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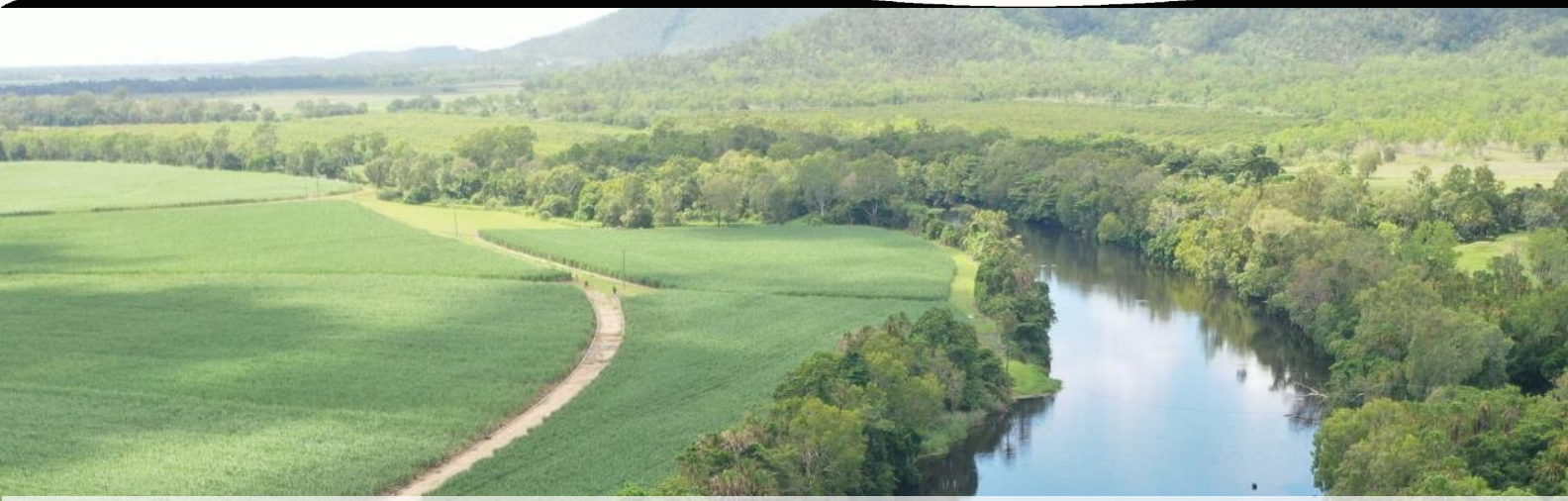
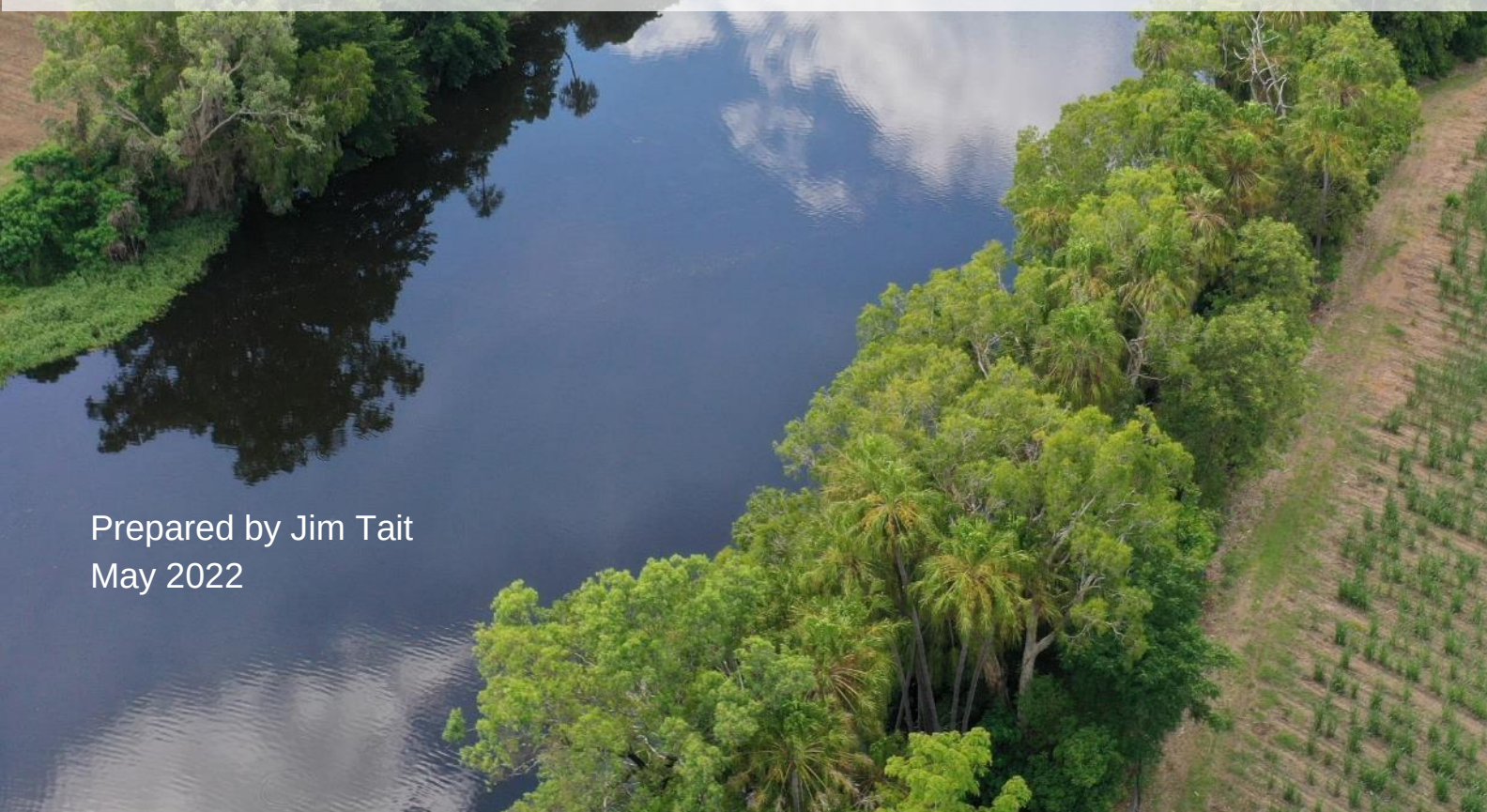


Ironbark Creek – Healey's Lagoon System Management Plan



Prepared by Jim Tait
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> List of abbreviations

BBIFMAC	Burdekin Bowen Integrated Floodplain Management Advisory Committee
BHWSS	Burdekin Haughton Water Supply Scheme
BMP	Best Management Practices
BOD	Biological Oxygen Demand
CAP	Conservation Action Planning
DIWA	Directory of Important Wetlands in Australia
DO	Dissolved Oxygen
ICM	Integrated Catchment Management
JCU	James Cook University
NRM	Natural Resource Management
RMA	Riparian Management Agreement
SMP	System Management Plan
TSS	Total Suspended Solids

> Executive summary

Econcern was contracted by NQ Dry Tropics in late 2021 to develop System Management Plans (SMPs) for five high value wetland systems located on the Lower Burdekin River floodplain approximately 50km south of Townsville, North Queensland. The development of these SMPs forms part of the Restoring the Bowling Green Bay Ramsar Wetlands project, funded by the Australian Government's National Landcare Program. These SMPs aim to improve environmental management outcomes in floodplain tributary and distributary creek systems that comprise the Cape Bowling Green Bay Ramsar wetland catchment. This current round of SMP development follows the initial SMP prepared by Econcern for the lower Burdekin floodplain's Sheep Station Creek catchment in 2020 (Econcern 2021). The Sheep Station Creek catchment was chosen as the initial focus for SMP development because it had the longest history of environmental management investment of any lower Burdekin wetland system. This has provided much learning and delivered a range of innovative management outcomes. Many of the management issues identified in the Sheep Station SMP are generic to the broader Lower Burdekin floodplain and, in the interest of document brevity, this initial SMP is referenced substantially in subsequent SMPs, including this document. However, as detailed in this SMP for the Ironbark Creek – Healey's Lagoon system, there are a range of distinct environmental management challenges associated with the unique landscape, hydrological setting, and development history of any individual wetland system. These need to be recognised in any prudent extension of wetland management planning strategies from one system to adjoining areas.

The Ironbark Creek – Healey's Lagoon system is within a distributary channel of the Haughton River, which connects via overbank flows in large flood events. It is 17km long from headwater to tidal influence and is comprised of three approximately equivalent-length geomorphic settings, including a creek channel, deepwater lagoon, and coastal plain drainage depression. It has a contributing catchment area of 5300ha, including irrigated agricultural floodplain in the east; less developed landscapes, including national park, in the west; and pastoral grazing land in the north. The hydrology of the modern system has been modified for use, namely to convey regulated flows pumped from the Haughton River to serve irrigators. The system has biodiversity values of state significance, including a good condition bioregional riparian vegetation corridor, deepwater fish habitats, 'of concern' regional ecosystems, vulnerable species, and state significant coastal wetlands.

The main environmental management issues of the Ironbark Creek – Healey's Lagoon system are associated with its altered hydrology that contribute to seasonal and cyclical proliferation of floating aquatic weed infestations and exotic aquatic grass domination of wet areas. In addition, there are fish passage barriers associated with poor reach conditions, including weed infestation and associated low dissolved oxygen; plus instream structures, loss of riparian vegetation, woody and grass weed infestation of remnant riparian vegetation, and associated hot fire risks.

The intended audience of this management plan is the range of management stakeholders associated with natural resource management (NRM) on the Lower Burdekin floodplain. These include riparian landholders, most of which are cane farmers; Sunwater; local government (Burdekin Shire Council); Traditional Owner groups (Gudjuda Reference Group); and the broader community, including community-based interest and NRM groups such as Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC), Lower Burdekin Landcare, and NQ Dry Tropics.

Over the past two decades these stakeholders have been involved in a range of innovative environmental management initiatives that have improved the condition of floodplain wetland systems. These cutting-edge management approaches have included the use of weed harvesters and excavators to remove neglected aquatic weed infestations; the development of cost-shared weed control programs instituted through Riparian Management Agreements (RMAs), and multiple riparian revegetation programs. At the time, these initiatives were truly innovative in the sense they had not been done before in the seasonal dry tropics, or – in the case of RMAs – Australia. Management initiatives in the Ironbark Creek – Healey's Lagoon system have included an aquatic weed control program established via an RMA, and riparian revegetation. This SMP seeks to build upon this gained experience and identify further environmental management opportunities that could be pursued with stakeholder support.

This plan was prepared following site field work and consultation with landholder and other management stakeholders throughout November and December 2021, and in February 2022. Through this field work, a literature review, and targeted stakeholder engagement, it was possible to identify system asset values, threats to these assets, and management strategies and nominated works to address threats. The condition of riparian zone vegetation was also mapped and a management planning map covering the system was prepared. This management plan examines the management needs of the wetland system under 10 issue areas covering:

1. Altered hydrology;
2. Aquatic weeds;
3. Water quality;
4. Fish passage barriers;
5. Lack of riparian vegetation;
6. Woody weeds;
7. Fire regime;
8. Grazing regime;
9. Critical habitat loss, and
10. Climate stress.

While each issue is examined separately in terms of management needs and opportunities, the relationship and interaction between issues is also identified where relevant to support integrated management recommendations and solutions. Implementation of this plan's recommendations depends entirely on voluntary adoption by relevant management stakeholders and the availability of sufficient resources to facilitate them. NQ

Dry Tropics will support the plan's implementation as funding becomes available by acting as a facilitator and coordinator of collective action by managing stakeholder groups and individuals, acting as an extension agency and broker for relevant information, and as a funder for specific activities and material resources that fall within the gamut of government-funded programs, or draw the support of other NRM sponsors.

> Background

Cape Bowling Green Bay Ramsar wetland

Ramsar wetlands are those that are recognised as wetlands of international importance and listed under the Ramsar convention. These are wetlands that are representative, rare, or unique wetlands or are important for conserving biological diversity. Australia currently has 66 Ramsar wetlands covering some 8.3 million hectares. Four are in Queensland including the coastal Cape Bowling Green Bay in the Lower Burdekin. As a signatory to the Ramsar convention, the Australian Government has a legal responsibility to ensure the wise use and conservation of Ramsar wetlands. To this end, NQ Dry Tropics has been funded by the Australian Government's National Landcare Program to restore high value wetland systems in the catchment of the Cape Bowling Green Bay Ramsar wetland. To approach this task strategically, a SMP was initially developed for an individual floodplain distributary stream that drains to the Ramsar site: Sheep Station Creek (Econcern 2021). Examining environmental management arrangements for this one entire creek catchment generated a useful SMP template. This can be applied, with some site-specific adjustment, to adjoining floodplain tributaries and distributaries comprising the Cape Bowling Green Bay catchment. Therefore, this SMP has been developed for the Ironbark Creek – Healey's Lagoon system.

Lower Burdekin floodplain – identifying assets and threats

This wetland system management plan uses terminology and methodology aligned with Conservation Action Planning (CAP), more broadly applied by NQ Dry Tropics within its NRM region. In essence, a CAP seeks to identify the 'assets' within a given planning region, identify 'threats' to these assets, and develop strategies which may serve to reduce the threats to assets. Assets are recognised to fall within a range of non-mutually exclusive categories including:

- Environmental;
- Economic;
- Social, and
- Cultural assets.

In seeking to serve the improved environmental management of the catchment of the coastal Ramsar wetland, this SMP is primarily focused on environmental assets. This notwithstanding, the greater dimension of environmental assets needs to be considered and promoted in presenting the case for their conservation. For example, a healthy wetland system has obvious environmental value. Where this same wetland provides for nature-based recreation such as birdwatching or fishing, it also holds social value. If fish populations supported by the wetland include commercially-targeted species, it also holds economic value. If the site is of significance to Traditional Owners or the history of non-indigenous Australians, it also has cultural value.

While some asset values are complimentary, they can also sometimes be in competition. For example, the developed irrigation water supply systems of the Lower Burdekin floodplain are very important economic assets that have delivered employment and economic benefit to the regional community. They have, however, often come at a cost to the health of wetland systems impacted by the consequent modification of floodplain hydrological regimes that has accompanied irrigation development. Other examples of value conflict can occur where appreciation of the recreational values of a wetland, for example, four-wheel driving may conflict with the conservation of sensitive biodiversity, or where a pasture species favoured as an asset for pastoral production acts as an invasive weed in wetland habitats. Ultimately it is for society's social, political, and legal systems to determine which values are managed for within a regional landscape. This SMP seeks to identify best management practice for identified environmental assets, while recognising that such management aspirations need to operate within a broader economic, social, and cultural context.

System Management Plan – scope and purpose

This SMP has been commissioned by NQ Dry Tropics to provide a blueprint for improved environmental management of the targeted wetland system. In doing so, it aims to support improved management and protection of the environmental assets of the Cape Bowling Green Bay Ramsar wetland on the coastal margin of the targeted system. The SMP's scope includes the ecological assets of the targeted wetland system, and also the biophysical condition, processes and management arrangements within the system's catchment area that may ultimately impact wetland condition.

This SMP aims to provide a 'go to' document for investment in the management of high value Burdekin floodplain wetlands. Recognising the vagaries of environmental management funding and the consequent often reactive nature of program investment, it provides a proactive planning tool that can direct management funding when it becomes available towards already-defined priorities. It also acts as a prospectus for those

seeking to pursue funding applications or sponsor environmental management. Further, this SMP also seeks to document historical wetland management gains, the implementation issues surrounding them, and provide recommendations to better address outstanding environmental management challenges facing the contemporary wetland system.

The SMP's intended audience is the range of natural resource management stakeholders associated with the Lower Burdekin floodplain. These include riparian landholders, most of which are cane farmers; Sunwater; local government (Burdekin Shire Council); catchment heavy industry (such as Wilmar); Traditional Owner groups (Gudjuda Reference Group); and the broader community, including community-based interest and NRM groups such as Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC), Lower Burdekin Landcare, and NQ Dry Tropics.

Over the past two decades these stakeholders have been involved in innovative management initiatives that have improved the condition of wetlands that were considered highly degraded in the early 2000s back to relatively healthy, though modified, aquatic ecosystems today (Econcern 2021). Innovative management approaches implemented have included the use of weed harvesters and excavators to remove neglected aquatic weed infestations; the development of a cost-shared aquatic weed control programs instituted through RMAs; fish passage provision around instream infrastructure, and reach-scale riparian revegetation programs. At the time, these initiatives were truly innovative in the sense that they were novel approaches for the seasonal dry tropics, or – in the case of RMAs – were Australian-firsts.

Implementation of this plan's recommendations depends entirely on their voluntary adoption by landholders and other relevant management stakeholders and the availability of sufficient funding and material resources to facilitate it. In the absence of a formal 'catchment management group', NQ Dry Tropics will support the plan's implementation by acting as a facilitator and coordinator of collective action through engagement of stakeholder groups and individuals. It will also act as an extension agency and broker for relevant information, and as a funder for specific activities and material resources that fall within the gamut of government-funded programs, or draw the support of other NRM sponsors.

Ironbark Creek – Healey's Lagoon system overview

Location and geomorphic setting

The Ironbark Creek – Healey's Lagoon system is located 45km south of Townsville and approximately 6km west of the township of Giru in the Lower Burdekin region. The 16.6km main channel stem of Ironbark Creek, including Healey's Lagoon, represents a historic flow path of the Haughton River. This has been maintained by a high flow distributary channel of the contemporary Haughton River that breaks out during flood events upstream, 8.3km south of Giru. The system has a local contributing catchment area of 5300ha nested within the Haughton River Basin that drains parts of the Haughton River floodplain in the east and hilly and mountainous uplands of the Ironbark Range and Mount Elliot escarpment in the west. The upper catchment of the system also includes 3km of farm drains constructed on prior streams and drainage depressions, and 6.6km of natural stream channel, which has parallel distributary channels for some of its length. The stream channel reach drains to 4.8km of deep channel-hosted lagoons, the main lagoon of which is 3km long and up to 90m wide.

Figure 1. Ironbark Creek – Healey's Lagoon Catchment (highlighted in white) relative to the Cape Bowling Green Bay Ramsar wetland site (green line), and Giru and the Haughton River (right).

The main lagoon terminates at Bruce Highway, and downstream there is a further 3.7km of coastal drainage depression that includes the confluence of Palm Creek (a distributary of St Margaret's Creek) and a terminal coastal lake known as the 'Reed Beds'. This is partially formed by earth bunds and is hosted on marine plains. The Reed Beds is subject to tidal influence on its downstream margin where it is bound by the Queensland Rail (QR) train line. Beyond is the Cape Bowling Green Bay National Park and Ramsar wetland, where the system becomes estuarine.

Hydrology – natural and modified

Like all wetlands in the seasonal dry tropics, the hydrology of the natural system was highly seasonal and related to the timing and magnitude of the annual wet season. However, the dry season hydrology of the contemporary Ironbark Creek system is dominated by regulated flows pumped by Sunwater from the Haughton River to an outlet confluence on Ironbark Creek immediately upstream of Bahr Road, which is 3.2km downstream of the Haughton River distributary outbreak. These flows provide both surface supplies and groundwater recharge for downstream irrigation use as part of the Burdekin Haughton Water Supply Scheme (BHWSS) managed and operated by Sunwater. Water is also pump-lifted from the downstream end of the main Healey's Lagoon and delivered to irrigators adjoining the Reed Beds via pipeline and open channel. The system's natural hydrology includes runoff from hilly, short, drainage networks forming the western half of the catchment; runoff from floodplain areas in its eastern catchment, and infrequent wet season flood overbank distributary breakout flows from the Haughton River down the system. Where contributing catchment areas have been developed to farmland, runoff hydrology has been modified by floodplain levelling and associated drain construction that increases rates of runoff. Fractured rock aquifers are also associated with the hilly western portion of the catchment, and these contribute natural recharge, in addition to artificial recharge, to shallow sand-bedded aquifers that underly much of the floodplain and associated alluvial landforms.

Land use, tenure and remnant vegetation

Much of the system, including most stream channels, are freehold land, although the main lagoon system, including an esplanade at its downstream end, is Crown land. A north-western portion of the catchment drains mountainous national park, and a node of forested crown reserve land is located at the upstream end of the main lagoon system. The south-western upper catchment also drains a large portion of leasehold land on the Ironbark Range. Downstream of the Reed Beds, the system discharges beneath QR line bridges into the Cape Bowling Green Bay National Park and Ramsar wetland site.

Approximately 25% of the catchment located on the eastern flank is irrigated cane land, while the western half of the catchment is dominated by remnant vegetation, including a section protected within national park. The remainder is at least partially cleared and used for grazing. There are also several hundred hectares of fruit tree horticulture, predominantly mangos, and also an achacha plantation of the lower floodplain of Palm Creek. Within cane land areas, most remnant vegetation occurs only within riparian corridors which are relatively continuous and, in some locations, formed of parallel distributaries. In the western catchment the landscape is more variegated with remnant patches and corridor linkages retained from foothills to mainstem drainage lines. Though most more extensive alluvial landforms have been cleared, some significant remnants remain in the north-west and south-west of the catchment, including on the coastal plain.

Key assets and values

Healey's Lagoon represents arguably the largest and best integrity floodplain lagoon remaining on the Lower Burdekin floodplain. It is a productive, deep water fish habitat that contains good barramundi populations and acts as a nursery for first year class fish. It also houses a diverse assemblage of other freshwater fish species, populations of both freshwater and estuarine crocodiles, several species of freshwater turtles and other reptiles, and provides good bird habitat for both wetland and riparian forest dependent species. Located at the bottom of the system, Reed Beds is a large brackish coastal lacustrine (lake). It is a palustrine wetland complex with high barramundi nursery and bird habitat values. The entire system is a Ramsar site interface catchment and provides a range of ecosystem services, including water quality treatment, primary production, and associated flows of material and biota. While some threats confront the system's fish passage function, it still provides good flood event connectivity for migratory species, including a passage bypass around Haughton River weirs to the upper Haughton catchment. The system has high terrestrial habitat values, including having one of the higher integrity contiguous riparian vegetation corridors (Ironbark Creek and sections of main lagoon) on the Lower Burdekin floodplain. The terrestrial fauna values are underpinned by a diverse suite of remnant habitat nodes that retain remnant vegetation corridor connectivity between foothills, coastal pain remnants and riparian corridors. These remnant habitats include coastal plain woodland and dense, diverse, and structurally-complex closed monsoon rainforest (on Crown reserve), and paperbark forest remnants that host rarer cover dependent fauna such as rufous owls.

Historical and current management

The system has been subject to several past and current management initiatives. This has included developing a flow-augmented water supply system operated by Sunwater. This involved establishing a Haughton River pumping station, the manipulation of lagoon water levels via an internal weir (since removed), and establishing a secondary pumping station at the bottom of the lagoon to supply water to downstream users. This was originally via open channel and subsequently via buried pipeline and open channel.

Specific environmental management initiatives have included revegetation conducted in the riparian zone on several reaches of Healey's Lagoon and on the lower reaches of Palm Creek near its confluence with Ironbark

Creek. RMAs have also been established between riparian landholders, Burdekin Shire Council, NQ Dry Tropics and Sunwater to fund sustained aquatic weed control.

Ongoing threats, management challenges

The main ongoing threats to the ecological condition of the system are associated with its regulated flow-altered hydrology. This has resulted in less marked seasonality, including reduced drawdown of dry season water levels. This has led to sustained seepage and associated hymenachne infestation of drainage depressions in the lower system, and also depression of seasonal salinity regimes and exotic pasture dominance over native aquatic vegetation in the terminal coastal wetland known as the Reed Beds. Altered hydrology combined with increased nutrient availability are also the nominated drivers of persistent infestation and seasonal proliferation of aquatic weeds, including floating species (water hyacinth, water lettuce, salvinia); submerged species (cabomba), and aquatic grasses (hymenachne, para, aleman) in the main lagoon system. There are also fish passage barriers threatening the system's productive fishery values. These include poor reach conditions caused by hymenachne infestation and associated low dissolved oxygen in the drainage depressions of the lower system; a piped road culvert in the upper system, and a low flow piped outlet at the bottom of the main lagoon system. The generally high value riparian vegetation corridor of the system remains functionally threatened by breaks in corridor connectivity, hot fire risks where ungrazed exotic grasses dominate stream and lagoon banks, and sleeper and potential new woody weeds, such as Siam weed. Land use intensification also remains a potential threat to remnant habitat and wildlife corridor connectivity where conservation values at a catchment scale are not captured by the Queensland vegetation management legislative framework.

> Methods – assessment and reporting

Stakeholder consultation

Stakeholder consultation for the preparation of this management plan was undertaken during November to December 2021 and February 2022 and involved:

- on-site consultation with riparian landholders distributed through the wetland system;
- meetings with representatives from community organisations involved in project work within the targeted wetland system, including Lower Burdekin Landcare, BBIFMAC and NQ Dry Tropics;
- consultative meeting with Sunwater;
- meeting with Burdekin Shire Council managers and operational staff involved in overseeing the aquatic weed control program service delivery; and
- informal engagement with researchers from research and development (R&D) providers that have worked across the Lower Burdekin floodplain, primarily at Tropwater, James Cook University (JCU).

For each interviewed landholder, engagement involved non-structured questioning about impressions of the environmental status of the creek; opinion of the adequacy of existing management arrangements; suggestions for additional or improved management approaches, and willingness and/or nominated preferences for conducting various on-ground environmental management works on the landholders' riparian landholdings. The latter are captured as 'nominated works' in Appendix 1 and presented on catchment management plan sheets (Appendix 2).

Literature review

Literature reviewed for preparation of this plan was sourced from 'grey literature' associated with previous NRM management plans, strategies, and consultant reports from the Lower Burdekin, plus formal scientific journal papers covering topics usually directly related to the Lower Burdekin floodplain study area. A range of information was also sourced online from Queensland Government agency sites including Queensland Globe (https://qldglobe.information.qld.gov.au/), Wetland Info (https://wetlandinfo.des.qld.gov.au/wetlands/), and DES regional ecosystem descriptions (https://apps.des.qld.gov.au/regional-ecosystems/).

Field work

Most field work was conducted in conjunction with landholders. Once site access permission was granted by landholders, some sites were subsequently revisited to gain additional information. Information was collected primarily by noted observation and digital images and included details about: riparian vegetation condition, weed infestation status, evidence of fire history, status of revegetation sites, potential fish passage barriers, water infrastructure, habitat values, incidental records of flora or fauna, observations of land degradation, and potential works sites. During the field work, an aerial drone was also used to gain high resolution aerial imagery of the hydrologically impacted and hymenachne-infested reaches downstream of the highway, and of the high value monsoon forest remnant at the top of the lagoon system (see photos 23 and 60). This imagery was useful for examining the hydrological connectivity status and pathways of the lower system and the condition of

the high value forest remnant. The main Healey's Lagoon was also surveyed by use of a flat-bottomed aluminium punt.

Management planning mapping

Maps of riparian vegetation condition were produced to inform environmental management planning for the wetland system (Appendix 2). These were generated by using a computer-based geographic information system (ArcGIS) to draw lines (polygons) around features on digital aerial images that depicted different classes of riparian vegetation condition. Eleven classes of riparian condition were defined, including overstorey vegetation, grasses, and within channel aquatic classes. These are below and in Appendix 2:

1. Remnant vegetation.
2. Degraded remnant.
3. Revegetated.
4. Exotic trees.
5. Grassland.
6. Exotic grasses.
7. Cumbungi.
8. Open water.
9. Native aquatic plant-covered water.
10. Floating aquatic weed-covered water.
11. Water with emergent aquatic plants.

Mapping system reaches into these riparian condition classes provides a basis for:

- examining the overall and relative ecological condition of the wetland system;
- identifying system-scale drivers of ecological degradation;
- developing generic management recommendations for reaches dominated by condition types;
- defining strategic priorities for restoration and protective management; and
- a timeline baseline to compare with future creek condition states.

In addition to riparian vegetation condition, GPS-referenced points collected in the field for reach asset values, management issues, and nominated works are also displayed on the management plan maps (Appendix 2).

> Summary system assets, threats, and nominated management strategies/works

Reach assets, threat management issues and nominated works compiled during the development of this system management plan are tabulated in Appendix 1 and presented on management planning maps (Appendix 2). They are described and summarised below.

Assets

These are ecological values associated with the wetland and/or adjoining riparian ecosystem that are significant at scales beyond this site alone. They are underpinned by criteria such as productivity, biological diversity, habitat connectivity, representativeness, and habitat provision that serve fish and wildlife populations and nature conservation objectives at reach, catchment, regional or even state scales.

The main ecological asset values identified for the Ironbark Creek – Healey's Lagoon system include:

- High integrity freshwater stream (Ironbark Creek) and deepwater lagoon (Healey's) aquatic environments that contain matters of state environmental significance and are considered of very high value in state Aquatic Conservation Assessments.
- A near-contiguous and high-integrity riparian vegetation corridor that extends through most of the system, including seasonal distributaries. This has high terrestrial habitat values, protects instream processes, and is of state biodiversity significance, forming a bioregionally-significant riparian wildlife corridor.
- A diverse range of supported aquatic and terrestrial wildlife species, including endangered and vulnerable bird, reptile, and plant species; a diverse community of freshwater fish, including migratory species; turtles, crocodiles, and other reptiles; waterbirds, and raptors

- State significant coastal wetland complex Reed Beds has very high bird habitat values for waterfowl, waterbirds, and migratory waders. It also provides habitat for Endangered, Vulnerable and Near Threatened (EVNT) species and forms part of a state significant bioregional terrestrial wildlife corridor.
- High value native vegetation remnants that are representative of the predevelopment landscape and contain rare or diverse vegetation assemblages including monsoon palm forest and coastal alluvial plain woodlands. These include matters of state environmental significance, for example, 'of concern' regional ecosystem and habitat for EVNT wildlife species that retain landscape corridor connectivity from drainage lines to adjoining hills and ranges.
- High value fish habitats, including key nursery and adult habitat for the migratory and recreationally and commercially important barramundi.
- A variegated aesthetic natural landscape with scenic lagoons, coastal wetlands, and native forest with a backdrop of the Mount Elliot massif, which provides amenity and nature-based recreation opportunities for both local residents and visitors to the region.

Threats/management issues

These include aquatic and riparian zone threat management issues that are characteristic of a wetland reach or specific to it. They also include threat management issues that occur at more than one site within the wetland system, and are well demonstrated by a particular reach example. Some identified threat management issues have impacts that affect the wetland ecosystem at a catchment scale.

The main system management issues for the Ironbark Creek – Healey's Lagoon system include:

- The impact of regulated inflows from the BHWSS that alter the hydrology and water quality of Healey's Lagoon and the Reed Beds via maintaining artificially high-water levels. This promotes aquatic weed growth and generates aseasonal seepage into coastal drainage depressions downstream of the Bruce Highway.
- Cyclical infestations of aquatic weeds that represent a symptom of the altered hydrology and water quality of the system. Under current control approaches, water quality (low dissolved oxygen, high nutrients) and weed reinfestation risks are perpetuated.
- An extensive infestation of aquatic grasses (including hymenachne, para grass and aleman) within a drainage depression reach of the system. This is driven by aseasonal flow seepage that creates a fish passage barrier of system-level significance under most wet season flow conditions.
- Degraded non-vegetated or open/narrow sections of the riparian vegetation corridor that undermine its function as a wildlife corridor and expose it to exotic grass understory infestation and associated hot fire risks.
- An emerging woody weed and ungrazed exotic pasture understory infestation risk to riparian and floodplain habitat remnants that include new (for example, Siam Weed) and sleeper (Chinee Apple) species that threaten to degrade habitat condition, including by hot fire impacts.
- Hot fire regimes associated with burns conducted late in the dry season within a habitat setting with large fire fuel loads.
- High flow capacity unvegetated farm drainage systems that lack flow detention function and discharge directly to the stream network.
- Incremental land use intensification that results in the loss of catchment habitat connectivity.

Nominated works

This is a non-exhaustive list of wetland system asset threat management strategies or works that were identified over the course of project field work, or subsequently during desktop-based assessment. They are proposals only and implementation would be subject to landholder endorsement, funding resourcing, appropriate agency approvals where required, and further landholder and management stakeholder engagement.

