, on complementary lands (principally for seasonal crops).

10.3.1.2 Nutrients

Management of nutrient impacts, and in particular, nitrogen, is more problematic. Similarly, modelling of precinct scale nutrient impacts is more complicated for nutrients than sediment, as it requires information on individual farm practices.

As detailed in Section 5.3, nitrogen losses are principally related to deep drainage following irrigation and heavy rainfall. Development of irrigated cropping involves the introduction of new nitrogen into the landscape through fertiliser application required as a consequence of the intensification of agriculture. Nitrogen losses though leaching can be reduced by best-practice nutrient management including:

- deep placement of fertiliser;
- timing of application;
- split applications; and
- application rates.

However, increased nitrogen input cannot be fully offset by best management practice. Practice change on complementary land provides one of the main potential avenues to reduce total nitrogen loss from the precinct, however, as cropping development and use of fertilisers in grazing is relatively limited, the associated "levers" available to reduce nitrogen impacts to waterways are also limited.

One of the main alternative opportunities is through hyacinth removal. Hyacinth flourishes in nutrient-rich waters and extract nutrients into plant biomass. Harvesting hyacinth provides a means to remove nutrients. Calculation of the mass balance, to objectively evaluate this "lever" has not been undertaken.

Phosphorus losses are less problematic than nitrogen. As general rule, Australian soils have a significant phosphorus buffering capacity and, apart from light sandy soils are generally efficient at binding applied phosphorus. Phosphorus export can therefore be managed in line with sediment management to avoid physical loss of sediment and bound phosphorus.

10.3.1.3 Pesticides

As outlined above, the main "lever" to minimise pesticide export to waterways is selection of low-mobility chemicals, in association with sediment management to reduce physical sediment loss and associated transport of attached pesticides.

10.3.1.4 Salinity

Time-to-fill modelling has demonstrated that salinity development is a low risk provided best management irrigation practice is employed to avoid saturation of the soil profile leading to excessive deep drainage and the associated potential for localised perched water tables. Irrigation monitoring using soil moisture probes, with placement informed by soil mapping, paddock design match to soil types, plus irrigation time and rate application monitoring, all elements of best practice, can be expected to avoid any risk of salinity development.

10.3.2 Barriers

Significant barriers to achieve no net Reef water quality impact from new irrigation developments and contributing toward achieving the Reef 2050 anthropogenic reduction targets include:

- ***Capacity of landholders to fully and effectively implement farm plans***: This is considered the greatest potential risk to the project. While interviews (Section 3) have indicated that landowners are seeking to improve productivity and/or value, and recognise the requirements under the Code of Practice to improve environmental sustainability, capacity to deliver on this intent varies, from farmers with no prior cropping experience, to

experienced irrigation farmers who may be challenged by the need to implement changed practice despite good intent. The need for comprehensive capacity building support is discussed more fully in Section 3.5.

- ***Availability of and access to land to implement offsets***: Issues related to capacity to implement offsets on land outside the areas developed to irrigated agriculture are discussed in Sections 4.4.3 and 5.3.1.

10.3.3 Relative implications

Reduction of sediment impacts to meet a proportional contribution to the Reef 2050 targets requires land use change over large areas (refer Section 4.4), or alternatively, investment in intensive works such as streambank or gully repair. However, there is a viable pathway to delivering on these offsets.

Reduction of nitrogen export to waterways to achieve no net impacts is a relatively smaller issue from a scale perspective but is more problematic to achieve given the lack of "levers" available to reduce the increased nitrogen inputs associated with intensification of agriculture withing the Precinct.

10.3.4 Current monitoring evaluation

Prior experience has indicated that, even with appropriate planning, design, and installation of monitoring equipment, there is considerable variation in the capability and capacity of landholders to review, interpret and act on monitoring results.

10.3.5 Evaluation of enterprise change required

A survey by Cotton Incorporated in the US found that cotton producers who use sensors for irrigation management achieved both higher water use efficiencies (cotton produced per unit of water) and higher yields than those who do not (Lieb *et al*, 2015). However, despite availability and strong scientific evidence, a number of Australian surveys of have found that only one quarter to a third of growers are using soil water monitoring tools to assist in irrigation scheduling (Stirzaker, 2006; Montagu and Stirzaker, 2008). While it is expected that this percentage has increased over time, these results indicate a challenge in adoption, and say nothing about the quality of adoption.

Collectively, these authors have identified a number of barriers to adoption:

1. Entrenched culture
2. Don't see the importance of scheduling
3. Investment doesn't pay
4. Hard to implement
5. Complexity and uncertainty
6. Science vs farmer perspectives
7. The wrong extension model

Of these:

- Entrenched culture is a potential issue for a small number of existing operators;
- The importance of scheduling is addressed through the conditions to issue water licences and the requirements identified in individual farm plans, but still requires a commitment on behalf of individual farmers

- The argument of "investment doesn't pay" has been widely addressed by many studies demonstrating the alternative. Communication of the value of monitoring is critical to effective extension and capacity building.
- "Hard to implement" is a significant potential barrier. Effective implementation of irrigation monitoring requires a level of technical complexity that requires considerable effort in effective extension and capacity building.
- "Issues of Complexity and uncertainty" are closely linked to the issue of scheduling being "Hard to implement", and similarly, requires considerable effort in effective extension and capacity building.
- "Differences in science vs farmer perspectives" arises from the failure of scientists to understand the worldview of the farmer and the constraints under which they operate. Farmers manage a business and need to address multiple considerations. Scientists tend to focus narrowly on a problem to identify a specific solution. These different perspectives can lead to a difference in the perception of the accuracy of information its usefulness. Effective capacity building and extension is paramount to bridge this divide.
- "The wrong extension model" is perhaps the most critical barrier to address to ensure effective practice adoption. The gap between the science and practice of irrigation scheduling is traditionally seen as a failure in adoption that should be addressed by extension. As an example, studies by Kaine et al (2005) and Lineham *et al*., (2005) show that farmers are more interested in saving time and increasing flexibility than saving water, and that while many farmers may be well informed about the benefit of soil water monitoring tools, other constraints prevented their adoption.

To address the significant constraint of getting the extension model wrong, Blacket (1996) recommends a 'learning based' approach that takes the farmer's current practice as the starting point, implicitly valuing their existing skill level and implementing change through a process in which information reduces the risk to the point that the farmer is willing to alter practices. Kolb's (1984) experiential learning cycle adopts this approach through four stages:

1. The farmer decides to take concrete action to do something about their irrigation 'problem' (eg. the purchase of a soil water monitoring tool).
2. Action leads to observation (look at the data) followed by reflection on the data (what does it say).
3. Generalisation (what's the pattern) and conceptualisation (what it means).
4. From this point the farmer can begin active experimentation (if I do this then that should happen) leading back to observation and the cycle begins again.

