SUPPLEMENTARY AQUATIC ECOLOGY TECHNICAL REPORT

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Bowen Gas Project SREIS

AUSTRALIA

Supplementary Aquatic Ecology Technical Report

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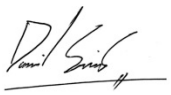
Approved by	Dan Simmons		14/04/2014	Senior Associate – Environmental Scientist

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1 INTRODUCTION AND OVERVIEW

1.1 Objectives

Changes to the Arrow Bowen Gas Project (the Project) description; or updates to relevant State or Commonwealth legislation since the submission of original Project Environmental Impact Statement (EIS) may potentially lead to new impacts from the proposed development. The objectives of this supplementary report are to:

1. Identify any potential environmental impacts and mitigation measures necessary to protect aquatic ecological values from revised Project activities.
2. Address particular submissions made following the public comment stage of the Project EIS.

The report:

- Summarises the aquatic studies completed for the Project EIS;
- Reviews changes to the Project description and any legislative changes relevant to aquatic ecology;
- Describes additional desktop investigations into aquatic values within the project area as necessary;
- Addresses public submissions on the Project EIS;
- Provides dossiers for conservation significant aquatic species known or likely to occur within the project area; and
- Identifies additional mitigation measures where impacts have been revised or identified.

1.2 Summary of Aquatic Ecology Studies Completed for the EIS

This section provides an overview of the aquatic ecological impact assessment completed for the Project EIS (Ecosure, 2012) and the main conclusions from that assessment.

The assessment identified and described aquatic ecology values within the Project development area through desktop research and field surveys in selected areas.

The previous EIS desktop study incorporated a detailed literature review and searches of government and non-government databases to inform the location of possible field survey sites and to broadly characterise the existing aquatic environment. Survey site selection was refined through field reconnaissance and consideration of physical and ecological factors. Aquatic field surveys were undertaken at 15 locations considered representative of the aquatic environment across the Project area. Of the sites surveyed, 13 were located within the Fitzroy Basin whilst only two suitable sites were identified and surveyed within the Burdekin Basin. Each survey site was sampled and surveyed for the following:

- Physico-chemical water quality parameters;
- Aquatic flora (macrophytes);
- Fish assemblages;
- Aquatic macroinvertebrates and macro crustaceans; and

- Turtles.

Data from the field surveys was described and included information such as aquatic flora and fauna species abundance and richness. Results from the desktop review and field surveys were used to summarise existing aquatic environmental values and discuss the sensitivity of these values to change.

1.2.1 Aquatic Ecosystems

Aquatic ecosystems within the Project area were found to be in moderately good health. Macroinvertebrate assemblages from pool beds and edge habitats were comparable and both assemblages were found to be typical of ecosystems exposed to low to moderate disturbance typical of land use in the area. The desktop and field investigations did not reveal any macroinvertebrate species (including crustaceans) of conservation value.

Fish assemblages within the Project area were relatively species poor and were dominated by a small number of taxa. The Mackenzie River was found to have the greatest number of fish species (13) recorded during a single survey. No fish species listed under State or Commonwealth legislation were recorded during field studies. However, three recorded fish species are endemic to the Fitzroy River Basin and are therefore of some conservation concern, including:

- *Macquaria ambigua oriens* (golden perch);
- *Scleropages leichardtii* (southern saratoga); and
- *Scortum hilli* (leathery grunter).

No turtle species of conservation value were recorded during the field surveys. Two species identified during desktop searches are considered possible occurrences, particularly within the Mackenzie River which is known habitat to both species:

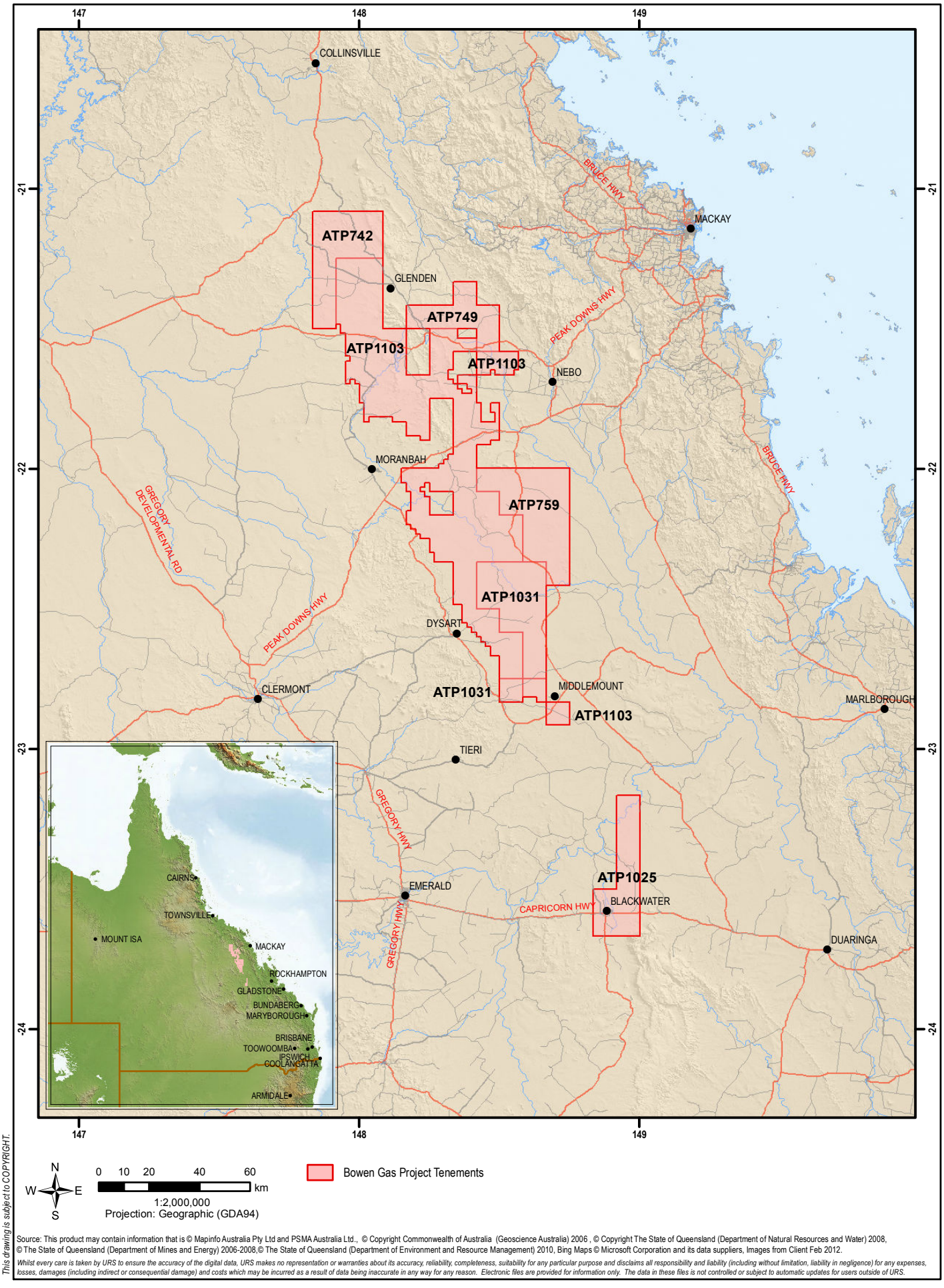
- *Rheodytes leukops* (Fitzroy river turtle); and
- *Elseya albugula* (southern snapping turtle).

Potential impacts from Project activities (construction, operation and decommissioning), identified by the EIS aquatic ecology impact assessment included:

- Degradation of water quality and smothering of benthic habitat from erosion and sediment transport processes;
- Loss of riparian or aquatic vegetation;
- Contamination of waterways resulting from fuel, oil or chemical spills;
- Altered surface water hydrology; and
- Spread and proliferation of pest species.

Commitments relating to minimising impacts to ecological values were developed and outlined in the Aquatic Ecology chapter (Section 16) and the Environmental Management Plan (Appendix Z) of the EIS. These commitments are still relevant to the Project and this SREIS. Commitments made during the EIS, were reviewed and incorporated into the potential impact and mitigation measures identified in Sections 5 and 6. The EIS outlines that the application of

buffers around riparian zones and the strategic timing of unavoidable works within buffer zones during the dry season is the primary means in which protection for aquatic ecology values will be achieved.



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GEOGRAPHICAL CONTEXT OF THE PROJECT AREA

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2 REGULATORY FRAMEWORK

The Aquatic Ecology Technical Report (Appendix O) of the EIS detailed the Commonwealth and State legislation, policy and guidelines relevant to the Project. A review was conducted of the legislation, policy and guidelines cited to determine if any changes had been made subsequently that could affect approvals or environmental permitting for the Project.

2.1 Queensland Government

The following Queensland Acts were reviewed as part of the EIS:

- *Environmental Protection Act 1994* (Qld);
- *Fisheries Act 1994* (Qld);
  - Fisheries Regulation 2008
  - Fisheries (Freshwater Management Plan) 1999
  - Fish Habitat Management Operational Policy (FHMOP 008) 2009
- *Nature Conservation (NC) Act 1992* (Qld); and
- *Land Protection (Pest and Stock Route Management) Act 2002* (Qld).

Other

- Draft Code of Environmental Compliance for Level 2 Petroleum Activities.

No changes to these Acts or guidelines relevant to the Project were identified.

2.2 Commonwealth Government

Commonwealth legislation reviewed as part of the EIS was restricted to the EPBC Act (1999). No changes to this Act relevant to the Project were identified.

2.3 Non-statutory Mechanisms

The following non-statutory mechanisms were reviewed as part of the EIS:

- Establishing environmental values and water quality objectives for the Fitzroy Basin Waters (2010);
- Fish Water Quality Guidelines for Fitzroy Freshwaters 2011 (DERM);
- Fitzroy River Sub-basin Environmental Values and Water Quality Objectives 2011 (DERM);
- Isaac River Sub-basin Environmental Values and Water Quality Objectives 2011 (DERM); and
- Mackenzie River Environmental Values and Water Quality Objectives 2011 (DERM).

No changes to these Acts or guidelines relevant to the Project were identified.

3 CHANGES IN PROJECT DESCRIPTION OF RELEVANCE TO AQUATIC ECOLOGY

A conceptual description of the Project was prepared to inform the EIS. This initial project description formed the basis for which initial baseline environmental studies were undertaken and guided the impact assessment studies conducted.

Since publication of the EIS for public comment in Q1 2013, Arrow's field development plan and conceptual design for the Project has advanced. This progression is the result of ongoing exploration activities that have improved Arrow's understanding of the gas resource, and the progress of Arrow's planning process.

Table 3-1 below details the changes to the project description relevant to aquatic ecology since the release of the EIS. This is an excerpt of the Project changes presented in the Project Description chapter (Section 3, Table 3-1) of the SREIS that relate to potential changes in impact extent on aquatic ecology values. The particular changes are discussed further in Section 5.

Table 3-1 Project changes since release of the EIS relevant to aquatic ecology

EIS Project Description	Description of Change (in SREIS)
Production facility locations were assumed to be located somewhere near the centre of each development area (**17** in total) of **12 km radius**.	The number of development (or drainage) areas has increased to **33** in total, however; each of these drainage areas now represent an approximate **6 km radius** catchment area for gathering well production (gas and water), and distributing to surface production facilities located at or near the centre of drainage area.
6,625 production wells were expected to be drilled throughout the Project area over the approximate 40 year Project life to maintain gas supply to the LNG plant.	Approximately **4,000 production wells** will be drilled throughout the Project area over life of the Project (approximately 40 years) to maintain gas feed to the LNG plant.
Total associated water volume to be extracted over the life of the Project is estimated at approximately **264,300 ML (over 40 years)** Average production = **7 GL/a** Peak production = **10 GL/a**	Estimated total water produced will be **153,000 ML (averages over 36 years** exclusive of 4 year ramp down period**)** Average production = **4.25 GL/a** Peak production = **10.4 GL**
The term integrated processing facility (IPF) was used in the EIS to describe the facility that would contain both gas compression and processing equipment and also a water treatment facility (WTF). The EIS presented the following dam sizes (per WTF): • Aggregation dam – 600 ML • Treated water dam – 600 ML • Brine dam (x2) – 960 ML	For the SREIS, the term 'IPF' is no longer considered and the WTFs will be co-located with the two central gas processing facility (CGPFs) with the potential of a 3rd WTF to be constructed near Blackwater at later stages of the Project. As part of the SREIS reference case and for planning purposes, the following preliminary dam sizing (per WTF) has been adopted (based on a nominal facility throughput of 20 ML/d): • Associated water storage (feed) dam – up to 400 ML (providing a minimum of 20 days storage) • Clear (treated) water dam – 600 ML • Brine storage dam(s) – 1,800 ML

3.1 Disposal of Coal Seam Gas Water

Disposal of coal seam gas (CSG) water may be necessary when beneficial use options are not economically and technically feasible, or in the case of residual volumes which are those volumes of CSG water that cannot be feasibly managed through beneficial use due to operational, technical, environmental or economic constraints. Previously the EIS disposal options included discharge to watercourses, injection into suitable formations and discharge to the ocean. However, the conceptual development of the Project has progressed and eliminated the options; injection to suitable formations and discharge to the ocean, see the Project Description chapter (Section 3) of the SREIS for more detail.

3.1.1 Discharge of Coal Seam Gas Water to Watercourses

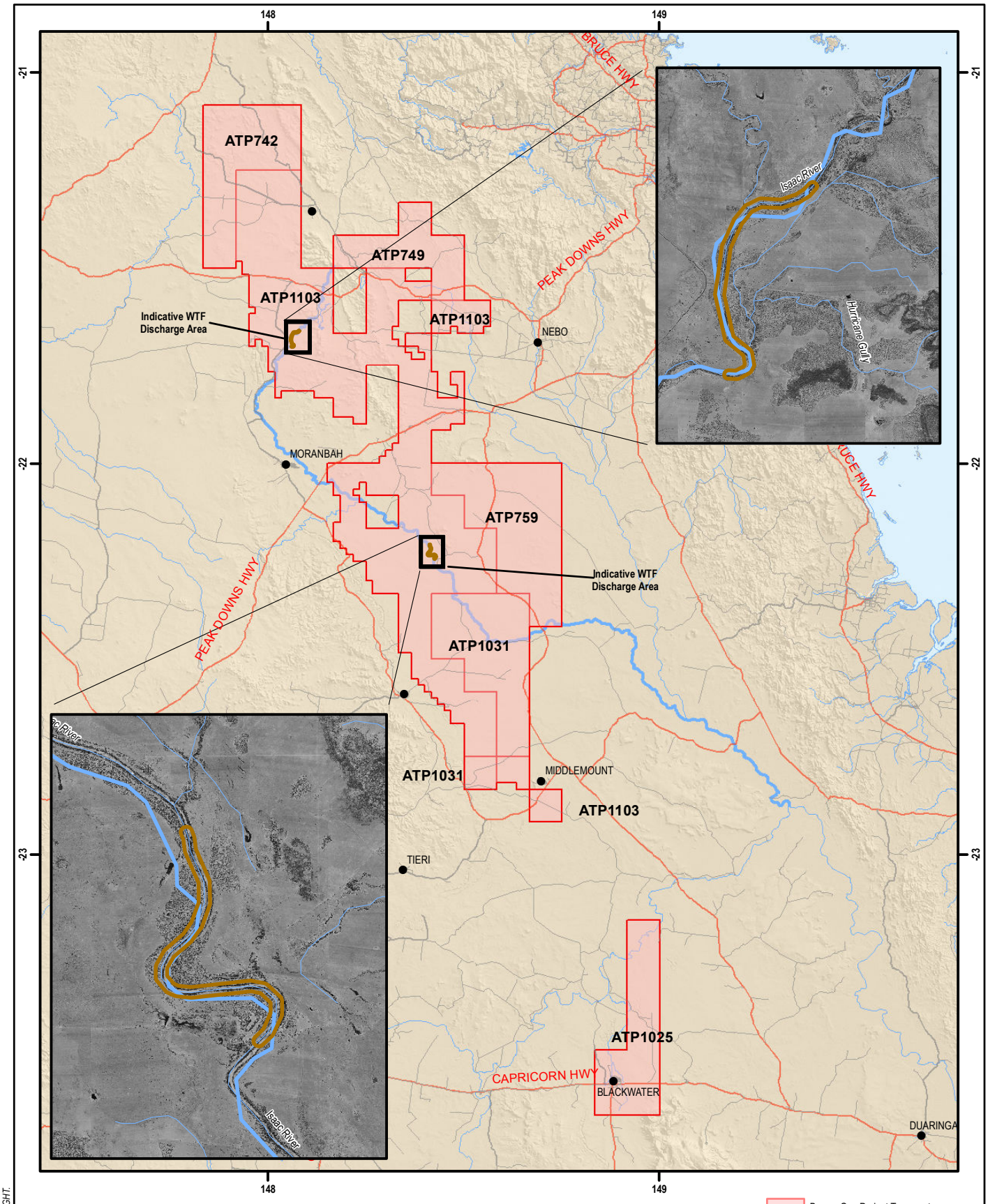
Management of residual volumes via discharge to a watercourse may be necessary to ensure that CSG production can continue during times where:

- Constraints to supply for beneficial use occur;
- Unforeseen events occur such as significant weather events;
- Operational upset conditions necessitate discharge; and
- The structural and operational integrity of dams is at risk.