Nominated works for the Ironbark Creek – Healey's Lagoon system include:

- Engage system landowners and other management stakeholders in an enhanced aquatic weed (and other environmental issue) management capacity via greater paid participation in the existing RMA. This could include forming a local catchment management group.
- Manage the regulated flow system. This includes possible infrastructure development to reinstate seasonal water level drawdown to Healey's Lagoon and/or prevent dry season seepage downstream of the Bruce Highway, and to alienate irrigation supply flows from the Reed Beds wetland.
- Create a suitable water quality preferential flow path for wet season fish passage across the aquatic grass-infested drainage depression reach of the system downstream of the Bruce Highway.

- Targeted riparian zone rehabilitation works. This could include revegetation, controlled grazing, and fire regime management to protect and consolidate the system's high value riparian vegetation corridors.
- Targeted woody weed and fire regime management to protect and improve the condition of high value habitat remnants on private and Crown land reserves.
- Establish a demonstration farm drainage system that incorporates controlled drainage rates, detention basins, revegetated channel margins, and wildlife corridors.
- Site demonstration of aquatic weed harvesting and processing to a locally-useable organic soil ameliorant.
- Engage landholders of connected remnant habitat, which is functioning as system wildlife corridors, to seek protection consolidation or rehabilitation.
- Rectify instream fish passage barrier presented by piped culvert road crossing.

> System management plan, key threats to assets and recommended management strategies

Wetland system catchments are perhaps one of the most readily-identified examples of an integrated system. In other words, changes in the condition of one component of the system influences and impacts the status of other components. When considering the management of a wetland system, the Integrated Catchment Management (ICM) approach developed in Queensland in the 1990s (DPI 1993) still offers one of the most useful frameworks for considering how management initiatives across a range of issues serve to deliver benefits for the system as a whole.

Based on consultation with management stakeholders, a literature review, and field investigations, the following 10 threat management issues have been identified as important to the ecological health of the Ironbark Creek – Healey's Lagoon system. These are:

1. Altered hydrology;
2. Aquatic weeds;
3. Water quality;
4. Fish passage barriers;
5. Lack of riparian vegetation;
6. Woody weeds;
7. Fire regime;
8. Grazing regime;
9. Critical habitat loss, and
10. Climate stress.

While each issue is examined separately in terms of threat management needs and opportunities, the relationship and interaction between issues is also identified where relevant to support integrated management recommendations and solutions. One example of a threat that operates across nearly all other threat management issues is the emerging impact of climate change, which has a demonstrated capacity to exacerbate existing environmental stress.

Altered hydrology

Types and impacts

The natural hydrology and associated ecology of wetlands within the seasonal dry tropics, including those of the Lower Burdekin floodplain, is highly seasonal and related to the timing and magnitude of the annual wet season. Annual inundation in response to wet season rainfall, connection to floodplain distributary channel flows, the subsequent cessation of flow, waterhole isolation and water level draw down through the dry season – sometimes to complete drying – provide key drivers and stimuli for biophysical processes that determine the ecological character of the Lower Burdekin's natural floodplain wetlands. These seasonal events provide for germination of aquatic plants, reproduction, movement and recruitment of fish populations, nesting, and breeding of waterfowl, flushing of organic matter, scouring, and habitat resetting within drainage channels, seasonal changes in water quality and processing, and assimilation of catchment nutrient loads.

In the contemporary, modified floodplain system, the hydrology of the majority of freshwater wetlands, including most stream networks, is influenced by irrigated farm and/or irrigation scheme development within contributing catchment areas. Irrigation tailwater including supply channel overflow from Sunwater's owned and operated Burdekin Haughton Water Supply Scheme (BHWSS) or individual farms, drain to low lying areas hosting wetlands. Often, in the case of the BHWSS, this is via large, constructed drains. Within both the Burdekin Delta and floodplain, distributary stream channels are used by both Sunwater and Lower Burdekin Water operations to convey water pumped from main rivers (Haughton, Burdekin) to deliver surface water for irrigators and to recharge shallow groundwater aquifers. Across large areas of the BHWSS, irrigation-driven groundwater rise has also occurred to the extent that some water tables now discharge to surface drainage networks. Elevated groundwater is also suspected of directly impacting the condition of native vegetation, including riparian zones in some areas of the floodplain.

Photo 1. Power line access track across the distributary channel break out from the Haughton River to Ironbark Creek has raised the channel invert level and the flow height required to initiate channel flow.

Photo 2. Seasonal draw down in a tributary lagoon of the Healey's Lagoon system illustrating stranding of floating mats of the aquatic weed Salvinia and isolation of fringing Para grass from the Water's edge, both of which provide enhanced control opportunities.

The collective impact of irrigation tailwater, channel overflow, pumped flows and elevated groundwater discharge is that historically seasonal floodplain stream systems such as Ironbark, Barratta, Collinson's, Sheep Station, Plantation, Kalamia, and Saltwater creeks, and many smaller unnamed distributary streams, are now perennial or semi perennial; maintaining connective flows or seepage between wetland water bodies that were historically isolated, or even dried during the dry season. These aseasonal inflows contribute to a reduction in dry season drawdown of lagoon water levels and altered water quality (higher turbidity and nutrient loading). This altered hydrology and water quality has generated major changes to wetland aquatic plant communities, increasing the abundance of fringing exotic aquatic grasses and floating weeds; decreasing the abundance of native water lilies, submerged aquatic plants, sedges, and other emergent aquatic plants; and impacting associated habitat values for wetland fauna, including birds, reptiles, and fish. The colonisation of historically drying, but now saturated, distributary channels by impenetrable stands of cumbungi bullrush has also impacted system water quality, fish passage, and hydraulic capacity in addition to habitat values. A positive habitat impact associated with increased stream perennially has been the development of denser and more diverse riparian vegetation zones along some previously seasonal creek systems. Some stakeholders have expressed concerns that this also represents a flow capacity impact, though comparisons with unshaded, weed filled channels have not been tested.

Other forms of altered hydrology impacting Burdekin floodplain and coastal wetlands include damming and bunding of stream channels and floodplain drainage depressions. These are usually established to form watering points and/or ponded pasture forage for grazing stock. In near-coastal areas such structures also inadvertently, or intentionally, exclude tidal ingress, the latter sometimes being employed by water managers as a saltwater intrusion prevention groundwater management tool. Where these structures are established in tidally-influenced areas, estuarine and brackish vegetation (mangroves, samphire flats, bulkuru sedge)

upstream of the bunds is replaced with freshwater vegetation, and downstream areas risk becoming hypersaline. In some catchment settings where inflows to impounded areas remain seasonal, the habitat quality of wetlands that establish within them can be good. Where such areas are subject to sustained aseasonal inflows and reduced seasonality, they usually become dominated by exotic aquatic grasses, floating weeds and/or cumbungi. Independent of bunding or damming, sustained aseasonal flows of freshwater into estuarine areas such as the Barratta Creek estuary is changing their salinity regime, water quality, and primary productivity as weeds such as hymenachne advance into areas previously characterised as tidal.

A basin-scale alteration of hydrology that also impacts floodplain wetlands is that associated with the upper catchment Burdekin Falls Dam. This dam acts as a detention area during high rainfall events across the basin, serving to reduce the height and frequency of Lower Burdekin flood peaks that previously would have broken out of the river channel into floodplain distributaries, scouring and resetting habitat conditions for channel hosted-wetlands. Riverbank levees constructed to prevent such outbreaks and protect farmland have also reduced the occurrence of these ecologically-important flows. Another consequence of the Burdekin Falls Dam capturing turbid flood events, that historically drained to clear river baseflows, is that water reticulated through irrigation scheme areas now remains turbid for most, if not all, of the calendar year. This sets a host of water quality-associated impacts in train for a river and floodplain system that naturally had high clarity water outside of the annual wet season.

System specifics

A diverse range of altered hydrology-associated threats to asset values were identified for the Ironbark Creek – Healey's Lagoon system. These are listed as management issues (M) in Appendix 1 and are mapped in Appendix 2. These include altered hydrology associated with changes to catchment and channel condition, and those associated with the conveyance of regulated flows through the system, with some of those interacting. These include:

- (M1) Increased rates of local catchment runoff due to farm drain development;
- (M3) Raising of the Haughton River outbreak flow levee height;
- (M14) Emerging changes in channel flow capacity due to sediment deposition and vegetation growth;
- (M18) Altered lagoon edge habitats due to reduced drawdown of dry season water levels;
- (M20) Proliferation of hymenachne growth that form fish passage barriers in drainage depressions inaccessible to grazing stock due to perennial wetness created by downstream seepage from Healey's Lagoon;
- (M22) Use of coastal wetland Reed Beds as supplemented pumping pool results in reduced seasonality, and
- (M23) Bunding of coastal wetland Reed Beds excludes tidal ingress (and contains aseasonal inflows) and reduces brackish habitat.

Photo 3. Irrigation recycle pit within a large capacity channel that forms part of a farm drainage system in the upper catchment of Ironbark Creek. Promoting revegetation of farm drain and increased detention of runoff would help to improve water quality and reduce soil erosion risks.

Photo 4. An area of in channel sedimentation being colonised by grass growth and paperbark tree recruitment. Ultimately, colonisation of this area with in-channel vegetation will lead to reduced channel flow capacity during flood events and increased farm erosion risks associated with channel breakout flows.

(M1) Farm drains in the upper catchment have replaced natural drainage lines with more direct and larger capacity channels intended to get water off farmland quick enough to avoid crop damage. Where drainage capacity is greater than that required to serve crop needs, the result can be rapid runoff that conveys catchment loads of sediment and/or nutrients more directly to receiving stream channels and may also cause farm soil erosion. Evidence of the latter was observed at some sites. To reduce such risks, it is beneficial to

have drainage networks designed to a drainage modulus (litres/sec/ha) that meets, but not exceeds, crop drainage needs. A further option is to include detention basins, or constructed wetlands, in the drainage network that pond water and slow the overall discharge rate to the creek system. This reduces potential erosion risks and allows for the settling of sediment and other contaminant loads and for some of the nutrient load to be processed.

(M3) Outbreak flows from the Haughton River form an important part of the natural hydrology of the Ironbark Creek system, playing a role in resetting habitat conditions, refreshing water quality, and forming the stream channel. A powerline maintenance access track built across the distributary channel breakout point has slightly raised the floor in the channel, increasing the height of the Haughton River flood flow level required to initiate flow down the creek system. This would impact the frequency and duration of breakout flows down the creek system with associated impacts to the creek's ecology.

(M14) During flood events, high flows can break out of the Healey's Lagoon channel at pressure points associated with bends and/or channel constrictions and flow across floodplain farmland. This presents both bank and farm erosion risks. In the mid-lower reaches of the lagoon, flow capacity of the channel has been impacted by both a historical low weir (since removed) and depositional sedimentation on the inside bend channel that has been colonised by aquatic grasses and paperbarks, further reducing channel capacity. While the colonising paperbark trees have habitat value, they could result in erosional pressure on the opposing bank and floodplain.

(M18) Healey's Lagoon is a regulated system with flows pumped to it from the Haughton River via Ironbark Creek to provide irrigation supplies and recharge shallow groundwater aquifers. A second pump station at the bottom of the main lagoon delivers water to downstream irrigators via a buried pipeline that discharges to an open channel. To maintain these operations, water levels within the lagoon are sustained at unnaturally high levels throughout the dry season. The loss of dry season drawdown impacts the ecological health and habitat value of the lagoon. Namely, no stranding of submerged weed biomass, loss of exposed bank habitat and emergent macrophyte zone, and promoting exotic aquatic grass weeds. It also results in downstream seepage causing perennial wetness and aquatic grass (hymenachne and para) dominance, and loss of ecological values in downstream drainage depressions.

(M20) Drainage depressions downstream of the highway impacted by seepage from Healey's Lagoon were historically seasonal wetlands that dried and were fully grazed in the dry season, leaving bare open channels to convey wet season flows. Perennial wetness has promoted the extensive growth of exotic aquatic grasses, primarily hymenachne and para, and also aleman. In wetter years the deeper areas of the drainage depressions do not dry sufficiently for grazing stock to access it, and the aquatic grasses form a large biomass of dead thatch and actively growing grass, covering the water's surface. During wet season high flow events much of this biomass is inundated and bacterial decomposition consumes available oxygen, creating anoxic (de-oxygenated) water conditions that present a water quality passage barrier to migratory fish species, including barramundi that attempt to recruit upstream from the downstream Reed Beds nursery area.

(M22) The most downstream user of regulated flows delivered through the system has their pump located at the upstream end of the coastal lacustrine (lake) wetland complex known as the Reed Beds. Water is supplied to the Reed Beds via an open channel fed by a piped supply pumped from the Reed Beds pumping station at the downstream end of Healey's Lagoon. Use of Reed Beds as a pumping pool results in significant hydrological impacts to the system. This includes reduced dry season drawdown, which impacts the ecological health and values of the Reed Beds. Namely, no stranding of submerged weed biomass, loss of exposed bank (waterfowl) habitat, and associated emergent macrophyte (aquatic plant) zone, and promotion of aquatic grasses (hymenachne, para, aleman), domination of lagoon margins to the detriment of native water lilies and other native aquatic plants, and water quality. Being a coastal wetland system historically subject to tidal influence, some important aquatic plant habitats within the system, like bulkuru sedge (*Eleocharis dulcis*) are also adapted to a seasonally-variable salinity regime, which has been lost to sustained freshwater inflows.

(M23) The Reed Beds was historically subject to tidal influence in the late dry season, which promoted important habitat resetting and a variable salinity regime that supported the growth of adapted plant species such as bulkuru sedge (*Eleocharis dulcis)*. Bulkuru is an important food and nesting resource for several waterfowl and waterbird species, like brolgas and magpie geese, and supports ideal water quality conditions and nursery habitat for post-larval barramundi. Prior to the occurrence of aseasonal flows into the system, the earth bunds on its downstream margins reduced tidal inflows and promoted exotic-ponded pasture growth. This retained wetland seasonality, including increasing salinity into the late dry season. However, with the advent of sustained supplementation inflows at the top of the wetland to provide an irrigation pumping pool, wetland hydrological and salinity regimes and associated ecological values have been more greatly impacted.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2 the listed works number is referenced.

1. Engage with landholder of Ironbark Creek distributary breakout point to seek support for reinstating original channel invert level. If supportive, seek funding for civil engineering proposal for works that can reinstate original channel breakout level while maintaining utility of powerline access corridor (W1).

2. Engage with landholders of upper Ironbark Creek catchment who have constructed farm drainage networks and explore interest and funding resources for establishing works demonstrating drainage modulus Best Management Practice (BMP). This includes incorporating revegetation and detention basins into the drainage system to reduce contaminant load transport capacity and farm erosion risks while providing in-channel weed control benefits and adding wildlife habitat value (W3, W4). See section *Water quality*.
3. Engage hydrologist expertise on behalf of lower lagoon reach landholders to assess likely contribution of in-channel sedimentation and vegetation colonisation on flood flow outbreak behaviour and farm erosion risks. Examine merits of works options including a) excavator reinstatement of channel capacity and/or b) establishment of denser riparian vegetation on levee banks to baffle outbreak flow velocities (W13).
4. BHWSS operator Sunwater investigate and implement, if viable, management options for regulated flow system for reinstating seasonal drying/drawdown and for reducing water logging of wetlands in downstream reaches of wetland system downstream of Bruce Highway (for instance, Bahr's Paddock, Reed Beds). Nominated options (W16, W20) include:
    a. Reducing and maintaining lower Healey's lagoon water levels through the dry season months as a means of reducing seepage/flows downstream of the Bruce Highway. See also section *Fish passage barriers*.
    b. Providing alternative means to surface water supply (such as piping) to supply water to downstream irrigation customers and avoid the need for Reed Beds Lagoon supplementation.

Aquatic weeds

Types and impacts

Aquatic weeds are arguably the most significant cause of ecological impact within lower Burdekin floodplain wetland systems (Waltham *et al* 2020, Tait 2013, Perna *et al* 2012, Veitch *et al* 2007, Tait & Perna 2001). They create blockages to flow and fish passage; outcompete native aquatic vegetation; generate high fire fuel loads in seasonally dry riparian vegetation (in the case of aquatic grasses); cause collapses in instream dissolved oxygen levels via organic loading; and cover open water surfaces, consequently impacting fish and other fauna habitat availability and quality. While these impacts are attributed to weeds, it should be recognised that observed weed infestation levels are often a symptom of other ecological impact drivers which promote weed proliferation. These include altered hydrology increasing aquatic habitat availability and reducing water level seasonality, and increased availability of nutrients associated with catchment land use, regulated inflows, and irrigation tailwater inflows. Given the ongoing use of the lower Burdekin floodplain's land and water resources for irrigated agriculture, these drivers of weed proliferation will, to some degree, remain part of most modified ecosystems and effective weed management needs to be ongoing if management stakeholders want wetland ecological values to be retained or improved. Considering the costs associated with aquatic weed management, there is a strong impetus for control practices to be as effective as possible and for innovative developments that provide for continuous improvement in management approaches.

A large range of aquatic weed species are recorded from the lower Burdekin floodplain with most plus some unique occurrences (for example, cabomba) recorded for the Ironbark Creek – Healey's Lagoon system (see Table 1). Aquatic weeds include floating, submerged, and fringing emergent growth forms including aquatic grasses. There are also a number of emerging aquatic weed risk species identified in the *Burdekin Shire Biosecurity Plan* (BSC 2020) that have been more recently recorded in the shire or adjoining regions (see Table 2). While exotic species are more commonly recognised as 'weeds', several native aquatic plants (see Table 1) have also become weedy in nature under the modified ecosystem conditions of the developed floodplain. Some native species (for example, cumbungi) are now responsible for major ecological and economic impacts. The impacts generated by aquatic weeds vary between species, although some impacts are common to most and often a suite of aquatic weed species are involved in impact-generating infestations (see Table 1).

Photo 5. Aquatic weed-free lower reach of the main Healey's Lagoon system in December 2021 following a flushing flow associated with a high rainfall event in November 2021.

Photo 6. The recreational amenity of Healey's Lagoon for fishing and nature-based recreation is appreciated by landholders and has improved with the RMA-supported aquatic weed control program.

System specifics

Management history and approaches

In the early 2000s, aquatic weed infestation levels in the Healey's Lagoon system reached a severe state that the lower lagoon's surface was choked for substantial parts of the year with resulting impacts to water quality, fish habitat and general amenity. The site was identified for funding under the GBR coastal wetland protection program, and the Burdekin Shire Council's mechanical weed harvester – in conjunction with a well-timed high flow event – removed weed mat infestations in 2005 (Burrows *et al* 2006). The Burdekin Shire Council and its land protection officer then engaged riparian landholders in an RMA. Building upon the experience gained from managing severe aquatic weed infestations elsewhere in the Lower Burdekin, the objective was to maintain the condition gains achieved via the weed harvesting operation. The RMA provided a means for landholders and other stakeholders to share the cost of a boat-based, chemical-spaying (glyphosate) control program for the main weed species of concern, including water hyacinth, water lettuce, salvinia, hymenachne and para grass. Other cost-sharing partners in the RMA included the Burdekin Shire Council, Sunwater and NQ Dry Tropics. Initially involving around six landholders, this RMA has operated for over fifteen years. It initially conducted up to six spraying interventions per year by both private contractor and council operators in the main Healey's

Lagoon system and in accessible smaller channel-hosted waterholes of Ironbark Creek upstream of the Woodstock Giru Road. This program was successful in reducing the extent and frequency of channel-blocking weed mats within the lagoon system, particularly for the larger floating species. It also prevented them from being colonised by binding Hymenachne grass growth as observed in other Lower Burdekin lagoon systems.

Despite some concerns expressed about the effectiveness of some individual spraying operations, landholders have generally offered support for the program and note the increased ecological health, amenity, and aesthetic value of the lagoon since the program has been implemented. However, in recent years the proportion of paying landholders participating in the RMA has diminished below a third. While other stakeholder members have continued their financial contributions and the Burdekin Shire Council has continued spaying operations within the system, there are lower numbers of spay interventions per year compared with earlier in the program.

Another weed management initiative instigated in the upper Ironbark Creek system over the same period as the operating RMA was the periodic release of salvinia biocontrol weevils (*Cyrtobagous salviniae)* by the local NRM group BBIFMAC (Burdekin Bowen Integrated Floodplain Management Advisory Committee). In the narrow-vegetated stream channels of the upper creek system, chemical spraying access is not readily possible and – unlike lower, larger lagoon reaches where wind acts to disperse salvinia – in the upper creek system its forms a complete surface covering. Weevil introductions proved successful in maintaining biocontrol agent populations in the upper reaches of the creek system, although salvinia infestations still occurred seasonally ahead of biocontrol effectiveness. In the past couple of years, BBIFMAC's weevil breeding facility has suffered setbacks bought on by resource constraints and equipment failure, and salvinia biocontrol introduction programs are currently discontinued.

Outstanding weed management issues and opportunities

Aquatic weeds are a ubiquitous management issue across the Lower Burdekin floodplain. Management needs and opportunities include both site and short-term issues, and longer term, regional scale, and aspirational management and innovation needs. Both are discussed below in relation to the Ironbark Creek – Healey's Lagoon system below. Where they relate to management issues listed in Appendix 1 or mapped in Appendix 2, the designated (M) number is referenced.

Persistent and cyclical re-infestations of system with floating aquatic weeds

Despite ongoing spraying-based control efforts, there are persistent and cyclical re-infestations of the lagoon and creek system with floating aquatic weeds (M19). These include surface-covering infestations of salvinia dominating entire reaches of the lagoon and creek, and the less extensive residual floating mats of the larger species water hyacinth and water lettuce. The reasons for reinfestation warrant examination in any planning strategy that seeks to improve management outcomes. Identified contributing factors include:

- sustained nutrient availability associated with inputs from catchment land use sources, including via groundwater connectivity (Burrows et al 2006, Davis et al 2014, 2017), and with regulated flows of Burdekin River water into the system (Perna 2003, 2004);
- cycling release of nutrients from spayed dead weed biomass that sinks in the water column;
- limitations in control intervention effectiveness, and
- retained weed plants and propagules that provide sources of reinfestation.

Photo 7. Isolated rafts of floated aquatic weed water hyacinth remaining in the upper lagoon system following control efforts earlier in the season. Attempts to completely eradicate potential reinfestation sources of aquatic weeds could extend the time between required control interventions.

Photo 8. Within the upper catchment of Ironbark Creek dense riparian vegetation shading limits the infestation potential of floating aquatic weeds like water hyacinth. This has only sparse isolated occurrences amenable to targeted eradication, which removes reinfestation sources for lower reaches.

Some of these issues, for example, nutrient availability, have limited prospects for immediate change given the intensive land use context of the contributing catchment, though some options are explored in the *Water quality* section. Developing nonchemical aquatic weed control methods that can avoid nutrient recycling from sunk spayed weed biomass, like physical harvesting and removal, and ideally its conversion to a commercial compost or organic soil ameliorant, remains an aspirational goal for serving management in the broader region and initial trials have been conducted (Econcern 2021). Improving control intervention effectiveness essentially boils down to making additional resources available to the control program to facilitate more frequent interventions, potentially over an enlarged operational area of the system and/or using different equipment or methods that support increased system access and more effective control. One opportunity for more effective control is to ensure that weed reinfestation sources, including in upper catchment areas, are targeted. This could include a 'line of control' approach that works through the system from upper to lower catchment areas. A strategic time to pursue such an approach is immediately following wet season flood-flushing flows that have removed most aquatic weed biomass leaving only small residual infestation to control (Econcern 2021). Given the limited participation of paying riparian landholders in the existing RMA covering the system, there is little prospect that greater management efforts could be expected from it. Full participation of all riparian landholders and greater resourcing of the existing RMA or, alternatively, developing a local 'catchment management group' that enjoyed the participation of all landholders and was suitably resourced – or both – could provide a viable path toward enhanced aquatic weed control in the Ironbark – Healey's Lagoon system.

Photo 9. The aquatic weed salvinia is a small-leaved floating fern that readily retains residual reinfestation sources throughout the upper reaches. Biocontrol currently provides the only persistent control option.

Photo 10. Distributary lagoons off the main channel host severe infestations of salvinia and are appropriate target sites for biocontrol agent releases.

Salvinia control

Being small-leaved and generally more mobile, salvinia is not as amenable to spaying-based control as some of the larger species given the likelihood of post spaying re-infestation sources always being available. Like most floating aquatic weeds, its abundance is attributable to underlying drivers such as nutrient availability. Until effective biomass removal control methods are developed and become available, bio control presents the most cost-effective option for controlling surface-covering infestations of salvinia (M24). If resources were available for enhanced aquatic weed control, including equipment to facilitate better access for spaying upper stream reaches, the viability of a post-flood flush 'line of control' approach (discussed in preceding section) for reducing salvinia re-infestation potential could also be a worthy of a trial.

Aquatic grass weeds

Aquatic grasses, including aleman, para and hymenachne, also sustain infestations on lagoon and creek margins and within wetland basins and drainage depressions throughout the system. These infestations are recognised to impact native aquatic plants and edge habitats and contribute to low dissolved oxygen levels (Burrows *et al* 2006). Most of these grasses are amenable to chemical-based control, although experience in other systems indicates aleman is resistant to the commonly-used herbicide glyphosate and requires targeted use of Verdict. Broad acre control methods that can be used for these grasses in open wetland basins and broader stream banks and levees include integrated use of managed hydrology, riparian vegetation shading, controlled grazing and burning regimes which are discussed in the *Altered hydrology, Lack of riparian vegetation, Grazing regime and Fire regime* sections. The only viable control methods for the narrow riparian margins of the main lagoon and creek channel waterholes, with permanently high-water levels, are targeted chemical control and promoting riparian vegetation shading. As discussed in the preceding section, re-instatement of dry season water level drawdown could increase management options for these grasses.

Photo 11. Healey's Lagoon has the only recorded lower Burdekin occurrences of the submerged aquatic Weed of National Significance (WONS) cabomba (*Cabomba caroliniana)*. Cabomba is prioritised for control and prevention of spread under the *Burdekin Shire Biosecurity Plan* (BSC 2020).

Photo 12. Cabomba forms dense 100% submerged covering infestations in upper Healey's lagoon. Night-time respiration of this submerged plant biomass collapses water dissolved oxygen levels, which are partially mitigated in the upstream end of the lagoon by regulated inflows from Ironbark Creek.

Cabomba

Healey's Lagoon is the only documented site occurrence in the Lower Burdekin for the submerged aquatic Weed of National Significance (WONS) cabomba (*Cabomba caroliniana)*. This species forms dense 100% submerged canopy-covering infestations within reaches of Healey's lagoon (Burrows *et al* 2006). It is a Category 3 weed under the *Queensland Biosecurity Act 2014* and prioritised for control with the management option of *prevention* nominated under the *Burdekin Shire Biosecurity Plan* (BSC 2020). The extent of infestations within the lagoon system renders it beyond viable cost-effective control and the main emphasis for management lies with prevention of spread to other sites. Education of waterway users and boat wash down protocols could assist in preventing its further spread in the region.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Pursue greater engagement of riparian landholders in aquatic weed control program to foster improved aquatic management outcomes.

    I. Burdekin Shire Council communicate amongst RMA cost-sharing organisation partners and seek endorsement for group-based correspondence to all riparian landholders of the Ironbark Creek – Healey's Lagoon system highlighting:

        i. Success of program to-date in controlling weeds that are Category 3 under the *Queensland Biosecurity Act 2014;*

        ii. Responsibilities under the *Queensland Biosecurity Act 2014* general biosecurity obligation (GBO);

        iii. Program annual costs and system interventions;

        iv. Existing partner contributions including from riparian landholders and proportion payment contributing landholders;

        v. Budgetary constraints on program and risks to its sustainability;

        vi. The 'value proposition' of the existing RMA arrangement and the desirable outcome of all landholders participating in costs; and

        vii. Opportunities for landholders to provide feedback or more directly be involved in delivery of control program.

    II. In conjunction with the above correspondence and/or at a NQ Dry Tropics-facilitated local community information session for the release of this System Management Plan, local stakeholder interest be gauged for the formation of a local Ironbark Creek Catchment Management Group, or equivalent. This group would have responsibility for overseeing the implementation of supported SMP recommendations including pursuing more direct engagement and development of the aquatic weed management program. Initial and ongoing communication for such a group could be facilitated by a dedicated social media page.

2. NQ Dry Tropics provide funding commitments, or source NRM sponsors, to support BBIFMAC salvinia biocontrol weevil breeding programs (W21). NQ Dry Tropics field officer conduct field work

investigations in conjunction with BBIFMAC personnel to ascertain current status of weevil populations within Ironbark Creek – Healey's Lagoon system. If effective populations are not present, plan a reintroduction program following successful weevil production.

Photo 13. Sinking mats of aquatic weed salvinia killed by biocontrol, or chemical spraying, releases contained nutrients back to the water and contributes to bacterial biological oxygen demand (BOD), which depresses water dissolved oxygen (DO) levels.

Photo 14. Horticulture on floodplain alluvial soils adjoining the Healey's Lagoon system could present a proximal location for use of organic soil ameliorants produced from compositing harvested aquatic weeds. Weed biomass removal would serve water quality improvement.

3. Trial catchment-based line of control approach for targeted floating aquatic weed species, for example, water hyacinth, within the creek and lagoon system. Form a stakeholder working group to resource, trial, identify, and procure equipment that could be used to access and spray/remove small residual infestation of floating aquatic weeds following a flood flow. Work toward implementation of the trial at the next wet season. Initiate trial following a large flood flow event and endeavour to eradicate weed refuges/reinfestation sources for a targeted species (suggest water hyacinth). Work from the top of the catchment downstream, with two or more closely-repeated events. Monitor eradication effectiveness, including timing and sources of reinfestation if it occurs.
4. Engage with local small crop horticulturists and/or interested canefarmers on adjoining Haughton floodplain areas to seek participants interested in using composted aquatic weed biomass as soil ameliorant in production systems. If willing participants are identified, seek sponsorship to fund local onsite demonstration trial of aquatic weed harvesting /conveyor operation and demonstration of compost pile formation. Follow through from compost production to utilisation in production systems and report and communicate on soil health/production benefits to encourage further R&D in the use of harvested aquatic weed biomass in production systems.
5. NQ Dry Tropics use release of this SMP as an opportunity to communicate to local management stakeholders about the ecological costs of exotic aquatic grass infestations, including their role in degradation of bird and fish habitat values, water quality decline, and creation of fish passage barriers. This could include information bulletins or social media posts. Promote the benefits of integrated control approaches, where appropriate, to include riparian shading, grazing, and burning regimes and chemical control. Seek willing landholders prepared to establish exotic grass control demonstration sites (W4, W6). See also *Lack of riparian vegetation, Grazing regime and Fire regime* sections.
6. NQ Dry Tropics establish a cabomba information board at publicly-accessible points on the Ironbark Creek – Healey's Lagoon system.

Table 1. Aquatic weeds of Lower Burdekin wetland systems

Common name (* = native)	**Genus species**	**Growth form, habit and main impacts**	**WONS**	Queensland *Biosecurity Act 2014* **category**	**Priority target weeds of BSC's *Aquatic Weed Management Plan 2020-2025***	**Management methods and notes**
Water hyacinth	*Eichhornia crassipes*	Floating species. Forms rafts that get colonised by other emergent and surface scrambling species, particularly aquatic grasses. Large infestation cover water surface of lagoons and channels and create anoxic (no dissolved oxygen) reaches and fish passage barriers. Blocks channel flows, increases flood risks and creates mosquito breeding habitat.		3	X	Physical (weed harvester, rake excavator), registered chemicals and biological (weevils). Raft concentration (i.e., culvert gates) and catchment isolation methods potentially useful. Nutrient removal via harvesting.
Water lettuce	*Pistia stratiotes*	Floating species. Floating plant with similar habit as water hyacinth. Contributes to mixed species floating weed mats.		3	X	Physical (weed harvester), biological (weevil) and registered chemicals. Nutrient removal via harvesting.
Salvinia	*Salvinia molesta*	Floating species. Prefers still water. Covers and shades water surface and contributes organic loading, decreasing dissolved oxygen levels.	X	3	X	Registered chemicals and biological (weevil). Nutrient removal via harvesting.
*Azolla	*Azolla spp*	Floating species. Prefers still waters. Floating plant with similar habit and potential impact to salvinia. Indicative eutrophication.		Not categorised		Physical – water quality management – indicative of high nutrients.
Para grass	*Urochloa mutica*	Emergent aquatic grass. Occurs in dense monocultural stands in moist drainage depressions and riparian vegetation understorey. Extends onto and binds floating weed mats. Shades shallows, excludes native aquatic plants, block channels, suppresses native vegetation recruitment, introduces high fire fuel loads into riparian zones, contributes high organic loading, depletes dissolved oxygen levels.		Not categorised		Physical (rake excavator), registered chemicals and grazing. Implementation of effective grazing systems including the use of water level drawdown is key to the management of this species.
Hymenachne	*Hymenachne amplexicaulis*	Emergent aquatic grass. Occurs on bank edge zone and grows into water ~2m deep. Extends onto and binds floating weed mats. Similar suite of impacts to para grass but extends into deeper water and not as far up bank onto levees.	X	3	X	Physical (rake excavator), registered chemicals and grazing. Use of haloxyfop down to the water line will protect the natural recruitment of native macrophytes and trees.
Aleman grass	*Echinochloa polystachya*	Emergent aquatic grass. Occurs on bank edge zone and grows into water ~2m deep. Extends onto and binds floating weed mats. Blocks channels. Outcompetes native aquatic plants on bank edge and shallows zones.		Not categorised		Physical (rake excavator), registered chemicals and grazing. Use of haloxyfop down to the water line will protect the natural recruitment of native macrophytes and trees.
*Rice grass	*Leersia hexandra*	Emergent aquatic grass. Extends onto and binds floating weed mats, forms major infestation in deeper waters of lower catchment bunded drainages.		Not categorised		Physical (rake excavator and/or weed harvester), registered chemicals and grazing. The effectiveness of the weed harvester on this species has not yet been assessed. Good waterfowl habitat.