10.3.6 Pilot precinct base change mapping and impact review

Precinct-scale monitoring is critical to establishing a baseline and tracking cumulative changes over time. As with the requirement for effective monitoring and management at the individual farm level, precinct scale monitoring and review will provide the means to assess performance against environmental conditions (compliance) and inform adaptive management (control).

Precinct scale sediment monitoring can be readily carried out by remote sensing analysis and sediment export modelling using the approach in this report to indicate the potential extent of required offsets and change in management practices required to mitigate sediment export.

Precinct scale monitoring of nutrient management is more challenging, as this requires integration of specific management data from each individual farmer. In this way, individual farm and precinct wide monitoring and adaptive management are inter-linked. This will require effective systems to capture, manage and assimilate individual farm monitoring data while protecting confidentiality. A smart approach to this challenge will link effective capacity building and extension to develop mutual trust and shared benefits resulting in productive and sustainable irrigation development.

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11. South Yaamba Precinct Water Quality Model

11.1 Critical monitoring elements for water quality

Management of:

- sediment export to the Reef from irrigated cropping development; and
- contribution of irrigation water application to deep drainage

are the two the critical core components of delivering on the Precinct Water Quality Plan given the pathways for nutrient and pesticide export are linked to sediment loss and deep drainage.

11.2 Sediment export

Monitoring of sediment export is critical for sediment directly, but will also indicate the potential for export of particular and adsorbed nutrients, as well as pesticides. A high rate of sediment export is not necessarily indicative of nutrient and pesticide export, but provides the conditions for this to occur where either nutrients have been used inappropriately (excess rate, inappropriate timing or placement), or pesticides have been used in excess with high mobility, persistence, and effect. Therefore, farmer records for nutrient and pesticide use will be required to complement remote sensing of sediment export to fully quantify effects on surface water quality.

Data sources for monitoring of sediment export using remote sensing and spatial monitoring are readily available. Change in groundcover, corrected for seasonal variation, provides the core variable data source required to qualitatively model changes in sediment export using DROVER.

Ground cover data is sourced from Queensland Government, with a minimum of blended monthly captures, 30m/pixel, and restricted to <60% woody vegetation (TERN: Monthly Blended Ground Cover version 3 - Landsat and Sentinel-2, JRSRP algorithm, Queensland coverage).

Other data sources: Rainfall (R); Soil Erodibility (K); Slope length (LS); Rock factor (RF); Slope (S), Conservation Practice factor (P), are readily available and as described in Silverwood and Yates (2024).

A strength of the modelling approach to estimation of sediment loss is that it can be applied monthly across the entire precinct to identify hot spots and/or inform changes in management for continuous improvement. Relative changes in sediment export can be expected to be robust.

A limitation of the approach is that modelled changes may vary from absolute quantities, although the alignment of DROVER results with long P2R sediment export estimates that have been calibrated to measured riverine sediment loads (Verterra data unpublished) indicates that sediment quantities are a close reflection of actual loads.

Notwithstanding, a more dynamic monitoring framework could be developed by matching modelled estimates to measured estimates from riverine monitoring. This, combined with machine learning applied to remote sensing of riverine turbidity levels provides a potentially powerful way to directly monitor sediment loads, and provide a more granular feedback loop to manage water quality.

CSIRO's AquaWatch Australia program, combined with a combination of permanent and in-stream monitoring stations, routine grab sample monitoring and continuous satellite monitoring via DROVER provides the potential to link changes in land management activities, to changes in surface water turbidity and provide a "weather service" for water quality. There exists the potential for collaborative develop of this water quality monitoring approach, which will have application across the entire Fitzroy and all Reef catchments.

11.3 Deep drainage and potential nitrogen leaching

Currently, deep drainage data is only potentially assessable by modelling based on rainfall records and individual farmer irrigation scheduling data. This is not a viable approach to monitor deep drainage to identify risks related to nitrogen movement into the groundwater system.

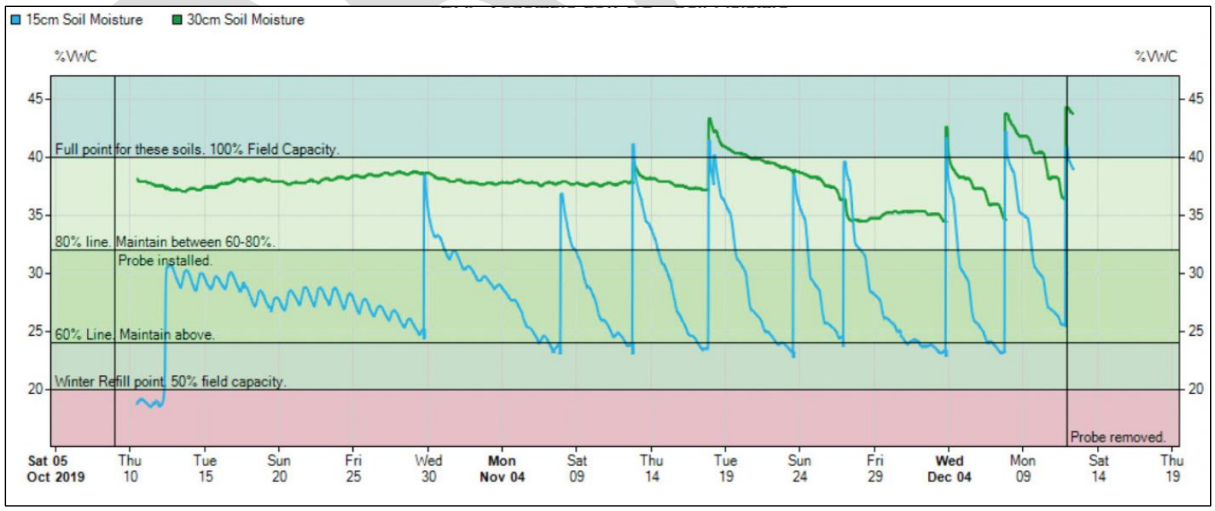
An alternative approach that provides benefit to all parties is the installation of soil moisture monitoring probes, combined with automated weather stations at representative locations within each irrigation development.