Discharge to watercourses would occur within environmental flow requirements determined by further assessments and in accordance with the relevant approval. The Surface Water chapter (Section 8) of the SREIS outlines the results of a discharge assessment which determined the capacity of the tentatively identified receiving environment to accept any CSG water discharges.

The study areas to characterise the values of the Isaac River focused on indicative reaches associated with potential WTF areas. Reaches of the Isaac River in which this report investigates are presented in Figure 3-1.

The potential impacts to aquatic ecological values from the Project description changes listed above, as well as potential discharge of CSG water to watercourses are addressed in this report. Site specific assessment will be undertaken as part of the site specific environmental approvals (EA) process once development plans are confirmed.



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BOWEN GAS PROJECT SREIS

STUDY AREAS FOR POTENTIAL WATER TREATMENT FACILITY LOCATIONS

4 UPDATES TO EIS FINDINGS

4.1 Submission Responses

Submissions received during the public consultation stage of the EIS raised concerns that the occurrence of wetlands within the Project area and associated impacts from Project activities were not adequately assessed in the EIS (Submission issues 190, 192, 193 and 194).

Submissions received also raised queries regarding the number of sampling sites used to derive baseline conditions for aquatic ecosystems (Submission issue 229). Issue 229 also states that "No commitment to conduct site-specific impact assessments where disposal to watercourses is to occur appears in the EIS".

Additional to the above, Submission issues 229 and 230 raise queries regarding the sensitivity of species to changes in water quality or flow as a result of Project activities. Submission issue 230 states "Significant impacts to aquatic ecosystems may occur when severe impacts occur on species that are not necessarily listed as endangered, threatened or vulnerable".

The responses to these submissions are provided in the Submission Responses chapter (Section 21) of the SREIS. Additional discussion is provided below.

4.2 Wetlands

A submission suggested that a revised assessment of impacts on wetlands within the Project area be undertaken. This section presents the results of the revised desktop review of publically available data sets and GIS mapping layers associated with wetlands, including:

- Queensland Wetland Mapping version 3;
- Ramsar Convention on Wetlands;
- Directory of Important Wetlands of Australia;
- Map of referable wetlands;
- Department of Environment and Resource Management (DERM) (now DEHP) report on Aquatic Conservation Assessments (ACA), using AquaBAMM, for the non-riverine and riverine wetlands of the Great Barrier Reef catchment (Rollason and Howell, 2012); and
- Wetlandinfo.

The review initially identified 109 riverine and 423 non-riverine wetlands incorporating a range of wetland types (described in Section 4.3.1), varying in ecological value. These wetlands incorporate riverine systems such as the Isaac River and non-riverine wetlands (lacustrine and palustrine wetlands) that range from modified dams to vegetated swamps.

Wetlands within the Project area are mapped and/or listed within numerous data sources (listed above) and, may occur more than once across the data sets. However, the Aquatic Conservation Assessments of the Fitzroy and Burdekin catchments encompass all wetlands identified from other datasets (such as referable wetlands). For this reason, particular attention was applied to this dataset, with recognition of other datasets given due to differing legislative purpose.

The analysis of wetland mapping identified that, of the listed wetlands, 66 riverine and 191 non-riverine wetlands occur within the Project gas drainage areas (focus areas for field development). Of the wetlands identified within gas drainage areas, 14 riverine and 29 non-riverine wetlands are identified as high or very high ecological value under EHP's AquaBAMM classification. An assessment of the identified wetlands within the Project area (Section 4.2.1 to Section 4.2.4) and gas drainage areas (Section 4.2.4.5) is outlined below. The potential impacts on these wetlands was assessed (Section 5.2) and mitigation measures from the EIS reviewed (Section 6.2).

Wetlands identified as supporting very high or high ecological value during the revised desktop review have been incorporated into Arrow's Risk Based Management Framework and Constraints Mapping. This will ensure that wetlands within the Project area are identified during the preliminary planning stages allowing for avoidance and mitigation management measures to be applied.

The results of the impact assessment identified no residual significant impacts on wetlands and associated aquatic values when mitigation measures such as the use of buffers (from construction) and ground-truthing surveys are implemented.

Wetlands within the Project area and associated gas drainage areas are presented in Sections 4.2.1, 4.2.2, 4.2.3 and 4.2.4 below.

4.2.1 Queensland Wetland Mapping

The Queensland DEHP defines wetlands as (DEHP, 2013):

"…areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres. To be a wetland the area must have one or more of the following attributes:

- *at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or*
- *the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or*
- *the substratum is not soil and is saturated with water, or covered by water at some time*."

A review of publically available wetland mapping layers identified the presence of lacustrine, palustrine and riverine wetlands. These are defined below:

- Lacustrine wetlands - are large, open, water-dominated systems (for example, lakes) larger than eight hectares. This definition also applies to modified systems (for example, dams), which are similar to lacustrine systems (for example, deep, standing or slow-moving waters).
- Palustrine wetlands - are primarily vegetated non-channel environments of less than eight hectares. They include billabongs, swamps, bogs, springs, soaks etc., and have more than 30% emergent vegetation.
- Riverine wetlands - are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water.

With respect to above, the following number of wetlands are mapped within the Project area:

- 454 lacustrine wetlands;
- 411 palustrine wetlands; and
- 109 riverine wetlands.

These wetlands are captured in a range of wetland mapping and conservation assessment tools such as AquaBAMM and the Map of Referable Wetlands.

Details of ecologically significant wetlands are discussed below.

4.2.2 Ramsar Convention and the Directory of Important Wetlands in Australia

A search of wetlands listed under legislation and/or international agreements was undertaken and include the Ramsar Convention on Wetlands and the Directory of Important Wetlands in Australia.

Lake Elphinstone is listed on the Directory of Important Wetlands and occurs adjacent to the Project area (approximately 100 m). No wetlands listed under the Ramsar convention or Directory of Important Wetlands in Australia are mapped within the Project area. A detailed impact assessment for potential impacts on Lake Elphinstone with regard to groundwater outside of the project area is outlined in the supplementary Groundwater Technical Report (Appendix E) of the SREIS.

4.2.3 Map of Referable Wetlands

EHP has undertaken a comprehensive mapping exercise for wetlands of high ecological significance (HES) and general ecological significance (GES) across Queensland. Statutory protection of these wetlands falls under the State Development Assessment Provisions (Module 11) which seeks to ensure that development is planned, designed, constructed and operated so as to not cause harm to the hydrology of wetlands in wetland protection areas (WPA) that protect matters of national and state environmental significance including the outstanding universal values of the Great Barrier Reef (GBR).

Within the Project area 37 wetlands were categorised as having HES under EHP‘s AquaBAMM classification.

Given this, the location of wetlands and the associated potential impacts are equivalent to that identified below from review of the Aquatic Conservation Assessments (ACAs) for the Fitzroy and Burdekin catchments.

4.2.4 Aquatic Conservation Assessments

Aquatic conservation assessments were undertaken using the AquaBAMM methodology for wetlands. AquaBAMM is a decision support tool that utilises existing information and expert input to assess conservation value in aquatic ecosystems (Clayton *et al.*, 2006). It uses a robust and easily accessible analysis of ecological or conservation values associated with a catchment that is useful for subcatchment and regional planning (Clayton *et al.*, 2006). It is applicable in freshwater riverine, freshwater non-riverine and estuarine wetlands (Clayton et al., 2006).

The method is based on a review of national and international literature but tailored towards the local situation and a thorough assessment of data availability (Clayton *et al*., 2006). It uses a database platform for data storage, manipulation and values assessment and outputs directly to a GIS platform for result presentation and interpretation. The output is an aquatic conservation assessment (ACA) for the study area.

In order to assess each wetland comparatively, detailed information for a range of criteria and indicators is required. The criteria and indicators used to score a wetland are detailed in Appendix A of this report. Categories in which the criteria and indicators are weighted are summarised below:

- Naturalness aquatic – determines naturalness of aquatic features by accounting for the presence (or absence) of exotic flora and fauna, aquatic assemblages and habitat features. Water quality and hydrological modification is also included;
- Naturalness catchment – presence of exotic species, level of disturbance to riparian zone and overall catchment, flow modification;
- Diversity and richness – Species diversity including flora and aquatic fauna, richness of macroinvertebrates, habitat types and geomorphic features;
- Threatened species and ecosystems – presence of EPBC Act and NC Act listed aquatic species as well as presence of listed regional ecosystems or threatened ecological communities;
- Priority species and ecosystems – presence of aquatic ecosystem 'priority' fauna and flora, presence of or habitat for migratory species, habitat for significant numbers of waterbirds, presence of 'priority' aquatic ecosystems;
- Special features – presence of distinct or unique geomorphic features, ecological processes or special habitat. Presence of significant habitat (e.g. Ramsar wetlands) or presence of unique hydrological regimes; and
- Connectivity – Contribution to the maintenance of significant species or populations as well as the contribution of the wetland to other ecosystems such as groundwater dependent, floodplain and estuarine and marine ecosystems.

Once a wetland has been assessed against the criteria and indicators above, an Aqua score or conservation category is determined. Conservation categories are detailed below in Table 4-1.

Table 4-1 AquaBAMM Wetland Conservation Categories

Conservation Value Category	Definition[1]
Very High	These wetlands have very high values across all criteria (aquatic naturalness, catchment naturalness, diversity & richness, threatened species, special features and representativeness), or they have very high representativeness values in combination with very high aquatic naturalness, catchment naturalness or threatened species values. They may also be wetlands nominated by an expert panel for their very high special feature values, regardless of values across other criteria.
High	These wetlands are mainly those that have very high aquatic naturalness or representativeness values in combination respectively with very high/high

Conservation Value Category	Definition[1]
	threatened species values or very high diversity and richness values. Other combinations of very high or high values amongst the criteria may also indicate one of these wetlands.
Medium	These wetlands have varied combinations of high and medium values amongst the criteria.
Low	These wetlands have limited aquatic and catchment naturalness values. They have varied combinations of medium and low values amongst the other criteria.
Very Low	These wetlands have very limited or no aquatic and catchment naturalness values and they lack any other known significant value. They may also be wetlands that are largely data deficient.

1 – Definitions obtained from Clayton et al., (2006)

As well as scoring and categorising wetlands, the ACAs of the Fitzroy and Burdekin catchments identify and describe other aquatic values typical of the catchments, including:

- Special features and priority ecosystems;
- Aquatic species richness riverine and non-riverine wetlands;
- Aquatic flora and fauna recognised as priority wetland species; and
- Migratory fauna regarded as priority wetland species.

4.2.4.1 Wetlands Mapped Within the Project Area

The ACAs of the Fitzroy and Burdekin catchments have identified a number of wetlands within the Project area across all wetland ecological categories (Rollason and Howell, 2012). Table 4-2 below details the number of wetlands within each wetland ecological category within both riverine and non-riverine wetland types. Figure 4-1 depicts the wetlands within the Project area.

Table 4-2 Riverine and Non-riverine Wetlands within the Project area

Wetland Ecological Category	Riverine	Non-Riverine
Very High	8	10
High	18	38
Medium	77	290
Low	4	-
Very Low	2	85
Total	**109**	**423**

As detailed in Table 4-2 above, non-riverine wetlands regarded as having very high (10 total) or high (38 total) ecological value are mapped within the Project area. This equates to approximately 11 % of wetlands within the Project area.

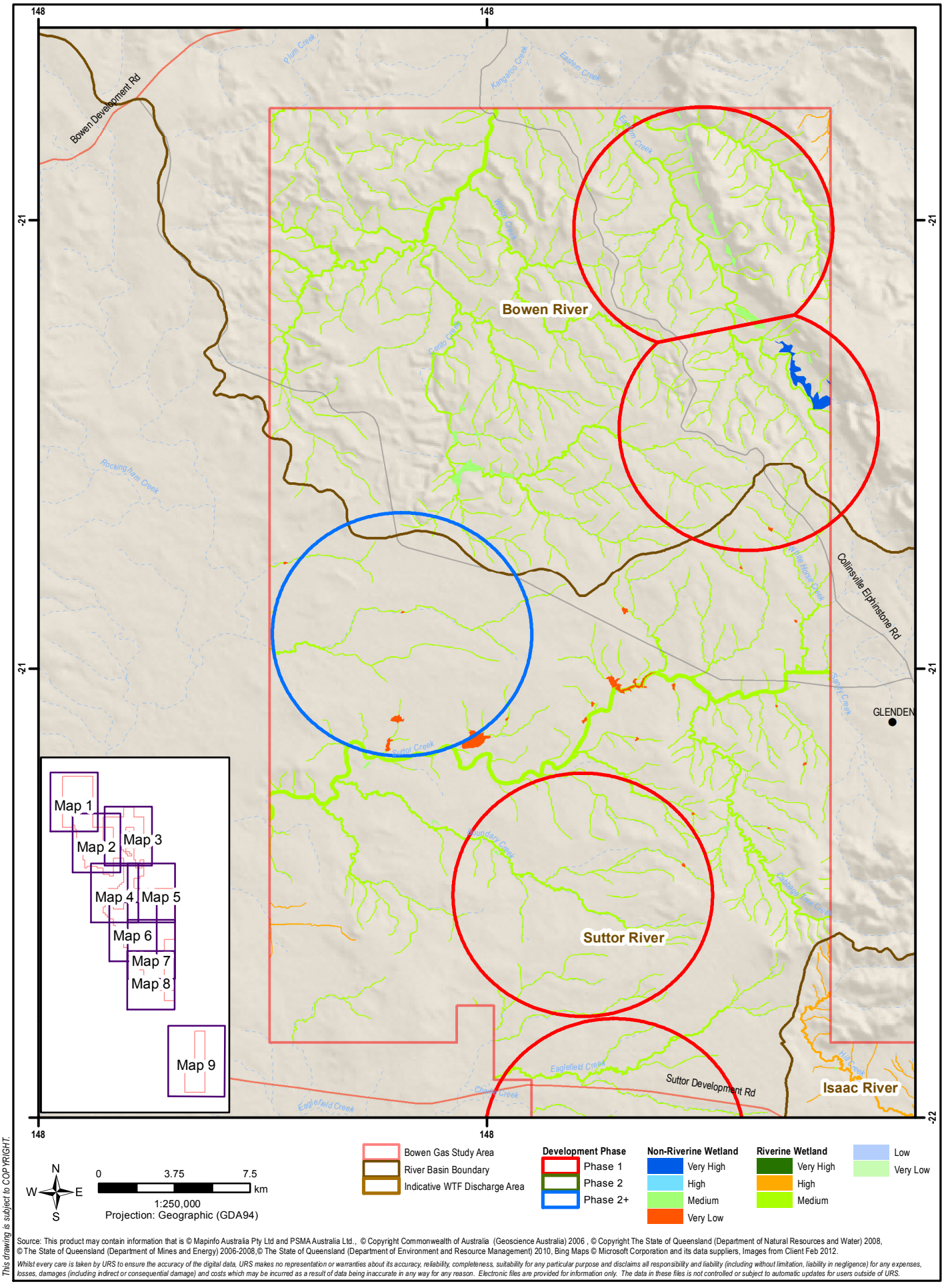
These wetlands are of conservational conservation value and incorporate referable wetlands which are mapped as wetland protection areas (e.g. regarded as HES wetlands) with high ecological significance).

Non-riverine wetlands which are scored as having medium ecological value (290 wetlands) comprise 68 % of the total non-riverine wetlands within the Project area. These wetlands are defined as wetlands which have varied combinations of high and medium values. Medium ecological value wetlands are not mapped as wetland protection areas on a map of referable wetlands.

Within the Project area, 85 low or very low non-riverine wetlands of ecological significance are mapped. These wetlands have limited or no aquatic and catchment values and lack other known significant values.

Within the Project area, riverine wetlands mapped as having very high or high ecological value total 8 and 18 respectively. Similarly to non-riverine wetlands, medium value riverine wetlands comprise 62 % of mapped wetlands within the Project area.

As detailed in Table 4-1, very high and high ecological valued wetlands support a range of aquatic values, including conservation significant species, high species diversity and richness, as well as high aquatic naturalness. Given this, the potential impact on these wetlands versus wetlands of medium ecological value or lower, have potential to be greater in significance. The potential impact on wetlands is detailed in Section 5.2, the mitigation measures and subsequent potential residual impacts are outlined in Section 6 and Section 7 respectively.