*'Water green'	*Ipomoea aquatica*	Emergent/floating aquatic vine. Occasionally extends onto and binds floating weed mats.		Not categorised		Physical – not generally a significant problem unless part of weed mat. Good habitat.
*Cumbungi	*Typha domingensis*	Emergent bull rush. Occurs in water edge zone in most of catchment but forms major infestations in lower catchment bunded drainages. Blocks channels, creates anoxic reaches/fish passage barriers due to high biological oxygen demand (BOD) of accumulated organic material. Decreases native plant diversity and waterbird habitat.		Not categorised		Registered chemicals, potentially water level manipulation and physical (burning, harvesting), i.e., removal of root stock with an excavator. Prevention of tailwater inflows/draining to create seasonal drying has been demonstrated to be very successful.
*Duckweed	Ceratophyllum *demersum*	Submerged aquatic. Forms dense non-rooted submerged beds. Causes depletion in dissolved oxygen values below levels lethal for aquatic organisms/fish during summer night-time respiration and/or turbid wet season inflows.		Not categorised		Physical – weed harvester, shading, water level manipulation, pump foot valve protection. Good habitat.
Cabomba	*Cabomba caroliniana*	Submerged aquatic. Cabomba is an aggressive perennial that can form dense canopies below the water surface. Infestations displace native plants and animals, affect water quality, and impede recreational water users.	X	3	X	Only recorded from Healey's Lagoon. Mechanical control – Hand-pull small infestations, taking care to remove entire plant to prevent re-infestation. Use harvesters on larger areas for temporary control. Herbicide control – Carfentrazone is currently the only herbicide registered for control of cabomba.
*Giant lotus	*Nelumbo nucifera*	Emergent lily bed. Mainly recorded from more seasonal sub catchment wetland reaches. Emergent plant of bank edge grows in water ~2m. Can block channels, creates foundation for accumulation of floating weed mats.		Not categorised		Registered chemicals, potentially water level manipulation and physical (harvesting, cutting). Good habitat.
*Umbrella sedge	*Cyperus exaltatus*	Emergent sedge aggressive secondary coloniser on floating 'platforms' weeds. Occurs throughout creek system in water edge zone but forms extensive occurrences in moist margins and depressions of lower catchment-bunded drainages.		Not categorised		Registered chemicals, potentially water level manipulation and physical (harvesting, cutting) – not major problem. Good habitat.
*Smart weed	*Persicaria decipiens*	Emergent plant that occurs in moist drainage depressions and riparian vegetation zones and extends onto and binds floating weed mats. Forms mono cultural stands usually in response to grazing pressure.		Not categorised		Registered chemicals, physical – not generally a significant problem unless part of weed mat. Good habitat.

Table 2. Emerging aquatic weed risk species of the Ironbark Creek – Healey's Creek system

Common name	Genus species	Growth form, habit and main impacts	WONS	Qld *Biosecurity Act 2014* category	Management methods and notes
Arrowhead 	*Limnocharis flava*	An anchored aquatic plant with erect stems that grows in saturated, fertile, and muddy conditions as a perennial plant in areas with sufficient moisture. Can also be annual where moisture is seasonal. Plants grow up to 1m above the waterline. Colonises shallow wetlands and margins of deeper waterways. Blocks channel flows, traps silt, increases flood risks, creates mosquito breeding habitat, reduces access to waterways and displaces native plants and animals. Has been recorded in the Townsville local government area.		2, 3, 4 & 5	No herbicides are registered to specifically control limnocharis and there are no known biological control agents. *Biosecurity Act 2014* requires that new infestations must: ● be reported to Biosecurity Queensland on **13 25 23;** ● be identified and removed by approved officers, and ● have locations recorded prior to removal. Classed as very high risk in *Burdekin Shire Council Biosecurity Plan* (BSC 2020).
Sagittaria 	*Sagittaria platyphylla*	Emergent aquatic perennial up to 1.5m tall. Grows in irrigation channels, drains, creeks, rivers, lagoons, dams, and wetlands. Establishment favoured by slow moving or static shallow water. Forms floating mats, blocking irrigation ditches, shallow dams, and waterways. Invades and degrades natural wetlands. Competes with native water plants. Has been recorded in the Townsville local government area.	X	3	No herbicides are registered to specifically control sagittaria. Off-label use permits PER80934 allow for the use of glyphosate as a foliar spray. Control is best carried out when water levels are low. Hygiene and containment measures need to be applied to prevent further spread downstream. Mechanical control – place all removed plant material in sealed plastic bag, leave in sunlight to decompose, then dispose of at council-approved landfill. Alternatively, leave material in sun to dry, then burn. Classed as very high risk in *Burdekin Shire Council Biosecurity Plan* (BSC 2020).
Water mimosa 	*Neptunia oleracea*	Floating perennial weed that attaches to bank at water's edge. Stems to 1.5m long, grow out over water and form spongy, fibrous covering between nodes. Grows on land in damp soil or on water as thick floating mats. Commonly found in and around freshwater pools, swamps, and canals. It is a nitrogen-fixing legume that releases nitrogen into water bodies. This can lead to increased algal blooms and encourage growth of other weeds. Restricts water flow and increases water loss through evapotranspiration. Smothers water surface, shading out native aquatic plants, leads to deoxygenated water and impacts fish populations and creates mosquito habitat. Has been recorded at Saltwater Creek in the Burdekin local government area. Has been subject to sale and distribution through Asian communities and gardeners.		2, 3, 4 & 5	No herbicides are registered for control and there are no known biological control agents. Mechanical control – Remove all plant matter from infested water body and pull plants out of surrounding banks, making sure to remove attached root system. Dispose of plant parts in an appropriate waste facility or rubbish bin. Water mimosa is a restricted invasive plant under the *Biosecurity Act 2014.* ● All sightings must be reported to **Biosecurity Queensland** within 24 hours of the sighting. ● It must not be given away, sold, or released into the environment without a permit. Classed as very high risk in *Burdekin Shire Council Biosecurity Plan* (BSC 2020).

Water quality

What are the issues and state of knowledge?

Water quality in seasonal Lower Burdekin floodplain wetlands is naturally variable through the year. Under natural predevelopment conditions, water quality in distributary stream systems and their hosted wetlands transitioned from turbid floodplain-inundating flows in the wet season, settling and clearing into the non-flow period of the early dry season, and then interacting with groundwater that maintained perennial lagoons during the water level drawdown period of the late dry season (Perna *et al* 2012). Seasonal 're-setting' of water quality would then follow with wet season rainfall leading to local catchment run-in, then flow initiation, and – in larger events – Burdekin or Haughton River overbank flushes down distributary systems (Davis *et al* 2017). In seasonal drying wetlands, water quality generally progressed through to the clearing phase and then into a critical period with higher temperature and turbidity and lower dissolved oxygen prior to drying.

In the contemporary, modified floodplain system, wetland water quality is largely driven by the condition of sourced Burdekin or Haughton River water supplying irrigators via regulated creek flows; aseasonal inflows of farm irrigation tailwater or BHWSS channel overflow; the condition of creek reaches, particularly their weed infestation status, and by the quality and contaminant load of surface and groundwater inflows from their catchment.

Some of the processes and key drivers of water quality associated with predevelopment hydrological conditions no longer occur as frequently in the natural seasonal period or at all; for example, flow cessation, dry season water level drawdown, groundwater domination of inflows, Burdekin/Haughton River overbank flood flow flushing and scouring (Perna *et al* 2012). However, even under the contemporary modified regime, wetland water quality still undergoes major seasonal variation with the early summer wet season, including pre flushing flow or flood inundation, being identified as the period of greatest water quality stress for hydrologically-modified systems (Burrows *et al* 2006, Veitch, *et al* 2007).

Very few sites within the lower Burdekin floodplain have been a focus for regular water quality monitoring programs. Therefore, our state of knowledge is mainly informed by studies examining water quality issues more generally across the floodplain and within selected drainages, and for some specific fish habitat and weed management investigations (Davis *et al* 2013, 2014, 2017, Veitch *et al* 2007, Loong *et al* 2005, Perna 2005, Pearson *et al* 2003, Hunter *et al* 1998, Hunter *et al* 1996, Keating *et al* 1995). Fortunately, there have been several specific investigations of the Ironbark Creek – Healey's Lagoon System (Burrows *et al* 2006, 2009, Loong *et al* 2006, Veitch and Burrows 2006).

Data collected in the Lower Burdekin and broader GBR catchment is available at:
https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef/modelling-and-monitoring

https://qgsp.maps.arcgis.com/apps/MapSeries/index.html?appid=9d1aad1e2b444ec6a1890e4032284147

Water quality issues known to generate or potentially cause aquatic ecosystem impacts in the Lower Burdekin floodplain, including the Ironbark Creek and Healey's Lagoon system and downstream receiving environments, such as the Cape Bowling Green Bay Ramsar wetland and the GBR World Heritage Area include:

- low dissolved oxygen (DO);
- high turbidity/total suspended solids (TSS);
- elevated nutrient levels;
- agri-chemical residues, and
- salinity.

The drivers/likely causes, potential impacts, and data and management notes for these issues are summarised in Table 4. Specific considerations for this system management plan are discussed below.

System specifics

Where discussed issues relate to management issues listed in Appendix 1 or mapped in Appendix 2, the designated (M) number is referenced. The level of low dissolved oxygen (DO) is the most critical water quality issue identified for the for the Ironbark Creek – Healey's Lagoon System in terms of observed ecosystem impacts. This issue's severity is primarily determined by the system's weed infestation status and the mitigating influence of regulated flows (Burrows *et al* 2006). Since floating aquatic weed infestations within the system have come under management, DO levels within the main lagoons have returned from chronic impact levels to a functional aquatic ecosystem. However, weed infestation is recognised as symptomatic of other primary condition divers which are still operating, including water quality, namely, elevated levels of nutrient availability, and altered hydrology (Burrows *et al* 2006, Econcern 2021). Wetlands within agricultural catchments of the lower Burdekin commonly record nutrient values above aquatic ecosystem guidelines (Loong *et al* 2006, Davis et al 2014, 2017). Nutrients sourced from catchment land use enter wetlands via catchment rainfall runoff, irrigation tailwater and groundwater inflows. BHWSS-regulated inflows to the system serve both as a 'refreshing flow' mitigator of low DO levels, and also as an additional source of nutrients – albeit low concentrations associated with colloids in sourced Burdekin River water – which add significant loads due to large throughput

volumes (Perna 2004). When present in Burdekin water, these colloids also increase the turbidity of Ironbark Creek from the regulated flow confluence downstream, though their impact reduces due to instream attenuation by the main lagoon reach, which generally exhibits clear albeit tannin-stained water quality. Riparian vegetation also

Photo 15. Revegetation of riparian zones that lie between receiving waterways and irrigated cane land provide opportunities for intervention and uptake of nutrient loads in surface run off, irrigation tailwater and sub surface groundwater inflows.

Photo 16. Incorporation of detention basins and riparian revegetation in agricultural drainage systems in the upper Ironbark Creek catchment would provide water quality, soil erosion and habitat benefits to the farm production and creek system.

mitigates low DO and other water quality impacts by shading shallow margins thereby reducing water temperature and increasing DO carrying capacity. Also, riparian vegetation shades out aquatic grasses and/or dense submerged aquatic plants, which reduces organic loading and chronic diel cycling impacts on DO respectively (Burrows *et al* 2006), also acting as a buffer/filter to agricultural runoff by intercepting sediment and the uptake of nutrient loads.

Based on past research findings and recent field observations, generalised water quality issues and conditions for the Ironbark Creek – Healey's Lagoon system can be described for six reach sections (Table 3 below).

Photo 17. Despite some evidence of elevated nutrient availability, the dense riparian vegetation canopy of the upper Ironbark Creek system helps to maintain suitable water quality for aquatic ecosystem health. It maintains cooler temperatures, higher dissolved oxygen (DO) levels, and limits the growth of aquatic weeds, or submerged aquatic plants, that could impact DO levels and cycling.

Photo 18. Groundwater inflows to the creek system upstream of pumped inflows from the Haughton River provide a clear well-oxygenated baseflow during some periods of the year.

(M1) Observations of farm drainages in the upper Ironbark Creek suggest that there are opportunities to improve drain function from a water quality perspective. Farm drains often replace natural drainage lines with more direct and larger capacity channels intended to get water off farmland quick enough to avoid crop damage. Where drainage capacity is greater than crop needs, the result can be rapid runoff that conveys catchment loads of sediment and/or nutrients more directly to receiving stream channels, potentially also causing farm soil erosion. This was observed at several sites. To reduce such risks, it is beneficial to have drainage networks designed to a drainage modulus (litres/sec/ha) that meets, but not exceeds, crop drainage needs. Also, to include detention basins or constructed wetlands in the drainage network that pond water and

slow the overall discharge rate to the creek network, allowing sediment to settle and, with appropriate aquatic vegetation, some of the nutrient load to be processed. Using riparian vegetation to line such drains can further stabilise channel margins, shade out channel grass weeds, and act as a high flow velocity baffle during larger events.

(M3) Outbreak flows from the Haughton River form an important part of the natural hydrology of the Ironbark Creek system, playing a role in resetting habitat conditions, refreshing water quality, and forming the stream channel. A powerline maintenance access track, built across the distributary channel breakout point, has raised the floor of the channel, increasing the height of the Haughton River flood flow level required to initiate flow down the creek system. This would impact the frequency and duration of breakout flows down the creek system with flow on impacts to the creek's upper catchment ecology.

Table 3. Generalised water quality issues for Ironbark Creek – Healey's Lagoon system reaches

Reach section	Water quality issues/Observed reach conditions
Ironbark Creek upstream of regulated inflow	Possibly reduced frequency Haughton River outbreak flows due to road leveed channel (M3). Water clear, upper reaches without flow have organic scum appear eutrophic, (nutrient polluted), some aquatic grass infestation but extent and water quality impacts mitigated by riparian shading. Lower reaches clear baseflow, apparent groundwater connections, oxygenated, good riparian shading, appears good ecosystem health. Farm drainage networks draining to reach very large capacity with limited detention function and evidence of local soil erosion (M1).
Ironbark Creek downstream of regulated inflow	Water opaque due to colloid load. High flow, well oxygenated good quality for ecosystem health. Broken riparian canopy, aquatic grass (hymenachne, para) infestations, some open reaches, isolated surface mats of salvinia, water clearer downstream to clear at Woodstock Giru Road crossing. Degraded tributary draining to reach grass-choked (likely low DO) source during catchment runoff.
Upper lagoon system	Water slightly opaque due to colloid load. High levels of incident sunlight, dense beds of submerged macrophytes with extreme levels of diel cycling of DO associated with plant night-time (or overcast day, turbid inflow) respiration, and low DO mitigated by regulated inflows – mitigation effect diminishes downstream. Lagoon edges and upper channel dominated by floating weeds water hyacinth and salvinia. Areas lacking riparian vegetation have broader fringing aquatic grass margins.
Lower lagoon system	Water clear but dark due to organic load/tannin staining. Submerged macrophyte density lower, therefore less diel cycling of DO levels associated with submerged plant respiration. DO levels on boundary of requirements for ecosystem health. Deeper water with deoxygenated lower layer. Cycling (growing, dying, sinking) infestations of surface-covering salvinia, broader aquatic grass margins occur where banks have sparser riparian vegetation.
Exotic aquatic grass-dominated drainage depressions (Highway – Reed Beds)	Shallow open (no tree cover) water, with dense stands emergent exotic aquatic grasses, warm temperatures in summer. Low seepage flow from upstream Healey's Lagoon, low DO levels due to bacterial decomposition submerged grass thatch, oxygen demand organic rich (peaty) soils. Low DO exacerbated by longer water resident times (fish passage barrier). Small areas shaded channel open, lower temperature, better DO status. Better DO status with high flow events that have shorter water residence times.
Coastal wetland complex (Reed Beds)	Large open (no tree cover) wetland basin with deeper basin sections but shallow exotic aquatic grass dominated margins. Warm shallows, exotic grass domination, organic loading generates low DO risks. These mitigated in vicinity of supplemented flow when operating and by water surface – wind, air interactions. Summer critical water quality period associated with higher temperatures, and deoxygenated flood inflows.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2 the listed works number is referenced.

1. NQ Dry Tropics communicate the water quality and ecosystem health benefits that have been achieved by the RMA-supported floating aquatic weed control program to system management stakeholders. This includes the need to maintain active cost-sharing participation and to seek continuous improvement and innovation in weed management approaches including the aspirational goal of developing biomass removal-based control (see *Aquatic weeds* section).
2. NQ Dry Tropics communicate the water quality and ecosystem health benefits of existing and yet-to-be-established riparian vegetation corridors to system management stakeholders. This includes fostering support for ongoing riparian zone management and revegetation efforts for: reducing water temperatures and increasing DO carrying capacity, shading out exotic aquatic grasses and excessive submerged aquatic plants, acting as farm run off buffers and interception areas and drainage channel weed control and erosion protection (W11, W12, W15). See *Lack of riparian vegetation* section.

3. NQ Dry Tropics communicate the underlying elevated nutrient driver of aquatic weed infestations to system management stakeholders. This includes seeking to showcase existing practitioners and/or engage 'early adopters' in trialling methods or practices that serve to reduce off-farm export of nutrients to the receiving creek/lagoon system. This could encompass on-farm Best Management Practices, riparian vegetation buffer establishment, and tailwater and runoff management.
4. NQ Dry Tropics seek funding resources and landholder engagement to establish a demonstration site redesign of a Best Management Practice farm drainage system within the Ironbark Creek catchment. The objective is to demonstrate designed drainage modulus (litres/sec/ha) that meets, but not exceeds, crop drainage needs; showcase detention basins or constructed wetlands in the drainage network that pond water and slow the overall discharge rate to the creek network, including appropriate in-basin aquatic vegetation for stripping some of the nutrient load; and the use of riparian vegetation to line drains to protect from erosion and stabilise channel margins, shade out channel grass weeds, and act as a high flow velocity baffle during larger events (W3, W4).
5. NQ Dry Tropics engage with Sunwater to explore regulated system management options that could reduce or cease aseasonal flows and seepage downstream of the Bruce Highway and into the Reed Beds (W16) (see *Altered hydrology* section).
6. NQ Dry Tropics seek funding resources and landholder engagement for the establishment of flood flow-path DO management options for exotic aquatic grass-dominated drainage depressions linking lower Healey's Lagoon to the Reed Beds W18 (see *Fish passage* section).
7. Engage with landholder of Ironbark Creek distributary breakout point to seek support for reinstating original channel invert level. If supportive, seek funding for civil engineering proposal for works that can reinstate original channel breakout level while maintaining utility of powerline access corridor (W1) (see *Altered hydrology* section).

Photo 19. Immediately downstream of the regulated flow confluence. The main Ironbark Creek channel colloid levels are elevated, reflecting the condition of the Burdekin River water delivered to, and pumped from, the Haughton River. Although nutrient levels associated with these colloids are pumped, through-put volumes still equate to ecologically-significant nutrient loading for receiving wetland systems.

Photo 20. Woodstock Giru Road crossing showing inflow to the top of the main lagoon reach. Depending on the level of turbidity in the regulated flow source water, much of the colloid load is attenuated by instream vegetation or precipitated by instream processes by the time it reaches the lower creek system.

Table 4. Lower Burdekin floodplain water quality issues

Issue	Drivers/likely causes	Potential impacts	Data and management notes
Low dissolved oxygen	● Aquatic weed-infested waterway reaches promoted by near-perennial regulated flows/sustained water levels and high nutrient availability. ● Biological Oxygen Demand (BOD) associated with bacterial decomposition of organic material produced or trapped by aquatic weeds, including grass margins inundated by higher wet season water levels. ● Night-time or turbid inflow-promoted respiration of submerged aquatic plants and attached periphyton. ● Prevention of instream photosynthesis/oxygen production by turbidity/weed shading. ● Prevention of aeration of water surface due to weed covering. ● High BOD of organic loads in catchment run in during wet season. ● Deoxygenated groundwater inflows. ● Lack of River overbank flooding flushes in wet season. ● Lack of riparian shading/higher water temperatures.	● Fish kills. ● Anoxic stream reaches that function as fish passage barriers. ● Deoxygenated 'blackwater' flows to downstream receiving environments, including upper reaches of estuaries. ● Reductions in instream productivity, biodiversity (including aquatic macro invertebrates) and fishery resources. ● Increased solubility and mobilisation of nutrients in sediments.	Issue well documented by site specific and regional catchment studies (Perna 2003, 2004, 2005, Loong *et al* 2005, 2006, Burrows *et al* 2006, Veitch and Tait 2007). Management needs/opportunities ● Reduced aquatic weed and submerged plant biomass. ● Greater riparian shading. ● Reduced instream nutrient availability. ● Reduced BOD/organic loading in catchment run-in. ● Targeted monitoring to increase understanding of specific issues, including: ○ Impact of regulated flow cessation on DO levels through lagoon system. ○ Role of BOD load in catchment run in on DO status ○ DO levels through exotic grass-dominated drainage depressions under different flow conditions. ○ Status DO in Reed Beds and impact of aseasonal inflows and aquatic grass infestation. ○ Benefit of regulated flow on wet season DO levels.
Turbidity	● Mean annual total suspended solid (TSS) loads underpinning turbidity have increased, on average, six-fold in GBR catchment rivers since European settlement. ● Burdekin Falls Dam receives turbid wet season flood flows and has minimal colloidal settlement. ● Irrigation supplies pumped from Burdekin River flows supplied from persistently turbid Burdekin Falls Dam. ● Catchment soil erosion and sediment loads carried in local catchment surface runoff influences turbidity levels during wet season.	● Multiple times the natural run-in loading of receiving water bodies with attached nutrients. ● Reduced instream primary productivity. ● Reduced submerged water plant diversity and density. ● Reduced success of visual predator fish and impacts to sensitive aquatic invertebrates (for example, filter feeders).	Issue well documented at a regional scale with few catchment studies (Perna 2003, 2004, Davis *et al* 2014, 2017). Management needs/opportunities ● Few management options exist for turbidity imported with Burdekin River water via Haughton pumping station and Ironbark Creek. ● For local contributing catchment area: there is opportunity to reduce sediment loads in runoff through management of soil erosion risks and catchment ground cover, and by the design of farm drain systems to prevent erosion and incorporate detention basins and controlled rates of runoff and discharge to stream networks.
Nutrient loading	● Nutrient load attached to colloids in irrigation supplies pumped from turbid Burdekin River. ● Catchment land and water use practices that result in off-farm/property losses (including via groundwater flows) of nutrients, for example, on farm fertiliser use, irrigation tailwater, and post-harvest runoff of high BOD sugar. ● Organic nutrients released from decomposing aquatic weed and submerged plant biomass, for example, following weed spraying and during elevated wet season flows.	● Eutrophication (nutrient pollution) of waterway. ● Promotion of aquatic weed/submerged plant growth and associated impacts. ● Algal blooms, dissolved oxygen crashes, and fish kills. ● Export of elevated nutrient loads to downstream receiving	Issue documented regionally, but no site data available. DES currently establishing real-time monitoring stations on regional creek systems. Previous regional monitoring has recorded Burdekin Wetland concentration exceedances above ecosystem health guidelines (Perna 2003, 2004, Loong *et al* 2005, Davis *et al* 2013. 2014, 2017). Management needs/opportunities ● Improve on-farm/property practices, for example, fertiliser application rates and practices and irrigation scheduling and volumes.

Issue	Drivers/likely causes	Potential impacts	Data and management notes
	● Wet season local catchment run-in of sediment and attached and dissolved nutrient loads. ● Mobilisation of nutrient loads accumulated in bottom sediments (particularly when water becomes anoxic).	environments, for example, Ramsar wetland and GBR lagoon.	● Removal and/or control of aquatic weed and submerged plant biomass. ● Promotion of riparian vegetation buffers and emergent aquatic plant stream margins with nitrate stripping/uptake functions. ● Design farm drainage systems to provide nutrient interception and processing capacity, including riparian and aquatic vegetation, detention basins and controlled rates of runoff/discharge.
Agri-chemical residues	● On-farm use and practices that lead to off-farm losses including inadequate chemical storage, application methods; timing (especially in relation to rain and irrigation events) and conditions; wash down, and irrigation practices. ● Off-farm movement via irrigation tailwater, groundwater accession and rainfall runoff. ● On-stream use for aquatic weed control.	● Direct lethal effects on periphyton and phytoplankton. ● Long-term, low-dose pesticide exposure can produce effects in freshwater organisms after several generations affecting growth, metamorphosis, locomotor activity, antipredator behaviours, immune capacity, infections, and gonadal condition. ● Sublethal effects on endocrine systems of fish and endocrine disruption in amphibians. ● Export of pesticide residue loads to downstream receiving environments. For example, Ramsar wetlands and GBR lagoon present impact risks to mangroves, seagrass, algal endosymbionts in corals and benthic microalgae.	Issue documented regionally, including in adjoining drainages, regional groundwater and at Burdekin farm drainages. Previous monitoring of floodplain creek system has recorded concentration exceedances above ecosystem health guidelines for both low and event flows. Research indicates mixed pesticide residues produce impacts effect equivalent to higher concentration (Davis *et al* 2013, 2017, Hunter *et al* 1998, Hunter *et al* 1996, Keating *et al* 1995). <u>Management needs/opportunities</u> ● Improved on-farm/property practices e.g., pesticide application rates and use timing in relation to rain and irrigation events, irrigation methods and applied volumes. ● Increase use of recycle pits and treatment wetlands. ● Real time monitoring and reporting at paddock/sub catchment scale to tie results to practices. ● Design farm drainage systems to provide contaminant load interception and processing capacity, including riparian and aquatic vegetation, detention basins and controlled rates of runoff/discharge.
Salinity	● Rising saline groundwater contaminating adjoining aquifers and/or discharging to surface water features ● Marine saltwater intrusion into coastal freshwater wetlands or aquifers promoted by high(er) sea levels or drawn down freshwater aquifers	● Physiological stress or death of freshwater biota or exposed terrestrial vegetation	Emerging management issue for BHWSS and near coastal areas. <u>Management needs/opportunities</u> ● Reduced accession surface water to groundwater. ● Management groundwater rise potentially including dewatering bores and conjunctive use/discharge. ● Bunding saltwater intrusion pathways and maintenance of hydraulic head for coastal freshwater aquifers. ● Accommodation of landward migration of coastal wetland mosaic.

Fish passage barriers

Fish movement needs

The Lower Burdekin floodplain's native freshwater fish community needs to undertake a range of movements to fulfill life history cycles, and to distribute to suitable floodplain distributary creek and wetland habitats (Veitch *et al* 2007, Carter and Tait 2010).

The main classes of life cycle movement are:

- Resident – can complete life history at resident site.
- Potamodromous – needs to move within catchment to different freshwater habitats, for example, from pools to running riffles, gravel beds, or off-stream floodplain swamps.
- Amphidromous – young recruit from marine environments, but adults breed in lower freshwater.
- Anadromous – lives in marine environment moves to freshwater to breed.
- Catadromous – breeds in marine/estuarine environments and recruits to freshwater.

Even resident species capable of breeding and recruiting juveniles without needing to move to different areas or habitats will still naturally undertake intra-catchment movements to distribute their population and colonise new areas. Potamodromous species are compelled to undertake intra-catchment movements within the wetland system to access required breeding and/or nursery habitats, for example, floodplain wetlands or flowing riffle reaches. Diadromous species are those that need to move between fresh and marine environments to reproduce and include several of the life cycle types (listed above). Most diadromous species in tropical Queensland, including the iconic barramundi, are catadromous; meaning they spawn as adults in marine waters and, as juveniles, recruit back to freshwater habitats. In evolutionary time, all species – regardless of their life history cycle – need to be able to move within their range to maintain healthy gene flow between populations.

System specifics

Natural connectivity patterns

The timing of fish movement activity is very much influenced by the opportunistic framework provided by the wet season conditions under which they evolved, although there is some component of movement behaviour that is opportunistic, such as attraction to flows. Historically, the distributary drainage systems of the Burdekin floodplain, such as Ironbark Creek, flowed seasonally during the wet season and transitioned to a chain of isolated lagoons in the dry season. Fish passage connectivity was only provided when catchment runoff, flood plain inundation and/or Haughton River channel flood outbreaks generated flow events.

Photo 21. High flow velocities through the piped culvert of the Woodstock Giru Road crossing (above) present a fish passage barrier under most flow conditions short of road inundation. Increasing the height of the downstream discharge apron and reducing the flow slope and velocity through the culvert could provide an interim solution until the culvert can be upgraded to a more fish passage-friendly box culvert or bridge crossing.

Photo 22. Dense populations of feral fish tilapia (*Oreochromis mossambicus)* occur throughout the upper Ironbark Creek catchment. While there are no effective control methods for this species, the maintenance of healthy fish habitat and predator populations facilitated by good fish passage is demonstrated to favour native species and limit tilapia numbers in other coastal wetland systems.

These connective flows provided opportunities for resident species to recolonise seasonal habitats and gave other life history types opportunities to access habitats required for successful breeding. In the case of catadromous species like barramundi, this involved movement of adults to estuary mouths to breed and return

movement of juveniles form coastal nursery swamps such as the Reed Beds to the main upstream lagoons. Under predevelopment conditions, catadromous fish could enter the Ironbark Creek from the top of the system via the Haughton River, as well as via the lower estuarine connected reaches.

Haughton River weirs (Giru and Val Bird) downstream of the Ironbark Creek distributary outbreak now limit the movement of migratory catadromous species up the Haughton system. However, during high connectivity with the Haughton River, the Ironbark Creek channel (via Reed Beds and Healey's Lagoon) still provides a potential fish passageway for estuarine breeding migratory fish to bypass the Haughton River weirs to reach the upper Haughton. This passageway may be partially responsible for the maintenance of estuarine breeding Jungle Perch in the national park upper Haughton sub catchments of Major and Spring Creeks, though the fish passage functionality of the contemporary system has known limitations documented by relatively comprehensive scientific research (Burrows *et al* 2006, Veitch and Burrows 2006, Burrows *et al* 2009). Although migratory fish like barramundi continue to be recorded in Healey's Lagoon and Ironbark Creek, their abundance and diversity is limited and indicative of operating fish passage barriers. This plan reiterates these past findings and proposed management solutions.

Types of barriers

Several fish passage barrier threats to asset values were identified for the Ironbark Creek – Healey's Lagoon system. These are listed as management issues (M) in Appendix 1 and are mapped in Appendix 2. They include instream structures and poor reach conditions including:

- (M10) Woodstock Giru Road crossing with a high flow velocity piped culvert, which acts as a fish passage barrier;
- (M17) piped culvert outlet under road crossing at the bottom of Healey's Lagoon, which presents a low flow fish passage barrier;
- (M20) regulated flow seepage downstream of highway that promotes hymenachne growth that is inaccessible to grazing stock and creates a water quality fish passage barrier; and
- (M21) lack of lower Palm Creek riparian shading and regulated flow seepage, which promotes hymenachne growth that is inaccessible to grazing stock and creates a water quality fish passage barrier.