Soil moisture monitoring probes are routinely used in irrigated cropping to efficiently manage irrigation water applications in order to optimise crop production and limit deep drainage to that necessary to provide a leaching fraction required to prevent build up of salts in the rootzone.

Soil moisture probes typically link wirelessly to an on-line interface that can be accessed by multiple parties. This provides the capacity to remotely support new irrigation farmers and existing irrigators not familiar with the use of soil moisture probes.

The typical output of a soil moisture probe is shown in Figure 30. This graph shows the ideal range in which soil moisture should be maintained to minimise crop stress and avoid deep drainage. Plant available water capacity (PAWC), the range in soil moisture conditions where plants can extract water, occurs between wilting point and field capacity (or drained upper limit). Below wilting point, the soil is too dry for plants to extract water. Above field capacity, the soil is saturated, plant water uptake ceases due to the associated low soil oxygen content and onset of waterlogging, and deep drainage will occur. Crop stress will occur when soil moisture is maintained between around 50% to 60% PAWC and field capacity. In the graph below, field capacity is exceeded at both 15cm and 30cm depth on a number of occasions.

Figure 30: Example of soil moisture probe output (DAF, 2020)



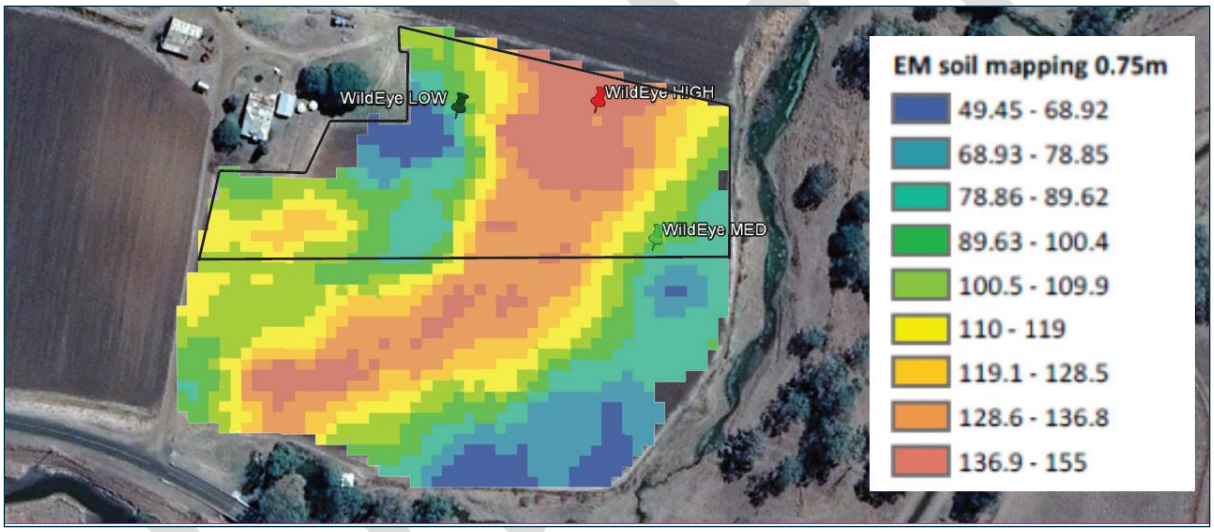
Placement of soil moisture probes should be based on a representative location of each soil type. In turn, mapping of soil type variation is best informed by soil electromagnetic (EM) surveying. An example soil EM map and use for placement of soil moisture probes in presented in Figure 31.

An EM survey map is a map identifying changes in soil properties. Soil sampling at representative locations across the range of EM values obtained can be used to correlate specific soil properties with the EM signal response. Typically, the EM signal responds to salinity, soil moisture (reflection of clay content), soil cation exchange (also a reflection of clay content and type), and compaction.

As with soil moisture probes, a pre-development EM survey provides benefit to all parties. Different parts of a paddock may have different soil types with significantly different physical, chemical and biological properties that impact permeably, irrigation rate, irrigation requirement and other crop management practices. A pre-development EM survey can assist with irrigation design by either allowing irrigation blocks to be matched to similar soil types or, for centre pivot irrigation, inform programming of variable rate application.

In addition to informing irrigation block design, an EM survey serves as a benchmark of pre-irrigation conditions. Follow up EM surveys are routinely used to characterise changes in soil properties over time, particularly an increase in salinity in the rootzone. This information can inform adaptive management such as application additional irrigation to leach salts below the rootzone.

Figure 31: Example soil electromagnetic survey and placement of soil moisture probes (DAF 2020)



Deep drainage *per se* does not necessarily equate to leaching of nitrogen to groundwaters, from where it can move laterally to surface waters and the reef. Application of nitrogen fertiliser in excess of crop demand is required for this to occur. Therefore, farmer fertiliser application records remain a necessary component of nitrogen risk monitoring. However, excess mineral nitrogen application (or inappropriate timing of nitrogen application) in combination with excessive deep drainage, (either from rainfall or irrigation) are both necessary to increase the risk of mobilising nitrogen to the reef.

11.4 Strategy and recommendations for implementation of the precinct plan

The following recommendations are made in relation to the strategy for implementation of the precinct plan in order to:

- Provide support and capacity building for farmers;
- Assist farmers achieve optimum crop production; and

- Minimise environmental impacts and deliver environmental benefits.

Recommended on-farm actions are:

1. Encourage farmers to undertake a pre-development EM survey to characterise soil type variation, soil sampling to quantify variation in soil characteristics.
2. Encourage and support farmers to utilise the results of the EM survey to inform irrigation block design and/or variable rate irrigation.
3. Encourage farmers to further utilise the results of the EM survey to inform representative placement and installation of soil moisture monitoring probes.
4. Encourage farmers to install an on-site automated weather station linked to the soil moisture probes to enable moisture probe interpretation for optimal irrigation management.
5. Encourage farmers to install flow meters on irrigation equipment enabling irrigation planning informed by soil moisture probes.
6. Require farmers to make records in relation to irrigation scheduling, fertiliser use and pesticide use, available to Sunwater/DES to enable identification of events impacting water quality.
7. Encourage and support farmers to undertake annual EM surveys, soil sampling and EM-soil correlation to track changes in soil properties over time and inform adaptive management.