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WETLANDS AND DEVELOPMENT PHASES MAP 1

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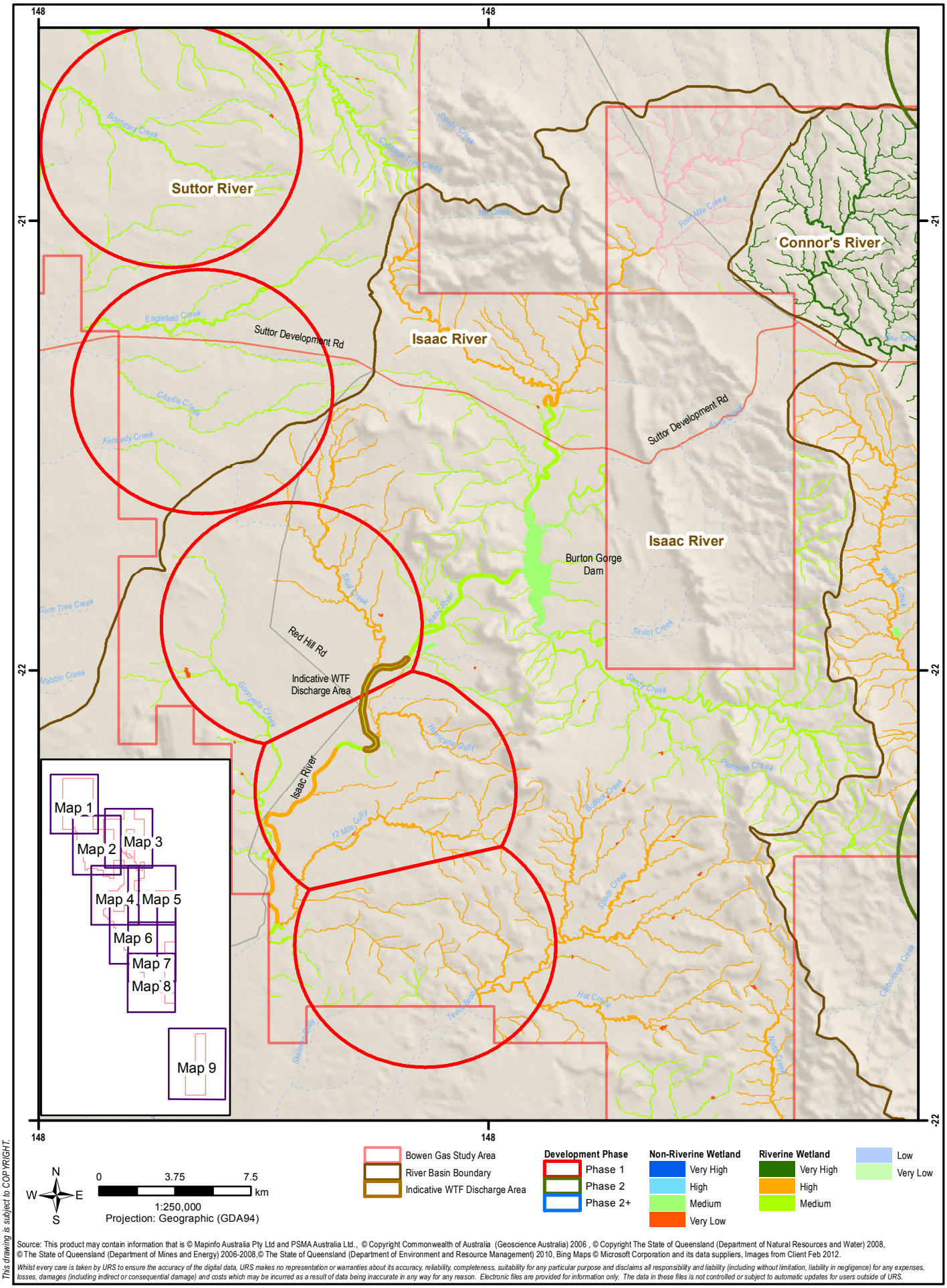

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WETLANDS AND DEVELOPMENT PHASES MAP 2

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AQUATIC ECOLOGY TECHNICAL REPORT

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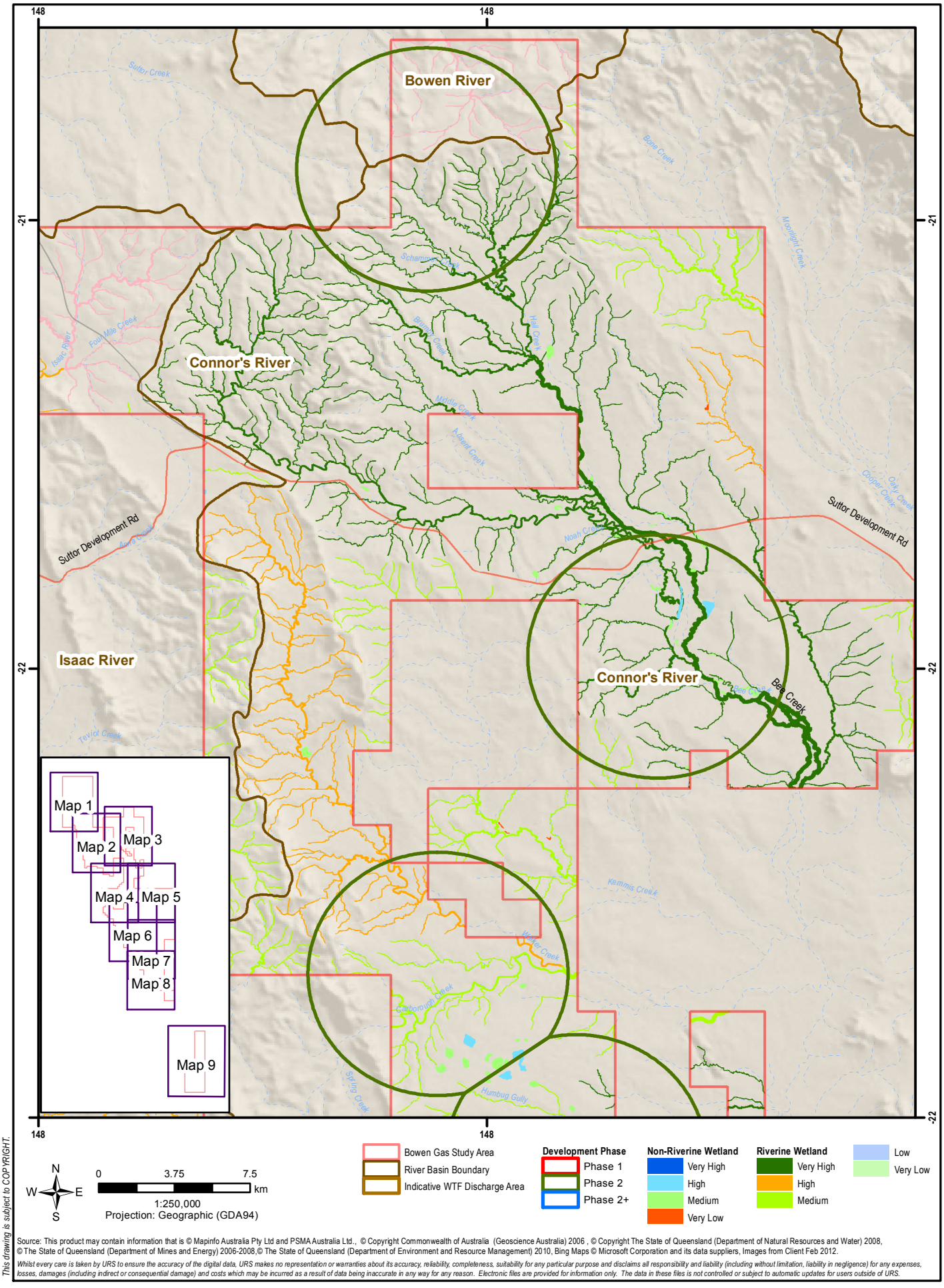

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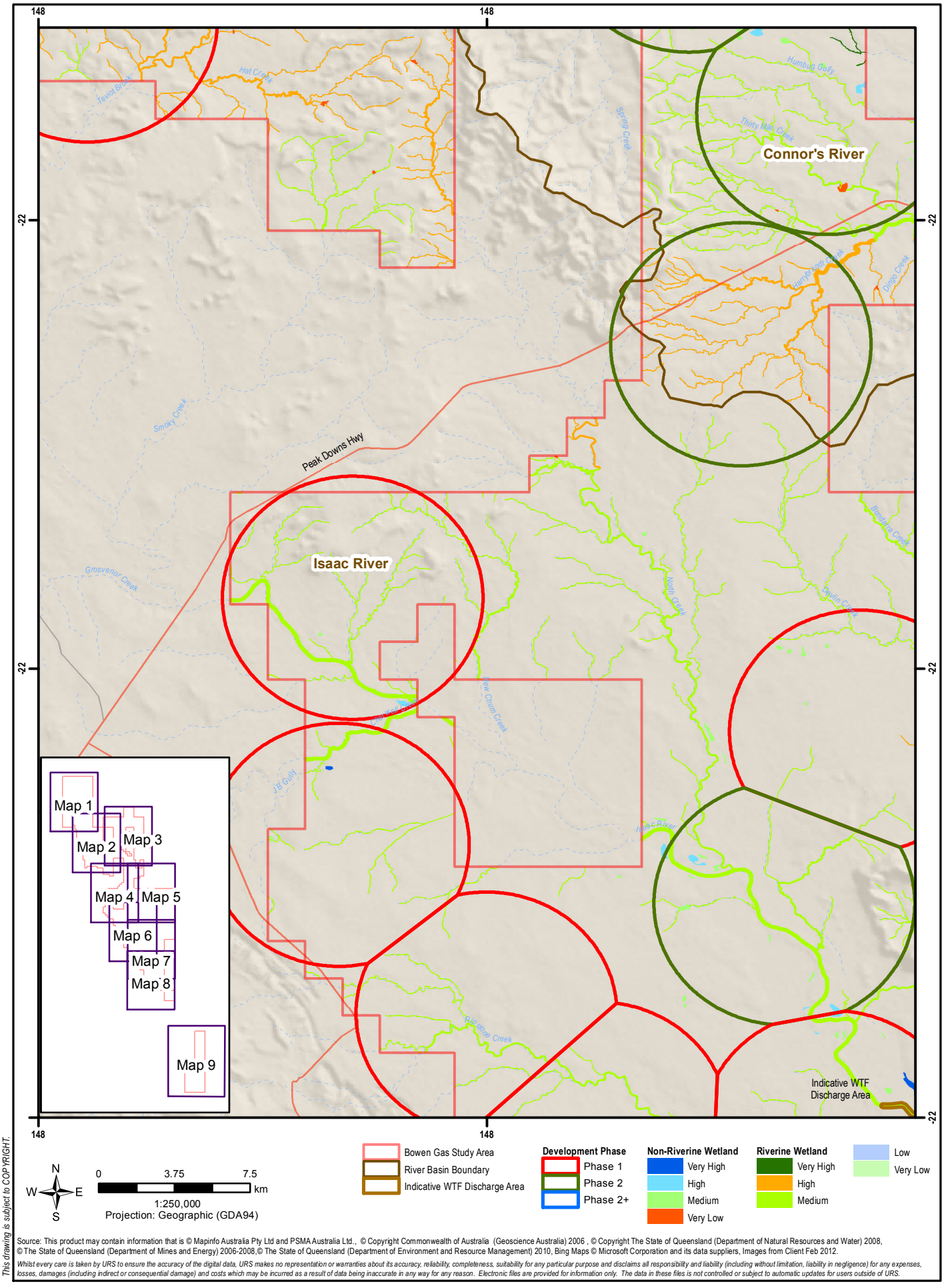
WETLANDS AND DEVELOPMENT PHASES MAP 3



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BOWEN GAS PROJECT SREIS

WETLANDS AND DEVELOPMENT PHASES MAP 4

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AQUATIC ECOLOGY TECHNICAL REPORT

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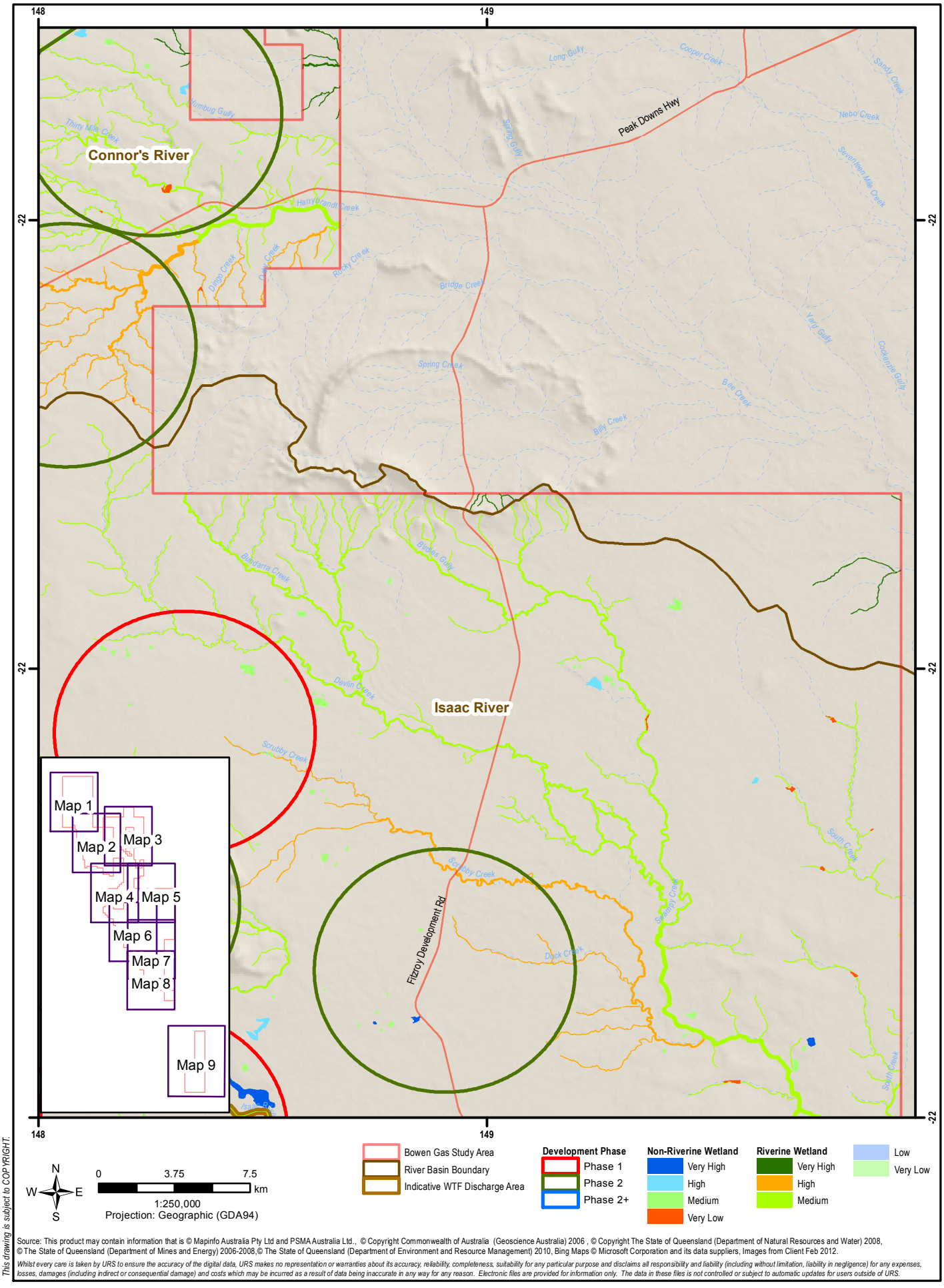

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BOWEN GAS PROJECT SREIS

WETLANDS AND DEVELOPMENT PHASES MAP 5

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AQUATIC ECOLOGY TECHNICAL REPORT

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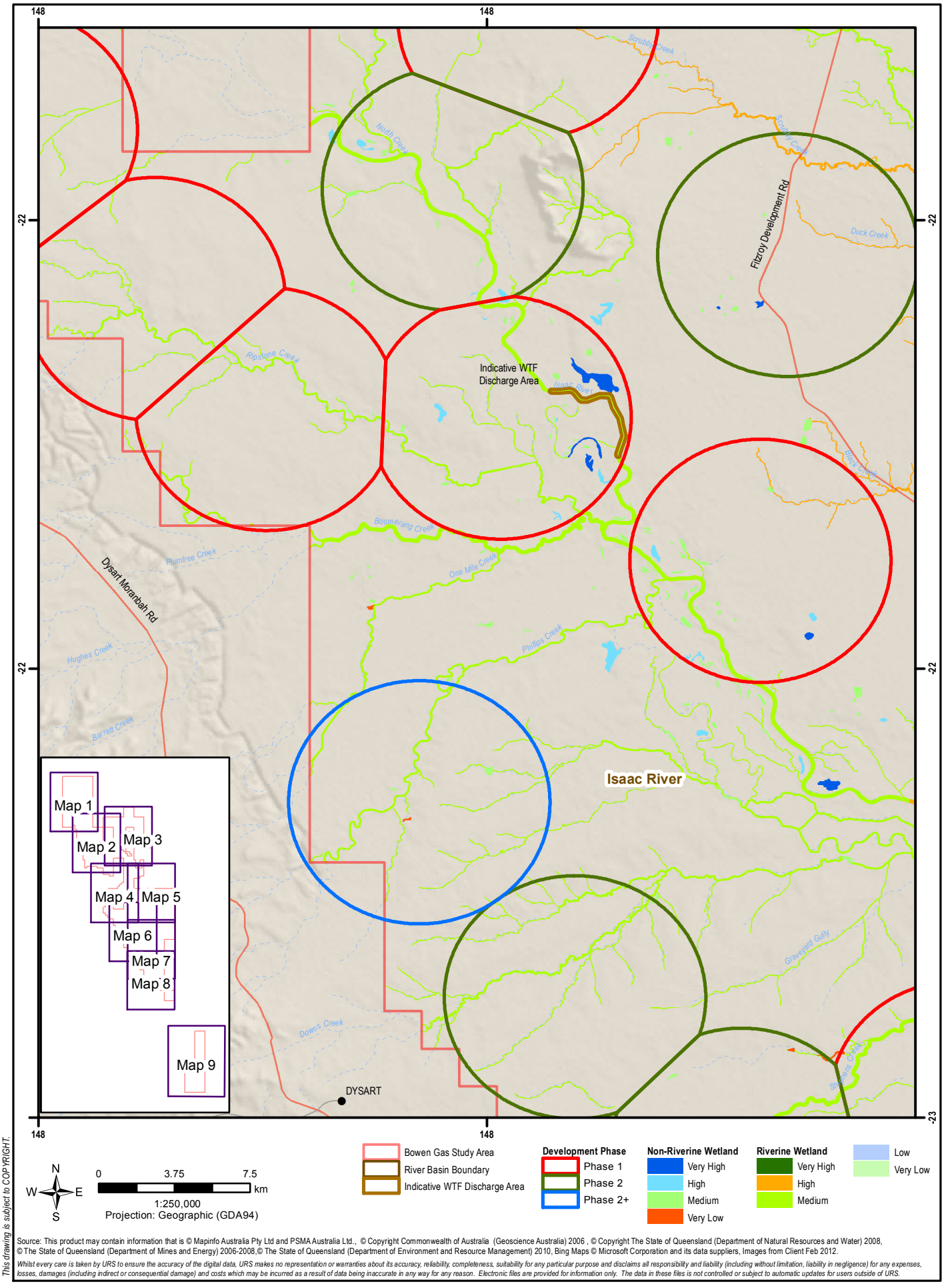