(M10) This Woodstock Giru Road crossing of Ironbark Creek has pipe culverts that convey high flow velocities (see Photo 21) that present a fish passage barrier under all-but-road-inundating flow levels. While much fish migration does occur during high flood inundating flow events, some species and/or size classes depend on movement during recessionary flows, which are entirely directed through the culvert pipes. Upper Ironbark Creek contains significant areas of high quality fish habitat. Maintenance of migratory fish access to upper reaches is important for the health and fishery productivity of the system.

(M17) A historical road crossing at the downstream end of Healey's Lagoon that is still used for local farm access has a piped culvert that presents a higher velocity flow fish passage barrier for some species, particularly when flows are solely directed through the piped outlet during base flow periods. Although fish passage is possible when this crossing is inundated during higher flows, some fish species and size classes prefer to move on lower flows when this crossing presents a barrier. The benefits of fish moving upstream to avoid degrading water quality conditions as flows slow in the hymenachne-dominated downstream reaches also presents a justification for passage improvement at this site.

(M20) As discussed in the *Altered hydrology* section, seepage downstream of the highway generated by Ironbark Creek's regulated flows promote aquatic grass growth that forms a large biomass of dead thatch and actively growing grass covering the water's surface. During wet season high flow events, much of this biomass is inundated and bacterial decomposition consumes available oxygen, creating anoxic (de-oxygenated) water conditions (see Photo 24). This presents a water quality passage barrier to migratory fish species, including barramundi, that attempt to recruit upstream from the downstream Reed Beds nursery area.

(M21) Palm Creek is a distributary of St Margaret's Creek that flows to a confluence with the Ironbark Creek system in the coastal drainage depression hydrologically-impacted by downstream seepage from Healey's Lagoon. Where Palm Creek retains riparian vegetation canopy cover aquatic grasses have not been able to dominate the steam channel. However, in its lower reaches, the stream naturally has a more open overstorey and grass infestation dominates the drainage channel. These poor reach conditions create anoxic (de-oxygenated) water conditions that present a water quality passage barrier to migratory fish species including barramundi and jungle perch that attempt to recruit upstream from the downstream estuarine complex.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage with road infrastructure owners Burdekin Shire Council to communicate identification of Woodstock Giru Road crossing of Ironbark Creek as a significant fish passage barrier. Ascertain timeline for any infrastructure upgrade proposals at the site. If road crossing upgrade is imminent,

ensure council is supported in meeting fish passage provision requirements at the site. If road crossing upgrade is not imminent engage fish passage expert resources to develop an interim fish passage solution. This could potentially involve lowering of the slope of flow (and velocity) through the piped culvert with or without inclusion of internal flow baffles within culvert pipes (W9).

2. Engage with road reserve and infrastructure landowners (Queensland Department of Resources and Department of Main Roads) and adjoining local landholder users of existing stream crossing to assess opportunities for alternative local access, for instance, use of adjoining old Bruce Highway crossing. Also determine possible support for removal of structure or replacement with low gradient causeway/fish rock ramp passageway. Resource development of options proposal and implement negotiated agreed solution (W17).
3. Engage BHWSS operator Sunwater to deliver regulated flow/water level management within Healey's Lagoon (see *Altered hydrology* section, recommendation 4). This would prevent aseasonal seepage downstream of the Bruce Highway and facilitate reinstatement of seasonal drying and grazing-based control of hymenachne within flood flow paths across Bahr's Paddock as a strategy to improve fish passage.
4. If this approach described in (3) above proves non-viable, examine alternative strategies including:
    a. Excavator rake clearing, or chemical spray followed by burning, of aquatic grass cover to form a preferential flow path from (i) outflow of Healey's Lagoon across Bahr's Paddock to tributary channel of Reed Beds, and (ii) bottom of Palm Creek channel across Bahr's Paddock to Reed Beds Road crossing. Revegetate the excavated flow path spoil levee (or burnt flow path) margin with dense shade-generating tree species, for example, Leichardt and paperbark trees, to maintain a grass-free wet season flow path (W18). See also *Innovative management* section.
    b. Gain support of BHWSS operator Sunwater to trial a pumped flow of Haughton River through the system during the wet season period as a means of enhancing fish passage connectivity across Bahr's Paddock via a sustained flow of suitable water quality (W18). See also *Innovative management* section.

Photo 23. Wetted flow paths defined by high resolution drone imagery extending across exotic aquatic grass-dominated drainage depressions (Bahr's Paddock). These run from the outflow of Healey's Lagoon (bottom left) to Reed Beds tributary channels, and from the bottom of Palm Creek (above left) to Reed Beds Road crossing.

5. Pursue revegetation of shade canopy-forming riparian tree species to exclude channel exotic grass growth and create fish passage conduit within the lower reaches of Palm Creek up to its boundary with Bahr's Paddock (W19).
6. If recommendation (3) above is not successful, pursue excavated clearing of aquatic grass cover to form a preferential flow path from the inflow of Palm Creek to Bahr's Paddock to confluence with the Ironbark Creek preferential flow path proposed in 4(a), or alternatively, along existing boundary drain to Reed Beds Road tributary channel crossing. Revegetate the excavated flow path margin (spoil levee) with dense shade-generating tree species, like Leichardt and Paperbark trees, to maintain a grass-free wet season flow path (W18).

Photo 24. An open water channel created by high flows from Healey's Lagoon to downstream of the Bruce Highway, which terminates in an exotic aquatic grass-dominated reach with poor water quality and fish passage.

Photo 25. Dense canopy cover provided by isolated stands of Leichardt and paperbark trees maintaining an open water channel conduit in their understorey.

Table 5. Life cycle movement requirements of fish recorded from floodplain freshwater wetland systems (*exotic)

Name	Genus and species	Life cycle movement
Tarpon	*Megalops cyprinoides*	Catadromous
Long-finned eel	*Anguilla reinhardtii*	Catadromous
Bony bream	*Nematalosa erebi*	Resident
Salmon catfish	*Arius graeffei*	Anadromous/Potamodromous
Rendahl's tandan	*Porochilus rendahli*	Potamodromous
Butter jew	*Neosilurus ater*	Potamodromous
Hyrtl's tandan	*Neosilurus hyrtlii*	Potamodromous
Snub-nosed gar	*Arrhamphus sclerolepis*	Resident
Long-tom	*Strongylura kreffti*	Resident
Fly-speckled hardyhead	*Craterocephalus stercusmuscarum*	Resident
Eastern rainbow fish	*Melaanotaenia splendida*	Resident
Barramundi	*Lates calcarifer*	Catadromous
Jungle perch	*Kuhlia rupestris*	Catadromous
Agassiz's glassfish	*Ambassis agassizii*	Resident
Sailfin glass perch	*Ambassis agrammus*	Resident
Spangled perch	*Leiopotherapon unicolour*	Potamodromous
Striped grunter	*Amniataba perchoides*	Resident
Mouth almighty	*Glossamia aprion*	Resident
Mangrove jack	*Lutjanus argentimaculatus*	Catadromous
Archer fish	*Toxotes chatareus*	Resident
Scat	*Scatophagus argus*	Catadromous
Bully mullet	*Mugil cephalus*	Catadromous
Giant herring	*Elops hawaiensis*	Catadromous
Milkfish	*Chanos chanos*	Catadromous
Silver biddy	*Gerres filamentosus*	Catadromous
Empire gudgeon	*Hypseleotris compressa*	Catadromous
'Boof headed' gudgeon	*Hypseleotris midgleyi*	Resident
Purple-spotted gudgeon	*Mogurnda adspersa*	Potamodromous
Snakehead gudgeon	*Giurus margaretacea*	Catadromous
Sleepy cod	*Oxyeleotris lineolatus*	Resident
Big-headed gudgeon	*Philypnodon grandiceps*	Potamodromous
Flathead goby	*Glossogobius giurus*	Amphidromous
Speckled goby	*Redigobius bikolanus*	Amphidromous
*Mosquito fish	*Gambusia holbrooki*	Resident
*Three-spot gourami	*Trichogaster trichopterus*	Resident
*Tilapia	*Oreochromis mossambicus*	Resident

Lack of riparian vegetation

What is it and why is it important?

The riparian zone is the interface between land and a watercourse or wetland. Riparian zone vegetation is an important component of the landscape because it supports a range of biophysical functions and values. These include:

- bank erosion protection;
- maintenance of channel stability and form;
- nutrient uptake;
- interception of sediment loads;
- providing leaf litter food sources and structural habitat, including root undercuts/snags for aquatic ecosystems;
- shading and cooling the water's edge and preventing dense submerged aquatic plant growth, thereby increasing the water's dissolved oxygen carrying capacity;
- excluding sun-loving aquatic and levee grasses, thereby helping to maintain open water habitat and channels, reducing wildfire fuel loads and risk, and decreasing pest rodent harbourage habitat;
- providing wildlife corridors and refuge habitats, including for predators of adjoining cane land pests; and
- flood protection by reducing catchment runoff rates and slowing the velocity of channel breakout flows.

In intensively developed landscapes like the Lower Burdekin, the riparian zone assumes additional importance because it is often the most significant area of remnant natural habitat. Given its location at the interface between terrestrial and aquatic ecosystems, the riparian zone is important to both, and the quality of instream aquatic habitats is often determined, to some degree, by the condition of the riparian zone (**Figure 3**). Due to these high ecological and catchment functional values, areas lacking riparian vegetation can present threats to the function and value of the aquatic ecosystem. Therefore, rehabilitation of the riparian zone is a priority focus for nature conservation and catchment management project investment.

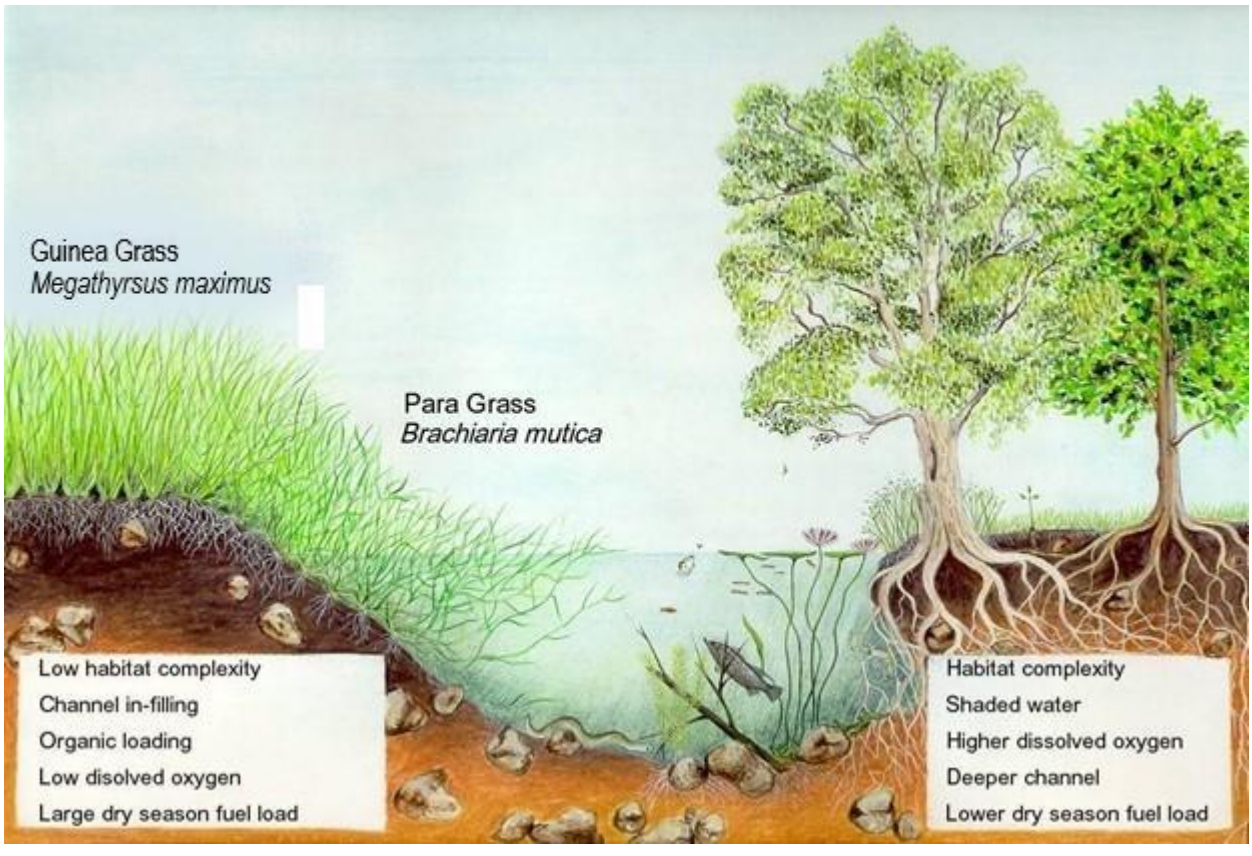

Figure 3. Contrasting ecosystem function and features of an exotic pasture-dominated (left) versus native vegetation-dominated (right) riparian zone (Illustration by Lois Genis).

Status of Burdekin floodplain riparian zones

In developed landscapes of the Lower Burdekin, the condition of the riparian zone has often been impacted by a range of land and water resource use pressures, some historical and some current. These include past and ongoing clearing of vegetation; altered stream flows, water levels or soil moisture; elevated nutrients; woody,

grass, and vine weed invasion; uncontrolled fire, stock grazing and trampling pressure; bank erosion; channelisation; land filling, and rubbish dumping.

Table 6. Riparian zone rehabilitation approaches for different existing condition contexts

Existing condition context	Potential rehabilitation strategy	Notes
1. Areas of remnant vegetation	Protect from clearing, monitor, and control weeds, implement fire management suited to vegetation type. **Extensive revegetation**.	Total fire exclusion is appropriate for fire sensitive and/or closed canopy riparian forests.
2. Areas of degraded remnant vegetation	If in ungrazed landscape, control/spay out exotic pasture grasses with grass selective herbicides. If in grazed landscape, manage stock grazing and trampling pressure to keep exotic understory pastures subdominant, allow natural seedling recruitment and avoid accumulation of large fire fuel loads. Monitor and protect natural regeneration, conduct 'in fill' planting revegetation (plus stock protection, weed control and watering maintenance) if required for denuded sections, implement fire management suited to vegetation type. **Extensive revegetation with 'fill in' intensive revegetation.**	Often includes some areas devoid of remnant native vegetation that may require more intensive rehabilitation approaches, for example, as per 3.
3. Areas with no remnant native vegetation, for example, reaches dominated by exotic grasses	In grazed landscapes stock exclusion fencing is required to support intensive revegetation efforts. Control/spay out weeds, prepare site for revegetation (holes, mulch, irrigation/watering), plant and maintain (stock protection, weed control, watering) and protect from fire at least until vegetation established at ~24 months. **Intensive revegetation.**	Initial site preparation may include use of controlled burn to open site access. Direct seeding with fire stimulated germination species (wattles) prior to burn, or ash bed germinating species (eucalypts, melaleucas) post-burn can add additional recruitment where seasonal/soil moisture conditions suit. Potential erosion risks of high rainfall or flows should be considered if site spray out or burning is planned.
4. Areas of remnant/degraded remnant vegetation with a high exotic pasture grass fire fuel load and associated hot fire risk	If site large enough/suitable, implement controlled grazing (or other means of grass weed control) and fire management suited to vegetation type. Control woody weeds, monitor and protect natural regeneration. **Extensive revegetation with 'fill in' intensive revegetation.**	If site includes areas devoid of remnant native vegetation consider fencing configurations that create protected grazing exclusion areas to allow more intensive rehabilitation approaches, as per 3. For small sites unsuited to grazing, for example, narrow riparian corridors, fire exclusion and alternate grass weed control preferable.
5. Areas of remnant/degraded remnant vegetation with sustained high grazing pressure	If possible, implement grazing spelling and monitor/protect natural regeneration. Alternatively, establish grazing exclusion fencing around areas of degraded remnant and rehabilitate as per 2, or fence off areas lacking native vegetation and rehabilitate as per 3. **Extensive revegetation with 'fill in' intensive revegetation.**	Extended spelling that allows accumulation of a fire fuel load and controlled burning suited to the vegetation type can promote recruitment of fire-germinated species whose abundance has been reduced under a sustained grazing regime.

Depending upon the condition of the riparian zone, different rehabilitation strategies may be appropriate (see Table 6 & 7). Where riparian vegetation has been lost completely or partially, revegetation is often a desired rehabilitation strategy. Both intensive and/or extensive revegetation methods may be applied for riparian zone rehabilitation, and these have been described in extensive detail along with the identification of riparian zone

rehabilitation objectives, operational planning, and suitable species selection in the Sheep Station Creek System Management Plan (Econcern 2021).

System specifics

Mapping of wetland system riparian vegetation condition undertaken for this project (Appendix 2) shows the Ironbark Creek – Healey's Lagoon system to have one of the highest integrity riparian vegetation corridors for a floodplain creek system within agricultural landscapes of the Lower Burdekin Region. There is a relatively contiguous good condition riparian vegetation corridor along almost all the creek and lagoon reaches of the system.

Photo 26. The near contiguous riparian vegetation corridor of Healey's Lagoon comprised of Leichardt, paperbark, damson, fig trees and other species, is one of the best within an agricultural landscape of the Lower Burdekin region.

Photo 27. Dense riparian vegetation canopy cover excludes grass understory reducing fire fuel loads and wildfire risk and rodent harbourage habitat.

Most of the upper creek system and some of the lagoon riparian zone retains intact remnant native vegetation, and most of the remainder is degraded remnant vegetation affected by the narrowness of the corridor and weed invasion. Where discussed items relate to management issues listed in Appendix 1 or mapped in Appendix 2, the designated (M) number is referenced. There are only a small number of sites within creek and lagoon reaches including adjoining distributary lagoon systems where the continuity of the riparian vegetation corridor is broken (M6, M8, M12, M13), and these areas tend to be dominated by exotic grasses.

Photo 28. This cleared degraded reach of Ironbark Creek dominated by para grass represents one of the few breaks in its riparian corridor. Re-establishment of corridor connectivity by revegetation would serve to improve aquatic and terrestrial habitat values and wildlife corridor function.

Photo 29. An upper Healey's Lagoon reach lacking riparian vegetation dominated by exotic aquatic grasses. Dense grass growth provides rodent harbourage habitat and a late dry season wildfire risk. It also impacts edge zone native habitats and water quality. Establishing riparian vegetation at this site would serve to exclude the grass understory and act as a nutrient interception zone for the adjoining production area.

The latter primarily includes aquatic para grass with less common hymenachne and aleman grass on the wetted margins and guinea grass and elephant grass on the more well-drained levees. While these grasses can provide some functional benefits (like bank stability), they generally have low ecological value and

generate management problems, including poor water quality, channel flow blockages (aquatic grasses), loss of native habitats, and hot fire risks in the dry season (see **Figure 3**). In addition to wildfire, they also pose other production risks (M7), including as the preferred harbourage habitat for rodent pests (Sugar Research Australia 2013). Downstream of the Bruce Highway there is no contiguous riparian vegetation along the drainage depression reaches of the system, though there could be merit in establishing such (see *Fish passage* section).

There are also some limited reaches of riparian vegetation that have been established by revegetation of lagoon banks. While not all revegetation efforts on the lagoon have been successful, some sites have developed good canopy structure and are hard to define from areas that have naturally regenerated. In terms of ecosystem health, a good observation from examination of time series aerial photography is that for much of the lagoon system, riparian vegetation cover and extent has increased substantially over the past 40 years. This may be attributed to regulated flows being established to the system as part of the Giru Benefited Area (Kavanagh 2017), which bought with it greater moisture availability in the riparian zone. There was also possibly an associated reduction in burning of the riparian zone as established canopy served to reduce grass understorey fire fuel loads.

Photo 30. A lower lagoon reach that experiences high flow channel breakouts and associated erosion risks. Increasing the density of bank binding riparian trees at this site would serve to further stabilise the channel bank and baffle the velocity of outbreak flows.

Photo 31. Exotic elephant grass (*Pennisetum purpureum*) has been promoted and planted as a bank erosion protective measure. This species still presents a wildfire risk and rodent harbourage. Dense riparian vegetation can better serve both bank erosion and flood protection roles.

Within the lower reaches of the lagoon system there are several sites where water threatens to scour and undercut bank areas, or breaks over the bank on the outside bend of the channel during high flood events and flows across adjoining floodplain farmland. This presents both bank and farm erosion risks (M14, M15). Historically, exotic elephant grass (*Pennisetum purpureum*) was promoted and planted as a bank erosion protective measure in such areas. While it has some benefits in this role, it does have limitations associated with shallow roots and a limited buffering capacity on outbreak flow speed during large events when it is flattened. It is also now recognised as a weed species that restricts riparian overstorey vegetation recruitment, presents a wildfire fuel load risk, and provides rodent harbourage (M16). A preferred habitat-benefitting option for areas at risk of bank erosion, is establishing dense riparian vegetation with bank-binding roots and sufficient stem density to buffer outbreak flow velocity. From a wildlife habitat perspective, a key riparian revegetation opportunity noted at some sites is to extend revegetation efforts beyond the immediate channel bank and onto adjoining levees or terraces. This allows for a habitat ‘node’ to be established rather than the usual narrow linear riparian vegetation corridor, which provides additional habitat value for dense cover-dependent species, including rufous owl and other predators of adjoining cane land pests (SRA 2013).

Although not a vegetation condition issue, litter management was also commonly encountered throughout the system in the form of the disposal of used fluming plastic in riparian vegetation areas. Not only does this litter look unsightly, being so close to an active watercourse, there is also a high prospect of it being mobilised during flood events and making its way to downstream aquatic and marine environments.

Photo 32. A within-channel terrace that could be revegetated to create a riparian habitat 'node' corridor. Alternatively, it could be grazed to create a native emergent aquatic plant-dominated water margin and bare bank habitat favoured by waterfowl.

Photo 33. Another example of a within-channel terrace that could be revegetated to create a riparian habitat 'node' corridor. Existing natural regenerative processes at this site only need to be protected and promoted to achieve site revegetation.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. NQ Dry Tropics use the release of this SMP as an opportunity to communicate the regionally-significant nature conservation value of the Ironbark Creek – Healey's Lagoon system riparian vegetation corridor to system management stakeholders, including the environmental and production benefits associated with it (see section introductory list).
2. NQ Dry Tropics field officers identify landholders associated with riparian revegetation/regeneration opportunity sites identified in this SMP, some of which have already expressed engagement interest. This includes engaging with them to gauge support and establish the nature of on-ground works suited to their properties' land use context; for instance, intensive revegetation, managed extensive regeneration, and potentially including woody weed, fire, and grazing regime-based management approaches. Seek funding resources to support works implementation (W6, W7, W8, W12, W14, W15).
3. NQ Dry Tropics seek sugar industry sponsorship to advertise and support a 'Clean Up Australian Day', or equivalent, event and organise property access, landholder support and a local community volunteer workforce to target discarded irrigation fluming from riparian vegetation areas of the Ironbark Creek catchment, and adjoining systems if support is obtained. This could be a communicative focus for the ecological and aesthetic management needs of riparian areas and for promoting the need for cultural change towards improved management.

Photo 34. The dense grass-excluding canopy created by the non-hardwood growth of the native cottonwood (*Hibiscus tiliaceus)* alludes to a potential role in excluding grass and aquatic weeds from constructed drainage channels.

Photo 35. Discarded irrigation fluming is commonly encountered in riparian vegetation areas of the Ironbark Creek catchment and could be a focus for a 'Clean Up Australian Day', or equivalent, environmental education event.

Table 7. Mapped riparian vegetation condition class – ecological value, management issues and identified revegetation needs and opportunities

Exotic grasses
● Has low ecological value, presents hot fire risks to remnant native trees and adjoining cane farms, and harbours rodent crop pests. ● Can provide suitable cover and bank stability for excavator-maintained channel reaches. ● Growth of aquatic grass species (para, aleman, hymenachne) onto water bodies blocks water flow and creates floating aquatic weed mats. This reduces water dissolved oxygen and creates biological oxygen demand (BOD) when grass decomposes in water, particularly when inundated by elevated flows/water levels, creating anoxic 'blackwater'. ● Fire risks can be reduced by fuel load reduction with controlled grazing where site conditions allow. ● Where no remnant native trees are present, revegetation is dependent on more intensive methods, for instance, seedling planting. ● A catchment-scale revegetation target is establishing a shade-generating overstorey tree canopy that controls grass density and reduces bank-side anchor points for aquatic grass species.
Remnant vegetation
● Has high ecological value, including providing habitat for fauna uncommon in developed landscapes. ● Mapped units can include significant areas of exotic grass and degraded remnant classes. ● Condition can trend positively or negatively depending on operating pressures, e.g., weeds, grazing regime, fire regime, physical disturbance, and hydrological change. ● Controlled grazing of exotic grass understorey can reduce fire fuel loads and associated hot fire risks and, with spelling, promote natural regeneration. ● Exclusion of fire, or a controlled burning regime, can promote increased canopy development and suppression of understorey fuel loads, and promote natural regeneration. ● Provides baseline comparison sites, target species lists, and seed sources for regeneration of equivalent reach areas. ● Provides nucleus areas for strategic regeneration of adjoining riparian areas. ● 'Fill in' planting can be used to increase mid and overstorey canopy development, though promoting natural regeneration is more appropriate where integrity is high. ● Priority management focus for remnant vegetation is protection and represents a more cost-effective investment than revegetation.
Degraded remnant
● Ecological value is variable depending on landscape context, but can provide important habitat resources, including feeding and nesting sites within a modified landscape. ● Mapped units usually include significant areas of exotic grass and may include exotic trees/woody weeds. ● Condition can trend positively or negatively depending on operating pressures, including weeds, grazing regime, fire regime, physical disturbance, and hydrological change. ● Controlled grazing of exotic grass understorey can reduce fire fuel loads and associated hot fire risks and, with spelling, promote natural regeneration. ● Exclusion of fire or a controlled burning regime can promote increased canopy development, suppression of understorey fuel loads, and promote natural regeneration. ● Remnant trees provide the opportunity to use more extensive revegetation approaches, for instance, the promotion of natural regeneration via seedling recruitment and growth. ● 'Fill in' planting/intensive revegetation can be used to target denuded areas, along with promoting natural regeneration within remnant stands. ● An integrated mix of intensive and extensive revegetation approaches is an appropriate management focus and provides a catchment-scale revegetation target.
Revegetated
● Observed ecological value is generally high, particularly where the area includes mature remnant stands or individual trees of the original vegetation community. ● Primary management focus is protection and maintenance, particularly in relation to reinfestation by grass weeds and associated hot/uncontrolled burn risks. ● Some sites warrant 'fill in' intensive revegetation to address areas denuded by uncontrolled burns and/or die-off of short-lived pioneer species. ● Good opportunity to increase habitat values by dedicated understorey/ground cover planting and introducing physical habitat features, like logs, artificial nest hollows.
Exotic trees
● Ecological value is limited in monocultural plantings (orchards) but can be higher when mixed with remnant native species. Can provide some nesting and feeding habitat resources and a range of useful functional values, for example, stabilising stream banks, and shading out aquatic grass weeds and duckweed around pump intakes. ● Where mixed with native tree species, selected control and clearing and 'in fill' revegetation can be used to regenerate sites toward native vegetation dominance.

Grassland
● ‘Catch all’ class for grassland areas that are not the ‘exotic grasses’ class associated the immediate riparian zone (above). When this includes native grasslands, it can have high habitat values for grassland-dependent species, particularly granivorous birds. ● Riparian areas that represent cleared areas are an appropriate focus for intensive revegetation, particularly adjoining lagoons subject to aquatic grass weed infestation.

Woody weeds

Types and impacts

Woody weeds threatening the condition of Lower Burdekin wetland systems include exotic trees and vines that infest riparian zones and catchment areas to the detriment of native habitat values, catchment processes, and production values. The key species recorded in the Lower Burdekin are listed in Table 8 (below). Although some woody weeds are utilised as shelter or food habitat resources by native fauna, their occurrence within native vegetation communities results in the competitive exclusion of native plants. Native fauna have evolved and developed direct or indirectly-dependent relationships with this native flora. For example, while canopy-dwelling birds may inhabit an exotic tree canopy, it will not support the same populations of native insect food sources that a native tree canopy will. The greatest scope for impact occurs where weeds have the invasive capability to dominate a regional ecosystem setting to the exclusion of native biodiversity and/or change native vegetation structure and/or function. For example, severe infestations of rubber vine can create 'vine towers' that completely smother and collapse host trees, destroying the vegetation structure required by dependent species, like closed canopies, and opening the vegetation community to further weed infestation, such as sun-loving grasses.

Photo 36. A small infestation of siam weed (*Chromolaena odorata)* located in the Haughton River distributary channel that forms the beginning of the Ironbark Creek system. This weed is a relatively new to the region and has not yet become widely established.

Photo 37. An apparently restricted candle cassia infestation in lower Palm Creek. Its ability to establish in dense para grass stands indicates it is a competitive species. Better documenting its distribution in local catchments could be prudent.

Where vegetation structure gets completely altered by woody weed infestation, secondary impacts may also be generated. For example, a rubber vine tower causing canopy collapse opens-up fire-sensitive riparian vegetation to secondary weedy grass infestation, which leads to its exposure to fire impacts. Dense canopy-forming woody weed species such has chinee apple can form closed canopy infestations that shade out understorey grass in formerly open woodland areas. This reduces pastoral productivity and exposes understorey areas to increased soil erosion in the event of heavy rainfall or floodplain overland flows.

Not all species are declared weeds under the *Queensland Biosecurity Act 2014*. Control methods vary from various forms of chemical spraying, including basal cut and foliage spraying; the use of bio controls like rubber vine rust fungus (*Maravalia cryptostegiae*); and the use of fire. Heavy machinery is also often used for clearing more dense infestations where access for other forms of control is limited, or control by other methods is cost exorbitant. Where heavy machinery is employed the risks to remnant vegetation stands mixed within woody weed infestations need to be managed to avoid impact to remnant habitat values.

In recent decades there has been substantial investment by NQ Dry Tropics in the control of woody weed infestations at Lower Burdekin wetland system sites, including two nationally significant wetlands: Serpentine Lagoon and Woodhouse Lagoon. Other sites have included Churches Lagoon (on Sheep Station Creek) and Collinson's Lagoon adjoining the Bruce Highway. An observed reduction in rubber vine infestation levels has also been noted over the past two decades at some sites, including Barratta Creek where rust fungus successfully established during a series of wetter years.

Levels of woody weed infestation vary between systems, but overall, the extent of infestation across the greater floodplain remains significant. Investment in further control needs to be informed by strategic priorities to make effective use of limited resources. Intervening in low level infestations, including at upper catchment sites before they spread downstream and/or become more extensive, represents prudent investment. Public investment in the resources required to tackle large extensive infestations can only be justified where there are high value wetland assets at stake and/or a production dividend that promotes landholder engagement and co-investment.

System specifics

Observed levels of woody weed infestation throughout the Ironbark Creek – Healey's Lagoon system were relatively low compared to many other wetland systems in the Lower Burdekin. It should be noted that observations were not the result of comprehensive or systematic surveys. Where discussed woody weed infestations relate to management issues listed in Appendix 1 or mapped in Appendix 2, the designated (M) number is referenced.

The most common observed species included:

- chinee apple predominantly in southern bank frontages of the upper catchment of Ironbark Creek upstream of the Woodstock Giru Road, and also including isolated examples within the riparian zone;
- stands of castor oil bush along exposed sunlit bank areas of the main lagoon system;
- isolated vine towers of elephant ear vine dominating riparian canopy trees in the upper creek system and main lagoons;
- scattered devils figs along lower reaches of Palm Creek and open drainage depressions upstream of the Reed Beds;
- dense stands of candle cassia growing within para grass stands in lower Palm Creek; and
- An isolated occurrence of Siam weed at the Ironbark Creek distributary channel break-off on the Haughton River bank.

Photo 38. Chinee apple stands within grazing areas of the upper Ironbark Creek catchment.

Photo 39. Although only occurring in low numbers, isolated chinee apple, such as this specimen in the Ironbark Creek corridor, present a 'sleeper' weed risk that could explode in numbers with good seasonal conditions, and warrants strategic control.