Recommended precinct-scale actions are:

8. Undertake regular, monthly precinct wide monitoring and modelling of sediment, nutrient and pesticide export from the range of data pools available (satellite vegetation, cover, soil moisture probe data, distributed weather stations, farmer records) for irrigation scheduling, fertiliser use and pesticide applications.
9. Provide support and capacity building for farmers to interpret soil EM maps, interpret soil moisture probe data, interpret soil tests to optimise fertiliser application rates and select and use minimum impact pesticides.
10. Provide incentives for practice change on undeveloped land (within and beyond land developed for new irrigation irrigation) to offset impacts and contribute to Reef 2050 targets.

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12. Model for Practice Change

12.1 Practice change goals

Successful delivery of the South Yaamba Reef Water Quality Precinct Plan will require strong stakeholder engagement and capacity building across the board. In turn, this will require appropriate management practices and controls at both the farm scale for individual irrigators, and precinct scale to manage not only the cumulative effects and impacts of land use change to irrigated cropping development, but also the effects and impacts of past land use on anthropogenic fine sediment loads to the Reef.

The associated goals underlying a model for practice change should aim to:

- Maximise crop production and soil health at the farm scale;
- Minimise potential negative impacts on sediment, pesticide and nutrient export;
- Offset any residual impacts on sediment, pesticide and nutrient export that cannot be avoided;
- Avoid any risk of local or regional impacts on salinity, either though groundwater rise or rootzone accumulation; and
- Contribute to a net positive outcome for the Fitzroy River and Reef water quality through precinct-wide practice change that contributes to the reef 2050 water quality targets for a 30% reduction in anthropogenic fine sediment load to the reef.

12.2 Information and capacity requirements

12.2.1 Planning and design

Practice change begins with detailed planning. A quantitative approach to planning enables alternative irrigation development designs to be evaluated and assessed to inform the dual objectives of maximising production and minimising environmental impact. This might include matching block designs to soil types; matching variable rate application to spoil types; soil moisture probe location; controlled traffic layout; avoiding erosion soils or slopes; planning sediment control structures, filter strips, etc.

Planning also includes proposed management practices. A quantitative approach to planning enables evaluation of the impact alternative crop types and crop combinations; establishment and harvesting windows; fertiliser application timing; choice of fertilisers; fertiliser placement; choice of pesticides and numerous other crop management decisions that can influence both productivity, returns and environmental impact.

Importantly, quantitative planning will allow evaluation of the capacity to minimise impacts and the requirement to undertake complementary management activities on land not developed for irrigation, such as grazing practice change to offset any net increase in sediment export.

Sediment abatement through grazing practice change over and above offsets to achieve a net neutral position and meet the minimum requirement of the Reef Regulations can be eligible for Reef Credits through EcoMarkets Australia: Fine Sediment Method Development, providing the potential for grazing productivity improvement, and the opportunity to earn an additional income stream, while also contributing the Reef 2050 Water quality target of a 30% reduction in anthropogenic fine sediment load to the Reef.

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In addition to the potential to go above net neutral sediment abatement and generate Reef Credits, complementary land management activities involving improved grazing practice may also generate soil carbon credits, proving another income stream opportunity.

Both Reef Credits and Soil Carbon Credits require project registration and development of a land management plan aimed at actively undertaking practices to improve vegetation cover, reduce sediment export and increase soil carbon.

12.2.2 Management

While a detailed design plan provides the "infrastructure" and "blueprint" for productive and sustainable management, implementation of the proposed management practices is critical to achieving expected commercial and environmental outcomes.

Landholders receiving water through the Rookwood Weir scheme range from new cropping practice at one end; through experienced dryland croppers with no irrigation experience; to experienced irrigation croppers at the other end. Across this range, it is unlikely any farmers have experience in collective contribution to achieve no net cumulative impact, and are even less likely to collectively achieve a net positive position.

Capacity building, education and development of a collective approach to sustainable irrigation development of the precinct are all necessary to deliver on the stated practice change goals. To achieve this, three major initiatives are proposed:

1. ***One-on-one support***, particularly for new croppers and irrigation farmers, to constructively review management practice implementation against planned activities, in order to build understanding and capacity; inform continuous farm practice improvement; and cumulative precinct performance. Getting the extension approach right (refer Section 10.3.5) is critical to effective delivery on this objective.
2. Development of a ***Community of practice*** among all irrigation farmers to facilitate peer to peer learning; experience and knowledge sharing; and feedback on remote monitoring to inform
3. Development of a wider ***Precinct sustainable management forum*** where all landowners (irrigators and graziers), scientists, agronomists, consultants and relevant government stakeholders (Sunwater, Advance Rockhampton, DETSI and DPI) can share information on cropping case studies, environmental offsets, precinct wide environmental performance, water quality improvements and nature positive opportunities.
4. ***Integration of individual farm and Precinct scale monitoring***. Effective implementation of individual farm management plans generally has the capacity to address no net impact but cannot achieve a proportional contribution to the Reef 2050 targets. Additionally, the modelling carried out in this report and the individual farm plans is based on scenario analysis. Retrospective monitoring at the farm and Precinct scale is critical to assess performance against targets (compliance) and inform adaptive management (control).

While it is recognised that a ***Precinct sustainable management forum*** is a novel concept, it acknowledges the fact that a collective effort is required among all landholders in the precinct, not only new irrigators, to achieve net zero water quality impact for some crops, and a reduction in anthropogenic sediment export for all agricultural pursuits (cropping, horticulture and grazing). The Forum will provide a means to build collective knowledge on best management practices, cumulative impacts, and opportunities for beneficial collaboration among landholders to generate sediment

offsets supporting irrigated development while improving productivity and generating potential new revenue streams.

In addition to generating collective sediment offsets, potential generation of soil carbon credits will provide an indirect benefit to reef health by contributing to sequestration of atmospheric carbon, a major contribution to increasing ocean temperatures leading to coral bleaching.

The proposed approach of establishing a ***Precinct sustainable management forum*** could potentially become a model for agricultural land management more widely, by recognising and embracing the collective and cumulative contribution of land managers to catchment, water quality and Reef health – thinking global and acting local.

12.2.3 Monitoring and continuous improvement

Monitoring at both the farm and precinct scale is critical to evaluating actual against planned performance and providing a feedback loop to enable continuous improvement.

At the farm scale comprehensive record keeping of management activities, combined with monitoring of site conditions, inputs and outputs is critical to quantitatively evaluate improvements in productivity and environmental performance.

Monitoring at the precinct scale will require dedicated resources to regularly evaluate water quality changes in response to cumulative activities across the entire precinct. Specific monitoring requirements are outlined in Section 11.

From the perspective of a model for practice change, quantitative monitoring data at both farm and precinct level, combined with timely and regular communication of monitoring results and management implications, is an indispensable tool for continuous improvements and meeting practice change objectives.