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BOWEN GAS PROJECT SREIS

WETLANDS AND DEVELOPMENT PHASES MAP 6

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AQUATIC ECOLOGY TECHNICAL REPORT

Figure: 4-1

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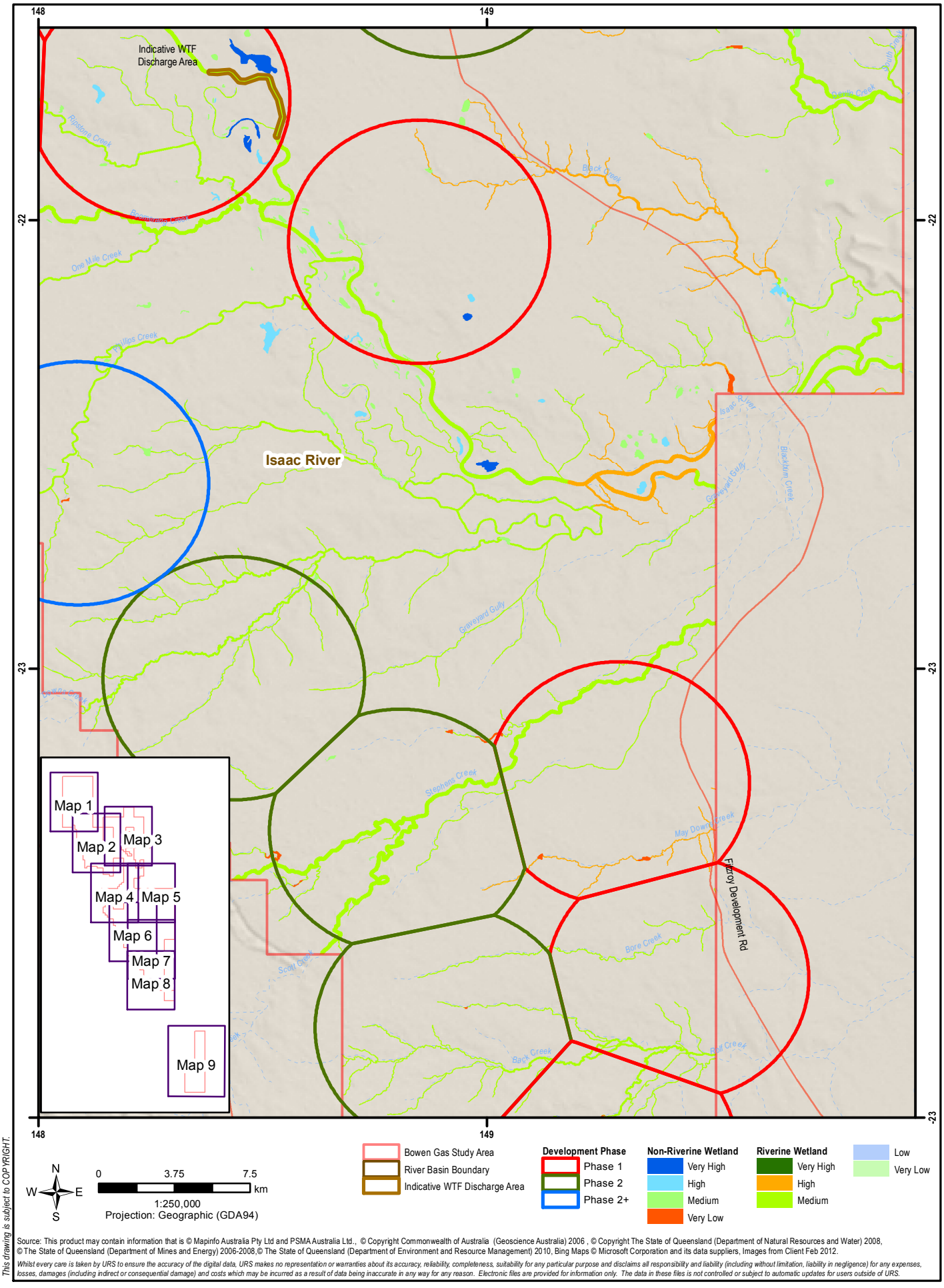

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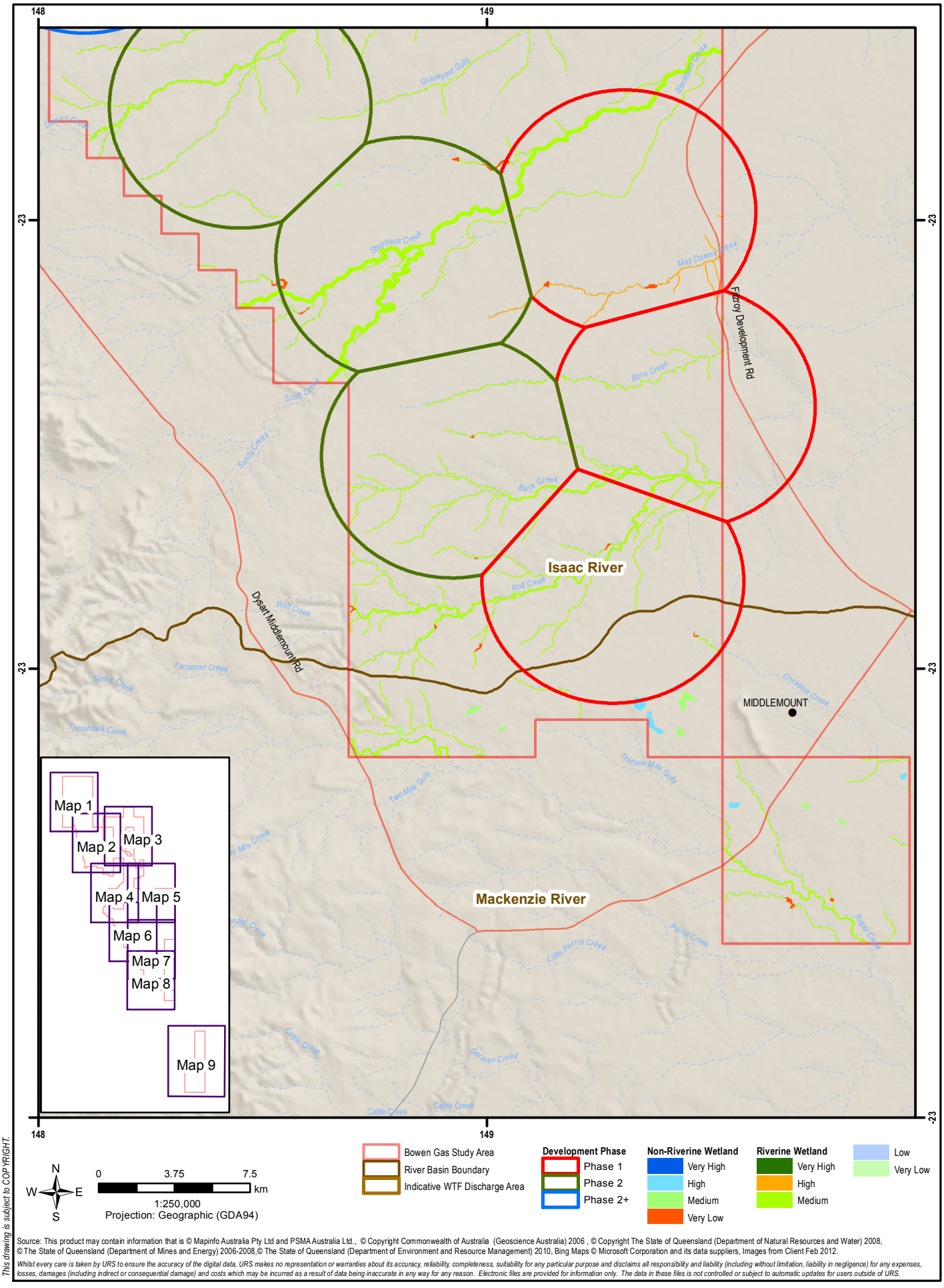
BOWEN GAS PROJECT SREIS

WETLANDS AND DEVELOPMENT PHASES MAP 7



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BOWEN GAS PROJECT SREIS

WETLANDS AND DEVELOPMENT PHASES MAP 8

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AQUATIC ECOLOGY TECHNICAL REPORT

Figure: 4-1

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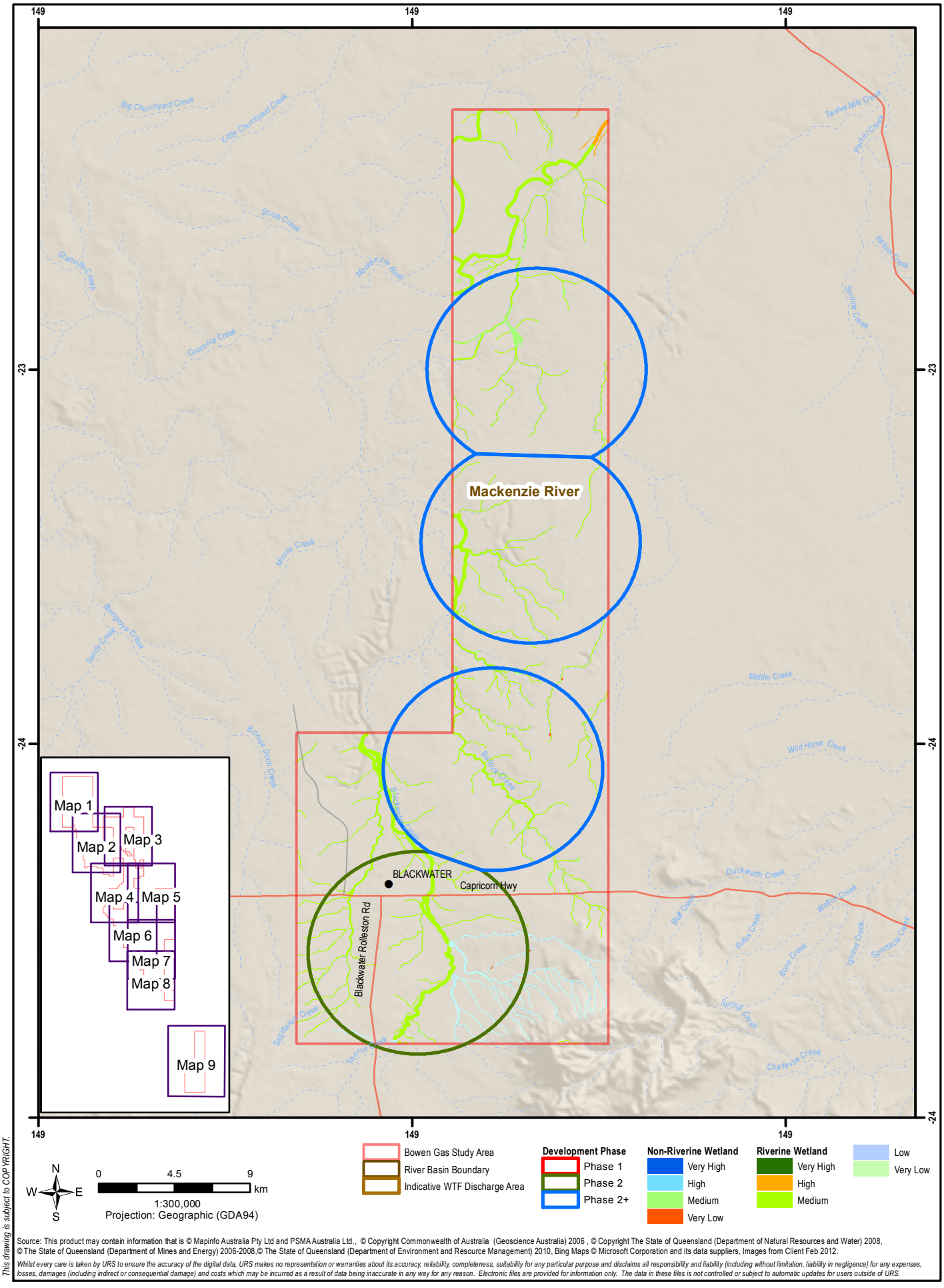

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BOWEN GAS PROJECT SREIS

WETLANDS AND DEVELOPMENT PHASES MAP 9

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AQUATIC ECOLOGY TECHNICAL REPORT

Figure: **4-1**

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4.2.4.2 *Priority Ecosystems and Special Features*

Priority ecosystems or special features within the Great Barrier Reef catchment were identified by expert panel review during the ACA. These areas were identified for their ecological values. Some special features nominated by either the aquatic flora and/or the aquatic fauna expert panels considered to have additional values (e.g. geomorphological or hydrological) were implemented as wetland ecology special features. Ecosystems identified within the ACA for the Fitzroy and Burdekin Catchment which are mapped within the Project area or have potential to be impacted include.

Table 4-3 Priority ecosystems and special features within the Project area

Special Feature	Identified Value[1]	Catchment	Relation to Project area
Denison Creek and Funnel Creek	The long, deep waterholes with paperbarks in this area support large numbers of platypus (*Ornithorhynchus anatinus*) and a mixture of fish species.	Fitzroy (Isaac sub catchment)	Occurs within 50 km of the Project area (east). Watercourses in the north east of the Project area flow into Funnel Creek.
Lake Elphinstone	Lake Elphinstone is listed on the Directory of Important Wetlands. The lake has unique geomorphology and is a good example of a sub-coastal lake that provides important habitat in the Fitzroy region. The lake is the largest natural freshwater body in Central Queensland.	Fitzroy (Isaac sub catchment)	Occurs within close proximity to the Project boundary (100 m).
Isaac River where it joins Mackenzie River down to Coolmaringa	This site has unique geomorphology and provides good habitat for saratoga.	Fitzroy (Mackenzie sub catchment)	Isaac River flows through the Project area. Junction with Mackenzie approximately 50 km east of the Project area (downstream).

1 – Priority ecosystems and descriptions sourced from Rollason, S.N. and Howell, S. (2012).

Table 4-3 above, shows that priority ecosystems occur outside the Project area boundary. The potential for direct impacts on these wetlands from activities such as land clearing is unlikely. However, downstream impacts on the identified values, particularly the riverine systems (Isaac River, Denison Creek and Funnel Creek) may occur. General mitigation measures outlined in the Project EIS and in Section 6 will minimise impacts from the Project on these identified values.

4.2.4.3 *Aquatic Species Richness*

As detailed above, the ACAs of the Fitzroy and Burdekin Catchment assessed flora and fauna species richness in the riverine and non-riverine wetlands. The results of this assessment are presented below.

Table 4-4 Species richness within riverine and non-riverine wetlands

Richness	Fitzroy Catchment		Burdekin Catchment	
	Non-riverine	**Riverine**	**Non-riverine**	**Riverine**
flora species	175	167	132	54
exotic flora	91	91	16	17
native fish species	47	58	33	49
reptile species	10	14	13	19
waterbird species	82	48	95	44
amphibian species	8	10	40	27
mammal species	4	4	1	3
macroinvertebrate species	1	7	2	1
exotic fauna species	19	20	20	22

Species richness across non-riverine and riverine wetlands is similar across fauna taxa, with exceptions including waterbird and amphibian species which have greater representation with non-riverine wetlands. It is important to note that the species richness shown above is for the entire Fitzroy and Burdekin catchments and is only an indication of potential richness within the Project area.

Potential impacts on wetlands within the Project area include a reduction in species richness. However, mitigation measures detailed in Section 6 will minimise the risk of species richness being adversely affected from Project activities.

4.2.4.4 Priority Aquatic Flora and Fauna

Section 4.2.4 the ACAs for the Burdekin and Fitzroy Catchments have identified a number of priority aquatic flora and fauna species. Additionally, migratory fauna (as described in Section 4.2.4) are also considered priority species within the Burdekin and Fitzroy Catchments. The presence (and absence) of these species were included during the panel review of wetlands. A full list of priority aquatic flora and fauna (including migratory species) is presented in Appendix B of this report.