Only chinee apple and candle cassia were observed to be approaching population densities that would create competitive exclusion risks for native vegetation. The extent of the apparently-restricted candle cassia infestation was not determined – though its establishment density within dense para grass stands – indicates it is a competitive species. It would seem prudent to better document its distribution within local catchments. Considering the species' ability to establish on para grass-dominated creek banks, it could also be useful to examine if it has any beneficial role as a space creator for the successionary establishment of taller native overstory tree plantings.

The observed relatively low density of chinee apple in riparian areas represents a cost-effective strategic target for control efforts. This species has a demonstrated capacity as a 'sleeper' weed that can recruit from low to high numbers in a small number of seasons of suitable conditions. Areas where slightly denser stands of chinee apple were observed, but still may represent strategic investment for control efforts, was in Crown land reserves at the top of the Healey's Lagoon system, and immediately upstream of the Woodstock Giru Road crossing of Black Gully (M9). Occurring on Crown reserves, these remnants have historically been protected from clearing and contain valuable remnant riparian woodland vegetation, including eucalypt and paperbark (melaleuca) species. However, despite its public tenure and high ecological values, these areas have not been actively managed and contain chinee apple and an understorey dominated by exotic grass weeds that offer exposure to dry season hot fire risks from surrounding areas. Public investment in improving these remnants' condition is warranted by their biodiversity value.

A small infestation of Siam weed (*Chromolaena odorata)* was located within the Haughton River distributary channel that forms the beginning of the Ironbark Creek system (M2). This weed is a relatively new arrival to the region and has not yet become widely established. While all observed plants were destroyed, these is a need to conduct further surveys and control to ensure that this destructive environmental weed does not become established within the system.

Photo 40. Isolated vine towers of elephant ear dominating riparian canopy trees in the upper Ironbark Creek system.

Photo 41. Towers of elephant ear vine dominating riparian canopy trees on Healey's Lagoon. Control of vine weeds serves to increase the rate and success of riparian revegetation efforts.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. NQ Dry Tropics field officers conduct a systematic survey for siam weed during its flowering period along both banks of the Ironbark Creek system from its breakout point on the Haughton River to the Woodstock Giru Road (W2). In addition, conduct extension activities with local landholders to ensure they are capable of identifying and reporting the species. Follow up survey and/or reported observations with resourced control efforts.
2. Engage with Burdekin Shire Council to identify resourcing opportunities for implementing chinee apple control in high value habitat remnants on Crown land reserves adjoining the Woodstock Giru Road at Black Gully and implement (W10).
3. Find resourcing opportunities for a weed control contractor to remove isolated chinee apple infestations within the immediate Ironbark Creek corridor. Provide incentives for private landholders to implement chinee apple control on the southern frontages of the upper Ironbark Creek system.
4. NQ Dry Tropics field officers conduct a systematic survey of the extent of candle cassia in lower Palm Creek. Document its current distribution for monitoring its rate of spread over the next one to two years, and then assess if the determined infestation rate warrants investment in control.

Table 8. Woody weeds of management concern on the Lower Burdekin floodplain

Common Name	Species	Growth habit	Comments/nature of impacts	Biosecurity status/control methods
Chinee apple	*Ziziphus mauritiana*	Large shrub or small spreading tree up to 8m tall and 10m in canopy diameter.	Forms dense impenetrable ground cover and native midstory-excluding, infestations.	Chinee apple | Business Queensland
Parkinsonia	*Parkinsonia aculeata*	Small, hairless tree up to 10m tall.	Forms dense impenetrable ground cover and native midstory-excluding, infestations.	Parkinsonia | Business Queensland
Prickly acacia	*Vachellia nilotica*	Thorny shrub or small tree up to 5–10m tall.	Forms thickets in open grassland /woodland, reduces ground covers.	Prickly acacia | Business Queensland
Yellow oleander	*Cascabela thevetia*	A large tree that can grow up to 10m high.	Outcompetes native canopy species. Poisonous to stock and humans.	Captain Cook tree or yellow oleander (daf.qld.gov.au)
Candle cassia	*Senna alata*	Shrub to about 4m tall.	Forms dense thickets along creek lines where it may out-compete native vegetation and overgrazed pastures.	Discover Nature at JCU - Senna alata - JCU Australia
Castor oil plant	*Ricinus communis*	A tall branching, annual or perennial shrub that grows to 3m.	Invades floodplains, riverbanks, may form thickets. Seeds, and to a lesser extent, the leaves are toxic to livestock and humans.	Castor oil plant | Business Queensland
Neem	*Azadirachta indica*	Fast-growing evergreen generally 15-20m tall, with crown diameter up to 20m.	Outcompetes native canopy species.	Neem tree | Business Queensland
Devils fig	*Solanum torvum*	An upright shrub or small tree usually growing 0.8-3m tall.	A weed of closed forests, forest margins, waterways (i.e., riparian areas), plantation crops, roadsides, pastures, disturbed sites, and waste areas.	Devil's fig | Weed Identification – Brisbane City Council
Leucaena	*Leucaena leucocephala*	Shrub up to 6m tall.	Forms thickets in riparian zones and alluvial plains, stalls native regeneration and excludes ground covers.	Leucaena | Business Queensland
Java plum	*Syzygium cumini*	Tropical evergreen tree that can reach heights of up to 30m.	Outcompetes native canopy species.	Environmental weed
Tamarind	*Tamarindus indica*	Moderate to large evergreen tree, up to 24 m in height, and 7m in girth.	Outcompetes native canopy species.	Environmental weed
Rubber vine	*Cryptostegia grandiflora*	Climbing vine up to 30m tall in trees, untidy shrub up to 1–2m tall.	Forms dense impenetrable ground cover-excluding, canopy-dominating/collapsing infestations.	Rubber vine | Business Queensland
Lantana	*Lantana camara*	Heavily-branched shrub growing in clumps, thickets, or vines.	Forms dense impenetrable ground cover excluding infestation that can extend to the midstory.	Lantana | Business Queensland
Elephant ear vine	*Argyreia nervosa*	Perennial woody vine climbing up to 10m high.	Forms canopy-dominating/collapsing infestations.	Elephant ear vine | Business Queensland
Siam weed	*Chromolaena odorata*	Dense, tangling bush up to 2-3m tall, scrambles up trees to 20m.	Forms canopy-dominating/collapsing infestations.	Siam weed | Business Queensland

Fire regime

Need

Inappropriate burning has long been recognised as a primary cause of deteriorating riparian vegetation condition in the Lower Burdekin region (BBIFMAC 1999). Fire impacts both sapling recruitment and mature trees. Field work undertaken for the preparation of this management plan identified that burning, particularly in the late dry season, continues to impact Lower Burdekin riparian vegetation condition (see Photos 46 and 47).

Most native vegetation within the region has some adaptation to fire, which is a natural feature of ecosystems within the seasonal dry tropics. However, most native vegetation has evolved within a certain set of 'fire regime' parameters (see insert box below). If the experienced fire regime is more intense or frequent than its adapted capacity, it will result in mortality of trees and saplings and corresponding declines in vegetation structure, species diversity and associated habitat values.

For native vegetation, fire is not only a destructive force, but also a regenerative one. Many types of riparian trees particularly wattles (*Acacia spp*.) and others, like casuarina and grevillea, have seed whose germination is promoted by fire. Other riparian species, like melaleuca and eucalyptus, have seed that is released from capsules by fire and readily germinates in an ash bed soil layer and/or ground cover openings created by burning. A range of weed species, including rubber vine and para grass, are fire sensitive and controlled burning can provide a riparian restoration tool, along with a fire risk mitigation role.

Fire regime – describes the pattern of burning experienced by a site, or suited to a particular vegetation community, and is commonly characterised in terms of:

- frequency (interval period between fires);
- seasonality (time of year);
- intensity (determined by burn conditions, including time of day, wind, soil moisture, fuel load), and
- extent (amount of habitat type or site burnt per event or year).

Without management attention to the fire regime experienced by the creek's riparian zone, valuable remnant habitat areas will continue to decline in condition and ecological gains made by revegetation of the creek's riparian zone can be lost.

Causes/constraints

There are several factors contributing to the often-destructive fire regime experienced by riparian zones within the Lower Burdekin region (Tait 2011). These factors may also be considered constraints to implementing an appropriate fire regime. They include:

Large fuel loads – Amongst many Lower Burdekin wetland riparian zones, habitat remnants are ungrazed. This factor, combined with invasive exotic grasses, like guinea grass/green panic, para grass and elephant grass commonly result in large annual fire fuel loads within habitat remnants. These exotic grasses produce greater standing biomass than native grass species and have a long growing season due to seasonally extended soil moisture promoted by regulated stream flows and irrigation tailwater.

Annual fire exposure – The Lower Burdekin remains one of the few sugar-growing regions in Australia where burning is employed pre-harvest to remove cane trash. Most remnant habitat areas on the floodplain occur near cane fields. Consequently, most are exposed to one or more close proximity annual burning events in surrounding cane fields. This presents a high likelihood of remnant habitat areas also experiencing an annual fire frequency; particularly where cultural practices have long favoured 'cleaning' up pest harbourages and fire fuel loads in remnant habitat areas during or after cane field burning.

Risks to cane crops promote late dry burning – Most cane farmers are unwilling to consider utilising fire as part of surrounding landscape management until cane crops have been harvested to avoid the risk of uncontrolled fire. At a regional level, cane harvesting is not completed until late in the dry season when conditions tend to promote 'hot' fires. This means that any intentional burning of habitat remnants after cane has been harvested is often damaging to vegetation structure, composition and ecological values, and there are fewer opportunities to conduct beneficial 'cool' or less intense 'controlled burns'.

Landscape setting

Appropriate fire regime guidelines suited to the native vegetation types that occur on the Lower Burdekin floodplain have been defined by state government agencies (see Econcern 2021). However, these guidelines assume that fire management is occurring in extensive natural landscapes. The Lower Burdekin floodplain is dominated by irrigated agriculture. Remnant natural habitat tends to occur as isolated 'islands' and non-continuous, narrow riparian corridors surrounded by a 'sea' of developed landscape. In this context, natural landscape fire management approaches that depend on patchy burning of the surrounding landscape mosaic cannot be utilised; particularly when most of the surrounding landscape is developed crop land. Limiting the extent of a vegetation type or remnant patch that is burnt in any one event or year is also challenging where it only occurs in small patches surrounded by a landscape that is burnt annually.

Implementing an appropriate (including no) fire regime

Photo 42. A dense stand of pyrophytic (fire loving) guinea grass growing between a farm headland and the creek riparian vegetation corridor. This grass growth represents a fire fuel load that presents hot wildfire risks to both farmland and fire-sensitive riparian vegetation.

Photo 43. A site example where riparian vegetation canopy extends to the edge of a farm headland, excluding grass growth and associated hot wildfire risks, and reducing rodent harbourage habitat.

The appropriate fire regime for floodplain vegetation remnants will vary with vegetation type and landscape setting. Importantly, it needs to be recognised that the most appropriate fire regime for many riparian habitat remnants is total fire exclusion. This applies particularly where the remnants include fire-sensitive species; are comprised of narrow riparian corridors with limited fuel loads; and are separated sufficiently from adjoining cane farms to avoid being an uncontrolled fire risk.

Regionally applicable guidelines for the implementation of appropriate controlled burning practices and fire regimes for Lower Burdekin wetland vegetation remnants within different farming landscape contexts were developed for the Sheep Station Creek System Management Plan (Econcern 2021). Burdekin land managers interested in the use of fire as an ecological management tool are referred to that document for more detailed information.

System specifics

The extent of fire damage to riparian vegetation communities observed within the Ironbark Creek – Healey's Lagoon system was very low relative to many other wetland systems in the Lower Burdekin region. However, locations with high fire fuel load risks and recent examples of potentially damaging hot fires were recorded and are discussed below. Where discussed items relate to management issues listed in Appendix 1 or mapped in Appendix 2, the designated (M) number is referenced.

Photo 44. A very limited fire fuel load develops beneath a closed canopy riparian vegetation zone, reducing fire risks to hot fire-sensitive riparian vegetation and adjoining farming areas.

Photo 45. Guinea grass growth dominating a section of Healey's Lagoon bank lacking riparian vegetation presents both a wildfire and weed risk to adjoining cane land.

The relatively good condition of the Ironbark Creek – Healey's Lagoon system's riparian vegetation is noted as a key ecological value (see Appendix 1) and has been discussed in preceding sections. One of the consequences of good riparian canopy development has been the suppression of understorey grasses and associated fire fuel loads and fire risk/occurrence. This was observed along most of the main lagoon system's

forested riparian margin where it was also noted that fire scars in some reaches were indicative of a previous grassier understory, and that current fuel loads would not support an equivalent intensity fire (see Photo 48). However, areas without riparian vegetation or with a sparse or open canopy, retained dense grass ground covers comprised of guinea, para or elephant grass that present a dry season fire risk to remnant vegetation and adjoining cane farms (M12, M13, M16). Some of the more extensive examples of this condition setting in the mid and lower reaches of the system were associated with tributary drainages rather than the main stem (M7). From a production perspective, it is also worth recognising that such dense stands of grass are the preferred harbourage habitat for rodent pests (Sugar Research Australia 2013).

Most of the upper Ironbark Creek system's riparian vegetation canopy is also well developed and acts to suppress dense grass understory and associated fire risk. Areas with dense grass margins occurring between the riparian forest and adjoining cane headlands (Photo 42), or where the continuity of the riparian vegetation corridor is broken (M5, M6), remain exposed to a dry season fire risk to remnant vegetation and adjoining cane farms. Evidence of localised hot fires were observed in small sections of the riparian corridor (see Photo 49), and this may be attributed to post-cane harvest 'clean up' burning of grass margins, or of accumulated livistona palm fronds, which some landholders view as a wildfire fuel load risk to adjoining fam areas

A fire conducted in the upper reaches of Ironbark Creek on a grazing property in the late dry season of 2021 (December) was observed to extend into fire-sensitive riparian communities. Although a grazing property, the area impacted appeared to still have high fire fuel loads prior to the burn. Open wetland riparian vegetation communities on the same property were also observed to exhibit past hot fire damage when field inspected in November 2021 (see Photos 46, 47). Although this earlier fire may have been conducted in a cooler season, fire scar evidence suggested that the burn had been relatively intense and possibly associated with an ungrazed understory. This property has been undergoing a relatively recent transition from cropping back to grazing, and observed burns could possibly have been employed to remove senescent rank growth as part of intended pasture renewal.

Photo 46. Open riparian woodland associated with seasonal distributary creek channels supports the dense growth of understory pasture grasses in the absence of grazing. This exposes the vegetation community to hot fire impacts.

Photo 47. Although associated with a grazing land use area, this open riparian woodland on a seasonal distributary was subject to a burn involving a large ungrazed exotic pasture fuel load. This resulted in hot fire condition impacts to the vegetation.

The ideal fire regime for ecological outcomes for the majority of the system's creek and lagoon riparian zone that occurs near cane land and has fire-sensitive closed canopy vegetation, or can develop it, is fire suppression; along with appropriate management of residual grass fire fuel load risks represents (Econcern 2021). The use of controlled cool burns enabled by the grazing of fire fuel loads and/or seasonal or day condition timing of burns is more appropriate for sites not immediately adjacent to cane land that have open floodplain woodland remnants, or more open wetland/riparian vegetation communities occurring on distributary channels, or elevated lagoon levees, away from wetted margins. A couple of high value vegetation remnants of this type and/or with significant fire risk exposure (M9, M11) were noted to occur on Crown reserve land tenures. These could potentially provide demonstration sites for local community engagement in ecological-based fire regime management.

Targeted use of fire could also play a role in the management of aquatic grass weeds such as hymenachne and para grass, which are fire sensitive. Native aquatic vegetation in both small seasonal wetland basins and larger coastal wetland complexes within the system, like Reed Beds, would benefit from the introduction of burning that reduced exotic grass dominance. Improving fish passage in coastal drainage depressions dominated by these grasses is another potential application, though this would depend on drier seasonal conditions or management of perennial seepage to these areas. Where existing grazing operations utilise these grasses, burning is unlikely to be supported by landholders due to the forage resources these grasses provide. However, in the case of fish passage provision, burning-off dead grass to remove its BOD along a sprayed-out flow corridor could potentially provide a tenable option (see *Fish passage* section).

Looking forward, landholders concerned about wildfire risk with interests in fire regime and fuel load management also need to be cognisant of altering landscape fire behavioural conditions and risk scenarios associated with emerging climate stress.

Photo 48. Healey's Lagoon bank. Fire scar evidence points to historical grass understory fuel conditions that provided for hotter fires than those associated with contemporary fuel loads under a closed riparian vegetation canopy cover.

Photo 49. 'Cleaning up' livistona palm fronds by burning remains a common cultural practice that results in more open canopy cover maintained by fire disturbance.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. NQ Dry Tropics use the release of this SMP as an opportunity to conduct a fire regime/controlled burning communication and extension program targeting riparian landholders, local fire wardens, and RFS members via shed meetings, other appropriate forums, field days and via published material. Key topics for communication include:
    a. Ecological impact of hot fire regimes and their association with an ungrazed exotic grass understory
    b. The appropriateness of fire exclusion as a 'burning regime' for riparian zones with or capable of supporting a closed vegetation canopy
    c. The role of riparian revegetation/canopy establishment as a fire risk reduction strategy
    d. The need to manage fire fuel loads and associated hot fire risks where they adjoin fire sensitive remnant habitat assets
    e. The fuel load, seasonal and day timing conditions, and fire conduction methods that support 'cooler' burn outcomes
    f. The role of controlled grazing in reducing fire fuel loads and supporting cooler burns, and
    g. The additional benefits of reducing grass fuel loads in riparian areas adjoining farmland i.e. reduction in rodent harbourage habitat.
2. As part of the proposed communication strategy identified above, devote specific extension efforts to riparian landholders of sites identified and mapped in this SMP (M5, M6, M12, M13, M16) that lack well-developed riparian vegetation canopy cover and have large fire fuel loads associated with an exotic grass understory. If possible, engage landholders in an appropriate wild/hot fire risk reduction strategy (W6, W7, W11, W12), potentially including:
    a. riparian vegetation canopy establishment;
    b. controlled grazing; and
    c. controlled burning.
3. NQ Dry Tropics engage with Burdekin Shire Council and any lessees associated with high value habitat remnants on Crown reserves adjoining the Woodstock Giru Road that are exposed to high fire fuel load and associated hot fire risks. Explore the opportunity for these reserves to be used as

demonstration sites and for community engagement about conducting controlled burns and/or other hot fire risk reduction strategies, like controlled grazing (W10).

Grazing regime

Why is it a useful tool?

For most Australian landscapes, the conventional wisdom regarding nature conservation-based management is that the impact of grazing animals should be kept out of disturbance-sensitive riparian and wetland areas. In contemporary riparian and wetland habitats of the Lower Burdekin floodplain, this convention is turned on its head because one of the greatest sources of wetland and riparian habitat threat is invasive exotic pasture species that can become dominant in the absence of grazing. These pasture species include a suite of aquatic grasses, such as para, hymenachne, aleman, and other species that occupy better-drained levee soils, like guinea grass.

Collectively, these grasses generate a range of impacts within wetlands and the riparian zone (see Figure 3) of floodplain wetland systems, including:

- out-competing native vegetation, including groundcovers and sapling recruitment;
- creating large dry season fire fuel loads that support 'hot' fires;
- smothering open water and shading out submerged and emergent edge native aquatic plants;
- degrading water dissolved oxygen levels by organic loading, reduced instream photosynthesis and less water surface – air interaction;
- degrading fish and waterbird nesting, feeding and egg laying habitats (including dry season-exposed banks used by waterfowl); and
- socio-economic impacts (including creating mosquito breeding habitat, crop weeds, water channel blockages).

Photo 50. This broad node of para grass-dominated riparian land occurs in lower Palm Creek on an organic 'no spray' property and has been nominated as a potential tree planting site by the landholder. Controlled grazing could be used to prepare this site for revegetation.

Photo 51. This terrace bank within the Healey's Lagoon channel provides an example of a site that could be grazed to create bare banks and native emergent aquatic plant (for instance, sedge) margins favoured by waterfowl.

It is within the context of the impacts caused by exotic pasture grasses that grazing, and the lesser disturbance of grazing animals, can be beneficial to the condition of riparian and wetland habitats. Ultimately, application of grazing as a habitat management tool requires an appreciation of its impact risks concerning native flora and fauna, bank compaction and soil erosion, seeking to minimise these while maximising the benefits of reducing exotic pasture dominance. Guidelines for the use of controlled grazing as a riparian and wetland habitat management tool have been developed for the Lower Burdekin region based on a research project involving a range of monitored management trials conducted over a decade ago (Tait 2011). Findings from those guidelines provide a basis for this management plan's recommendations, yet interested readers should refer to that document and the system management plan developed for Sheep Station Creek (Econcern 2021) for a more comprehensive treatment of the issue.

Controlled grazing is not a suitable management approach for all sites and is not needed where other methods can be preferentially, or more effectively, applied to control grass weeds, like establishing riparian vegetation canopy shading. However, controlled grazing is a useful management tool because it can be utilised at a landscape scale and fills an important role where other methods may have limitations, such as chemical and mechanical control, or tree canopy shading established by revegetation. Importantly, all these methods are not mutually exclusive, and the best riparian zone rehabilitation outcome may be achieved by an integrated or sequential application of more than one approach.

In terms of site suitability constraints, the main reasons why controlled grazing may not be suitable at some sites include:

- steep banks/erosion prone soils;
- incompatible adjoining land uses;
- species vulnerable to grazing disturbance and/or presence good condition or grazing-sensitive habitats; and
- site too small, or shape/configuration has high fencing costs, lacks high water stock refuge, or presents ineffective fencing security.

In contrast to controlled grazing, uncontrolled grazing and associated stock trampling, bank erosion and pugging of wetland and riparian areas can also present a threat to wetland system ecological values. These threats are relevant concerns where wetland systems fall predominantly within grazing as opposed to agricultural land use areas.

System specifics

Most riparian and wetland areas within the agriculture-dominated reaches of the system are too small or narrow and lack insufficient pasture resources to support long term grazing land use. Areas of the system that are used for grazing include the southern bank frontages of the upper Healey's Lagoon and Ironbark Creek system and the drainage depression reaches downstream of the Bruce Highway through to the Reed Beds. While these areas represent a focus for more traditional grazing regime management, there are also opportunities to use grazing as a grass weed management tool at some sites with smaller riparian and wetland frontage areas. Where discussed opportunities relate to a value or management issues listed in Appendix 1 or mapped in Appendix 2, the designated (V or M) number is referenced.

Environmental benefits from the application of controlled grazing can include reduced fire fuel loads and hot fire risks; promotion of native vegetation regeneration by reduction of hot fire risks and beneficial disturbance of dense exotic pasture cover; grazing-based clearing of sites in preparation for more intensive forms of revegetation; and promotion of native wetland plant cover within seasonal wetland basins (Tait 2011). If dry season water level drawdown could be reinstated to the main lagoon system, there could also be additional opportunities to use grazing to control exotic pasture margins on some of the shallower sloped bank areas, particularly where the adjoining bank includes broader bank terraces and levees. For many cane farming riparian landholders, there is little interest in accommodating grazing animals near cane fields due to perceived potential conflicts. However, where landholders have grazing management experience or a family interest in grazing animals such as horses, there can be support for accommodating grazing-based management of wetland frontage areas. In other Lower Burdekin areas, like Sheep Station Creek (Econcern 2021), farmers have also been prepared to let trusted graziers/horse owners utilise grazing opportunities/forage resources on their farms where responsibility for stock and fencing infrastructure is delineated and accepted. The main sites nominated that present opportunities for grazing-based management of grass weeds and associated fire risks, and improve riparian and aquatic vegetation condition, include:

- areas of Ironbark Creek frontage that have been historically cleared of riparian vegetation (M6, M8);
- seasonal wetland basins (V7);
- cleared tributary drainages (M7);
- broader levees and nodes on lagoon banks (M12);
- tributary/distributary lagoons (M13); and
- where large fire fuel loads within or surrounding Crown reserves present risks to valuable remnant habitat (M9, M11).

Beyond riparian frontage zones in agricultural landscapes there are also identified opportunities for targeted grazing regime management to pray a role in improving the environmental condition or function of wetland systems in existing extensive grazing land use areas. These include:

- reducing fuel loads to allow cooler burns in more open structured riparian vegetation communities on upper Ironbark Creek distributary channels (M5);
- reducing fuel loads to allow cooler burns in valuable alluvial plain habitat remnants (V6, V18);
- increasing the openness and reducing the biomass of aquatic grasses within nominated fish passage preferential flow paths (M20, M21); and
- reducing the dominance of exotic aquatic grasses and increasing the diversity of native fringing aquatic plants within the Reed Beds wetland complex (M22, M23).

As discussed in Tait (2011), the effectiveness of applied grazing regimes in reducing the dominance of exotic aquatic grasses can be improved where manipulations of hydrology (water level) and introduction of controlled burning can also be applied.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. NQDT seek resources to provide incentives (for example, support for fencing infrastructure) and engage with landholders at sites identified by this SMP as being potentially suited to the use of grazing-based management of grass weeds and riparian/aquatic vegetation condition. Canvas interest in establishing management works sites (W6, W7).
2. Use the release of this SMP as a focus for a communication and extension program with grazing stakeholders within the Ironbark – Healey's Lagoon system regarding environmentally beneficial outcomes that can be achieved within the system using targeted grazing regimes. Seek to provide incentives that encourage landholder engagement in grazing regime-based management of wetland environments with an initial engagement focus around:
    - reducing fuel loads to allow cooler burns in more open structured riparian vegetation communities on upper Ironbark Creek distributary channels;
    - reducing fuel loads to allow cooler burns in valuable alluvial plain habitat remnants;
    - increasing the openness and reducing the biomass of aquatic grasses within nominated fish passage preferential flow paths; and
    - reducing the dominance of exotic aquatic grasses and increasing the diversity of native fringing aquatic plants within the Reed Beds wetland complex.
3. Provide project officer support to engage with grazing stock owners within the system and regionally to identify opportunities for establishing a mobile habitat grazing capacity. Project officers would also provide expertise to monitor habitat condition indicators at nominated trial and demonstration sites.
4. Engage with local government and appropriate state agencies to gain support for using seasonally applied grazing pressure to reduce fire fuel loads in high value Crown reserves and to allow for the introduction of controlled 'cool' burning (W10).
5. NQDT document results of grazing-based management trials and promote outcomes and learning via publications and landholder forums.

Critical wildlife habitat

Under the *Queensland Nature Conservation Act 1992* critical habitat is defined as:

> (1) habitat that is essential for the conservation of a viable population of protected wildlife or community of native wildlife, whether or not special management considerations and protection are required, and
>
> (2) may include an area of land that is considered essential for the conservation of protected wildlife, even though the area is not presently occupied by the wildlife.

Beyond this statutory definition applied to threatened wildlife species listed under state or federal legislation, the concept of critical habitat can be considered more generally as *habitat types or features that are essential to the maintenance of specific wildlife species or groups within a particular landscape or area*.

Conserving and improving the wildlife biodiversity that occurs within the Lower Burdekin floodplain is an aspirational goal supported by most stakeholders. Understanding what constitutes critical habitat is important for effective wildlife conservation. Since European settlement in the Lower Burdekin, there has been a reduction in the diversity and population sizes of a range of wildlife species previously occurring in the region, which has coincided with the development of pastoral and agricultural land uses. For example, few younger generation residents know koalas were once common in bluegum forests on the levees of the Burdekin River.

During the author's own lived experience in the region from the 1960s to the present, there are several wildlife species that can be anecdotally reported to have become rare or even extinct from areas within the catchment. These include northern quolls, otherwise known as 'native cats' which occurred in the Mount Kelly area until at least the early 1970s. Spectacled hare wallabies, known as 'pademelons' by Burdekin locals, were once common in coastal floodplain areas until the 1980s and are now only recorded in rangeland areas on the margin of agricultural production areas. Further, large, diverse (multi species) finch populations are now reduced in species number and population size, and frill neck lizards – once commonly-encountered in habitat remnants – are now a notable record. While the loss of wildlife species can be attributed to a general reduction in available habitat area, habitat fragmentation and feral predators, the loss of critical habitat is often a key cause that can be operating even where areas of remnant habitat remain.

Photo 52. The high site habitat values of the Ironbark Creek – Healey's Lagoon system are underpinned by its landscape context, which includes high levels of remnant vegetation retention in the riparian zone and on adjoining alluvial plains. Wildlife corridor linkages adjoin foothills and protected mountain ranges, including Mount Elliot within the Cape Bowling Green Bay National Park.

Photo 53. Feeding red-tailed black cockatoos within the riparian forest of Healey's Lagoon. Riparian forest represents critical habitat to many woodland bird species.

The intention of identifying this ecological asset type and threats to it is to foster greater appreciation of what sorts of features can constitute 'critical habitat' in riparian and other habitat remnants of Lower Burdekin floodplain landscapes, and how this knowledge can feed into landscape management decisions that support the conservation of wildlife. A non-exhaustive list of critical habitat features known to be significant on the floodplain and their associated values and management implications are presented in Table 9.

Some of the main implications of management issues surrounding critical habitat include:

- Fire regime – the impact of burning regimes and exotic grass fuel loads on vegetation condition has been widely covered elsewhere in this report. It is important to recognise that uncontrolled burns, particularly hot fires, also impact a range of critical habitat features, including tree hollows, woody debris and shed tree bark.
- Cultural practices – some of the practices that lead to a loss of critical habitat come, not from required production activities, but from held cultural values including an attraction to parkland clearing, 'cleaning up the farm', and removing problem trees. Greater educational extension to landholders on the value of critical habitat features and the wildlife they support could assist in changing some of these practices.

- Habitat rehabilitation beyond overstorey trees – in recent decades the concept of habitat rehabilitation has generally become synonymous with tree planting, particularly overstorey trees. Greater recognition of the importance of critical habitats should lead to the inclusion of a broader range of activities under habitat rehabilitation, including revegetation of components besides overstorey (for instance, mid storey and ground covers) and establishing physical habitats such as logs, woody debris, and nesting hollows/boxes.
- Recognising regional landscape ecology – a landholder's perspective on the importance of habitat features or their management needs is often constrained to their own property boundaries. Awareness of the broader landscape ecology can inform better management by promoting recognition of the regional importance of site features; for instance, contributions of tree stands to functional wildlife corridors and/or regional uniqueness/importance of habitat features on a property.

System specifics

Where discussion relates to values, management issues or nominated works listed in Appendix 1 or mapped in Appendix 2, the designated (V, M or W) number is referenced.

Photo 54. Water python (*Liasis fuscus)* observed on the banks of Healey's Lagoon is just one example of a pest rodent predator species accommodated within good riparian habitat.

Photo 55. Krefft's river turtle (*Emydura macquarii krefftii)* utilising critical snag habitat. The integrity of the Healey's Lagoon riparian vegetation means that snag habitat is not limited within the lagoon system.

The Ironbark Creek – Healey's Lagoon system retains exceptional biodiversity values which are of state significance (see Appendix 1). The high wildlife habitat value of the system is underpinned by its landscape context and integrity, which includes a near-contiguous riparian vegetation corridor; associated complex instream habitats; high levels of remnant vegetation retention on adjoining alluvial plains; and high levels of wildlife corridor connectivity to adjoining foothills and protected mountain ranges, including Mount Elliot within the Cape Bowling Green Bay National Park (Photo 52). During field work conducted for the preparation of this plan, diverse vegetation communities and a range of critical habitat-dependent wildlife species were encountered. State endangered, vulnerable and near threatened species and essential habitat records for the system include two birds, a reptile, and an endangered plant:

- the endangered black-throated finch (white-rumped subspecies) – *Poephila cincta;*
- the vulnerable squatter pigeon (southern subspecies) – *Geophaps scripta;*
- the vulnerable estuarine crocodile – *Crocodylus porosus*; and
- the vulnerable shrub – *Sannantha papillosa.*

In contrast to other distributary creek systems on the Burdekin floodplain, the primary focus for critical habitat management within the Ironbark Creek – Healey's Lagoon system is on recognition and protection of the habitat values that are retained within the landscape, although scope for further improving and consolidating these should also be considered. Many of the following recommendations reiterate those from earlier plan sections, but are nominated as a general focus for critical habitat management within the system:

- Improve the integrity and connectivity of the riparian vegetation corridor throughout the system (see *Lack of riparian vegetation* section).
- Conduct an audit of mature tree/hollow availability within the system's more recently regenerated riparian vegetation corridor as a basis for targeted nesting box installation.
- Improve the condition of valuable habitat remnants on Crown land tenures by investment in woody weed and fire regime management (M9, M11) (see *Woody weeds* and *Fire regime* sections).