12.2.4 Incentives for precinct-wide practice improvement on non-irrigated lands

Given the scale offset requirement in addition to best management practice within irrigation developments to achieve the Reef 2050 sediment reduction target, and in some cases to achieve no net impact relative to the current baseline, complementary practice change on unirrigated land well-beyond individual properties implementing new irrigation development will be required if Sunwater is to meet its EPBC compliance obligations. As Sunwater has no control outside landowners purchasing water for new irrigation developments, it will be mandatory to consider a program of incentives for other landowners within the Precinct to implement improved land management practices that reduce sediment. This may include grazing practice change, gully or streambank remediation and implementation of other erosion control measures, and potentially, establishment of a sediment and nutrient trading scheme.

12.2.5 Verification of land stewardship and market access

The concept of a the proposed Model for Practice Change for the precinct may be considered a microcosm of the global trend in achieving net zero carbon emissions to address climate change (centred round the Paris Climate Accords), and the more recent movement to net positive environmental management to counter biodiversity loss (centred around the Kunming-Montreal Global Biodiversity Framework and other international commitments to protect and preserve reef

health). Responsibility for meeting these commitments is increasingly being shared with industry and government, recognising our collective community responsibility for nature repair.

From 1 January 2025, the Australian Sustainability Reporting Standards (ASRS) will require certain entities, generally listed companies with consolidated revenue of $500 million or more; consolidated assets of $1 billion or more; or employees of 500 or more; to report about climate-related risks and opportunities that could reasonably be expected to affect the entity's cash flows. The ASRS also provides for voluntary reporting by any entity on sustainability-related risks and opportunities.

Similarly, the related Taskforce on Nature-related Financial Disclosures (TNFD) provides a voluntary framework for sustainability reporting by corporations that wish to align their environment, social and governance (ESG) credentials with the Global Biodiversity Framework or the International Sustainability Standards Board (ISSB).

As voluntary adoption and regulatory requirement for sustainability reporting gathers momentum, impacts can be expected to flow through the value chain. For example, McDonald's sources around two-thirds of its annual global beef supply from Australia. If (and when) the company either makes a voluntary pledge or is required by legislation to become nature positive, farmers would have to prove they are actively engaged in regeneration activity and practice responsible land stewardship. Those that can't, could lose sales (AFR, 2024). Numerous companies, such as Aldi, have already begun to move down this path by setting a target to end deforestation (AFR, 2024), requiring suppliers to verify their sustainability credentials.

These trends in reporting, and demonstrating action on, not only sustainable management, but regenerative, nature positive practices, is aligned with delivery of the Reef 2050 targets and indicates both the business case and the opportunity to increase productivity and competitiveness while contributing to nature repair. It also underlines the importance of taking these considerations into account in the design of a fit-for-purpose Model for Practice Change for the South Yaamba precinct.

12.2.6 Transition plans to go from current practices to best management practice

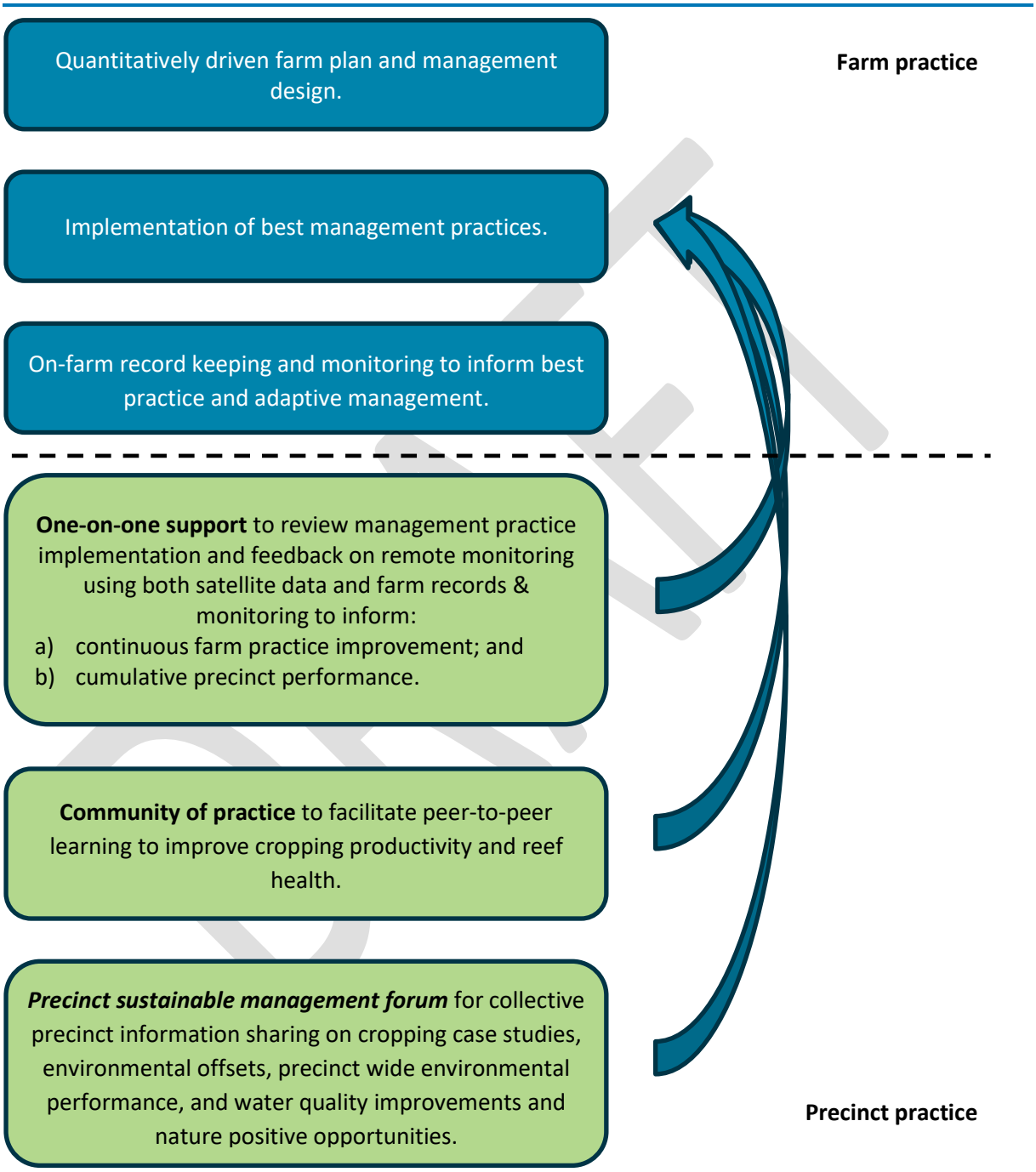
Existing irrigators will require considerable support in education and re-training to assist in moving from current management to best management practice. This has a psychological dimension in change management that may not be as pronounced in new irrigation farmers without entrenched ideas. An integrated approach to the collective actions discussed above, particularly in relation to support for appropriate implementation of the proposed management practices, and evidence-based feedback through monitoring and continuous improvement, will contribute toward this objective.