4.2.4.5 Current Field Development Planning

Field development planning has advanced since preparation of the EIS, with the overall Project development area now being separated into 33 smaller drainage areas. Each drainage area is a 6 km radius catchment area for gathering well production (gas and water) to surface production facilities located at or near the centre of the circle. Each of these centrally located surface production facilities is a field compression facility (FCF). The indicative locations of gas drainage areas are shown in Figure 4-1.

The application of the drainage area approach has allowed for a refined analysis of the number of wetlands potentially affected by the Project. The focus of development will occur within the drainage area, although the potential for impacts beyond the drainage area boundary has also been considered.

Thirty-three indicative drainage areas are located across the Project tenements. These have been scheduled for development across three distinct Phases; 1, 2 and 3.

Given the above, the number of wetlands mapped within the 33 drainage areas is outlined in Table 4-5 below.

Table 4-5 Wetlands mapped within the proposed drainage areas

Wetland Ecological Category	Riverine	Non-Riverine
Very High	4	8
High	10	21
Medium	49	134
Low	1	-
Very Low	2	28
Total	**66**	**191**

The potential impacts on wetlands from Project activities are detailed in Section 5 and the mitigation measures and subsequent potential Residual Impacts are outlined in Section 6 and Section 7 respectively.

4.3 Proposed Water Treatment Facility (WTF) development area (Moranbah)

At the time of this report, site specific data relating to the ecological characterisation of the Isaac River and associated environmental values for potential WTF discharge areas were unavailable. Numerous regionally specific studies have been reviewed to gain an appreciation of the reach of water way in the area of the proposed WTF localities.

Field assessments undertaken during the Bowen Gas Project EIS, coupled with existing data collected during numerous other EIS investigations and monitoring studies, provide useful information to generally characterise the reaches of the Isaac River within the footprint of the proposed WTF development areas. This information, although not site specific, allows for an understanding of the site conditions in order to estimate preliminary potential impacts from future development. The results of the literature review are provided below.

4.3.1 Description of Isaac River and habitat

The Isaac River is an ephemeral stream with a mobile sand bed. Instream habitat generally consists of intermittent pools and runs, with edgewaters providing habitat during flows. Substrate is dominated by coarse sand, with leaf litter forming the base of most pools. Few permanent pools exist, although natural rock formations do exist that provide semi-permanent habitat to aquatic species. URS (2011) describes the Isaac River as homogeneous throughout the Moranbah region with little natural variation. Localised differences in habitat may occur.

4.3.2 Fish

A survey was completed across 15 sites within the Project area as presented in the Aquatic Ecology Technical Report (Appendix O) for the EIS. Of the sampling effort from the EIS, two sampled sites correlate with the two study areas identified in this supplementary report to characterise the values of the Isaac River associated with potential WTF localities.

Sample site AQ10A is located slightly upstream of the northern survey reach of the Isaac River, and sample site AQ16 is located slightly downstream of the southern survey reach of the Isaac River associated with potential WTF localities..

Similarly, aquatic biodiversity data collected as a part of the BMA Red Hill EIS project focuses on the Isaac River (and tributaries) close to the study areas of the Isaac River associated with the potential WTF localities.

Additionally, numerous other monitoring studies undertaken by URS (2013) and WBM Oceanics (2005) also detail fish species observed in this area. Fish species documented to occur within the potential WTF localities are provided in Table 4-6 below.

Table 4-6 Fish species observed at relevant survey sites associated with the potential WTF localities

Species	Common Name	Bowen Gas Project EIS*		BMA Red Hill EIS
		WTF 1*	WTF 2**	WTF 1***
Ambassis agasizzii	Olive perchlet	✓	✓	✓
Craterochephalus stercusmuscarum	Fly-specked hardyhead	-	✓	-
Hypseleotris sp1	Midgley's carp gudgeon	-	✓	-
Leiopotherapan unicolor	Spangled perch	✓	✓	✓
Macquaria ambigua oriens	Golden perch	✓	✓	-
Melanotaenia splendida splendida	Eastern rainbowfish	✓	✓	✓
Mogurnda adspersa	Purple-spotted gudgeon	✓	-	✓
Nematalosa erebi	Bony bream	✓	✓	✓
Neosilurus hytilii	Hyrtle's tandan	✓	✓	✓
Oxyeleotris lineolata	Sleepy cod	✓	-	✓
Porochilus rendahli	Rendahl's catfish	✓	✓	-
Scortum hilii	Leathery grunter	✓	✓	-

* Data collated from site AQ10A (Arrow Bowen Gas EIS Appendix O)
** Data collated from site AQ16 (Arrow Bowen Gas EIS Appendix O)
*** Data collated from Isaac River sites – during late wet season (BMA Redhill EIS Appendix K)

No fish species recorded during recent surveys are listed as threatened. A total of 10 fish species were recorded within the vicinity of the northern reach of the Isaac River associated with the potential WTF locality. Similarly, ten fish species were recorded at the site close to the potential WTF locality near the southern reach area of the Isaac River study site. As shown above in Table 4-6, the community structure of the two sites is similar, differing by three species. It is expected that all fish species identified above will occur at both locations during periods of flow given the habitat features of the Isaac River are typically homogenous within the Moranbah region.

Earlier fish sampling undertaken by WBM Oceanics (2001; 2005) in a tributary upstream of Moranbah provides evidence that Western carp gudgeon (*Hyseleotris klunzingeri)* may also be present in the vicinity of the northern Isaac river reach associated with the potential WTF locality. Their presence in the Isaac River may be limited, as spawning sites are highly vulnerable to elevated or erratic flow regimes (Pusey *et al* 2004). *Hypseleotris sp1* and *Scortum hilii* were also noted in the 2005 fish survey. Pusey *et al* (2004) also indicates that a further three species, Barred grunter (*Amniataba percoides),* Mouth almighty (*Gossamia aption*) and Flathead gudgeon (*Philypnodon grandiceps*) may also be present in the study area as their spatial range overlaps the area.

Ecosure (2012) note the difference in both species diversity and abundance with seasonal flow regime in the Isaac River. Surveys conducted in October 2012 (early wet) and April 2013 (late wet) shows a decrease in species diversity, although an increase in relative abundance. For example, a total of two *Oxyeleotris lineolata* individuals were captured in the October 2012 sampling event, while 117 individuals were collected in the April 2013 sampling event.

Water quality tolerance

Different fish species display a range of water quality tolerances, often dependent upon localised conditions (Pusey *et al* 2004). Provided in Table 4-7 are the water quality ranges for sites within close vicinity of the northern and southern reaches of the Isaac River associated with the potential WTF localities.

These water quality results were sourced from the Arrow Bowen Gas EIS and BMA Redhill EIS investigations. Water quality tends to be quite variable, likely influenced by seasonal flows. Pusey *et al* (2004) provide published water quality tolerance ranges for the fish previously identified within the study area.

In general, water quality encountered at the sites is well within the tolerance ranges for most fish species; however the following exceptions are identified:

- Eastern Rainbowfish (*Melanotaenia splendida*): pH and electrical conductivity recorded during the recent Arrow Bowen Gas EIS slightly exceeds the maximum tolerance value; and
- Sleepy Cod (*Oxyeleotris lineolata*): electrical conductivity recorded during the recent Arrow Bowen Gas EIS greatly exceeds the maximum tolerance value.

Table 4-7 Water Quality Ranges recorded previously at survey sites close to the proposed WTF sites

Parameter	Bowen Gas Project EIS#		BMA Red Hill EIS
	WTF 1*	**WTF 2****	**WTF 1*****
Temperature (ºC)	Not available	Not available	14.1-20.7
Dissolved oxygen (%sat)	82-100	60-78	Not available
Dissolved oxygen (mg/L)	Not available	Not available	5.45-7.18
pH	8.4-8.5	8.2-8.45	5.1-8.4
Electrical Conductivity (µS/cm)	500-1400	450-480	752-909
Turbidity (NTU)	5-15	5--6	5-144

* Data collated from site AQ10A (Arrow Bowen Gas EIS, Appendix O)
** Data collated from site AQ16 (Arrow Bowen Gas EIS, Appendix O)
*** Data collated from Isaac River sites – during late wet season (BMA Redhill EIS, Appendix K)
# Values is approximate, as exact data was not available at the time of publication

4.3.3 Macroinvertebrates

Macroinvertebrates sampling from the recent Bowen Gas Project EIS identifies 18 taxa during both sampling seasons near the northern reach of the Isaac River associated with potential WTF localities. Sampling undertaken during the Red Hill EIS identifies 28 taxa from the similar area. Differences in total taxa may be attributable to stream flows (whether high or low) and macrophyte availability at the sample site. OE50 Signal scores assigned to the site are considered moderate, achieving an AusRivAS modelling banding of B. This infers that the site may be slightly impacted as fewer taxa were observed than were expected to occur under reference conditions. Stream Invertebrate Grade Number – average level – 2 (SIGNAL 2) was employed in the Red Hill EIS (in lieu of AusRivAS modelling) to assess the health of the stream. Consistent with the results of the Bowen Gas Project EIS, these results also indicate slight to moderate levels of impact to the stream in the broader area.

Macroinvertebrate sampling undertaken for the Bowen Gas Project EIS in the vicinity of the southern reach of the Isaac River associated with the potential WTF locality indicates similar results to that reported for upstream. Seasonal variation in macroinvertebrate taxa appears to occur at this site. No other data could be obtained to verify these results.

A summary of the macroinvertebrate sampling undertaken in the vicinity of the proposed development areas is provided in Table 4-8.

Table 4-8 Macroinvertebrate statistics recorded at survey sites close to the proposed WTF sites

Statistic	Bowen Gas Project EIS		Red Hill EIS
	WTF 1*	WTF 2**	WTF 1***
Taxa collected in early wet (October 2011) season	18	19	Not sampled
Taxa collected in late wet (April-May 2012) season	18	15	28
OE50 SIGNAL	0.95 (edge) 0.94 (pool)	0.96 (edge) 0.94 (pool)	Not defined
AusRivAS Band*	B (edge) B (pool)	B (edge) B (pool)	Not defined
SIGNAL 2	-	-	3.7

* Data collated from site AQ10A (Arrow Bowen Gas EIS, Appendix O)
** Data collated from site AQ16 (Arrow Bowen Gas EIS, Appendix O)
*** Data collated from Isaac River sites – during late wet season (BMA Redhill EIS, Appendix K)

4.3.4 Turtles

Turtles were assessed as a part the Bowen Gas Project EIS with desktop studies identifying the Fitzroy River turtle (*Rheodytes leukops*) as a possible occurrence in the Fitzroy River tributaries, such as the Isaac River. The Fitzroy River turtle is listed as 'vulnerable' both in Queensland and nationally (NC Act, EPBC Act).

General surveys were undertaken as part of the EIS field program, whilst targeted surveys for the Fitzroy River turtle were not included due to the specialised and highly intensive methods required. No observations of the Fitzroy River turtle were made during the EIS field sampling. Records for the turtle (Museum data) indicate that core habitat for the species occurs downstream of the Project area where required habitat such as flowing streams and permanent waterbodies are present. Given the habitat preferences of this species and that the Isaac River is ephemeral; this species is an unlikely occurrence within Isaac River.

Within the remainder of the Project area, the Fitzroy River turtle is considered to have a low likelihood of occurrence given the absence of core habitat which occurs outside of the Project area. However, due to the potential for indirect impacts such as water quality degradation and that the species is known in the wider region, the Fitzroy River turtle has been included in MNES significant impact assessment and potential habitat mapping within the MNES Report (Appendix J) of the SREIS. Within the MNES report, review of the species and its habitat is provided as well as the assessment of potential impacts and associated mitigation measures.

4.3.5 Aquatic flora

Data relating to aquatic flora present within the northern and southern reaches of the Isaac River associated with the potential WTFs is limited. To characterise the flora assemblages likely to be present, a summary of the data provided in the EIS is presented below.

The Bowen Gas Project EIS identifies two species of macrophyte observed during the field surveys of 2012 and 2013. *Juncus sp* (a common rush) was observed at sample site AQ10A, close to the northern reach of the Isaac River associated with the potential WTF locality. URS

(2011) in their ecological assessment suggests *Lomandra longifolia* (Lomandra) is also quite widespread through this area.

One macrophyte species *Phragmites australis* (Common Reed) was also observed at the downstream AQ16 sample site, close to southern reach of the Isaac River associated with the potential WTF locality.

No conservation significant species were recorded.

4.3.6 Summary of Aquatic Environmental Values

One EPBC Act listed species has the potential to occur within the proposed WTF development area:

- Fitzroy River turtle (*Rheodytes leukops*) (Vulnerable).

As noted in Section 4.3.4 the likelihood of the Fitzroy River turtle being present within the development area is low given the lack of preferred habitat. Further information on the Fitzroy River turtle is provided in the MNES Report (Appendix J) of the SREIS.

5 POTENTIAL IMPACTS

An assessment of the potential impacts to the aquatic environment arising from proposed activities associated with the Bowen Gas Project was completed for the EIS process in 2012. The EIS assessment outlined standard operational measures that will be taken to minimise the potential impacts identified at the time. In the interim, the proposed activities associated with the BGP have been refined, and greater detail is available in relation to the arrangement of project infrastructure; expected peak flows for produced water, and designed water treatment capacity across the Project area.

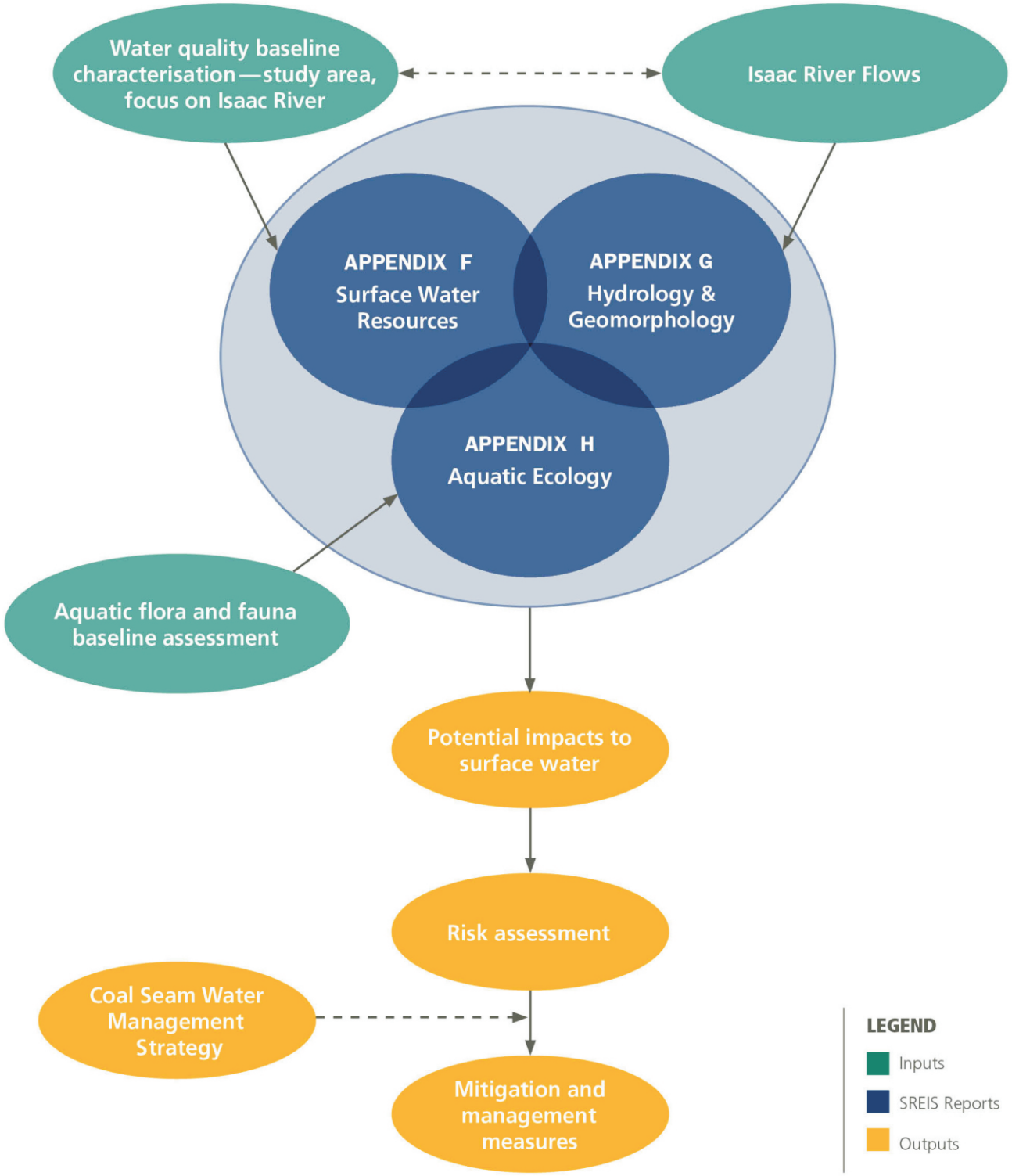
Thus, the purpose of the SREIS aquatic ecology impact assessment is to provide further detail for impacts and mitigation measures, as well as addressing any knowledge gaps identified during the legislative review or public submission stage since the EIS. The discussions of mitigation measures within this section contain some references to earlier management options outlined in the BGP EIS documentation; notably the Aquatic Ecology Technical Report (Appendix O) and the Surface Water Technical Report (Appendix N).