- Protect existing refugial habitats by weed and fire management, including surrounding buffer areas, and create additional refugial habitat areas by targeted regeneration/revegetation of broader riparian habitat 'nodes' as opposed to narrower 'corridors' (M11) (see *Woody weeds, Fire regime* and *Lack of riparian vegetation* sections).
- Identify connective (and broken) habitat corridors linking the main riparian system to adjoining foothills and alluvial plan remnants. Seek to ensure for their retention, consolidation and/or re-establishment in the landscape (M4, W4, W5).
- Conduct works, including application of landscape management tools like grazing and fire, to re-establish preferential flow-path fish passageways in coastal drainage depressions (see *Fish passage barriers* section).
- Improve coastal wetland condition by re-establishing hydrological and salinity seasonality and reducing the dominance of exotic aquatic pasture species (see *Grazing regime* section).

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Photo 56. Black Ironbox (*Eucalyptus ravertetiana)* a rare tree species classified as vulnerable under the federal *EPBC Act* within the high value Haughton River riparian forest habitat complex at the headwaters of Ironbark Creek.

Photo 57. A large lace monitor (*Varanus varius)* in the riparian forest of lower Palm Creek is another example of biodiversity supported by remnant riparian habitat.

Photo 58. A farm drain managed with chemical spraying in the upper Ironbark Creek catchment. Revegetation of this drain with riparian vegetation would provide wildlife corridor connectivity to the adjoining foothills, protect the drain from erosion, shade out grass weeds, slow high flow velocities, and improve water quality at its discharge point to Ironbark Creek.

Photo 59. Sandbar habitat such as this on the bank of Healey's Lagoon is limited in availability and critically important to nesting reptiles. The landholder reports that this site is used annually by a large freshwater crocodile.

Photo 60. This highly biodiverse monsoon palm forest at the headwaters of Healey's Lagoon occurs on a Crown reserve. Its high value and potentially publicly accessible land tenure warrants public investment in the maintenance of its condition.

Photo 61. This rufus owl (*Ninox rufa)* observed within the monsoon palm forest (left) is a classic example of a dense cover-dependent species, which is also an efficient predator of rodents in adjoining farm production areas.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced. As identified above, most identified critical habitat management needs have been addressed by recommendations in preceding plan sections. Some specific critical habitat recommendations are presented below.

1. NQ Dry Tropics extension officers use mapped information presented in this SMP as a basis for engagement with landholders that have identified (connected, tenuous, or broken) wildlife habitat corridors on their properties. Ascertain their interest in protective or restorative works and engage and resource where opportunities exist (W5).
2. NQ Dry Tropics extension officers engage with landholders of farm drainage systems that connect remnant foot slope vegetation with the main creek riparian corridor in the upper Ironbark Creek catchment. Seek their support for revegetation of the drainage channels that provide wildlife corridor connectivity in addition to other nominated hydrology/water quality/weed management benefits (W4).
3. NQ Dry Tropics field ecologists conduct an audit of mature tree/hollow availability within the Ironbark Creek – Healey's Lagoon system's more recently regenerated riparian vegetation corridor as a basis for a targeted nesting box installation program. Seek resources and conduct landholder engagement to implement.

Table 9. Examples of 'critical habitat' within the Lower Burdekin floodplain and implications for management

Critical habitat	Why important	Wildlife species/groups that benefit	Management implications/opportunities
Tree hollows	Provide nesting and nursery sites that are protected from the elements and predators.	Arboreal mammals (gliders, possums), microbats, hollow nesting birds.	Fire management to avoid uncontrolled burning loss of old trees. Avoidance of old tree clearing. Establishing artificial nest boxes can benefit dependent species.
Fringing 'riparian' communities	Has greater structural complexity, diversity, and associated feeding (fruit, nectar) and nesting resources than surrounding woodlands (or agricultural landscapes).	Migratory passerines, (songbirds), honey eaters, parrots, raptors.	Rehabilitation of riparian forests in agricultural landscapes will support populations of dependent species reduced during development habitat losses.
Riparian – Ecotone margins	Greater diversity of habitat and food resources available, as includes both riparian and the adjoining woodland vegetation.	Arboreal mammals (gliders, possums), nectivorous birds, raptors.	Clearing to margin of riparian zones often results in loss of ecotone woodland component in retained vegetation. An ecotone is essentially the boundary between different vegetation assemblages or ecosystem types. Natural recruitment is possible where there are remnant trees. Best opportunities are in broader development set-back corridors.
Mid/understorey trees	Provides a broader range of food resources (wattle gum, broad leaf tea tree nectar, associated insects) than what is provided by overstorey canopy trees alone.	Arboreal mammals (gliders, possums), nectivorous birds, insectivorous bats.	Need to challenge commonly desired parkland clearing aesthetic of 'cleaning up' 'useless scrub' trees, often mid storey vegetation (like broad leaf tea tree). Need to include in targeted revegetation species.
Bare lagoon banks	Naturally occurring via dry season drawdown of lagoon water levels, provides predator safe roosting and resting areas for waterfowl.	Flock-forming waterfowl, like grass (or plumed) whistling ducks.	Lagoon drawdown now more limited, or no longer occurs, due to modified hydrology. Could trial use of intense grazing, burning, or spraying to create.
Remnant vegetation corridors/landscape linkages	Provides opportunities for disturbance-sensitive wildlife to move between remnant habitat areas in developed landscapes to access food resources, find mates and distribute young to new areas.	Arboreal mammals (gliders, possums), macropods, dasyurids (quolls), reptiles.	The value of small vegetation remnants, even individual trees, can be important in providing this critical habitat and needs to be communicated to avoid incremental loss. Regional wildlife corridors transect most systems (see Appendix 1 values).
Exposed sand beds	Provide nesting sites for aquatic reptiles.	Turtles and freshwater crocodiles.	Now a limited resource due to lack of water level drawdown. Control of grass weeds could be used to create.
Closed 'rainforest'	Provides roosting sites protected from exposure to elements and predators and offers food resources for frugivorous (fruit-eating) fauna.	Owls, flying foxes, pigeons, frogs.	Fire sensitive. Existing closed forest reaches/sites warrant protection. Capacity to create with riparian revegetation should be supported at suited sites.
Low ground covering bushes	Provides shelter from predators and refuge/resting areas for small mammals in open woodland habitats.	Small macropods, like spectacled hare wallabies, rufous bettongs, dasyurids (quolls), ground-nesting birds.	Impacted by pasture improvement, slashing, intensive grazing, and culture of 'parkland clearing', 'cleaning up scrub' as desired aesthetic. Fauna survey of sites retaining this critical habitat could demonstrate its value. Also, useful revegetation target.
Logs/woody debris	Provides safe refuges for numerous species of small-to-medium-sized vertebrates.	Reptiles (snakes, lizards), dasyurids (quolls), and invertebrates.	Lost to frequent burning and 'cleaning up' of habitat remnants. Comparison fauna surveys of sites could demonstrate its value. Inclusion in rehabilitation objectives valuable.
Rank grasses	Provides grass seed food sources for granivorous birds.	Finches, pigeons.	Critical habitat supported by grazing spelling/timing.
Shed tree bark	Important refugial habitat for arboreal reptiles (like geckos) and numerous invertebrates, insects, spiders, etc.	Geckos, microbats, invertebrates.	Lost to frequent/hot burning. Target for fire regime management.

Flow-connected coastal drainage depressions	Provides migratory pathway for diadromous fish to move between estuarine and freshwater habitats of the catchment.	Diadromous fish, like barramundi, mangrove jack, mullet, milkfish.	Impacted by aseasonal flows and cumbungi/anoxic reach establishment. Key system-scale rehabilitation target for most catchments.

Climate stress

Types and impacts

The most recent and 6th Intergovernmental Panel on Climate Change report provides compelling evidence that the greater than 1°C global heating the planet has experience sine 1890 is unequivocally the result of human activity, and is proceeding at a rate that is unprecedented over millennia (IPCC, 2022). In Australia, CSIRO modelling has examined the future impact of global heating on regional climate patterns. These outputs can be interpreted at a local government boundary scale: Future Climate Dashboard | LongPaddock | Queensland Government.

Based on the globe's current greenhouse gas emissions trajectory, predicted impacts of most relevance to wetland system management include:

- Temperatures in Australia will increase by between 2.8 and 5.1°C by 2090 compared to 1986-2005; heatwaves are to become more intense, more frequent and of longer duration; and the number of days of severe fire danger are likely to increase in southern and eastern Australia.
- Rainfall amounts are expected to decrease over southern Australia, accompanied by more frequent and more severe droughts. While rainfall trends for northern Australia are more uncertain, greater variability and more frequent, intense, extreme rainfall events are projected.
- Fewer, but more severe, tropical cyclones are projected.
- Global sea levels are expected to increase by 45 to 82cm by 2090, but these levels may be higher if a tipping point is reached which commits one or more land-based ice sheets to irreversible melting.
- Extreme high sea-level events will occur more frequently, increasing the risks of saltwater intrusion, flooding, and erosion in coastal areas.
- In line with global trends, seawaters around Australia are becoming more acidic (>30% since pre-industrial), as the oceans absorb much of the CO_2 released by human activities.

(NCCARF 2019) Climate change and sea-level rise in the Australian region | CoastAdapt

These projected changes – many of which have been increasingly realised over the past decade – have severe consequences for nature and human society, including agricultural production systems. For wetland system management, the following issues are nominated for consideration in the Lower Burdekin region:

Temperature and water quality

Risk – Higher water temperatures, increased rates instream bacterial decomposition of organic matter resulting in lower dissolved oxygen (DO) levels; more widespread and frequent summer fish kills; and water quality fish passage barriers.

SMP focus – Greater extent riparian vegetation shading of waterway margins; reduced weed infestation/organic loads into waterway; and role for supplemented/pumped flows to increase DO during critical periods.

Catchment water quality

Risk – Higher intensity rainfall (potentially coming off the back of extended/more extreme dry seasons); higher rates of runoff (potentially in drought stressed catchments); increased soil erosion and contaminant load carrying capacity; and loads exported more directly to receiving stream and wetland systems.

SMP focus – Improvement in contributing catchment condition, particularly vegetation condition; soil erosion pressure points; and increased focus of designed drainage modulus controls (litres/hectares/second) in constructed farm drainage networks, including re-establishing/improving runoff detention function (for example, constructed basins, vegetated drainage lines).

Flood resilience

Risk – Higher intensity rainfall; higher rates of runoff; greater flood peaks; greater frequency of channel breakout flows (and associated erosion) across agricultural floodplains; and potential for erosion and undermining/undercutting of stream banks.

SMP focus – Improving condition (contiguousness and width) of riparian vegetation corridors to shade-out channel-blocking weed growth; secure stream channel stability and baffle the velocity of channel breakout flows; retain and re-establish floodplain overstorey vegetation to baffle overland flow velocities; manage floating aquatic weed and aquatic grass abundance to prevent channel blocking/infrastructure-destroying debris dams; retain natural wetland flow detention areas; and re-establish runoff flow detention within contributing catchment areas.

Fire regime

Risk – Extended dry seasons; higher air temperatures; lower soil moisture conditions; reduced cool burn season, more extreme, hotter fire outcomes, with greater consequent death of mature trees and impacts to fire sensitive vegetation; degradation of vegetation structure; and loss of habitat values.

SMP focus – Reduction of fire fuel loads in understorey of valuable riparian and wetland/floodplain habitat remnants by promoting canopy closure and/or controlled grazing; promoting cultural change away from farm 'clean up' burning; promoting controlled, cool burning regimes by remnant habitat landholders; incorporating fire breaks in property/farm layouts; and engaging fire wardens in ecological fire management principles.

Fauna refugia

Risk – Drier climate; failed wet seasons; higher air temperatures; reduced soil moisture; and poor plant fruiting/flowering, which places fauna species, like bats, birds, and tree-dwelling mammals, under behavioural, physiological and/or nutritional stress, including lack of shelter, overheating, and lack of food.

SMP focus – Retention, protection (from fire, weeds, clearing, stock pressure) and rehabilitation of dense, structurally complex, floristically diverse, or highly productive habitat remnants. This includes riparian and floodplain forests adjoining streams, lagoons or wetland basins, and habitat nodes including fire refuges within variegated/developed landscapes.

Invasive species

Risk – Terrestrial ecosystems include native vegetation stressed in terms of growth vigour and/or attained structure by a climate trending towards a bio-climatic envelope outside its adaptive range, namely, too hot, dry, or wet. Other associated stressors, like larger cyclonic, flood, and extreme fire disturbance, present openings for opportunistic weeds or novel insect pests to gain a dominant niche. In aquatic ecosystems, the risk encompasses aquatic habitat quality being degraded outside of optimal conditions for native aquatic species. This includes the water being too hot, having low dissolved oxygen, and/or turbidity, which present advantageous conditions for opportunistic and generalist feral fish species, other novel aquatic pest species, or pathogens to gain a dominant niche. Higher temperatures, failed wets (no flushing flow), and elevated water nutrient status (no flushing dilution) support a longer and more vigorous growing season for aquatic weeds.

SMP focus – Management investment in the condition of terrestrial and aquatic ecosystems to increase system resilience by reducing pest and weed species abundance and maintaining active vigilance regarding identification and proactive control of 'sleeper', or new pest species, within the system.

Revegetation species providence

Risk – Seed or seedlings produced from local providence native plant stock may become stressed during their growth, in terms of their vigour, by climate trending toward a bio-climatic envelope outside its adaptive range, namely, too hot, dry or wet. Stress can also be caused by disturbances like larger cyclonic, flood, drought, and extreme fire events occurring at a frequency, or for a duration, greater than the species has evolutionarily developed adaptive capacity.

SMP focus – Encourage vigilant observation by landholders and NRM practitioners working within the region of the vigour and potential die back of species comprising local vegetation communities across age classes. This includes areas that have undergone revegetation. Trial and compare the growth success of locally-occurring species from seed stock providences from outside (north, inland) the local latitudinal and longitudinal range.

Landward migration of coastal wetland mosaic

Risk – Sea level rise will increase the landward reach of tidal incursion within coastal wetlands. If protective barriers are created or increased to prevent this occurring, existing brackish environments below barriers will become marine, and important brackish habitats will be lost from the coastal wetland mosaic, potentially in conjunction with a reduction in fish passage connectivity. The ultimate transgression of such barriers could also create highly disturbed environments where freshwater vegetation dies in response to rapid salinity changes.

SMP focus – Identify opportunities, including incentives, to encourage the unimpeded incursion of tidal influence into the lower end of coastal wetland systems. This could include by supporting new bund development within upper reaches of coastal wetland basins in exchange for controlled breaching of existing lower reach bunds. This would allow for the staggered incursion of sea level rise into existing lower freshwater reaches of coastal wetlands, creating a brackish habitat, and facilitating an overall landward migration of the costal wetland habitat mosaic.

Ironbark Creek – Healey's Lagoon system specifics

Considering the landscape, land use and condition context of the Ironbark Creek – Healey's Lagoon system, seven of the eight issues described above are nominated as having particular relevance for system management planning intended to build climate stress resilience. These issues include:

- temperature and water quality;
- catchment water quality;

- flood resilience;
- fire regime;
- fauna refugia;
- invasive species; and
- landward migration of coastal wetland mosaic.

Summarising the identified SMP focal points discussed for these issues above, an Ironbark Creek – Healey's Lagoon system that was managed to have resilience in the face of climate stress would have the following features:

- Contiguous shaded riparian vegetation corridor to maintain cooler water temperatures and exclude aquatic grasses from bank margins along the entire length of the wetland system. This includes the upper creek channel, main lagoons, and along designated preferential flow paths though coastal drainage depressions to tidal influence.
- Farm drainage networks within its contributing catchment area that are designed to effectively cope with extreme rainfall events in a way that controls rates of runoff to avoid erosion of drainage channels and adjoining farmland, and to limit the transport of mobilised contaminant loads directly to the creek system. Such a system would be characterised by channels stabilised by bank-stabilising and flow-baffling riparian vegetation, detention basins that capture first flush events and lower the overall slope of the drainage networks, and broad diffuse connections to the receiving stream channel.
- Ability to withstand large, floodplain-inundating breakout flows from the Haughton River, including secondary breakouts flows from the Ironbark Creek or Healey's Lagoon channel, across adjoining floodplain farmland without significant damage to channel integrity or erosion of adjoining floodplain areas. Dense, broad, flow-baffling bands of riparian vegetation along all river, creek and lagoon channel margins would provide a means by which channel bank integrity could be secured against erosive forces and breakout flow velocities reduced. Equivalent revegetation of farm tributary drainage lines and depressions would also add flood resilience to the landscape by breaking up preferential flow paths.
- Proactive controlled burning and fire regime management. The system includes and is surrounded by extensive areas of remnant vegetation, some of which is fire sensitive and currently carries large fire fuel loads. Proactive management of extreme dry and heat associated hot wildfire risks would include promoting riparian vegetation closure to reduce grass understorey, controlled grazing and/or cool burning of fire fuel loads adjoining fire sensitive vegetation assets and/or production areas, and maintaining functional fire breaks between extensive areas of unmanaged fire-prone remnant vegetation and vulnerable assets.
- Recognised wildlife refuge habitats that have been consolidated through targeted regenerative activities (revegetation, weed, fire control) and are actively protected from threats. Examples could include riparian vegetation areas that incorporate denser refugial habitat nodes where channel benches or tributary confluences occur, or better condition wetland or floodplain vegetation stands that are poorly represented in the post development landscape.
- Controlled populations of weeds and feral invasive species via sustained management commitments and vigilance to identify and eradicate infestation source areas, novel, or sleeper species, and to maintain the resilience of native terrestrial and aquatic ecosystems. For example, for feral fish, a competitive advantage for native species occurs where there is good water quality, high connectivity, natural hydrology, good habitat availability and native predator abundance.
- A planned retreat of production areas and infrastructure from tidally-influenced areas to allow for the landward migration of the coastal wetland mosaic. In the case of the lower Ironbark Creek – Healey's Lagoon system, this could entail removal or relocation of existing tidal bunds inland, and protected/promoted succession of marine vegetation. For example, samphire flats and mangroves into newly-created brackish zones.

Recommendations

1. Engage all management stakeholders in:
    a. the understanding of projected climate conditions over forthcoming decades and their likely expression on Lower Burdekin floodplain landscapes, including within wetland and production systems, and
    b. identifying local site and individual, along with regional and collaborative, responses, and management initiatives that can serve to increase the resilience of natural resource assets of the floodplain to projected climate stress.

> Innovative management

Why we need innovation

Environmental management is an imperfect science that is best progressed by an adaptive approach. This enables different methods to be trialled and successes pursued, while mistakes are used as opportunities for learning and for avoiding in future efforts. There has been major improvement in the ecological condition of Lower Burdekin wetland systems due to management investments made over the past two decades. However, as identified through this plan, there are still outstanding environmental management issues confronting most wetland systems. To achieve further improvements in the environmental condition of the wetland systems, there needs to be an ongoing commitment to improving management capacity and outcomes, while recognising the resource constraints for the tasks at hand. There is an adage that, "to continue to do the same thing and expect a different result, is the definition of madness". To take the next step and deliver a new level of improved wetland system management outcomes requires things to be done differently. In some instances, this might involve doing existing approaches better. In other cases, it may call for investigating and applying innovative approaches – essentially drawing on new advanced and original methods.

Much of the environmental management gains achieved for Lower Burdekin wetlands over the past two decades can be attributed to innovation. The use of weed harvesters and excavators to remove neglected aquatic weed infestations, developing a cost-shared weed control program instituted through RMAs, and large reach-scale riparian revegetation outcomes, are all initiatives that Burdekin wetland management stakeholders should be proud of. At the time, these initiatives were truly innovative in the sense it was the first time they had been applied in the seasonal dry tropics, or – in the case of RMAs – in Australia.

During the development of the initial SMP for Sheep Station Creek, 15 other innovative management methods, tools, and approaches were proposed. These are listed below, but are described in full in the Sheep Station Creek SMP (Econcern 2021). Two additional innovative management approaches (points 16 and 17 below) were also proposed during the development of the Woodhouse Lagoon SMP (Econcern 2022a), and another (point 18) was trialled and developed by NQ Dry Tropics Wetland Manager Scott Fry in recent years.

1. Excavated channel weed control via shade planting.
2. Alternate channel weed control methods utilising small in-channel machinery.
3. Pumped environmental 'freshening' flow during wet season critical water quality period.
4. Weed control via effective biomass removal and economically viable soil ameliorant product development.
5. Use of mobile herd to deliver controlled grazing outcomes through catchment.
6. Alternate distributary channel fish passage bypass route.
7. Establishing riparian forest and native water lily shading to reduce submerged plant growth.
8. Catchment line of control for floating aquatic weeds.
9. Establishing farm drainage line revegetation/detention function.
10. Use of monitoring drones.
11. Conducting cool burns in cane land habitat remnants.
12. Direct seeding vegetation regeneration methods for exotic grass-infested riparian zones.
13. Instream physical habitat interventions.
14. Fenceless grazing systems.
15. Alternatives to chemical weed control.
16. Waiving of overland flow/water course access/licencing fees for aseasonal flows originating from farm irrigation and/or BHWSS tailwater flows.
17. Intervention and re-use of farm/scheme area irrigation tailwater for off-stream pasture production
18. Use of drones for aquatic weed spraying.

System specifics

Given the overlap in land and water use and condition context of the Ironbark Creek – Healey's Lagoon system with the Sheep Station Creek system, many of the innovative management approaches proposed for Sheep Station Creek are applicable. Nine of the listed 15 points (1, 3, 4, 7, 8, 9, 10, 11, and 15) are incorporated in management recommendations in this SMP and the complete set have some relevance.

Point 10, '*use of monitoring drones',* was employed during the development of this SMP to collect low altitude high resolution aerial imagery for identifying wetted areas that defined flow paths overgrown by aquatic pastures in drainage depressions downstream of Healey's Lagoon (see *Fish passage* section).

The main area of innovation included in management approaches suggested as part of the development of the Ironbark Creek – Healey's Lagoon system SMP is '*establishing a suitable water quality fish passage preferential flow path through an aquatic grass weed-dominated drainage depression via riparian shading'*. While this proposal builds on an earlier version proposed for the same site by Veitch and Burrows (2006), it differs in only proposing grass clearing, not soil excavation, and therefore avoids potential acid sulphate soil risks. It also offers two forms of potential grass clearing, excavator rake, or spay out and burn; the latter possibly being advantageous in avoiding heavy machinery in a wetland and best delivered by employing a chemical spray-equipped drone. It also and seeks to secure the flow path long term by establishing riparian

vegetation canopy shading to exclude grass growth from the flow path margin and to provide water temperature cooling to help manage the DO status of slower flows with longer site residence time. Finally, the proposal is married to an innovative management suggestion developed as part of the Sheep Station Creek SMP, which is to use a '*pumped environmental 'freshening' flow during wet season critical water quality period'.* This component of the proposal would only be employed if unregulated wet season outflows from Healey's Lagoon were found to have too poor a DO status and/or too long a residence time to provide suitable fish passage conditions through an established preferential flow path. Monitoring of water quality (do) and fish movement would be integral to an assessment of this innovative trial.

Two other management suggestions nominated in this SMP may be considered innovative for the Lower Burdekin region, while being considered relatively standard approaches elsewhere. These include (1) the proposal to alienate irrigation supply flows from the Reed Beds wetland, and (2) the formation of a dedicated catchment management group to support enhanced aquatic weed and other environmental management of the Ironbark Creek – Healey's Lagoon system.

While the Lower Burdekin floodplain is awash with aseasonal flows and altered hydrology impacts in receiving aquatic environments downstream of irrigation scheme and regulated flow systems, there has been only a few examples to-date of water managers successfully alienating aseasonal inflows to naturally seasonal wetland systems. The efforts of Lower Burdekin Water in lower Sheep Station Creek's coastal drainage depressions and past efforts of the (then) South Burdekin Water Board at Alma and Iyah creeks near Inkerman, represent the only known precedents (Econcern 2021). If Sunwater successfully alienated irrigation supply flows from the high value Reed Beds coastal wetland complex this would represent a significant opportunity for further developing such management approaches for other similarly impacted wetland systems in the region.

Catchment management groups have been in existence since (and even before) the integrated catchment management (ICM) approach was developed in Queensland in the 1990s (DPI 1993). Conspicuous by their absence in the Lower Burdekin region, they potentially overlap in scope with roles that have been played by industry bodies, for example, Lower Burdekin Water; government agencies like Sunwater; and community NRM groups like BBIFMAC. However, forming local catchment management groups in the region is justified by the waning paid participation of riparian landholders in RMAs; ongoing aquatic weed management challenges; and a broadening scope of wetland system management planning needs, beyond just industry concerns.

Recommendations

1. Engage landholder of aquatic grass-dominated drainage depression fish passage barrier downstream of Bruce Highway, and water manager Sunwater, and secure resources to trial and monitor (DO and fish movement):
    a. establish *a suitable water quality fish passage preferential flow path through an aquatic grass weed-dominated drainage depression via riparian shading*, and, if required;
    b. conduct a *pumped environmental 'freshening' flow during the wet season critical water quality period* in conjunction with the preferential flow path trial.
2. Establish a consultative SMP stakeholder group to conduct formal meetings with Sunwater. The objective is to explore the implementation of BHWSS management arrangements and establish infrastructure that alienates regulated flows and/or scheme tailwater inflows from seasonal wetland systems. Nominate the Reed Beds and the drainage depression reach of the Ironbark Creek – Healey's Lagoon system downstream of the Bruce Highway as an initial management focus.
3. Gauge local stakeholder interest for an Ironbark Creek catchment management group, or equivalent. This would be done at NQ Dry Tropics-facilitated local community information session for the release of this SMP. The group would be responsible for overseeing the implementation of supported SMP recommendations, including pursuing more direct engagement and development of the aquatic weed management program. Initial and ongoing communication for such a group could be facilitated by a dedicated social media page.

> Bibliography

ACTFR. 1994a. Burdekin River Irrigation Area Flora and Fauna Survey. Report No. 94/10 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

ANZECC & ARMCANZ 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

BDTNRM (2005) Burdekin Dry Tropics Natural Resource Management Plan (2005-2010). Produced by the Burdekin Dry Tropics Board for the Burdekin Dry Tropics Community, Townsville.

Burdekin Dry Tropics Natural resource Management Plan 2016-2026 https://drive.google.com/file/d/0B2eYGb5_l-adVXJVOVN2bWcyOFE/view

BBIFMAC (1999) A Community based Natural Resource Management Strategy for the Burdekin – Bowen Floodplain Subregion of the Burdekin Dry Tropics prepared for the Burdekin – Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC).

BSC (2020). Burdekin Shire Council Biosecurity Plan 2020 – 2025. Produced by the Burdekin Shire Council, Ayr.

BSC (2020b). Burdekin Shire Council Aquatic Weed Control Plan 2020 – 2025. Produced by the Burdekin Shire Council, Ayr.

Brizga, S.O., Kapitzke, R., Butler, B., Cappo, M., Connolly, N., Lait, R, Pearson, R.J., Pusey, B., Smithers, S., & Werren, G.L. (2006). Burdekin Basin Draft WRP. Environmental Assessment Report. Phase 1 – Current Environmental Condition. Department of Natural Resources and Mines, Queensland.

Blackman J.G., (1978) The Swamps - A Habitat in Motion. In Exploration North - Australia's wildlife from desert to reef. H.J. Lavery (ed). Richmond Hill Press 1978.

Blackman J.G., Perry, T.W., Ford, G.I., Craven, S.A., Gardiner S.J. and De Lai R.J. (1999). Characteristics of Important Wetlands In Queensland. Environment Protection Agency, Queensland.

Burdekin Region Water Quality Improvement Plan 2016 https://drive.google.com/file/d/0B2eYGb5_l-adNGY0RERCWFB2aDQ/view

Burrows, D., Veitch, V., Loong, D., Perna, C., and Butler, B., (2006). Monitoring of the Health and Fish Passage Issues of Healey's Lagoon Following Removal of an Extensive Mat of Floating Aquatic Weeds. Report No. 06/11 June 2006 Prepared by Australian Centre for Tropical Freshwater Research James Cook University Townsville, Qld 4811

Burrows, D., Perna, C., Davis, A., and Knott, M., (2009). Examination of Fish Passage into Healey's Lagoon and Ironbark Creek, Haughton River Catchment, North Queensland. Report No. 09/09 February 2009 Prepared by Australian Centre for Tropical Freshwater Research James Cook University Townsville, Qld 4811

Carter, J., Tait, J.T.P., Kapitzke, R. and Corfield, J. (2007). Final Report Burdekin Dry Tropics NRM Region Fish Passage Study. 17 November 2007. Prepared by Alluvium Consulting for Burdekin Dry Tropics NRM.

Carter, J & Tait, J 2010, Freshwater Fishes of the Burdekin Dry Tropics, Townsville.

Christian, CS, Paterson, SJ, Perry, RA, Slayter, RO, Stewart, GA and Traves, DM 1953, 'Survey of the Townsville - Bowen Region, North Queensland, 1950', Land Research Series No. 2, CSIRO, Melbourne.

Connolly, N., Kahler, C, Mackay, S, Fry, S. and Cameron, R. 2012. Variations in wetland condition across Land Zones in the lower Burdekin. Aquatic weed distributions determined by underlying differences in water and salinity regimes. A report prepared for the NQ Dry Tropics NRM. Department of Environment and Heritage Protection, Queensland Government.

Coastal Ecosystem Management – Lower Burdekin Floodplain (GBRMPA 2013) http://elibrary.gbrmpa.gov.au/jspui/bitstream/11017/2901/2/Case_study_water_planning_Burdekin.pdf

Davis, A.M., et al., (2013) Environmental impacts of irrigated sugarcane production: Herbicide run-off dynamics from farms and associated drainage systems. Agric. Ecosyst. Environ. (2011), doi:10.1016/j.agee.2011.06.019

Davis A.M. et al. (2014) Water Resource Development and High Value Coastal Wetlands on the Lower Burdekin Floodplain, Australia. In: Wolanski E. (eds) Estuaries of Australia in 2050 and beyond. Estuaries of the World. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7019-5_13

Davis, Aaron M., Pearson, Richard G., Brodie, Jon E. , and Butler, Barry (2017) *Review and conceptual models of agricultural impacts and water quality in waterways of the Great Barrier Reef catchment area.* Marine and Freshwater Research, 68 (1). pp. 1-19.

DES (2021). Department Environment and Science, Queensland Government, Regional ecosystems descriptions, licensed under Creative Commons Attribution 4.0 sourced on 10 January 2021

DPI (1993). The Condition of River Catchments in Queensland. *A Broad Overview of Catchment Management Issues.* Queensland Department of Primary Industries Integrated Catchment Management 1993.

Draft Environmental Values and Water Quality Objectives for the Estuarine and Coastal areas of the Lower Burdekin region (Burdekin Dry Tropics NRM)

Freshwater wetlands of the Barratta Creek catchment management investment strategy. Report prepared by Econcern and Tropwater for the Burdekin Dry Tropics NRM (Tait, J. and Veitch, V. 2007) https://researchonline.jcu.edu.au/cgi/users/login?target=https%3A%2F%2Fresearchonline.jcu.edu.au%2F29261%2F1%2F29261_Tait_2007.pdf

Hooker, N 2010, Native Grasses for Revegetation in the Townsville Region, Coastal Dry Tropics Landcare Inc., Townsville.

Hunter HM, Eyles AG and Rayment GE (1996) Downstream Effects of Land Use. Queensland Department of Natural Resources.

Hunter, H.M., Hargraves, P.M. and Rayment, G.E. (1998) 'Pesticide Residues in Surface Waters of the Burdekin River Irrigation Area' Draft Report Department of Natural Resources, Resources Sciences Centre.

Hunter, H.M. (2012). Nutrients and herbicides in groundwater flows to the Great Barrier Reef lagoon: processes, fluxes and links to on-farm management. ISBN: 978-1-7423-0969.September, 2012

Intergovernmental Panel on Climate Change [IPCC]. (2022). *IPCC Sixth Assessment Report: Impacts, adaptation and vulnerability*. https://www.ipcc.ch/report/ar6/wg2/Keating, B.A., Bauld, J., Hiller, J., Ellis, R., Weier, K.L., Sunners, F. and Connell, D. (1995) 'Leaching of Nutrients and Pesticides in Queensland Ground Waters,' in Hunter, H.M., Eyles, A.G. and Rayment, G.E. (eds) *Downstream Effects of Land Use*, Department of Natural Resources, Brisbane.