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12.2.7 Model for practice change

Based on the foregoing discussion, a proposed model for practice change across the precinct is illustrated diagrammatically in Figure 32.

Figure 32: Model for practice change



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Appendix 1: Current or proposed landholder agricultural management practices and aspirations questionnaire

	Current or proposed management practice	*Minimum standard - Grains Water Quality Risk Framework (2017-22)*	*Best Management Practices – The Code, Sunwater Land Management Code of Practice*	Transition actions to meet The *Code (progress within 6mths, achieved within 3yrs)*
Soil Management				
1.1 Use of tillage • Compaction zones?		Efforts are made to maintain stubble cover during fallows. Stubble usually needs to be cultivated to allow for planting and/or fertiliser is applied using full disturbance implements.	*Crops must be planted into standing stubble from the previous crop/s.* *Tillage must only be used when required to deal with severe compaction (including for first tillage of the field), nutrient stratification, as part of a strategy to manage certain difficult weeds (which may involve occasional zonal or 'patch' tillage) or to destroy an existing crop type and replace with an alternative.* *Fertiliser must be applied using zero-till machinery.*	
1.2 Crop selection		*Crop rotation based on planting opportunities and gross margin, with little or no consideration of stubble cover.* *Back to back pulse crops may be grown if commodity prices are high.*	*Maintaining >30% stubble cover must be a high priority when choosing crops.* *Successive low stubble crops are avoided.* *Back-to-back pulse crops must not occur.* *Grain crops may be planted into marginal soil moisture for the purpose of increasing ground cover.*	
1.3 Wheel traffic		*All farm equipment except headers and mobile grain bins operates on the same wheel spacing and consistent implement width.*	*A controlled traffic system is in place with all tractors and implements, headers and mobile grain bins operating on the same set of wheel tracks.* *All machines must operate under GPS guidance of at least 4 cm pass to pass accuracy.*	
1.4 Erosion control • Description of landforms, (slope, slope length, aspect, watercourses)		*Contour and diversion banks, are present and regularly maintained.*	*Contour and diversion banks must be present and regularly maintained. The placement and design of banks must be informed by a skilled third party.* *Secondary forms of sediment control, such as sediment traps, must be in place including for first tillage of a field or when destroying a crop.*	
Nutrient Management				
2.1 Determine nutrient requirements. • Fertiliser type • soil type • soil sample frequency • historic yield data		*Regular soil analysis, in conjunction with yield/protein information, is used to make N management decisions*	*Yield mapping data informs precise variable fertiliser rate control for specific management zones.* *Pulse crops must be regularly included in the crop rotation to reduce the need for N fertiliser.*	
2.2 Influence of stored soil moisture on yield and N fertiliser decisions • Soil moisture, salinity? G-dots? EC? • Actions taken to improve performance/yield (eg foliar nutrition) • Any audits undertaken • Local agronomist?		*Stored soil moisture is monitored throughout the fallow and informs decisions on yield potential and appropriate fertiliser rates.*	*Stored soil moisture must be monitored throughout the fallow and decision support tools must be used to indicate yield potential when selecting fertiliser application rates*	
2.3 Application timing to minimise potential losses and maximise uptake of N fertiliser • timing and method of application		*Normal practice is that N fertiliser is only applied late in the fallow and/or when there is a full soil moisture profile.*	*N fertiliser is applied early in a fallow to minimise probability of losses. Fertiliser may be applied as split applications (e.g., during the fallow, at planting and/or in crop).*	

	Current or proposed management practice	*Minimum standard - Grains Water Quality Risk Framework (2017-22)*	*Best Management Practices – The Code, Sunwater Land Management Code of Practice*	Transition actions to meet The *Code (progress within 6mths, achieved within 3yrs)*
Chemical Management				
3.1 Targeting herbicide application • timing, rates, application method		*Knockdown and residual herbicides are usually applied through conventional boomspray with 100% paddock coverage.*	*Farmer must bandspray residual herbicides, and/or target specific zones within paddocks rather than apply to 100% of the paddock.*	
3.2 Use of residual herbicides		*The same residual herbicide program (fallow and in crop, pre- and post-emergent) is used in each paddock every year, in response to possible or anticipated weed pressure.* *High-risk products are usually applied once per season and prior to commencement of the wet season*	*Residual herbicide use must be confined to paddocks, parts of paddocks and seasons when weed pressure is high. Application of multiple below-label rates of residual herbicides through the year is preferred to full label rates.*	
3.3 Efficient herbicide application • application method		*Boomspray operates in a controlled traffic system to minimise overlap.*	*Boomspray must operate under machine guidance of at least 10 cm pass to pass accuracy in a controlled traffic system.* *Boom must have automated section and individual nozzle controls to further minimise overlap.*	
3.4 Pesticide selection • Approaches to integrated pest management		*Pesticide product choice is based on efficacy and cost effectiveness of control.*	*Pesticide choice must be informed by assessment of control efficacy AND environmental risk, and lower toxicity products must be selected wherever feasible.* *Product choice must consider the amount of active ingredient applied, its relative toxicity, half-life, solubility, and soil adsorption properties and their interaction with the soils on the farm.*	
Irrigation scheduling				
4.1 Irrigation scheduling • Proposed irrigated enterprise/goals, yield expectations • Amount of water sought for irrigation		4.1 -4.5 Not listed in the Water Quality Risk Framework, need to confirm minimum standard to be classified as 'partial best practice achieved.'	*Objective tools must be used regularly to modify irrigation applications.*	
4.2 Matching irrigation interval and volume to crop requirements and soil limitations. • amount of land envisage using irrigated water on		*"as above"*	*Must have an automated irrigation system and application rate must be suited to crop stages and soil type.*	
4.3 Water reuse /Minimising irrigation losses		*"as above"*	*Must have full water reuse. Water quality tests of recycled water must be completed at least twice during the irrigation season unless there is no opportunity to test. Tests must include Total N, Total P and TSS.*	
4.4 Irrigation tail water capture and re-use • Groundwater presence/usage		*"as above"*	The BMP and Audit descriptions in The Code does not align for 4.3 and 4.4.	
4.5 Production indicator		*"as above"*	*BMP not listed in The Code, Audit states* 'As *per Farm Plan'*	