The key changes to the proposed project activities, applied since the EIS, that may potentially contribute to the following impacts on the aquatic environment within the project area include:

- Change in size/distribution of project infrastructure footprints;
- Greater certainty around 'field water treatment/storage' facilities;
- Brine management options have been assessed further by Arrow (since the EIS) and a preferred option has been identified;
- Reduction in project lifecycle water production (estimated total water produced will be 153,000 ML (averages over 36 years exclusive of 4 year ramp down period)) and number of wells (approximately 2500 wells less than at EIS stage); and
- Drainage areas (which form the basis for field development staging) have been reduced in area (now a 6 km radius), and approximately doubled in number (now 33 drainage areas); drainage areas are now spread out more evenly both temporally and spatially across the project area.

These activities, their potential associated impacts to the existing aquatic environment, and applicable mitigation measures, are discussed further in Table 5-1 and Sections 5 and 6 below. Residual impacts are presented in Section 7.

Whilst this technical report specifically addresses the aquatic ecology aspects of any likely impacts related to activities described in the updated project description, these studies are considered together and in a holistic manner with Project impacts related to surface water quality and hydrology and geomorphology (refer to the Surface Water Technical Report (Appendix F) and Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS). The different and inter-relating aspects that determine river health such as water quality, river hydrology, geomorphology and aquatic ecology were assessed in order to protect all environmental values associated with the Isaac River. This holistic approach was utilised in the assessment of impacts associated with potential discharges of CSG water. This complex interrelationship is depicted in Figure 5-1. The CSG Water and Salt Management Strategy (Appendix D) of the SREIS will provide direction for management of discharges to the receiving environment without causing environmental harm.



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BOWEN GAS PROJECT SREIS

OVERVIEW OF IMPACT ASSESSMENT PROCESS FOR THE SURFACE WATER ENVIRONMENT

URS

AQUATIC ECOLOGY TECHNICAL REPORT

Figure: 5-1

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Table 5-1 SREIS Impact Assessment Summary

Project Component	EIS Scenario (2012)	SREIS Scenario (2014)	Associated Potential impacts	Key Changes in Degree of Potential Impact	Applicable Mitigation Measures
Drainage areas	17 'catchment areas' of up to 12 km radius, over approximately 8,000 km^2 project area.	33 'drainage areas' of up to 6 km radius, over approximately 8,000 km^2 project area.	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation. • Potential release of contaminants to watercourses (adverse effects on aquatic habitats).	• Reduction in size of each drainage area, but increase in number of drainage areas; contributing to an overall reduction in the intensity of development on a *regional* scale. • May result in increased *localised* impacts compared with EIS scenario.	Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply.
Production wells	• 6,625 production wells drilled over 40 years. • Single well pads only.	• Approximately 4000 production wells drilled throughout the Project area over life of the Project (up to 40 years). • Some multi-well pads of up to 12 (6 vertical production plus 6 lateral) wells.	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation.	• Reduced intensity of development on a *regional* scale, however the introduction of multi-well pads may increase the degree of potential *localised* impact and risk to aquatic ecosystems.	Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply.

Project Component	EIS Scenario (2012)	SREIS Scenario (2014)	Associated Potential impacts	Key Changes in Degree of Potential Impact	Applicable Mitigation Measures
Linear infrastructure	• Pipeline gathering network required to connect each well pad to gas compression infrastructure. • Associated roads and access tracks for wells and pipelines.	• Overall net reduction in area required gathering network. • Net reduction in area of associate roads and access tracks.	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation, • Removal of riparian vegetation.	• Net reduction in total area for gathering network infrastructure including pipelines, access tracks and roads. Reduced intensity at a *regional* and *local* scale.	Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply.
Gas compression infrastructure	Four (4) integrated gas and water processing facilities (IPFs) of 800 m x 250 m area, with dams up to 1km^2 in area. One (1) Field Compressor Facility per drainage area, with a footprint of up to 200 m x 250 m.	• Two (2) Central Gas Processing Facilities (CGPFs) located near Peak Downs and Red Hill. • One (1) Field Compressor Facility per drainage area (skid-based, modular design with footprint up to 200 m x 380 m in area).	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation.	• Reduced footprint and number of gas processing facilities. • Larger footprint area for FCFs.	Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply.

Project Component	EIS Scenario (2012)	SREIS Scenario (2014)	Associated Potential impacts	Key Changes in Degree of Potential Impact	Applicable Mitigation Measures
Water treatment facilities	• Maximum dam footprint 0.6 km^2. • FCFs will most likely be of skid-based modular construction. • Integrated Processing Facilities (IPFs) may have peak flows of between 15-30 ML/day of field produced water, allowing that some areas will produce more water than others.	• Water Transfer Stations in field (pumping and surge tanks); typically associated with an FCF. • One (1) WTF associated with each CGPF. Feed dams, treated water dams, and brine storage facilities will be located at each WTF. • WTF1: Peak flow capacity of 12.9 ML/day. • WTF2: Peak flow capacity of 20 ML/day. • Potential third WTF located near Blackwater may be commissioned during Phase 2 of the Project. • Raw water can be transferred between WTFs (concept only). • Modular water treatment/storage units at FCFs (such as oily water reclamation systems) can treat up to 5-20 ML/day of produced water.	• Release of treated and untreated CSG water to surface watercourses (potential adverse effects on aquatic habitats). • Uncontrolled release of contaminated water to grade and/or watercourses due to spills (from water gathering lines; trucks transporting wastewater and treated water from water transfer stations). • Reduced risk of adverse impacts to aquatic values, with fewer discharge points (a function of having fewer WTFs).	• Reduction in number of WTFs, but retained a similar treatment capacity to that proposed for the EIS scenario. • 40% reduction in maximum area for WTF dams, potentially decreasing the overall impact of WTF construction/operation • Potentially lower risk of uncontrolled release to surface waters, due to reduced number of discharge locations.	• Mitigation measures outlined in the Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply. • Section 9.2.2.4 (Discharge of CSG Water to Waterways) (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Sections 9.1 and 9.2 of the Surface Water Technical Report (Appendix F) of the SREIS.

5.1 Potential Impact Assessment Method

The potential impacts on aquatic values were assessed using the significance assessment method. This method is detailed below.

5.1.1 Significance Assessment Method

The significance of an impact is assessed by considering the vulnerability or sensitivity of the environmental value and the magnitude of the impact, before and after the application of mitigation and management measures. It assumes the impact will occur and that the worst case will be identified and assessed. The significance of the residual impact is assessed assuming successful implementation of proposed mitigation and management measures.

5.1.1.1 Sensitivity of an Environmental Value

An environmental value's sensitivity is determined by its susceptibility or vulnerability to threatening processes, and consequently, its intrinsic value. Model attributes that define sensitivity were revised by the technical specialists to reflect the specific focus of the technical study. The model attributes of sensitivity are:

- **Conservation status**: assigned by governments (including statutory and regulatory authorities) or recognised international organisations through legislation, regulations and international conventions.
- **Intactness**: an assessment of how intact an environmental value is. It is a measure (with respect to its characteristics or properties) of its existing condition, and particularly its representativeness.
- **Uniqueness or rarity**: an assessment of its occurrence, abundance and distribution within and beyond its reference area, e.g., bioregion/ biosphere.
- **Resilience to change**: an assessment of the ability of an environmental value to adapt to change without adversely affecting its conservation status, intactness, uniqueness or rarity.
- **Replacement potential**: an assessment of the potential for a representative or equivalent example of the environmental value to be found to replace any losses.

Applying these attributes enables the sensitivity of an environmental value to be ranked as high, moderate or low. Table 5-2 lists the model criteria adopted for sensitivity.

Table 5-2 Criteria for Sensitivity

Sensitivity	Description
High	• The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance. • The environmental value is intact and retains its intrinsic value. • The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area which is poorly represented in the region, territory, country or the world. • It has not been exposed to threatening processes, or they have not had a noticeable impact on the integrity of the environmental value. Project activities would have an

Sensitivity	Description
	adverse effect on the value.
Moderate	• The environmental value is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers. • The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements. • It is relatively well represented in the systems/areas in which it occurs but its abundance and distribution are limited by threatening processes. • Threatening processes have reduced its resilience to change. Consequently, changes resulting from Project activities may lead to degradation of the prescribed value. • Replacement of unavoidable losses is possible due to its abundance and distribution.
Low	• The environmental value is not listed on any recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations e.g., historical societies. • It is in a poor to moderate condition as a result of threatening processes which have degraded its intrinsic value. • It is not unique or rare and numerous representative examples exist throughout the system / area. • It is abundant and widely distributed throughout the host systems / areas. • There is no detectable response to change or change does not result in further degradation of the environmental value. • The abundance and wide distribution of the environmental value ensures replacement of unavoidable losses is achievable.

5.1.1.2 Magnitude of Impact

The magnitude of an impact on an environmental value is an assessment of the geographical extent, duration and severity of the impact. These attributes are defined as follows:

- Geographical extent: an assessment of the spatial extent of the impact where the extent of impact is defined as site, local, regional or widespread (i.e. state-wide, national or international).
- Duration: the timescale of the effect (i.e. if it is short, medium or long term).
- Severity: an assessment of the scale or degree of change from the existing condition, as a result of the impact. This could be positive or negative.

Applying these attributes enables the magnitude of an impact to be ranked as high, moderate or low. Table 5-3 lists the model criteria adopted for magnitude.

Table 5-3 Criteria for Magnitude

Magnitude	Description
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of site-specific environmental management controls are required to address the impact.
Moderate	An impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management

Magnitude	Description
	controls.
Low	A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.

5.1.1.3 Significance of an Impact

The significance of an impact on an environmental value is determined by the sensitivity of the value itself and the magnitude of the impact it experiences. The significance assessment matrix below (Table 5-4) shows how, using the criteria above, the significance of an impact is determined.

Table 5-4 Significance Assessment Matrix

	Sensitivity of Environmental Value		
Magnitude of Impact	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

The classifications (major, high, moderate, low or negligible) for significance of an impact are as follows:

- **Major** Significance of Impact - arises when an impact will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
- **High** Significance of Impact - occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.
- **Moderate** Significance of Impact - although reasonably resilient to change, the environmental value would be further degraded due to the scale of the impact or its susceptibility to further change. The abundance of the environmental value ensures it is adequately represented in the region, and that replacement, if required, is achievable.
- **Low** Significance of Impact - occurs where an environmental value is of local importance and temporary and transient changes will not adversely affect its viability provided standard environmental management controls are implemented.
- **Negligible** Significance of Impact - impact on the environmental value will not result in any noticeable change in its intrinsic value and hence the proposed activities will have negligible effect on its viability. This typically occurs where the activities occur in industrial or highly disturbed areas.

5.1.1.4 Application of Significance Assessment Method

Once determined, the sensitivity of an environmental value does not change unless proposed actions or activities reduce the value's vulnerability to adverse effects. The impact magnitude is assessed prior to and after the application of mitigation measures. Combining this assessment with the sensitivity of the environmental value enables the significance of the impact to be determined and, following the application of mitigation, the significance of the residual impact. The change in significance is a measure of the effectiveness of the proposed mitigation. The residual impacts on aquatic values are detailed in Section 7.1.

5.2 Potential Impact on Wetlands

The following key Project activities have the potential to impact on wetlands:

- Site clearing and levelling;
- Construction of access tracks;
- Use of vehicles/plant/machinery near wetlands and waterways;
- Waste management;
- Gathering systems;
- Drilling operations; and
- Altered Surface Hydrology.

The potential impacts on wetlands from the above activities are consistent with the impacts detailed in the EIS on aquatic ecosystems, including:

- Degradation of water quality and smothering of benthic habitat from erosion and sediment transport processes;
- Reduction in aquatic biodiversity;
- Loss of riparian or aquatic vegetation;
- Contamination of wetlands and waterways resulting from fuel, oil or chemical spills;
- Altered surface water hydrology; and
- Spread and proliferation of pest species.

The application of mitigation measures outlined in the Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS and the buffer zones to be applied to wetlands using Arrow's risk based framework as detailed in the Constraints Mapping Appendix (Appendix BB) of the EIS and summarised in Section 6.1 of this report, will ensure impacts on wetlands are mitigated. General mitigation measures associated with protecting aquatic values and committed to by Arrow during the Projects EIS will further reduce the environmental impacts on wetlands and aquatic habitat. These mitigation measures are also presented in Section 6 below.

5.3 Specific impacts to the Isaac River from Proposed Construction and Operation of Large Infrastructure (CGPFs and WTFs)

Section 5 (Appendix O) of the EIS details the general impacts to aquatic ecology values at a broader scale, and encompasses the greater project development area. This report presents

the potential impacts on aquatic values identified from the desktop investigation. The potential impacts from construction and operation of large infrastructure such as the CGPFs and WTFs may also be revised once site specific investigations have taken place.

As detailed in Section 3.1, the discharge of residual volumes of CSG water into adjacent watercourses may be necessary to ensure that coal seam production can continue during times where:

- Constraints to supply for beneficial use occur;
- Unforeseen events occur such as significant weather events;
- Unforeseen or unusual operational conditions necessitate discharge; and
- The structural and operational integrity of dams is at risk.

Discharge to watercourses would occur within environmental flow requirements and in accordance with the relevant approval. The discharge rates, timing, frequency and duration of CSG water releases that will be considered as part of the EA process will address a number of variables including stream flows, stream water quality and CSG water quality. Under these circumstances, CSG water discharges would have insignificant impacts on the Surface Water receiving environment.

The potential impacts associated with the discharge of CSG water into watercourses are detailed below (Table 5-5), and are assessed for the following scenarios:

- Uncontrolled release of untreated CSG water;
- Uncontrolled release of treated CSG water;
- Uncontrolled release of both treated and untreated CSG water;
- Controlled release of untreated CSG water;
- Controlled release of treated CSG water; and
- Controlled release of both treated and untreated CSG water.

The potential impacts associated with the construction of the large infrastructure (CGPFs and WTFs), i.e. removal of aquatic or riparian vegetation, were addressed in the Project's EIS with no additional impacts identified during this assessment. As such, Table 5-5 only addresses the potential impacts on the aquatic environment from the discharge of CSG water.

An environmental flow (Spells) analysis was undertaken in conjunction with this aquatic technical report; the results are presented in the Hydrology and Geomorphology Technical Report (Appendix G) of the SREIS. Spells analysis provides an indication of the low and high flow regime under certain climatic conditions at a particular location within a catchment, using the entire available data record. The potential impact from the discharge of CSG water on hydrology and surface waters (and thus the receiving aquatic environment) can then be assessed. The potential impacts detailed in Table 5-5 below, has incorporated results from the Spells analysis, as applied to potential impacts on relevant aquatic ecological values.