Loong, D., Butler, B., Burrows, B., Aaron Davis, A., and Faithful, J., (2005). Limnological Assessment and Benchmarking of Key Sentinel Wetlands in The Burdekin Catchment, North Queensland ACTFR Report NO. 05/09. Draft Report to the Burdekin Dry Tropics Board as part of the National Action Plan for Salinity and Water Quality for the Burdekin Catchment: Priority Action Project No. 4. Australian Centre for Tropical Freshwater Research James Cook University, Townsville, Qld 4811

Loong, D., Butler, B., and Burrows, D. (2006) Water Quality And Aquatic Health Assessment Of Healey's Lagoon, Haughton River Catchment, North Queensland – Appendix To ACTFR Report No. 06/11 December 2005 Prepared by Australian Centre for Tropical Freshwater Research James Cook University, Townsville, Qld. 4811

Perna, C. 2003. Fish Habitat Assessment and Rehabilitation in the Burdekin Delta Distributary Streams. Report No. 03/22 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Perna, C., 2004. Impacts of Agriculture and Restoration of the Habitat Values, Water Quality and Fish Assemblages of a Tropical Floodplain. Masters of Science Thesis, James Cook University, Townsville, Australia, 144pp.

Perna, C. and Burrows, D. 2005. Improved dissolved oxygen status following removal of exotic weed mats in important fish habitat lagoons of the tropical Burdekin River floodplain, Australia. Marine Pollution Bulletin 51: 138-148.

Perna, C. O'Connor, R. and Cook, B, 2012(a), *Hydroecology of the lower Burdekin River alluvial aquifer and associated groundwater dependent ecosystems*, Department of Environment and Resource Management, Queensland Government.

Perna, C.N., Cappo, M., Pusey, B.J., Burrows, D.W., Pearson, R.G., 2012(b). Removal of aquatic weeds greatly enhances fish community richness and diversity: an example from the Burdekin River floodplain, tropical Australia. River Res. Appl. 28, 1093–1104. https://doi.org/10.1002/rra.1505

Power, T., (2017) Gooseponds Fish Hotels – Increasing habitat complexity. Summary report for Mackay Regional Council. Catchment Solutions, Mackay

Smith, B., Burrows, D., Veitch, V., Tait, J. and Hudson, D. (2007). Great Barrier Reef Coastal Wetland Protection Program Pilot Program 2005-2007– *Final Report June 2007.* Prepared for the Commonwealth Department of Environment and Water Resources by a consortium including Conservation Volunteers Australia, Wetlandcare Australia, Econcern and the Australian Centre for Tropical Freshwater Research, James Cook University.

Sugar Research Australia (2013). Rat Management in sugarcane. Booklet B14023.

Tait, J.T.P (1999) A Community based Natural Resource Management Strategy for the Burdekin – Bowen Floodplain Subregion of the Burdekin Dry Tropics prepared for the Burdekin – Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC).

Tait, J and Perna, C. (2001) Fish Habitat management challenges on an intensively developed tropical floodplain – Burdekin River North Queensland. RIPRAP Edition 19 LWRRDC's Riparian Lands Management Journal

Tait, J.T.P (2004) Burdekin Dry Tropics Natural resource Management Plan: Regional Overview. Report for the Burdekin Dry Tropics Board. Econcern.

Tait, J.T.P (2005a) Sheep Station Creek Draft Catchment Management Plan – *Key Management Issues – Chapter 5 - Riparian and Remnant Vegetation. Draft report prepared for the Lower Burdekin Landcare Association.*

Tait, J.T.P (2005b) Sheep Station Creek Draft Catchment Management Plan – *Appendix 7 – habitat Complexes Draft report prepared for the Lower Burdekin Landcare Association.*

Tait, J.T.P (2005c) Sheep Station Creek Draft Catchment Management Plan – Appendix 9:

Sheep Station Creek Revegetation Master Plan – A Proposal –Draft report prepared for the Lower Burdekin Landcare Association.

Tait, J.T.P (2009) Sheep Station Creek Draft Catchment Management Plan – Key Management Issues – Water Quality DRAFT February 2009

Tait, J.T.P. & Veitch, V. (2007). Freshwater Wetlands of the Barratta Creek Catchment – Management Investment Strategy. Report prepared for the Burdekin Dry Tropics Board by Econcern and Australian Centre for Tropical Freshwater Research (ACTFR) October 2007.

Tait, J., 2011, Guidelines for the Use of Grazing in the Management of Exotic Pasture Weeds in Wetland and Riparian Habitats. Developed for the Coastal Floodplains of the NQ Dry Tropics NRM Region. WetlandCare Australia, Ballina, NSW.

Tait, J.T.P. (2013) Coastal Ecosystem Management: Lower Burdekin Case Study. An examination of management arrangements for coastal ecosystems and processes linked to the ecological health of the Great Barrier Reef World Heritage Area on a floodplain dominated by irrigated agriculture. Report prepared for the Great Barrier Reef Marine Park Authority by Econcern July 2013.

Wetlands in the Great Barrier Reef Catchments Management Strategy
https://wetlandinfo.ehp.qld.gov.au/resources/static/pdf/management/policy/wetlands-gbr-strategy2016-21v13.pdf

Tonkin, Z. and Lyon, J. (2016). 'Is Wood Good for Fish'. In *RipRap* Edition 39. Published by the Australian River Restoration Centre, Canberra.

Veitch, V., and Burrows, D., (2006). Fish Passage Issues of Healey's Lagoon Following Investigation of Water Quality Issues Impacting on Fish Migration Report No. 06/22 November 2006 Prepared by Australian Centre for Tropical Freshwater Research James Cook University Townsville, Qld 4811

Veitch, V., Tait, J., Burrows, D.W., 2008. Fish Passage Connectivity Issues Lower Sheep Station Creek: Dry and Wet Season Investigations of Water Quality and Fish Assemblages. Australian Centre for Tropical Freshwater Research (08/02), James Cook University, Townsville.

Waltham, N.J., Fixler, S., 2017. Aerial herbicide spray to control invasive water hyacinth (Eichhornia crassipes): water quality concerns fronting fish occupying a tropical floodplain wetland. Tropical Conservation Science 10. https://doi.org/10.1177/ 1940082917741592

Waltham, N.J, Coleman, L.,1 , Buelow C., Fry S. & Burrows, D., (2020) Restoring fish habitat values on a tropical agricultural floodplain: Learning from two decades of aquatic invasive plant maintenance efforts. Ocean & Coastal Management Volume 198, 1 December 2020, 105355

> Appendix 1 – Reach values, management issues and nominated works descriptions

Reach values (V)
Short description – V1: Healey's Lagoon – Large perennial lagoon system with good condition riparian forest corridor
V1 – Full description Healey's Lagoon is one of the largest and, arguably, best integrity floodplain lagoons occurring on the Lower Burdekin floodplain, particularly for a farming dominated landscape. It has well-developed near-contiguous fringing riparian vegetation and is a productive, deepwater fish habitat that hosts barramundi populations and acts as a nursery for first-year class fish. It also contains a diverse assemblage of other freshwater fish species, both freshwater and estuarine crocodiles, several species of freshwater turtles, and other reptiles; and provides good bird habitat for a diverse range of wetland and riparian habitat-dependent species, including raptors. The high fish habitat values of this lagoon are associated with the lagoon's size and depth; its proximity to downstream estuarine nursery areas; complex instream habitat structure, including abundant snags; undercut banks and aquatic vegetation; and its productivity, including a large freshwater herring population. The site has been assessed to be of state biodiversity significance, forming part of a bioregional riparian corridor, containing at least one 'of concern' regional ecosystem, and providing habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. Matters of state environmental significance recognised at the site include wildlife habitat for endangered or vulnerable species. The lagoon obtains a very high value in state riverine Aquatic Conservation Assessments.
Short description – V2: Good condition, high biodiversity value, riparian vegetation corridor, and associated fish passageway
V2(a–c) – Full description One of the notable high ecological values of Healey's Lagoon and Ironbark Creek, relative to many other deepwater lagoons and floodplain distributary creeks in the Lower Burdekin, is its near-contiguous fringe of canopy-forming riparian vegetation comprised of a diverse assemblage of tree species. This riparian vegetation is dominated by paperbarks, livistona palms, Leichardt trees, and eucalypts, but also includes a significant component of broadleaf rainforest associated species such as figs, pongamias, blackbeans and white cedars. This fringing riparian vegetation provides a connected forest habitat corridor with associated benefits, for example, a movement corridor for cover-dependent wildlife, bank stability, instream habitat complexity, reduction in flood flow breakout velocity (and associated floodplain soil erosion), water shading and cooling, grass weed exclusion, fire risk reduction, and reduced rodent harbourage. This vegetation corridor extends along most of both banks of Healey's Lagoon and extends upstream along Ironbark Creek, all the way to the Haughton River, where it originates as a flood breakout distributary channel. In the upper Ironbark Creek reach, canopy shading provided by riparian vegetation covers most of the creek channel and serves to exclude channel-choking exotic aquatic grasses, maintaining open water habitats with better water quality and fish passage characteristics. During high flow connectivity with the Haughton River, the Ironbark Creek channel (via Reed Beds and Healey's Lagoon) provides a fish passageway for estuarine breeding migratory fish to bypass the passage barriers presented by Haughton River weirs (Giru and Val Bird) to reach the upper Haughton. This passageway is believed to be responsible for the maintenance of estuarine breeding jungle perch in the national park upper catchment of Major and Spring creeks. This riparian corridor has been assessed to be of state biodiversity significance, forming part of bioregional riparian corridor, and containing at

least one ‘of concern’, regional ecosystem. Other matters of state environmental significance include GBR riverine regrowth regulated vegetation. The integrity of the lagoon and creek’s riparian vegetation also contributes to the very high value they receive in state riverine Aquatic Conservation Assessments.
Short description – V3: Distributary habitat node.
V3 – Full description This node of high value riparian habitat occurs where remnant vegetation extends beyond the main Ironbark Creek channel to link with a parallel distributary channel. A diverse mix of habitat types occur in close proximity including a perennial creek channel, seasonal wetlands with fringing paperbarks, closed riparian forest, livistona palm forest, fringing open eucalypt woodland and grassland. Collectively the site represents a broad suite of the habitat diversity associated with the broader catchment. This habitat diversity underpins higher nature conservation value due to the site’s capacity to support a greater biodiversity of fauna and flora. This contrasts with many remnant riparian habitat areas within agricultural landscapes which are restricted to a narrow corridor of riparian vegetation (often non continuous) representative of only the immediate creek channel vegetation. This riparian habitat node falls within an area assessed to be of State biodiversity significance, forming part of a bioregional riparian corridor, and containing at least one ‘of concern, regional ecosystem. Other Matters of State Environmental Significance include GBR riverine regrowth regulated vegetation. The integrity of the riparian vegetation also contributes to the very high value the site receives in State riverine Aquatic Conservation Assessments.
Short description – V4: Seasonal Wetlands and Distributary Habitat Remnants
V4 – Full description These high value seasonal wetlands occur within a distributary channel parallel to the main Ironbark Creek channel with which it links via remnant vegetation. The site is comprised of seasonal channel hosted lagoons with fringing paperbarks and adjoining open eucalypt woodland and grassland. This more open structured vegetation contrasts with the more closed vegetation type associated with the main creek channel. Unlike much of the lower Ironbark Creek, which is hydrologically modified by flow supplementation, these wetlands (and the adjoining upper Ironbark Creek reach) retain natural seasonal hydrology, filling during wet season flows and drawing down in water level as the dry season progresses. This seasonality supports native aquatic plants and other biota adapted to seasonally variable conditions. Most of the site is used for grazing, and this serves to reduce the dominance of exotic aquatic grasses within the wetlands, although they are subject to floating aquatic weed infestation (salvinia). GBR riverine regrowth regulated vegetation at the site represents a matter of state environmental significance. The site is also assessed to have very high value in state riverine Aquatic Conservation Assessments.
Short description – V5: Catchment wildlife corridor.
V5 (a–g) – Full description These wildlife habitat corridors have been identified where remnant vegetation, usually associated with drainage lines, provides habitat linkages between remnant vegetation of adjoining foothills and/or alluvial plains and the riparian habitat corridor of the man Ironbark Creek channel. This connectivity is critically important for a range of disturbance sensitive/cover dependent wildlife, such as arboreal mammals like squirrel gliders, that need to utilise the habitat resources of different habitat types to survive and require close proximity tree cover to be able to move through the landscape. One of the common consequences of agricultural

development on alluvial plains adjoining distributary creeks is that such habitat connectivity is severed by clearing. It is a notable and somewhat unique (within the Lower Burdekin) feature of the Healey's Lagoon – Ironbark Creek system that the western half of the catchment is bound by extensive wildlands of the Ironbark Range and Mount Elliot and that remnant native vegetation – both remnant patches and corridor features – extend to the alluvial plains of the lowlands. This represents a high nature conservation value of the system and one that needs recognition to be maintained or improved. These corridor linkages include defined watercourse and GBR riverine regrowth regulated vegetation which are matters of state environmental significance.

Short description – V6: Alluvial plain vegetation remnant.

V6 (a–d) – Full description

The conservation value of these alluvial plain habitat remnants is underpinned by their representation of the types of vegetation assemblages that have been largely lost to agricultural and pastoral development. Consequently, they tend to provide habitat for floodplain fauna and flora that is under some level of survival pressure due to regional habitat loss. Retention of such remnants in the residual post-development landscape, and promoting the habitat corridor linkages with them, provides a strategic landscape ecology approach for regional nature conservation. Matters of state environmental significance recognised within these remnants include endangered and 'of concern' regional ecosystems, and suitable habitat for endangered or vulnerable wildlife species. State biodiversity significance is attributed to their contribution to a bioregional terrestrial corridor and representing at least one 'of concern' regional ecosystem.

Short description – V7: Seasonal wetlands.

V7(a – d) – Full description

The conservation value of this range of variably-sized and conditioned wetlands is underpinned by their retention of seasonal hydrology. Several of these sites are grazed and these have not become dominated by exotic aquatic grass cover due to the seasonal effectiveness of control provided by cattle being able to access any established exotic pasture species. Consequently, when inundated during the wet season they provide open water habitats and opportunities for the growth of native aquatic plants that have been excluded from other wetlands within the catchment due to modified hydrology and exotic grass infestation. These habitat types are utilised by a host of wetland fauna ranging from invertebrates to frogs, floodplain fish species and waterbirds. This representation of a habitat type reduced due to broader system modification, and their use by local species adapted to seasonal habitats, contribute to their conservation value. State non-riverine wetland Aquatic Conservation Assessments assess them to be of medium conservation significance.

Short description – V8: Perennial deepwater upper catchment lagoon

V8 – Full description

This channel-hosted lagoon system within the upper Ironbark Creek system shares many values with the larger downstream Healey's Lagoon, including well-developed near contiguous fringing riparian vegetation; productive, deepwater fish habitats; a diverse assemblage of freshwater fish, freshwater crocodiles, several species of freshwater turtles; and other reptiles and bird habitat for a diverse range of wetland and riparian habitat-dependent species, including raptors. High fish habitat values are associated with the lagoon's size and complex instream habitat structure, including abundant snags, undercut banks and aquatic vegetation. Fish passage connectivity to the site is impinged by a downstream culvert crossing associated with the Giru Woodstock

Road. The site obtains very high values in state riverine Aquatic Conservation Assessments and has state biodiversity significance, forming part of a bioregional riparian corridor, and containing at least one 'of concern' regional ecosystem.
Short description – V9: Seasonal distributary wetland remnant.
V9 – Full description This high value seasonal wetland occurs within a distributary channel parallel to the main Ironbark Creek channel with which it shares a tenuous remnant habitat linkage. The site is comprised of seasonal channel-hosted lagoons with fringing paperbarks and open eucalypt woodland. Unlike the adjoining Ironbark Creek channel, which is hydrologically modified by flow supplementation, this wetland retains natural seasonal hydrology, filling during wet season flows and drawing down in water level as the dry season progresses. This seasonality supports native aquatic plants and other dependent biota, including waterfowl adapted to seasonally variable conditions. Exposed lagoon banks associated with low dry season water levels are a particularly rare habitat throughout the hydrologically-modified Lower Burdekin region and are a critically important waterfowl habitat. Most of the site is used for grazing, and this serves to reduce the dominance of exotic aquatic grasses within the wetlands, although they are subject to floating aquatic weed infestation (salvinia). The site obtains very high values in state riverine Aquatic Conservation Assessments and has state biodiversity significance, forming part of bioregional riparian corridor; contains at least one 'of concern' regional ecosystem; and provides habitat for endangered, vulnerable or near threatened (EVNT) wildlife species.
Short description – V10: Floodplain habitat remnant on Crown reserve.
V10 – Full description This habitat remnant occurs in close proximity to the larger remnant habitat complex provided by Healey's Lagoon. Its conservation value is underpinned by representation of floodplain paperbark and eucalypt woodland that have been extensively lost to agricultural development. This vegetation provides habitat for fauna that is under some level of regional survival stress. Although its condition is threatened by woody and exotic grass weed infestation and associated hot fire risks, its Crown land tenure presents public interest and access opportunities, and also a case for management investment that could secure and improve its nature conservation value. The site has state biodiversity significance, forming part of a bioregional riparian corridor; contains at least one 'of concern' regional ecosystem; and provides habitat for endangered, vulnerable or near threatened (EVNT) wildlife species.
Short description – V11: Rare monsoon palm-rainforest remnant on Crown reserve.
V11 – Full description This rare and highly diverse palm rainforest habitat remnant occurs within a Crown land reserve located on the upstream margin of the larger remnant habitat complex provided by Healey's Lagoon. Its conservation value is underpinned by the rarity of monsoon rainforest remnants within the broader region; its diversity of plant species; its structural complexity; and the associated feeding and nesting resources it provides for frugivorous, nectivorous and insectivorous birds and bats and other wildlife species, including reptiles and other mammals. Its closed canopy structure and size also suits dense cover-dependent species, such as rufus owls, that were recorded at the site during field work. Its Crown land tenure and frontage to Healey's Lagoon presents public interest, access, and nature-based recreation use opportunities and a case for management investment that could secure and improve its nature conservation value. The site has state biodiversity significance, forming part of bioregional riparian corridor; contains at least one 'of concern' regional ecosystem; and provides habitat for endangered, vulnerable or near threatened (EVNT) wildlife species.

Short description – V12: Riparian habitat nodes.
V12 (a–g) – Full description These riparian habitat nodes represent sites where the extent of remnant riparian vegetation extends beyond a narrow bank side corridor to include adjoining terraces or levees, or junction points with riparian vegetation associated with tributary drainages. Relative to the narrower corridor of habitat provided by most bankside riparian vegetation, these nodes have a larger core area and greater diversity and structural complexity, providing additional habitat resources; particularly for cover-dependent species such as owls and arboreal mammals. They represent features worthy of protection and/or consolidation by targeted revegetation. These identified riparian habitat nodes occur within an area assessed to have very high value in state riverine Aquatic Conservation Assessments.
Short description – V13 Seasonal distributary lagoons.
V13 (a–d) – Full description The existing conservation value of this range of variably-sized and conditioned distributary lagoons is mainly underpinned by their retention of seasonal hydrology lost from much of the broader system, although surrounding irrigated farming is likely to contribute some tailwater inflows. Despite their seasonal hydrology, all these sites are surrounded by cane land and are ungrazed, and most have become dominated by exotic aquatic grasses that impact their water quality and habitat value. Grass weeds adjoining some of the lagoons are controlled by landholders, which maintains open water and some native aquatic plant habitat. One has a small area of remnant riparian vegetation. These lagoons' greatest, though unrealised, nature conservation value is associated with their potential for rehabilitation via riparian revegetation and aquatic grass/weed control. Despite existing condition impacts, they are assessed to have very high value in state non-riverine Aquatic Conservation Assessments and are recognised as matters of state environmental significance as ecologically significant wetlands, and for having regulated vegetation including GBR riverine regrowth within 100m of the mapped significant wetlands.
Short description – V14: Perennial distributary lagoon with remnant alluvial plain, riparian forest, and foot slope connectivity
V14 – Full description This remnant habitat complex has very high values underpinned by juxtaposition of a diversity of ecosystem types, such as deepwater lagoon, riparian forest, and remnant alluvial plain woodland. This includes rarer types (alluvial plain woodland) largely lost to development, and good habitat corridor connectivity to large tracts or remnant vegetation associated with the foot slopes of adjoining hills. The lagoon distributary shares many aquatic fauna habitat values with the main Healey's Lagoon, including for fish, reptiles, and birds, yet – unlike Healey's Lagoon – still retains seasonal hydrology characteristics. The alluvial plain woodland and riparian forest also has high bird and mammal habitat values. This value is recorded in state government assessments as being of regional biodiversity significance; containing at least one 'of concern' regional ecosystem; providing habitat for endangered, vulnerable or near threatened (EVNT) wildlife species; and for having very high condition and ecosystem diversity. Matters of state environmental significance include suitable habitat for endangered or vulnerable wildlife species. State riverine wetland Aquatic Conservation Assessments give the site a very high value.
Short description – V15: Perennial distributary tributary lagoon.
V15 – Full description

This lagoon is located within a distributary channel upstream of its confluence with the main Healey's Lagoon. It shares many of the aquatic habitat values of the main lagoon, but has a poorer condition and less complex instream habitat due to the poor status of its fringing riparian vegetation which is reduced to isolated patches. This lagoon's greatest, though unrealised, nature conservation value is associated with its potential for rehabilitation via riparian revegetation and aquatic grass/weed control. Despite existing condition impacts it is assessed to have very high value in state riverine Aquatic Conservation Assessments and to have matters of state environmental significance associated with providing wildlife habitat for endangered or vulnerable species.

Short description – V16: Haughton River riparian and ecotonal forest and back levee wetland wildlife refugia

V16 – Full description

This habitat complex occurs on the banks of the Haughton River at the headwaters of the distributary channel that forms Ironbark Creek, with which it shares contiguous riparian vegetation and associated ecological and biological connectivity. This remnant habitat complex has very high values underpinned by juxtaposition of a diversity of ecosystem types (riparian forest with rainforest elements, ecotone eucalypt woodland and a back levee seasonal wetland), and by good habitat corridor connectivity between the two regionally-significant riparian corridors associated with the Haughton River and Ironbark Creek. The size, density, diversity, and structural complexity of the habitat at this site provides shelter, nesting and feeding resources for frugivorous, nectivorous and insectivorous birds and bats and other wildlife species, including reptiles and other mammals. Closed canopy components also suit dense cover-dependent species such as rufus owls. The Crown watercourse tenure of most of the site and frontage to the Haughton River also presents public interest, access, and nature-based recreation use opportunities and a case for management investment that could secure and improve its nature conservation value. The site is of state biodiversity significance, forming part of a bioregional riparian corridor; contains at least one 'of concern' regional ecosystem; and provides medium habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. It is also assessed to have very high condition and ecosystem diversity and high ecosystem value and context and connection. The site falls within an area assessed to have very high value in state riverine wetland Aquatic Conservation Assessments.

Short description – V17: High value remnant floodplain vegetation and seasonal open wetland retaining native aquatic plants.

V17 – Full description

The value of this site is comprised of the combined value of a high value remnant floodplain vegetation stand and an adjoining seasonal wetland. The vegetation is representative of alluvial plains regional ecosystem types that have largely been developed in the Lower Burdekin and consequently supports fauna under some survival stress due to habitat loss. The seasonal wetland is part of a broader wetland complex, most of which is impacted by modified hydrology and associated invasion by exotic aquatic grasses. This specific wetland has retained open water habitat via a combination of factors including seasonality, greater basin depth and higher salinity resulting from old marine plain sediments. The retention of open water habitat at the wetland provides for maintenance of some native aquatic plant communities and its greater use by waterfowl and waterbirds. Both sites are recognised to be matters of state environmental significance, including as an ecologically-significant wetland with adjoining endangered and 'of concern' regional ecosystems; essential habitat regulated vegetation; and habitat suited to endangered or vulnerable, and 'least concern' wildlife species. State biodiversity significance is associated with it forming part of a bioregional riparian corridor; containing at least one 'of concern' regional ecosystem; and providing medium habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. This site (V17) is also assessed to have very high condition and high ecosystem diversity.

State non-riverine wetland Aquatic Conservation Assessments report a very high conservation significance. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national *Directory of Important Wetlands in Australia* (DIWA).
Short description – V18: Alluvial coastal plain remnants.
V18 (a–b) – Full description The conservation value of this adjoining pair of coastal alluvial plain vegetation remnants is underpinned by the representation of regional ecosystem types that have largely been developed in the Lower Burdekin and, consequently, have importance to fauna under some survival stress due to habitat loss. Other value is represented by the regional connectivity that these remnants provide between coastal plain/wetland and mountainous protected areas, like Mount Elliot, Cape Bowling Green Bay National Park. These remnants are recognised as matters of state environmental significance and contain endangered or 'of concern' regional ecosystems; essential habitat regulated vegetation; and habitat suited for endangered or vulnerable wildlife species. State biodiversity significance is associated with these remnants forming part of a bioregional corridor; containing at least one 'of concern' regional ecosystem; providing state habitat for endangered, vulnerable or near threatened (EVNT) wildlife species; and having very high value for condition, ecosystem diversity and context and connection.
Short description – V19: Monsoon rainforest remnant.
V19 – Full description This closed paperbark/monsoon forest remnant (and adjoining similar smaller patches) occurs on the upstream margin of the large coastal wetland habitat complex associated with the Reed Beds. Its conservation value is underpinned by the relative rarity of monsoon forest remnants within the broader region; its diversity of plant species; its structural complexity; and the associated feeding and nesting resources it provides for nectivorous, insectivorous, and frugivorous birds and bats and other wildlife species, including reptiles and other mammals. Its dense canopy structure and core size also suit cover-dependent species such as rufus owls. The site has state biodiversity significance being an ecologically significant wetland, forming part of a bioregional corridor, providing habitat for endangered, vulnerable or near threatened (EVNT) wildlife species and having very high value for condition and ecosystem value, and high value for ecosystem diversity. Matters of state environmental significance include high ecological significance wetlands and provision of habitat for special least concern wildlife species. State non riverine wetland Aquatic Conservation Assessments rate the site as very high conservation significance. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national *Directory of Important Wetlands in Australia* (DIWA).
Short description – V20: The Reed Beds high value coastal wetland complex/barramundi nursery
V20 – Full description This large coastal wetland complex, known locally as the Reed Beds, has very high bird habitat values for waterfowl, waterbirds, and migratory waders. It also provides fishery nursery habitat particularly for commercially and recreationally-important barramundi. It is known to host large individuals of saltwater crocodile. Its high values include matters of state environmental significance, including being part of a strategic environmental area (designated precinct); an ecologically significant wetland containing endangered and/or of concern regional ecosystems; regulated vegetation up to 100m from the mapped wetland boundary; and providing wildlife habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. State biodiversity significance is associated with it being an ecologically significant wetland; forming part of a bioregional terrestrial corridor;

containing at least one 'of concern' regional ecosystem; and providing medium habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. It is also assessed to have very high values for condition, size, ecosystem value, wildlife refugia, context and connection and high ecosystem diversity. State non-riverine wetland Aquatic Conservation Assessments define the area as being of very high conservation significance. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national *Directory of Important Wetlands in Australia* (DIWA).
Short description – V21: Constructed lake wetlands.
V21 (a–d) – Full description This group of constructed lakes have been formed by damming drainages emanating from small catchments of the Mount Elliot range. Although 'constructed wetlands', their deeper basin design and management regime including grazing, results in relatively large open water bodies hosting a range of native aquatic plant species on their shallower margins. These aquatic plants and adjoining open water habitats present valuable habitat resources whose availability has been reduced in the broader landscape due to aquatic weeds and hydrological modification of the Lower Burdekin floodplain. These dams would support a diverse range of wetland fauna including waterfowl, waterbirds, reptiles, and fish. Although natural aquatic habitats were lost in the construction of these dams, recognition of the habitat contribution dams can make to regional wetland fauna populations is important and can serve to tailor their design and management toward improved biodiversity outcomes.
Management issues (M)
Short description – M1: High rates of runoff through farm drainage channels to the stream network.
M1(a & b) – Full description Farm drains often replace natural drainage lines with more direct and larger capacity channels intended to get water off farmland quick enough to avoid crop damage. Where drainage capacity is greater than that required to serve crop needs the result can be rapid runoff that conveys catchment loads of sediment and/or nutrients more directly to receiving stream channels, which may also cause farm soil erosion. To reduce such risks, it is beneficial to have drainage networks designed to a drainage modulus (litres/sec/metre squared) that meets, but not exceeds, crop drainage needs and/or to include detention basins or constructed wetlands in the drainage network that pond water and slow the overall discharge rate to the creek network. This allows sediment to settle and some of the nutrient load to be processed.
Short description – M2: Siam weed (*Chromolaena odorata)* infestation located at top of creek system.
M2 – Full description During field work conducted for the project an infestation of Siam weed (*Chromolaena odorata)* was located within the Haughton River distributary channel that forms the beginning of the Ironbark Creek system. This weed is a relatively new arrival to the region and has not yet become widely established. While all observed plants were destroyed, there is a need to conduct further surveys and control to ensure that this destructive environmental weed does not become established within the system. See Siam weed | Business Queensland.
Short description – M3: Constructed Infrastructure (road crossing) within Haughton River outflow distributary raises flow breakout height.