Appendix 2: Current or proposed erosion and sediment control practices questionnaire

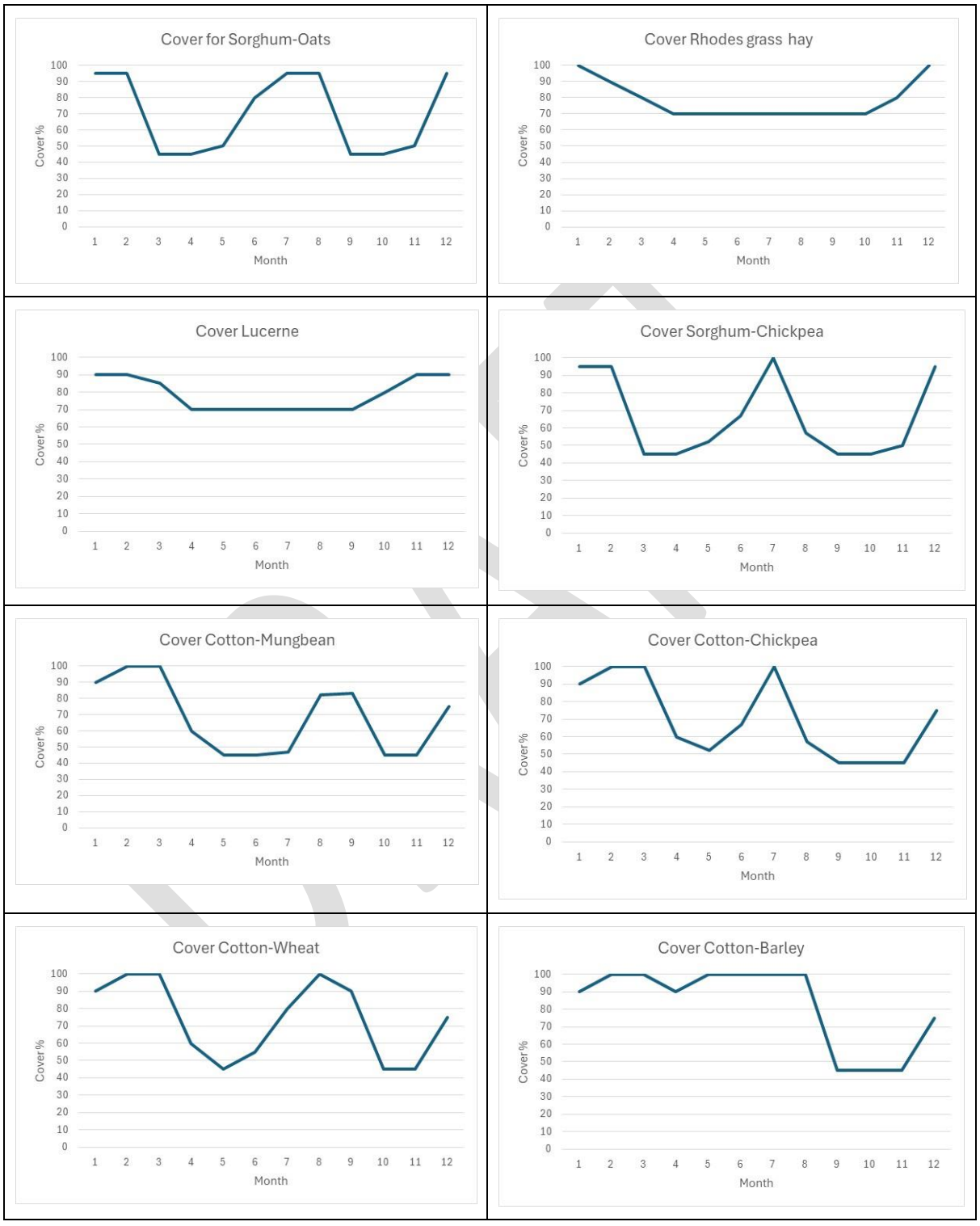
	Current or proposed sediment and erosion control practices	Notes / potential issues Note this will be elaborated on once GIS data/ irrigation design is reviewed
1.1 Controlling runoff	☒ Do you have any clean or dirty water diversions? ☒ Do you have any vegetated buffer zones? ☐ Do you have any contour banks? ☐ Do you have any constructed wetlands? ☐ Do you have any other type of erosion controls?	
1.2 Fallow management	☒ Do you have, or propose, any cover crops (between main cropping)? ☒ Do you have, or propose, to leave any crop residue (e.g. stubble, mulch)? ☐ When do you expect the ground to be left bare? ☐ How long do you expect the ground to be bare?	
1.3 In-field erosion control	☐ Do you propose any clean or dirty water diversions? ☐ Do you propose any vegetated buffer zones? ☐ Do you propose any contour banks? ☐ Do you propose any constructed wetlands? ☐ Do you propose any other type of erosion controls?	
1.4 Roadway and headland maintenance	☐ Are any existing or proposed roads located near any concentrated flows? (identify creek crossings, roads in valleys, etc.) ☐ Are any existing or proposed roads planned to run directly up/down slope? Provide details. ☐ How do you plan to construct new roads (construction method)? ☐ Do you plan to install any erosion prevention control measures? ☐ Do you currently have any eroded tracks or roads?	
1.5 Flow concentration	☐ Have you identified ny areas where overland sheet flows are likely to be concentrated (e.g. roads, drains, deep rip lines)? ☐ Are any mitigation measures planned?	
1.6 Sediment control	☐ Do you currently have any sediment control measures on farm? (e.g. buffer zones, mulch/compost berms, sediment traps)? ☐ Are you planning any sediment control measures on your proposed development areas, such as: ☐ Vegetated Buffer Zones (Type 3) ☐ Sediment Fences (Type 3) ☐ Straw bale barriers (Type 3) ☐ Rock Filter Dams (Type 2) ☐ Sediment Dams (Type 1) ☐ Do you have, or propose, any other type of sediment controls?	
1.8 Drainage controls	Do you currently have any drainage control measures on farm? (e.g. catch drains, diversion banks, contour banks, level spreaders)? ☐ Are you planning any drainage control measures on your proposed development areas, such as: ☐ Catch drains ☐ Grassed swales / diversion banks ☐ Contour banks ☐ Level spreaders ☐ Do you have, or propose, any other type of drainage controls?	