Table 5-5 Impact assessment for CSG water release scenarios on the Isaac River

CSG Water Release Scenario	Contributing Factor	Potential Impacts	Magnitude of Impact	Significance of Impact
Uncontrolled release of *untreated* CSG water	Flooding (dams over capacity; inundation of infrastructure)	• Slight increase in receiving environment salinity, although unlikely to exceed receiving environment 80th percentile value of 428 µS/cm as Isaac River flows will likely be at greater than 75th percentile flow volume for flooding to occur. • Salt tolerances of fish are presented in Appendix B of this report. All fish presented have tolerance to salt higher than the 80th percentile of the Isaac River. Increased salinity in receiving environment is thus likely to have a low to negligible impact on fish. However other aquatic flora and fauna with reduced tolerance to high salinity may be impacted.	Low	Low
	Dam failure	• During periods of low flow, sudden release of large volumes will be outside of the natural flow regime. • Potential inundation of riparian margins not usually inundated during dry season. • Transport of large quantities of sediment and large woody debris downstream disturbing existing aquatic habitat (i.e. smothering of benthic habitat). • During periods of high flow, there may be a slight increase in salinity within the receiving environment which may impact on aquatic fauna. However it is unlikely to exceed Isaac River 80th percentile value of 428 µS/cm. Salt tolerances of fish are presented in Appendix B of this report. All fish presented have tolerance to salt higher than the 80th percentile of the Isaac River. Increased salinity in the receiving environment is thus likely to have a low to negligible impact on fish. However other aquatic flora and fauna with reduced tolerance to high salinity may be impacted.	Moderate	Moderate
	WTF operational emergency	• Similar impacts to those listed above for dam failure.	Moderate	Moderate
Uncontrolled release of *treated* CSG water	Flooding (dams over capacity; inundation of infrastructure)	• Decrease in salinity within receiving environment (due to dilution). Greatest impact would be to hydrology, with an increase in water level and discharge. • Potential inundation of riparian margins areas. • May result in mobilisation of sediment within the channel near discharge location, with transport of sediment 'slug' downstream resulting in degradation of downstream aquatic habitat.	Low	Low
	Dam failure	• During periods of low flow, sudden release of large volumes (will be outside of the natural flow regime.	Moderate	Moderate

CSG Water Release Scenario	Contributing Factor	Potential Impacts	Magnitude of Impact	Significance of Impact
		• Potential inundation of riparian margins and floodplain areas not usually inundated during dry season; exacerbation of high water level during wet season resulting in degradation of downstream aquatic habitat. • Alteration of biological triggers e.g. fish spawning triggered by flood flows, and or uniformity in water temperature. • Physical disturbance of aquatic habitat/substrate at the point of discharge.		
	WTF operational emergency	• Similar impacts to those listed above for dam failure.	Moderate	Moderate
Uncontrolled release of both *treated and untreated* CSG water	Flooding (dams over capacity; inundation of infrastructure)	• Potential water quality impacts resulting from combined sources (higher salinity of treated CSG water, combined with large volumes of both streams) could be difficult to interpret. • Increase salinity in the receiving environment (depending on ratio of untreated to treated CSG water). • Potential inundation of riparian margins and floodplain areas. • May result in mobilisation of sediment within channel near discharge location, with transport of sediment 'slug' downstream resulting in degradation of downstream aquatic habitat.	Low	Low
	Dam failure	• This event is considered to be highly unlikely (i.e. for more than one dam to fail on site at the same time), however if it did occur there may be the following impacts: – During periods of low flow, sudden release of large volumes (greater than annual volumes listed in the Surface Water Technical Report (Appendix F) of the SREIS) will be outside of the natural flow regime. – Potential inundation of riparian margins and floodplain areas not usually inundated during dry season; exacerbation of high water level during wet season. – Mobilisation and transport of large quantities of sediment and large woody debris downstream. – Physical disturbance of aquatic habitat/substrate at the point of discharge. – During periods of high flow, there may be a slight increase in salinity within the receiving environment, however it is unlikely to exceed Isaac River 80th percentile value of 428 µS/cm.	High	High
	WTF operational emergency	• This event is considered to have a higher probability of occurrence than for dam	Moderate	Moderate

CSG Water Release Scenario	Contributing Factor	Potential Impacts	Magnitude of Impact	Significance of Impact
		failure in the same scenario. It is more likely to be able to be moderated or controlled using emergency engineering solutions. However, the same impacts as listed for dam failure (above) would apply, albeit at a reduced extent.		
Controlled release of *untreated* CSG water	Release according to environmental authority conditions (where beneficial use is not appropriate/available)	• Controlled release of untreated CSG water would only occur at levels governed by the environmental authority. As such the discharge rates, timing, frequency and duration of CSG water releases that will be considered as part of the EA process will address a number of variables including stream flows, stream water quality and CSG water quality. Under these circumstances, CSG water discharges would have insignificant impacts on the Surface Water receiving environment. • The potential impact on aquatic ecology from CSG water discharge under EA conditions is considered low to negligible.	Low	Low to negligible
Controlled release of *treated* CSG water	Release according to environmental authority conditions (where beneficial use is not appropriate/available)	• Controlled release of untreated CSG water would only occur at levels governed by the environmental authority. As such the discharge rates, timing, frequency and duration of CSG water releases that will be considered as part of the EA process will address a number of variables including stream flows, stream water quality and CSG water quality. Under these circumstances, CSG water discharges would have insignificant impacts on the Surface Water receiving environment. • The potential impact on aquatic ecology from CSG water discharge under EA conditions is considered low to negligible.	Low	Low to negligible
Controlled release of both *treated and untreated* CSG water	Release according to environmental authority conditions (where beneficial use is not appropriate/available)	• Controlled release of untreated CSG water would only occur at levels governed by the environmental authority. As such the discharge rates, timing, frequency and duration of CSG water releases that will be considered as part of the EA process will address a number of variables including stream flows, stream water quality and CSG water quality. Under these circumstances, CSG water discharges would have insignificant impacts on the Surface Water receiving environment. • The potential impact on aquatic ecology from CSG water discharge under EA conditions is considered low to negligible.	Low	Low to negligible

6 MITIGATION MEASURES

6.1 Risk Based Framework

The risk based framework outlined in the EIS Framework Approach Chapter (EIS Section 7) and the associated Constraints Mapping (Appendix BB) of the EIS identifies the Project activities allowed to be undertaken within or near environmental values based on the inherent level of constraint.

As identified above, wetlands vary in ecological value, thus also varying in the level of constraint. Given this, surface water constraints are detailed below in Table 6-1 below.

Table 6-1 Surface Water Constraints

Sensitivity	Surface Water Value
No Go Zone	Within mapped wetlands, including: • Referable wetlands of High Ecological Significance • Non-riverine wetlands mapped as having high or very high ecological value in the GBR AquaBAMM report
High	Within Watercourses
	Within Waterways
Moderate	Within 100 m of springs*
	Within 200 m of mapped wetlands*, including: • Referable wetlands of High Ecological Significance • Non-riverine wetlands mapped as having high or very high ecological value in the GBR AquaBAMM report
	Wetlands not shown on the map of referable wetlands*, including: • Non-riverine wetlands mapped as having medium, low or very low ecological value in the GBR AquaBAMM report
	Within 200 m of lakes*
	Within 50 m of 1st and 2nd order waterways and watercourses*
	Within 100 m of 3rd and 4th order waterways and watercourses*
	Within 100 m of 5th order and above waterways and watercourses*
Low	Nil

* Buffers outlined above are indicative based on the current regulatory conditions and may be subject to change in the future.

Table 6-2 summarises the risk-based constraints framework used to determine the level of environmental management require for project activities.

Table 6-2 Risk-based constraints framework

Constraint	Project Activities			Applicable Framework
	Drilling Wells	Installing Gathering Lines	Facilities Installation	
'No Go'	N	N	N	Avoidance principle applies. No activity permitted. Procedural and behavioural controls in place to ensure strict compliance.
High	Y	Y	N	Controls apply. These are discussed below
Moderate	Y	Y	Y	Standard operating procedures apply for wells and gathering lines. Site specific controls must be in place for water treatment and storage facilities to ensure that aquatic ecosystems are not affected by altered surface water hydrology
Low	Y	Y	Y	Standard operating procedures apply

6.2 Wetland Mitigation Measures

The EIS committed to the adoption of riparian buffer zones [Commitment B196] along all watercourses with the exception of required creek crossings. The size of buffers is as defined by current regulatory conditions and level of constraint identified in the Project's constraints mapping as outlined in Section 7 of the Environmental Framework chapter and detailed in Constraints Mapping (Appendix BB) of the EIS.

The application of buffers around non-riverine wetlands will reduce the impact from Project activities on these ecosystems. A 200 m buffer will be implemented around referable wetlands mapped as having HES. Wetlands not mapped on the map of referable wetlands, but considered to support very high to high ecological value (as identified by the ACAs for the Fitzroy and Burdekin Catchment) will also have a 200 m buffer implemented. This buffer is consistent with guidelines supplied in the *State Development Assessment Provisions, Module 11: Wetland protection and wild river areas*.

It is recognised that wetlands of medium ecological value (Section 4.2.4) have potential to support aquatic values of conservation significance. To assist in mitigating impacts on these wetlands, pre-clearing surveys will be undertaken prior to development to quantify the presence of EVNT species or habitats. Following further field survey and revised mapping, possible habitat may be revised to "habitat known" or can be revised to areas in which the absence of EVNT habitat is known. This is consistent with commitments B132 and B155 as presented in the EIS (refer to Table 6-3).

The application of buffers and preclearance surveys as well as the general project mitigation commitments listed in Table 6-3 below will minimise impacts on wetlands, with the aim that:

- Project activities are not undertaken within a wetland in a wetland protection area;
- Adequate buffers are applied to wetlands of very high and high ecological significance;

- The existing surface water hydrological regime of the wetland protection area is maintained;
- The existing groundwater hydrological regime of the wetland protection area is protected;
- Development adjacent to the wetland protection area does not result in measurable change to the quantity or quality of stormwater entering the wetland;
- Vegetation clearing within the wetland or wetland buffer is avoided where possible;
- Wetland vegetation is retained where possible; and
- Construction activities do not introduce or exacerbate the occurrence of exotic flora and/or fauna.

6.3 Impact mitigation for construction and operation of WTFs

An analysis of the Project description changes potentially affecting aquatic ecology and an assessment of potential impacts as a result of the proposed development of the WTFs has been undertaken (Section 5). Generic mitigation and avoidance measures stipulated in the Arrow Bowen Gas EIS remain relevant to mitigation of the impacts detailed in Section 5. Additionally, project commitments to avoid and reduce significance of impacts and are presented in Table 6-3 below.

Table 6-3 Project commitments to avoid and reduce significance of impacts to aquatic ecology values

No.	Commitment
B094	Inspect at risk erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained
B172	Design washdown facilities to ensure that runoff is contained on site and does not transfer weed seeds, spores or infected soils to adjacent areas. Treat or dispose of washdown solids in a registered landfill
B180	When sourcing maintenance materials, ensure that such materials as bedding sand, topsoil, straw bales and sand bags are brought to site only after it is ascertained that the materials are not contaminated with weeds and plant or animal pathogens. Request a weed hygiene declaration form from the supplier where there is possible risk of contamination in products
B191	Develop a declared weed and pest management plan in accordance with the Petroleum Industry – Pest Spread Minimisation Advisory Guide (Biosecurity Queensland, 2008). Undertake species-specific management for identified key weed species at risk of spread through Project activities (mesquite, parthenium, African lovegrass and lippia). Increase weed control efforts in areas particularly sensitive to invasion. The pest management plan should include, as a minimum, training, management of pest spread, management of pest infestations and monitoring effectiveness of control measures
B194	The use of vehicles and machinery near waterways will be avoided wherever possible and expected to be minimal
B195	CSG water received from the field and brine concentrate will be managed in dams adjacent to WTFs
B196	Buffer zones will be adopted for Project activities (with the exception of required creek crossings), in different areas of constraint, as defined by the project's constraints mapping (outlined in Section 7 and detailed in Constraints Mapping (Appendix BB of the EIS).

No.	Commitment
	The buffers outlined below are indicative based on the current regulatory conditions, however these may be subject to change in future. The buffers that will be implemented for the project will be in line with the regulatory requirements at the time of implementation. Indicative buffers at this time include: • In areas mapped as high constraint a buffer of 100 m, measured from the bank edge, will be adopted during all phases of the Project, with a further 100 m constrained to low impact activities • For areas mapped as moderate constraint, the following buffer zones, measured from the bank edge, will be adopted during all phases of the Project: — a riparian buffer of 50 m width on either side of first and second order streams
B198	Construction of access tracks will be kept to a minimum, with the use of existing tracks and roads preferred wherever possible
B199	Tracks will be restricted in riparian zones and durations of impacts minimised, except in the immediate vicinity of creek crossings
B202	Construction that will potentially affect waterways will occur during dry months (periods of low rainfall and low flow) where possible. The use of machinery and vehicles on stream beds and banks will be avoided wherever possible
B205	Where possible trenching within or in the vicinity of watercourses would occur during the drier months of the year, which will reduce the potential for water quality decline as a result of sediment mobilisation
B207	A Water Management Plan, Erosion and Sediment Control Plan, and Waste Management Plan will be designed to avoid or minimise the potential impacts of Project
B208	Limit the use of herbicides in the vicinity of watercourses or within riparian zones. Use non-toxic, non-persistent (i.e., biodegradable) herbicides to treat weeds, except on properties where organic or biodynamic farming is practiced, for which the method of weed treatment is to be agreed with the landowner
B209	Monitoring where required will be undertaken including water quality, aquatic macroinvertebrates, fish, and other aquatic / semi-aquatic fauna
B210	A sampling program will be undertaken if discharge or emergency release is required
B211	The reporting of monitoring analysis results would include both standalone and cumulative interpretation to provide for a comprehensive understanding of significant change, if any, over time
B214	Where a discharge triggers a mandatory incident procedure that includes the need for point-source assessment, at a minimum, water quality would be assessed at the point source, as well as downstream of that point to the estimated downstream limit of impact
B217	Routinely inspect for pest flora and evidence of pest fauna species within Project disturbed areas
B227	Design gathering lines and tracks to avoid watercourses, drainage lines and riparian areas (particularly permanent watercourses or perennial aquatic habitat), where practicable
B230	Plan construction and maintenance activities to minimise movement of plant and equipment between properties or areas with weed infestations
B231	Identify declared weeds during the preconstruction clearance survey
B232	Store stockpiled, cleared vegetation away from watercourses or drainage lines

No.	Commitment
B233	Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled paddocks, this may not be practicable, and backfilling should be carried out in consultation with the landowner
B345	Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of CSG water
B391	Onsite waste storage areas will be developed in accordance with industry practice and relevant waste management regulations

7 RESIDUAL IMPACTS

7.1 Residual Impacts

The residual impacts on aquatic values following the application of mitigation measures detailed above are outlined in Table 7-1 below. The consideration of mitigation measures has minimised the potential for impact on the aquatic environment, particular for erosion and sedimentation impacts. The residual impacts associated with the uncontrolled release of CSG water are still considered moderate given the potential magnitude of such a release.

Table 7-1 Residual impacts to Aquatic Values potentially arising from BGP activities

Project Component	Associated Potential Impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
Drainage areas	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation. • Improper disposal of wastes from construction and operations activities. • Potential release of contaminants to watercourses (adverse effects on aquatic habitats).	• Those listed in Section 6 of this report. • Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply. • Mitigation measure Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of Appendix N of the EIS still apply.	• Potential release of sediment and contaminated water to aquatic ecosystems if management controls fail (for example, sediment fence is washed away).	Low	Low
Production wells	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation.	• Those listed in Section 6 of this report. • Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply. • Mitigation Measure Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of Appendix N of the EIS still apply.	• Potential exists for localised impacts on aquatic ecosystems. For example, larger volumes of sediment may be mobilised from larger multi-well pads. Resulting in localised impacts on aquatic ecosystems (i.e. reduced water quality and possible smothering of benthic habitat).	Low	Low to negligible
Linear infrastructure	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation.	• Those listed in Section 6 of this report. • Mitigation measures outlined in Chapter 16, Section 16.6 and Appendix O, Section 6 of the	• Whilst a reduced area of disturbance from the EIS, potential exists for localised impacts on aquatic ecosystems. In particular,	Low	Low to negligible

Project Component	Associated Potential Impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
		EIS still apply. • Mitigation Measure Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of Appendix N of the EIS still apply.	the potential release of sediment into waterways and watercourses where pipeline and road crossings occur.		
Gas compression infrastructure	• Alteration of flows and flow paths. • Degradation of aquatic habitats from erosion and sediment mobilisation.	• Those listed in Section 6 of this report. • Mitigation measures outlined in the Chapter 16, Section 16.6 and Appendix O, Section 6 of the EIS still apply. • Mitigation Measure Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3 of Appendix N of the EIS still apply.	• Potential exists for localised impacts on aquatic ecosystems. For example, larger volumes of sediment may be mobilised from larger multi-well pads. Resulting in localised impacts on aquatic ecosystems (i.e. reduced water quality and possible smothering of benthic habitat).	Low	Low to negligible
Water Treatment Facilities					
Uncontrolled release of *untreated* CSG water	• Potential adverse effects on surface water quality and thus receiving aquatic environments. • Transport of large quantities of sediment and large woody debris downstream disturbing existing aquatic habitat (i.e. smothering of benthic habitat).	• Those listed in Section 6 of this report. • Mitigation measures outlined in the Aquatic Ecology chapter (Section 16.6) and Aquatic Ecology Technical Report (Appendix O, Section 6) of the EIS still apply. • Mitigation measures outlined in the Surface Water Technical Report (Appendix N, Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3) of the EIS still apply.	• Uncontrolled release of large volumes of untreated CSG water during times of low flow will have the following potential impacts: – During periods of high flow, potential residual impact to aquatic habitat (e.g. large woody debris) by flushing or degradation (e.g. smothering of benthic habitat). – During periods of no	Moderate	Moderate

Project Component	Associated Potential Impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
		• Section 9.2.2.4 of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Sections 9.1 and 9.2 of the same report.	flow, minimal direct residual impact on aquatic fauna (e.g. fish due to the likely absence of most aquatic species during low flow conditions. Secondary residual impacts on aquatic fauna may occur by the removal and/ or degradation of aquatic habitat.		
Uncontrolled release of *treated* CSG water	• Dilution of receiving environment water resulting in decreased salinity (high flow conditions). • Sedimentation and/or removal of aquatic habitat.	• Those listed in Section 6 of this report. • Mitigation measures outlined in the Aquatic Ecology chapter (Section 16.6) and Aquatic Ecology Technical Report (Appendix O, Section 6) of the EIS still apply. • Mitigation measures outlined in the Surface Water Technical Report (Appendix N, Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3) of the EIS still apply. • Section 9.2.2.4 of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along	• Residual impact from uncontrolled release of CSG water (treated) will have greatest impact on aquatic habitat through removal or degradation processes.	Moderate	Moderate

Project Component	Associated Potential Impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
		with information outlined in Sections 9.1 and 9.2 of the same			
Uncontrolled release of both *treated and untreated* CSG water	• Potential water quality impacts from combined sources including increase salinity. • Loss or degradation of aquatic habitat.	• Those listed in Section 6 of this report. • Mitigation measures outlined in the Aquatic Ecology chapter (Section 16.6) and Aquatic Ecology Technical Report (Appendix O, Section 6) of the EIS still apply. • Mitigation measures outlined in the Surface Water Technical Report (Appendix N, Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3) of the EIS still apply. • Section 9.2.2.4 of Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Sections 9.1 and 9.2 of the same report.	• Residual impact from uncontrolled release of CSG water (treated and untreated) will have greatest impact on aquatic habitat through removal or degradation processes.	Moderate	Moderate
Controlled release of *untreated* CSG water	• Increase of water level as governed by EA conditions.	• Those listed in Section 6 of this report. • Mitigation measures outlined in the Aquatic Ecology chapter (Section 16.6) and Aquatic Ecology Technical Report (Appendix O, Section 6) of the	• Residual impact from increase of water level in receiving environment	Low	Low to negligible

Project Component	Associated Potential Impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
		EIS still apply. • Mitigation measures outlined in the Surface Water Technical Report (Appendix N, Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3) of the EIS still apply. • Section 9.2.2.4 of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any releases from WTFs to the receiving environment, along with information outlined in Sections 9.1 and 9.2 of the same report.			
Controlled release of *treated* CSG water	• Release according to environmental authority conditions (where beneficial use is not appropriate / available).	• Those listed in Section 6 of this report. • Mitigation measures outlined in the Aquatic Ecology chapter (Section 16.6) and Aquatic Ecology Technical Report (Appendix O, Section 6) of the EIS still apply. • Mitigation measures outlined in the Surface Water Technical Report (Appendix N, Sections 9.2.2.1, 9.2.2.2 and 9.2.2.3) of the EIS still apply. • Section 9.2.2.4 of the Surface Water Technical Report (Appendix N) of the EIS specifically applies to any	• Residual impact from increase of water level in receiving environment	Low	Low to negligible

Project Component	Associated Potential Impacts	Applicable Mitigation Measures	Residual Impact	Magnitude of Residual Impact	Significance of Residual Impact
		releases from WTFs to the receiving environment, along with information outlined in Sections 9.1 and 9.2 of the same report.			