M3 – Full description Outbreak flows from the Haughton River form an important part of the natural hydrology of the Ironbark Creek system, playing a role in resetting habitat conditions, refreshing water quality, and forming the stream channel. A powerline maintenance access track built across the distributary channel breakout point has raised the floor in the channel increasing the height of the Haughton River flood flow level required to initiate flow down the creek system. This would impact the frequency and duration of breakout flows down the creek system with flow on impacts to the creek ecology.
Short description – M4: Loss of wildlife habitat corridor connectivity from foothills to creek riparian corridor.
M4 – Full description Drainage lines form an important component of habitat corridors used by arboreal (tree dwelling) mammals and other disturbance-sensitive species to move through variegated landscapes that have been partially cleared and/or developed to farmland. Creek lines are particularly important in providing linkages between areas used for food resources at different times of the year, for example, foothill forests versus lowland riparian and paperbark forests. Where land use intensification and clearing, or other forms of riparian vegetation impact like weeds and hot fires, result in breaks in the connectivity of these drainage line corridors, wildlife access to habitat resources is impacted.
Short description – M5: Hot fire impacts to riparian vegetation.
M5 – Full description Ungrazed pasture grasses, such as guinea grass, create large fuel loads for dry season fires. When burning is conducted with large fuel loads in the late dry season, the resulting hot fires can severely impact fire sensitive riparian vegetation, causing the death of mature trees and degrading the canopy extent and condition of valuable riparian vegetation communities. This facilitates further access for invasive species.
Short description – M6: Exotic pasture-dominated creek banks create a break in riparian vegetation corridor and hot fire risks.
M6 (a–e) – Full description Where creek banks have been historically cleared and subsequently colonised by exotic pasture grasses (like guinea and para grass), recruitment of native tree saplings are generally stalled by grass competition. Where ungrazed, these pasture grasses also create large fuel loads for dry season fires. The resulting outcome are areas where the connectivity of the riparian vegetation is broken and subject to ongoing degradation risks. BSES research has also found that ungrazed grassy creek banks are prime harbourage habitat for cane field rodents, and that forested creek banks provide less suitable habitat and support their natural predators, including owls and snakes.
Short description – M7: Exotic pasture-dominated tributary drainages with poor habitat value, high fire risk and rodent harbourage.
M7 – Full description

In the absence of active management, the habitat value of residual drainage lines within cane farming landscapes are often impacted by clearing, exotic grass infestation, other weeds, and hot fire impacts. The fire fuel load within these habitat remnants not only impacts remnant vegetation, but also poses fire risks to adjoining cane farming areas. BSES research has also found that ungrazed grassy drainage lines are prime harbourage habitat for cane field rodents and that forested creek banks provide less suitable habitat and support their natural predators, including owls and snakes.
Short description – M8: Degraded riparian vegetation reach (a–b) creating significant break in Ironbark Creek riparian corridor connectivity.
M8 – Full description One of the notable high ecological values of the Ironbark Creek system is its near-contiguous riparian vegetation corridor that provides connected riparian forest habitat from the Haughton River to the Healey's Lagoon system. Along its course there are some limited areas where historical clearing, exotic grass infestation, and associated hot fires have impacted the riparian vegetation condition or extent. This locality (8a – 8b) represents the most significant corridor break along its full extent.
Short description – M9: Unmanaged remnant vegetation on Crown reserve subject to woody and exotic grass weeds and hot fire degradation
M9 – Full description This remnant occurs on a Crown reserve, and its tenure has historically protected it from clearing. It contains valuable remnant riparian woodland vegetation including eucalypt and paperbark (melaleuca) species. Despite its public tenure and high ecological values, it has not been actively managed and contains woody weeds and an understorey dominated by exotic grass weeds that expose it to dry season hot fire risks from surrounding areas.
Short description – M10: Woodstock Giru Road crossing with high flow velocity piped culvert acts as fish passage barrier.
M10 – Full description This road crossing has pipe culverts that have high flow velocities presenting a fish passage barrier under all but road-inundating flow levels. While much fish migration does occur during high flood inundating flow events, some species and/or size classes depend on movement during recessionary flows which would be entirely directed through the culvert pipes. Upper Ironbark creek contains significant areas of high-quality fish habitat and maintenance of migratory fish access to upper reaches is important for the health and fishery productivity of the system.
Short description – M11: High habitat value closed monsoon rainforest on Crown reserve lacking management of weed and fire risks
M11 – Full description This land is Crown reserve, and its tenure has historically protected it from clearing. It contains valuable remnant vegetation including closed monsoon rainforest, palm forest and riparian woodland. The reserve has been leased for grazing purposes and

grazing occurs on its western portion. Despite its public tenure and high ecological values, it has not been actively managed and is subject to woody and exotic grass weed infestation, grazing impacts, and hot fire risks on its external boundaries.
Short description – M12: Reaches of Healey's Lagoon lacking fringing riparian vegetation
M12 (a–g) – Full description One of the notable high ecological values of Healey's Lagoon, relative to many other deepwater lagoons in the Lower Burdekin, is its near-contiguous riparian vegetation corridor that provides a connected riparian forest habitat corridor and associated benefits, for example, weed exclusion, water shading and cooling, fire risk reduction and reduced rodent harbourage, along most of the Healey's Lagoon bank. There are some limited areas where historical clearing, exotic grass infestation and associated hot fires have impacted the condition, extent, and connectivity of riparian vegetation.
Short description – M13: Back levee/distributary channel lagoons lacking riparian vegetation.
M13 (a–f) – Full description There are numerous distributary channel-hosted lagoons associated with the lower Healey's Lagoon system. Historically these lagoons would have had a more seasonal hydrology than they now experience, plus less developed fringing riparian vegetation than the main perennial system. Historical clearing, exotic grass infestation and associated hot fires have also impacted the condition, extent, and connectivity of riparian vegetation on these distributary lagoons. Under contemporary conditions of greater perenniality, these systems could host a more contiguous riparian vegetation margin which would provide both terrestrial and aquatic habitat values and production area benefits. This includes grass weed exclusion, water shading and cooling, reduction wildfire risk, and reduced rodent harbourage.
Short description – M14: Bank erosion and flood outbreaks across farmland on outside bend of constricted lagoon channel.
M14 – Full description During flood high flow events water breaks over the bank on the outside bend of this reach of the lagoon channel and flows across floodplain farmland presenting both bank and farm erosion risks. The flow capacity of the channel at this site has been impacted by both a historical weir wall (since removed) that has the reach shallow and depositional sedimentation on the inside of the bend that has been colonised by aquatic grasses and paperbarks, further reducing channel capacity.
Short description – M15: Bank undercutting and flood outbreaks across farmland on outside bend of lagoon channel.
M15 – Full description During flood high flow events water scours and undercuts the lagoon bank and breaks over the bank on the outside bend of this reach of the lagoon channel and flows across floodplain farmland presenting both bank and farm erosion risks.
Short description – M16: Riparian vegetation recruitment stalled and subject to hot fire risk by exotic grass that also provides rodent harbourage.
M16 – Full description

Historically exotic elephant grass (*Pennisetum purpureum*) was promoted and planted as a bank erosion protective measure. While it has some benefits in this role, it does have limitations associated with shallow roots and a limited buffering capacity on outbreak flow speed during large events when it is flattened. It is also now recognised as a weed species that restricts riparian overstorey vegetation recruitment, presents a wildfire risk to adjoining farms, and provides rodent harbourage.

Short description – M17: Piped culvert outlet of bottom of lagoon presents a low flow fish passage barrier.

M17 – Full description

A historical road crossing at the downstream end of Healey's Lagoon, that is still used for local farm access, has a piped culvert that presents a high velocity flow fish passage barrier when flows are solely directed through the piped outlet during base flow periods. Although fish passage is possible when this crossing is inundated during higher flows, some fish species and size classes prefer to move on lower flows when this crossing presents a barrier.

Short description – M18: High water levels sustained by flow regulation impact dry season drawdown and drive downstream seepage.

M18 – Full description

Healey's Lagoon is a regulated system with flows pumped to it from the Haughton River via Ironbark Creek to provide irrigation supplies and recharge shallow groundwater aquifers. A second pump station at the bottom of the main lagoon delivers water to downstream irrigators via a buried pipeline that discharges to an open channel. To maintain these operations and because of them, water levels within the lagoon are sustained at unnaturally high levels throughout the dry season. The loss of dry season drawdown impacts the ecological health and value of the lagoon, including no stranding of submerged weed biomass, loss of exposed bank habitat and emergent macrophyte zone, and promotion aquatic weeds. It also promotes downstream seepage, perennial wetness, aquatic grass invasion, and loss of ecological values in the downstream drainage depressions.

Short description – M19: Altered hydrology and nutrient levels promote aquatic weed infestation cycles further exacerbated by control methods.

M19 – Full description

Throughput of regulated flows and the associated loss of dry season drawdown of lagoon water levels creates conditions, including elevated nutrients, that promote the extensive growth of aquatic weeds within Healey's Lagoon. These include floating species water hyacinth, water lettuce, and salvinia, and fringing aquatic grasses hymenachne and para. RMAs, including funding commitments established with riparian landholders and other partners, support a Burdekin Shire Council-operated weed spraying program that successfully manages the level of aquatic weed infestation experienced by the lagoon, although efforts need to be ongoing for management gains to be sustained. One of the consequences of controlled aquatic weeds by chemical spraying is that weed biomass sinks within the lagoon impacting water quality and maintaining high organic nutrient loading.

Short description – M20: Regulated flow seepage downstream of highway promotes hymenachne growth that is inaccessible to grazing stock and creates fish passage barrier.

M20 – Full description

Downstream seepage generated by Healey's Lagoon regulated inflows and associated high water levels create near-perennial wetness in receiving drainage depression. These were historically seasonal wetlands that dried in the dry season, leaving bare open channels. The perennial wetness has promoted the extensive growth of exotic aquatic grasses primarily hymenachne and para, and also including aleman. In wetter years, the deeper areas of the drainage depressions do not dry sufficiently for grazing stock to access it, and the aquatic grasses form a large biomass of dead thatch and actively-growing grass covering the water's surface. During wet season high flow events, much of this biomass is inundated and bacterial decomposition consumes available oxygen, creating anoxic (de-oxygenated) water conditions that present a water quality passage barrier to migratory fish species, including barramundi, that attempt to recruit upstream from the downstream Reed Beds nursery area.

Short description – M21: Lack of lower Palm Creek riparian shading and regulated flow seepage promotes hymenachne growth that blocks fish passage.

M21 – Full description

Palm Creek is a distributary of St Margaret's Creek and flows to a confluence with the Ironbark Creek drainage system within a coastal drainage depression hydrologically impacted by downstream seepage from Healey's Lagoon. This seepage is caused by regulated inflows and associated high water levels within Healey's Lagoon. The resulting near-perennial wetness has promoted the extensive growth of exotic aquatic grasses, primarily hymenachne and para, and also aleman. Where Palm Creek retains riparian vegetation canopy cover, aquatic grasses have not been able to dominate the steam channel. However, in its lower reaches the stream naturally has a more open overstorey and grass infestation dominates the drainage channel. In wetter years, the deeper areas of the drainage depressions do not dry sufficiently for grazing stock to access it and the aquatic grasses form a large biomass of dead thatch and actively growing grass covering the water's surface. During wet season high flow events, much of this biomass is inundated and bacterial decomposition consumes available oxygen, creating anoxic (de-oxygenated) water conditions that present a water quality passage barrier to migratory fish species, including barramundi and jungle perch, that attempt to recruit upstream from the downstream estuarine complex.

Short description – M22: Regulated inflows to Reed Beds for irrigation use impacts seasonality (water levels, salinity) and ecological health.

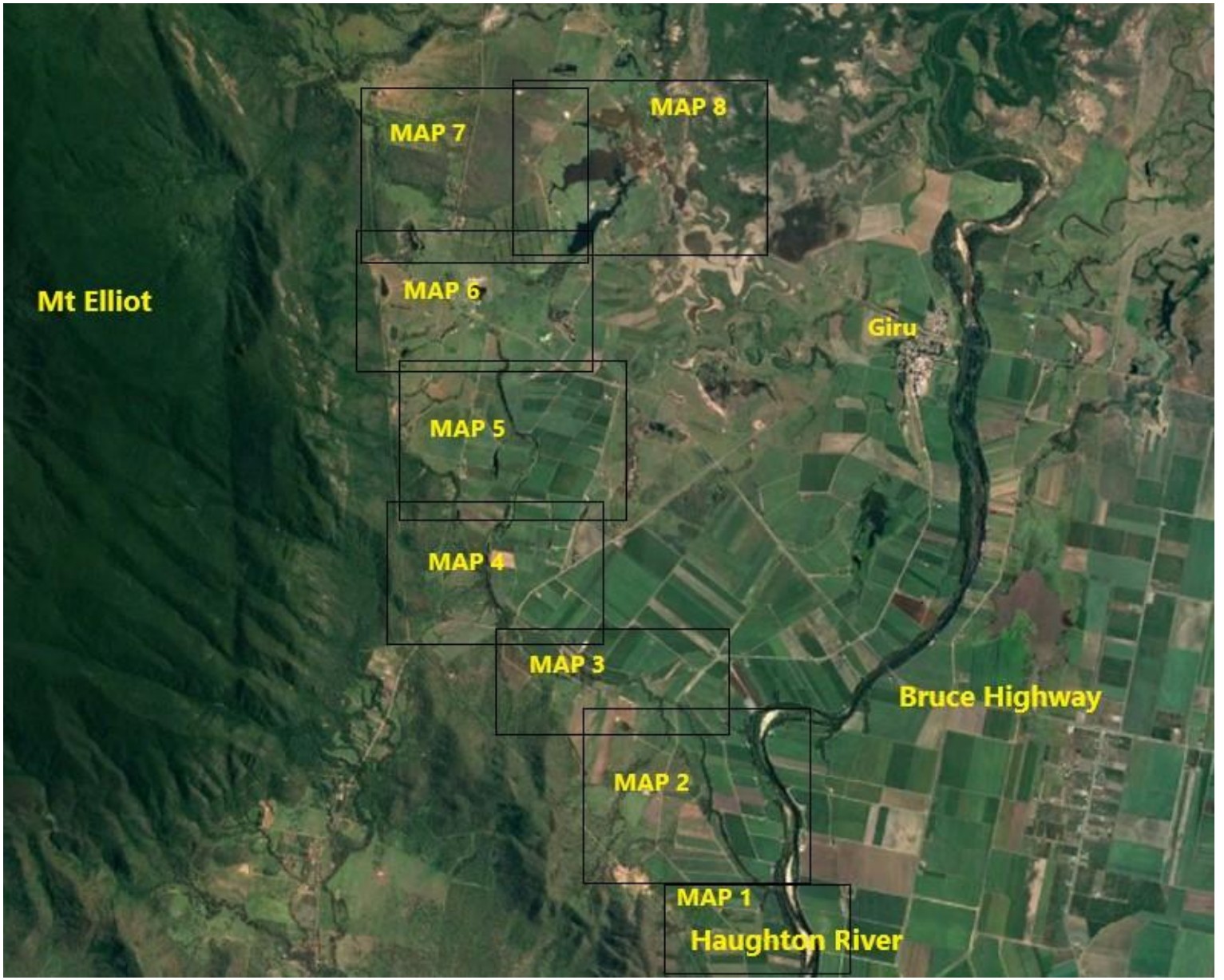
M22 – Full description

The most downstream user of regulated flows delivered through the system has a pumping station at the upstream end of the coastal wetland complex known as the Reed Beds. Water is supplied to the Reed Beds via an open channel fed by a piped supply pumped from the downstream end of Healey's Lagoon. Use of Reed Beds as a pumping pool results in significant hydrological impacts to the system, including reduced dry season drawdown, which impacts the ecological health and values of the Reed Beds. For example, no stranding of submerged weed biomass; loss of exposed bank (waterfowl) habitat and associated emergent macrophyte (aquatic plant) zone; and promotion of aquatic grass (hymenachne, para, aleman), which dominates the lagoon margins to the detriment of native water lilies and other native aquatic plants and water quality. Being a coastal wetland system historically subject to tidal influence, some important aquatic plant species within the system, like bulkuru sedge, are also adapted to a seasonally variable salinity regime, which has been lost to sustained freshwater inflows.

Short description – M23: Saltwater intrusion bunds and regulated freshwater inflows impact wetland salinity regime and ecology.
M23 – Full description The Reed Beds is a coastal lacustrine (lake) wetland system that was historically subject to tidal influence in the late dry season, which promoted important habitat resetting and a salinity regime that supported the growth of adapted plant species such as bulkuru sedge. Bulkuru sedge is an important food and nesting resource for several waterfowl and waterbird species like brolgas and magpie geese, and also creates ideal water quality conditions and nursery habitat for post-larval barramundi. The establishment of earth bunds on the downstream margins of this coastal wetland complex to exclude tidal inflow and promote exotic ponded pasture growth, along with sustained aseasonal inflows at the top of the system to provide irrigations supplies, has impacted the hydrological and salinity regime and associated ecological values of this system.
Short description – M24: Cyclical infestations of floating aquatic weed *Salvinia molesta* throughout upper catchment.
M24 – Full description Salvinia is a floating aquatic weed that is distributed through inaccessible upper reaches and adjoining distributary systems of Ironbark Creek upstream of areas subject to RMAs and boat-based aquatic weed spraying control programs. Due to its small plant size, salvinia infestations in large open reaches of the lower lagoon system are often mobile and disturbed by wind. In narrower upper reaches, its surface mats are not as disturbed by wind, and it forms dense surface-covering infestations that block sunlight to the water column and create water quality impacts. An effective bio control weevil has been previously introduced to the catchment, but its populations are not sustained long-term following salvinia-dispersing flood events. Reintroduction efforts need to be maintained to obtain bio control benefits for this floating aquatic weed.
Short description – M25: Cabomba category 3 invasive aquatic plant established in lower lagoon.
M25 – *Cabomba caroliniana* is a category 3 restricted invasive plant under the *QLD Biosecurity Act 2014*. Healey's Lagoon, Ironbark Creek and Majors Creek in the upper Haughton catchment currently represent the Lower Burdekin region records for this aquatic weed. Education of waterway users and boat wash down protocols are an important requirement for preventing its further spread in the region.
Nominated Works (W) The below section contains short descriptions only. For more information regarding these nominated works, refer to the mapping and recommendations throughout the SMP.
Short description – W1: Reinstatement/lowering of distributary channel breakout level.
Short description – W2: Siam weed survey of riparian corridor.
Short description – W3: Promotion of flow detention/re-vegetation to reduce drainage rate.
Short description – W4: Revegetation of drain and receiving basin for channel weed control, erosion protection, flow velocity baffling and wildlife corridor and habitat.
Short description – W5: Extension and engagement in wildlife corridor protection and regeneration.
Short description – W6: Grazing and/or revegetation-based exclusion of pasture grasses from riparian zone.

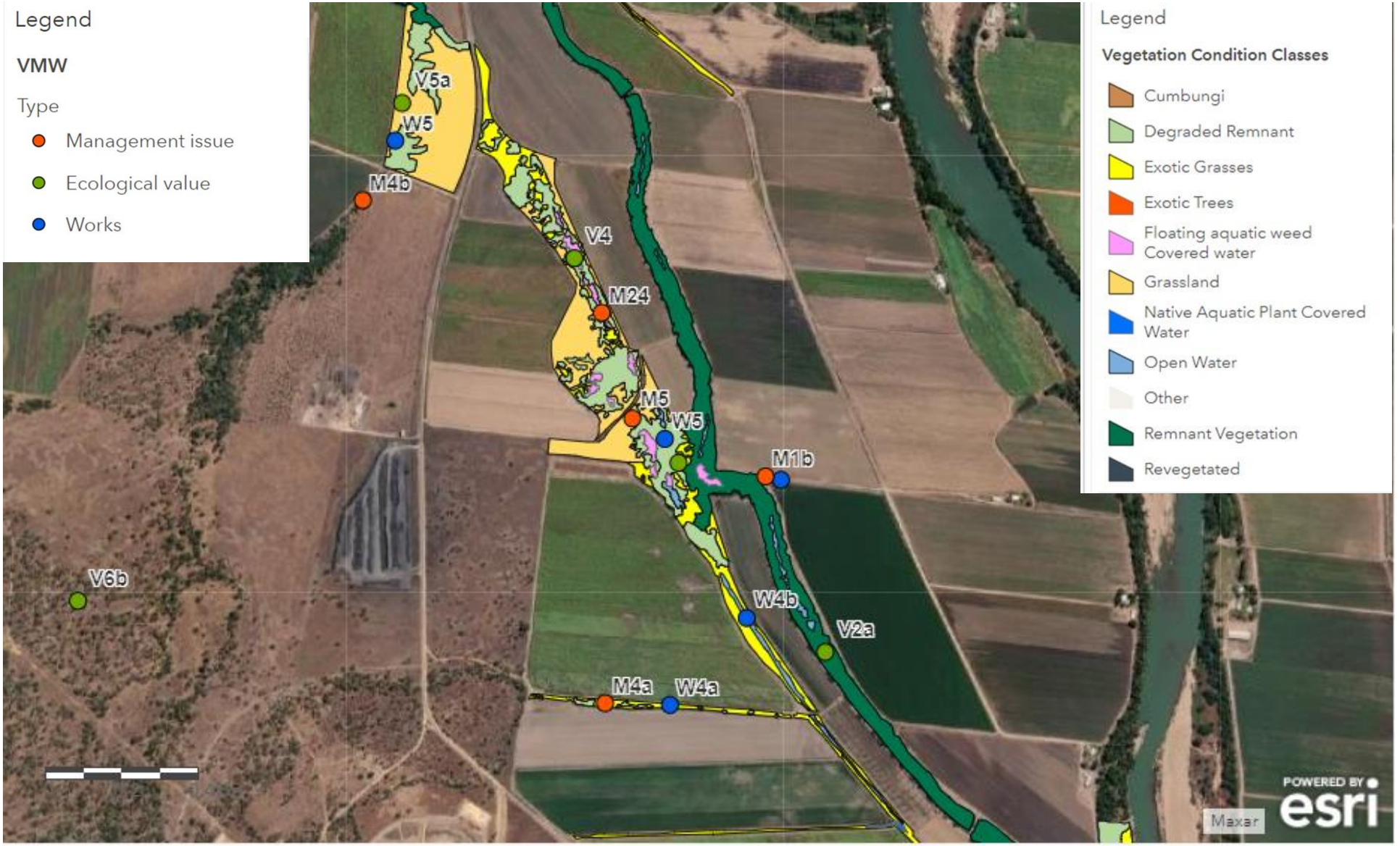
Short description – W7: Revegetation to reduce wildfire risk and rodent harbourage and create habitat.
Short description – W8: Revegetation to re-establish riparian habitat corridor connectivity.
Short description – W9: Providing improved fish passage at piped culvert road crossing.
Short description – W10: Investment in weed and fire risk management and assessment of public use options for Crown reserve habitat areas.
Short description – W11: Revegetation of Healey's Lagoon frontage.
Short description – W12: Revegetation of riparian habitat node.
Short description – W13: Assessment of channel reinstatement options and benefits.
Short description – W14: Revegetation protection of high flow breakout point.
Short description – W15: Riparian revegetation to establish shaded margin and additional habitat values on tributary lagoon.
Short description – W16: Management of regulated flow system to reinstate lagoon water level seasonality and reduce downstream seepage.
Short description – W17: Establish a rock ramp fishway to rectify piped culvert fish passage barrier present during baseflows.
Short description – W18: Establish a shaded vegetated fish passage channel in conjunction with regulated flow management.
Short description – W19: Extension of revegetated riparian corridor to create shaded open channel suitable for fish passage.
Short description – W20: Investigate and implement alternative means of irrigation water supply to downstream user to avoid need for reed beds supplementation.
Short description – **W21: Maintenance of salvinia bio-control weevil population recruitment in lagoon system.**
Short description – **W22: Document extent of candle cassia infestation in lower palm and occurrence in adjoining drainages.**

> Appendix 2 – Management plan map sheets separate attachments



MAP1

MAP 2



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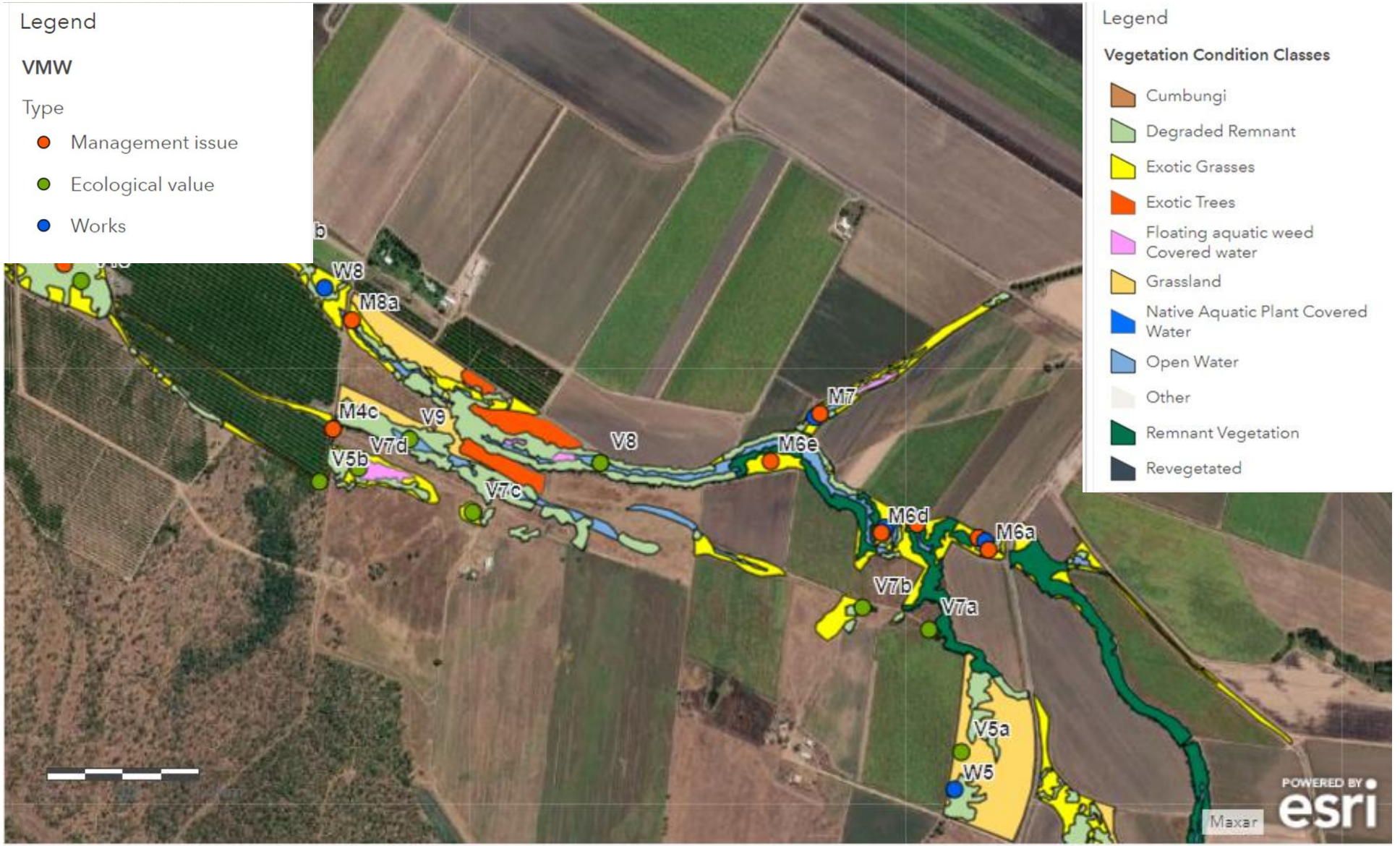

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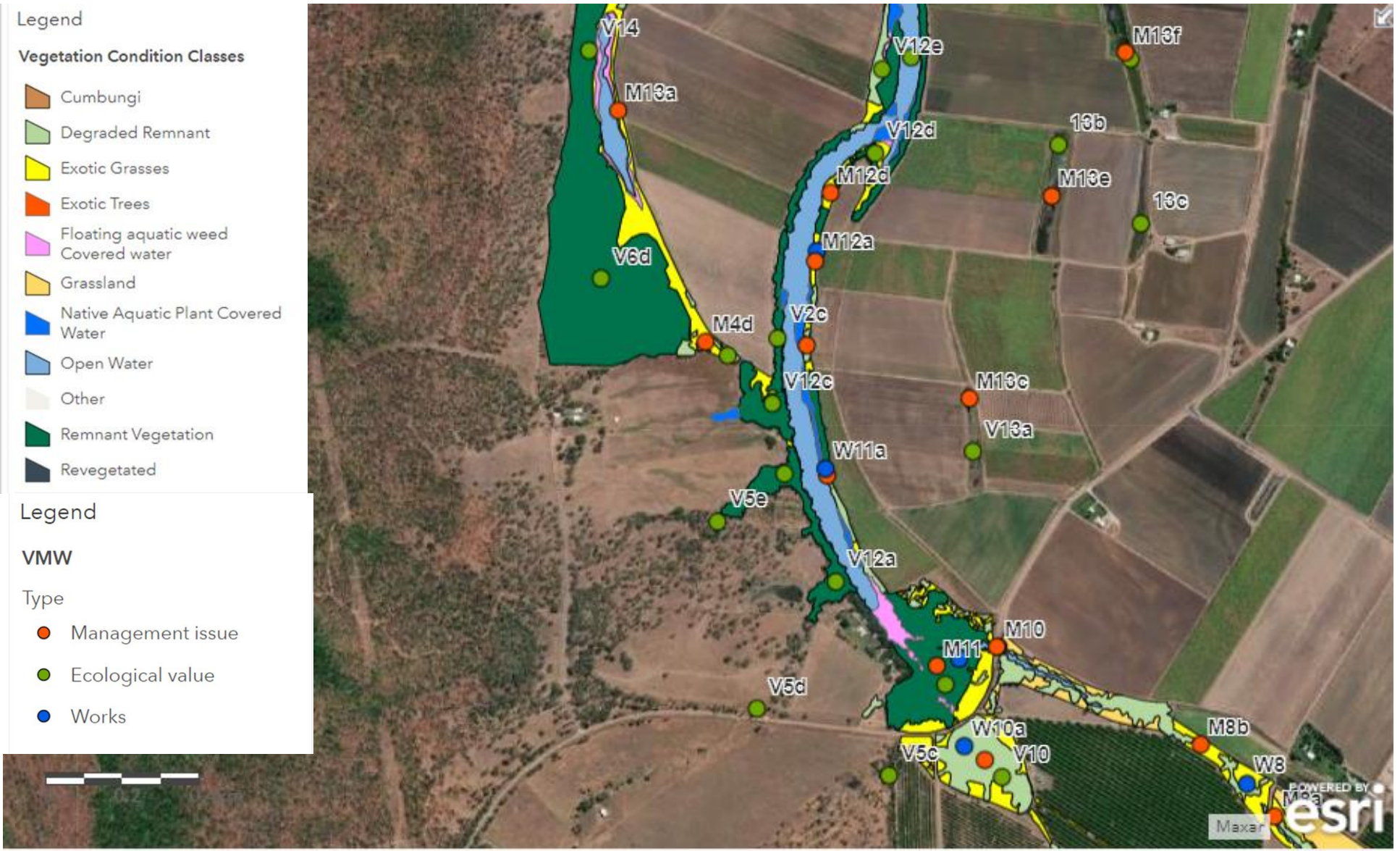
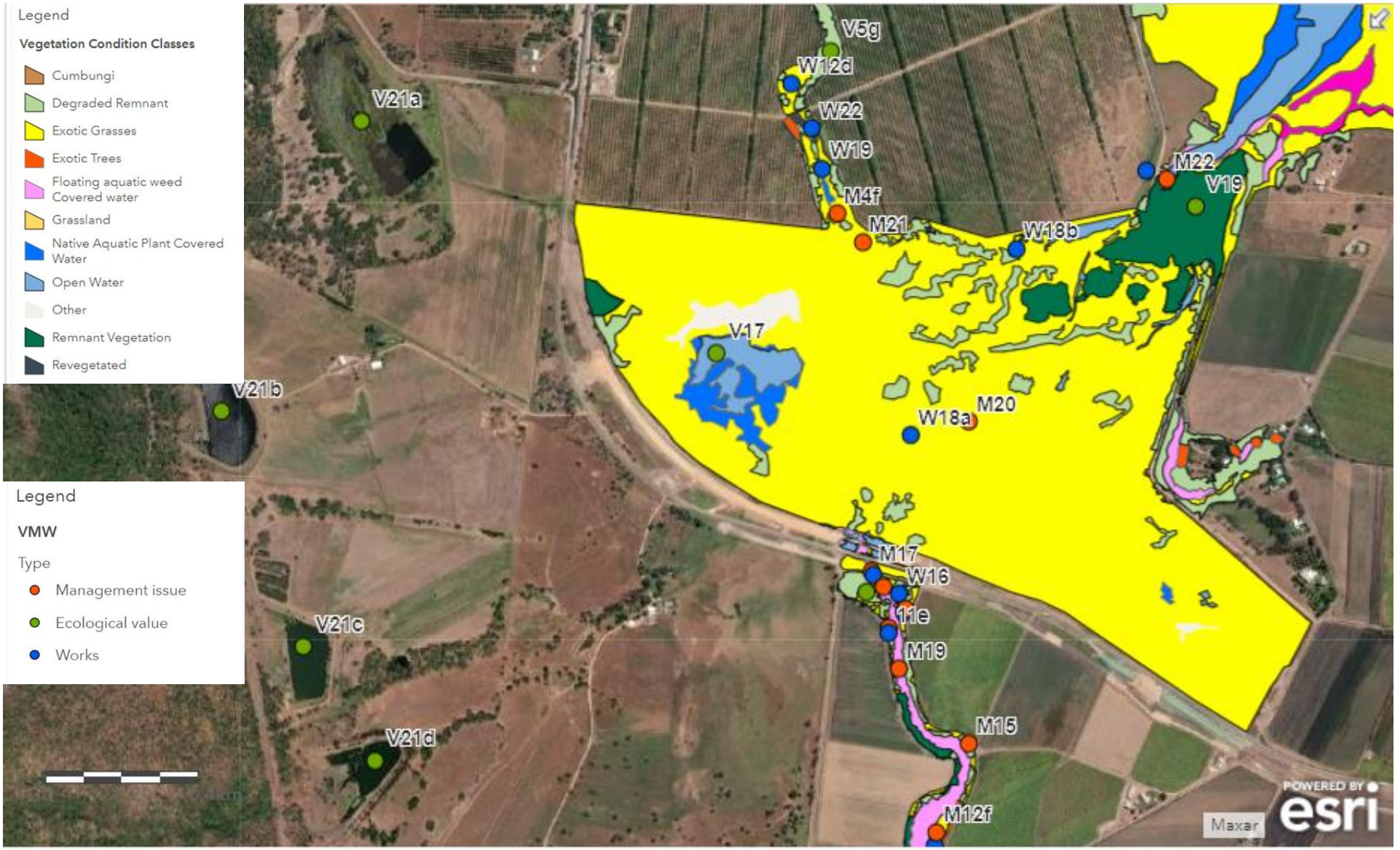


MAP 5

MAP 6



MAP 7

MAP 8