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Appendix 3: Aquatic risk of pesticides ranked lowest to highest risk x class and applicable crops

Active Ingredient	Class	Measure of Mobility and Persistence	Measure of Effect	Aquatic risk value	Cotton	Chickpea	Lucerne	Lychee	Macadamia	Mung Bean	Oat	Rhodes	Sesame	Sorghum	Soybean	Wheat
Propiconazole	Fungicide	36.8	3.0	1.10	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE
Triadimenol	Fungicide	1345.4	0.3	3.36	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE
Chlorothalonil	Fungicide	0.134	3450.0	4.61	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Tebuconazole	Fungicide	241.7	23.9	57.86	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
Flutriafol	Fungicide	9977.3	1.05	104.80	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE
Diquat	Herbicide	0.0	334.5	0.0	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Paraquat	Herbicide	0.01	148.1	0.0	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Pendimethalin	Herbicide	0.01	30530.6	0.0	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
Trifluralin	Herbicide	0.01	6260.9	0.0	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE
Trinexapac-ethyl	Herbicide	0.1	2.2	0.003	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Haloxyfop	Herbicide	21.8	0.0390	0.009	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	TRUE	FALSE
Isoxaflutole	Herbicide	0.06	326.1	0.183	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE
Fluroxypyr	Herbicide	26.9	2.0	0.538	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE
Glufosinate-ammonium	Herbicide	5.93	10.4	0.618	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Glyphosate	Herbicide	11.7	13.0	1.518	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Dicamba	Herbicide	86.6	4.6	3.977	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE
Picloram	Herbicide	1871.1	0.3	6.014	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE
Asulam	Herbicide	48.0	15.7	7.525	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE
2,4-D	Herbicide	18	52	9.271	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Imazapic	Herbicide	6.33	234.1	14.83	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE
Fluazifop-P	Herbicide	39.9	48.0	19.16	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE	FALSE
Trifloxysulfuron	Herbicide	177.4	100.0	177.37	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
MCPA	Herbicide	71.0	494.3	351.03	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE
Metsulfuron-methyl	Herbicide	268.1	291.7	782.06	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE
Terbuthylazine	Herbicide	66.5	1250.0	831.76	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Halosulfuron-methyl	Herbicide	40.2	2074.5	834.21	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Metribuzin	Herbicide	168.2	600.0	1009.0	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE
Amicarbazone	Herbicide	305.4	350.0	1069.0	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
Terbutryn	Herbicide	100.0	3055.6	3056.2	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE
Diuron	Herbicide	136.0	2478.3	3369.6	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE
Flumioxazin	Herbicide	4.1	85365.9	3518.4	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
S-Metolachlor	Herbicide	68.9	7513.0	5174.3	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
Hexazinone	Herbicide	1274.0	480.0	6115.4	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
Atrazine	Herbicide	1138.3	781.6	8896.4	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	TRUE
Ametryn	Herbicide	154.7	20000.0	30938.3	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Metolachlor	Herbicide	1170.0	3756.5	43951.9	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
MSMA	Herbicide	1353.8	5830.7	78936.5	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Bifenthrin	Insecticide	0.01	208333.3	0.0	TRUE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Permethrin	Insecticide	0.01	10000.0	0.0	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE
Carbofuran	Insecticide	34.6	1500.0	519.6	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Trichlorfon	Insecticide	6.27	17647.1	1107.2	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE
Imidacloprid	Insecticide	1045.5	4166.7	43564.0	TRUE	FALSE	TRUE	TRUE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	FALSE	TRUE
Fipronil	Insecticide	776.8	5618.0	43641.3	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Clothianidin	Insecticide	3938.2	1724.1	67899.9	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Chlorpyrifos	Insecticide	4.00	21276595.7	850694.1	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE
Cadusafos	Insecticide	182.1	2197802.2	4001266.9	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Fluensulfone	Nematicide	25.8	160.0	41.3	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE

Appendix 4: Baseline vegetation cover for each modelled crop or double crop combination



Appendix 5: Rookwood Weir Land Management Code of Practice

The Rookwood Weir Land Management Code of Practice applies to:

- each purchaser of water from Rookwood Weir who proposes to use water for the purpose of irrigated agriculture;
- new Irrigators as well as existing Irrigators purchasing extra allocation;
- all types of irrigated agriculture and all scales that purchase Rookwood Weir water; and
- to the irrigated agriculture on a property irrespective of the availability of other sources of water or the proportion of total water supply afforded by the water purchased from Rookwood Weir on that property.

The direct objectives of the code are to:

- Establish standard Land Management Practices for a range of crop types to be implemented by Irrigators who purchase water from the project;
- Meet the targets of the Reef 2050 Long-Term Sustainability Plan ("Reef 2050 Plan", updated December 2021) and the Reef WQIP;
- Ensure water quality objectives are achieved through the implementation of the land and water management practices; and
- Establish mechanisms for ongoing compliance with the Code by water purchasers and for the effectiveness of the Code with respect to achieving and maintaining water quality objectives.

The Code only applies to Irrigators using water from Rookwood Weir, so its implementation will contribute to achieving the above objectives but due to other sources of impact beyond the reach of the Code, it cannot by itself ensure those outcomes.

The broader objective of the Reef WQIP of direct relevance to the Code is:

- Improved land management – activities on agricultural lands should be such that they are at least compliant with what is agreed as current best management practices for the agricultural land practice.

Achievement of these objectives will ensure that agricultural enterprises that utilise water from Rookwood Weir for the purpose of irrigation are appropriately managed to protect water quality discharging to the Great Barrier Reef.

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Appendix 6: Reef Regulations

The Reef Regulations require all new or expanded cropping and horticulture activities on five hectares or more without a cropping history to have an environmental authority (permit) from 1 June 2021.

The Reef Regulations will require compliance with minimum operating standards. Guidelines on minimum cropping standards in the Fitzroy are not planned for release until December 2024, however, they are anticipated to require:

- Development of a farm plan, considering layout and environmental considerations;
- Maintenance of general property management records;
- Determination of fertiliser application rates based on soil testing;
- No activity within five metres of the defining bank of a waterway or the seasonal highwater line at the point of flooding; and
- Mitigation of any risks that may lead to either export of nutrients (especially N &P) or fine sediment to the Great Barrier Reef.

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