8 MONITORING AND REPORTING

Monitoring and reporting will follow the frameworks set out in the EIS. The EIS monitoring recommendations detailed below will be complimented by the surface water values monitoring program outlined in the SREIS Surface Water Technical Report (Appendix F).

Water Quality Monitoring During Construction and Operation

The above mitigation measures and monitoring protocols were committed to by Arrow during the Project's EIS. Specifically, the commitments which encompass the mitigation and monitoring detailed above include:

- A Water Management Plan, Erosion and Sediment Control Plan, and Waste Management Plan will be designed to avoid or minimise the potential impacts of Project [B207];
- Monitoring, where required, will be undertaken including water quality, aquatic macroinvertebrates, fish, and other aquatic / semi-aquatic fauna [B209];
- A sampling program will be undertaken if discharge or emergency release is required [B210];
- The reporting of monitoring analysis results will include both standalone and cumulative interpretation to provide for a comprehensive understanding of significant change, if any, over time [B211];
- Where a discharge triggers a mandatory incident procedure that includes the need for point-source assessment, at a minimum, water quality would be assessed at the point source, as well as downstream of that point to the estimated downstream limit of impact [B214];
- Routinely inspect for pest flora and evidence of pest fauna species within Project disturbed areas [B217]; and
- Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of CSG water [B345].

One additional commitment has been identified to avoid and reduce significance of impacts to aquatic ecology values:

- For the reaches associated with each WTF locality, a baseline set of water quality data will be established by taking three replicate water quality meter records from one site upstream and one site downstream of the discharge point. Samples will be taken under flow conditions (typically steady state low flows).

Release of treated CSG water to natural watercourses

The release of treated CSG water to natural watercourses is discussed in detail in the Surface Water Technical Report (Appendix F) of the SREIS.

9 CONCLUSION

The supplementary assessment of aquatic values reviewed Project description changes and updates to relevant State or Commonwealth legislation since the submission of original Project EIS. This review identified any new potential impacts from the proposed development as well as provided mitigation measures. Submission responses made following the public consultation stage of the EIS were also addressed.

The assessment outlined above, identified new potential impacts associated with the potential for discharge of CSG water. Target areas for potential water discharge locations were identified within reaches of the Isaac River associated with the possible localities of WTF facilities. A literature review of these areas was undertaken and aquatic values described.

The assessment of aquatic values within the Isaac River describes the river as typically homogeneous throughout the Moranbah region with little natural variation. Instream habitat generally consists of intermittent pools and runs, with edgewaters providing habitat during flows. Twelve fish species have been previously recorded within the river near the reaches of the Isaac Study as potential discharge areas.

No fish of conservation significance were identified. The water quality tolerance of fish recorded within the Isaac River was reviewed with water quality encountered at the sites being well within the tolerance ranges for most fish species.

Macroinvertebrate sampling undertaken during existing studies determined that the discharge locations achieved an AusRivAS modelling band of B, inferring that the discharge locations are slightly impacted and support fewer taxa than would be expected under reference conditions.

The Fitzroy River turtle was identified during the literature review as possibly occurring. However, review of habitat preferences and habitat suggest this species is highly unlikely to occur within the reaches of the Isaac River given the absence of permanent flowing water. Within the remainder of the Project area, the Fitzroy River turtle is considered a low likelihood of occurrence given the absence of core habitat which occurs outside of the Project area. However, due to the potential for indirect impacts such as water quality degradation and that the species is known in the wider region, the Fitzroy River turtle has been included in MNES significant impact assessment and potential habitat mapping within the MNES Report (Appendix J) of the SREIS.

EIS Submission responses recommended further review of wetlands within the Project area. A revised review of wetland values was undertaken using a range of literature sources and GIS analysis such as referable wetland mapping and the aquatic conservation assessments of the Fitzroy and Burdekin Catchments.

Wetlands within the Project area include referable wetlands of high ecological significance. The number and location of wetlands within the Project area are detailed in Section 4.2.The potential impacts identified from changes to the Project description were reviewed. The reduction in infrastructure resulted in a reduction in impact intensity of development on a regional scale. However, an increase in localised potential impacts may occur.

The potential impacts resulting from the discharge of CSG water was also assessed against a range of scenarios, including the release of treated and untreated water during controlled or uncontrolled conditions.

The impact assessment identified that the uncontrolled release of untreated and/or treated CSG water pose the greatest risk to the aquatic values through loss and degradation of habitat. However, the application of mitigation measures determined that residual impacts are reversible and temporary with a resulting moderate significance.

10 REFERENCES

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APPENDIX A AQUABAMM CRITERIA AND INDICATORS

Indicators	Measures	
1 Naturalness aquatic		
1.1 Exotic flora/fauna	1.1.1	Presence of 'alien' fish species within the wetland
	1.1.2	Presence of exotic aquatic and semi-aquatic plants within the wetland
	1.1.3	Presence of exotic invertebrate fauna within the wetland
	1.1.4	Presence of feral/exotic vertebrate fauna (other than fish) within the wetland
1.2 Aquatic communities/ assemblages	1.2.1	SOR1 aquatic vegetation condition
	1.2.2	SIGNAL2 score (Max)
	1.2.3	AUSRIVAS2 score – Edge (Min band)
	1.2.4	AUSRIVAS2 score – Pool (Min band)
	1.2.9	AUSRIVAS2 score – Riffle (Min band)
1.3 Habitat features modification	1.3.1	SOR1 bank stability
	1.3.2	SOR1 bed & bar stability
	1.3.3	SOR1 aquatic habitat condition
	1.3.4	Presence/absence of dams/weirs within the wetland
	1.3.5	Inundation by dams/weirs (% of waterway length within the wetland)
	1.3.14	Aquatic habitat condition using acknowledged metric
1.4 Hydrological modification	1.4.2	Percent natural flows – modelled flows remaining relative to predevelopment
	1.4.7	WRP (Water Resource Plan) hydraulic habitat
	1.4.8	HEV (High Ecological Value) areas
1.5 Water quality	1.5.10	Water quality index/score – an acknowledged metric calculated considering local, state or national water quality guidelines
2 Naturalness catchment		
2.1 Exotic flora/fauna	2.1.1	Presence of exotic terrestrial plants in the assessment unit
2.2 Riparian disturbance	2.2.1	% area remnant vegetation relative to pre-clearing extent within buffered riverine wetland or watercourses
	2.2.2	Total number of regional ecosystems relative to pre-clearing number of regional ecosystems within buffered riverine wetland or watercourses
	2.2.3	SOR1 reach environs
	2.2.4	SOR1 riparian vegetation condition
2.3 Catchment disturbance	2.3.1	% "agricultural" land-use area (i.e. cropping and horticulture)
	2.3.2	% "grazing" land-use area
	2.3.3	% "vegetation" land-use area (i.e. native veg + regrowth)
	2.3.4	% "settlement" land-use area (i.e. towns, cities, etc)
2.4 Flow modification	2.4.1	Farm storage (overland flow harvesting, floodplain ring tanks, gully dams) calculated by surface area
3 Diversity and richness		
3.1 Species	3.1.1	Richness of native amphibians (riverine wetland breeders)
	3.1.2	Richness of native fish
	3.1.3	Richness of native aquatic dependent reptiles
	3.1.4	Richness of native waterbirds
	3.1.5	Richness of native aquatic plants

Indicators	Measures	
	3.1.7	Richness of native aquatic dependent mammals
3.2 Communities/ assemblages	3.2.1	Richness of macroinvertebrate taxa
	3.2.2	Richness of regional ecosystems along riverine wetlands or watercourses within a specified buffer distance
3.3 Habitat	3.3.1	SOR1 channel diversity
	3.3.2	Richness of wetland types within the local catchment (e.g. SOR sub-section)
	3.3.3	Richness of wetland types within the sub-catchment
3.4 Geomorphology	3.4.1	Richness of geomorphic features
4 Threatened species and ecosystems		
4.1 Species	4.1.1	Presence of rare or threatened aquatic ecosystem dependent fauna species – NC Act4, EPBC Act5
	4.1.2	Presence of rare or threatened aquatic ecosystem dependent flora species – NC Act4, EPBC Act5
4.2 Communities/ assemblages	4.2.1	Conservation status of wetland Regional Ecosystems – Herbarium biodiversity status, NC Act4, EPBC Act5
5 Priority species and ecosystems		
5.1 Species	5.1.1	Presence of aquatic ecosystem dependent 'priority' fauna species (expert panel list/discussion or other lists such as ASFB6, WWF, etc)
	5.1.2	Presence of aquatic ecosystem dependent 'priority' flora species
	5.1.3	Habitat for, or presence of, migratory species (Expert Panel list/discussion and/or JAMBA7/CAMBA8 agreement lists and/or Bonn Convention)
	5.1.4	Habitat for significant numbers of waterbirds
5.2 Ecosystems	5.2.1	Presence of 'priority' aquatic ecosystem
6 Special features		
6.1 Geomorphic features	6.1.1	Presence of distinct, unique or special geomorphic features
6.2 Ecological processes	6.2.1	Presence of (or requirement for) distinct, unique or special ecological processes
6.3 Habitat	6.3.1	Presence of distinct, unique or special habitat (including habitat that functions as refugia or other critical purpose)
	6.3.2	Significant wetlands identified by an accepted method such as Ramsar, Australian Directory of Important Wetlands, regional coastal management planning, World Heritage Areas, etc
	6.3.3	Ecologically significant wetlands identified through expert opinion and/or documented study
6.4 Hydrological	6.4.1	Presence of distinct, unique or special hydrological regimes (e.g. spring fed stream, ephemeral stream, boggomoss)
7 Connectivity		
7.1 Significant species or populations	7.1.1	The contribution (upstream or downstream) of the spatial unit to the maintenance of significant species or populations, including those features identified through criteria 5 and/ or 6
	7.1.2	Migratory or routine 'passage' of fish and other fully aquatic species

Indicators	Measures	
		(upstream, lateral or downstream movement) within the spatial unit
7.1 Groundwater dependant ecosystems	7.2.1	The contribution of the special unit to the maintenance of groundwater ecosystems with significant biodiversity values, including those features identified through criteria 5 and/or 6 (e.g. karsts, cave streams, artesian springs)
7.3 Floodplain and wetland ecosystems	7.3.1	The contribution of the spatial unit to the maintenance of floodplain and wetland ecosystems with significant biodiversity values, including those features identified through criteria 5 and/or 6
7.5 Estuarine and marine ecosystems	7.5.1	The contribution of the spatial unit to the maintenance of estuarine and marine ecosystems with significant biodiversity values, including those features identified through criteria 5 and/or 6

APPENDIX B FISH WATER QUALITY TOLERANCES

Taxon	Common Name	Habitat	Water Quality Range					Reference
			Water Temp (ºC)	DO ($mg.L^{-1}$)	pH	Conductivity (μScm^{-1})	Turbidity (NTU)	Pusey et al. (2004)
Ambasis agasizii	Agassiz's glassfish	Widespread species occurring in coastal and inland drainages of eastern Australia. The true northern limit of this species in Queensland is unknown. Found in a variety of freshwater habitats, including still or slow-flowing parts of large lowland rivers, upland rivers and streams.	11-33 Absolute tolerances of this species may be greater.	0.3-19.5 Range from hypoxic to supersaturated.	6.3-9.9 Occurs in mildly acidic to basic waters.	19.5-15,102 Salt tolerances appear reasonably high.	0.2-144 Usually occurs in waters with much lower turbidity than 144 NTU.	p.294-295
Amniataba percoides	Barred grunter	Widely but patchly distributed within river systems and may be found from relatively low gradient lowland and upper reaches, but is rarely collected from high gradient tributary streams.	21-35 Average temperatures reflect those of most of northern Austalia and reflect that this species is naturally restricted to these areas.	0.2-11 This species is moderately tolerant to hypoxia given the low dissolved oxygen levels recorded in floodplain lagoons.	4.5-8.46 Occurs over a wide pH range. It is suggested that the optimum pH range for his species is 5.5-8.	2-780 Recorded from freshwater only. Is probably able to withstand high conductivities for a short period only.	0.28-360 Frequently found in clear waters, however can be found in very turbid waters.	p.363-365
Glossamia aprion	Mouth almighty	Occurs in streams of zero to low flow. Rarely collected more that 20cm from some form of cover. Occurs most frequently in areas less than 60cm in depth and was most frequently collected in the lower two-thirds of the water column.	17.1-38 Found over a wide range of temperatures but most frequently encountered in waters between 21-30.	1.1-11.9 Tolerant of a wide range of dissolved oxygen concentrations and moderately tolerant of hypoxia.	4.9-9.1 Recorded over a wide range of Ph, but has a tendency to occur in neutral to slightly acidic waters.	2-1,429 Clearly a freshwater species and is able to tolerate very dilute waters.	0.1-500 Recorded over a wide range of water clarity. Species is a visual feeder and low visibility is likely to impact on this species in the long term.	p.414-415
Hypseleotris klunzingeri	Western carp gudgeon	Occurs in a variety of habitats including small coastal streams, large rivers and their floodplains, coastal wetlands, dune lake and stream systems, and river impoundments.	8.4-31.7 Tolerant of a wide range of water temperatures.	0.6-12.8 Tolerant of a wide range of dissolved oxygen concentrations.	4.8-9.1 Tolerant of a wide range of water acidity.	19.5-5,380 Tolerant of a wide range of conductivity.	0.5-65 Tolerant of a wide range of turbidity.	p.523-524
Hypseleotris sp. 1	Midgley's carp gudgeon	Occur in a variety of lotic and lentic habitats including small coastal streams, throughout large rivers and their floodplain habitats (billabongs and wetlands), coastal wetlands, dune lake and stream systems and river impoundments.	8.4-31.2 Minimum and maximum tolerances are likely to be wider than those recorded.	0.3-19.5 Occur in hypoxic to super-saturated conditions.	4.4-8.9 Occurs in relatively acidic to mildly acidic to basic waters.	51-4,123 Salinity tolerances of this species may be reasonably high.	0.1-331.4 Usually occurs in water with much lower turbidity than the maximum.	p.513-515
Leiopotherapon unicolor	Spangled perch	Found in a wide range of conditions including desert springs and bores, billabongs, impoundments, rivers and streams.	4.1-41.8 Acclimatisation history important in determining tolerance levels.	0.4 to 40% saturation This species is able to extract oxygen from hypoxic waters.	4-8.6 This species is found in waters ranging from turbid to very clear.	30-54,000 Salinity tolerance is very broad. This species has been collected from springs of low salinity (0.02%). The upper limit has been experimentally determined to be that of seawater (35.5%).	152-250 Present in floodwaters as well as inland drainages that often stay turbid for a very long time.	p.371-373
Macquaria ambigua	Yellowbelly	Inhabits rivers, creeks, billabongs and lakes of the lower Murray-Darling system. Prefers habitats containing relatively deep , slow-flowing water, cover, shade and shelter.	4-35 Tolerates a wide range of temperatures.	3-15 Able to tolerate low oxygen levels.	7.1-7.8 Generally live in neautral to slightly basic waters.	224-3,000 Can transition from fresh to saline waters.	12-240 Typically found in turbid, lowland rivers.	p.328-330
Melanotaenia splendida	Eastern rainbowfish	Widely distributed along the eastern coast of Queensland. Preferred habitat consists mainly of small streams up to large, low gradient, lowland rivers including wetland habitats and floodplain lagoons.	15-32.5 Tolerance to elevated temperatures may be slightly higher in wild populations of some regions.	1.1-10.8 Preference for well oxygenated water, however it is evident that low dissolved oxygen waters exist in some habitats.	5.13-8.47 Well developed tolerance to a variety of pH conditions.	6-790 Varies between adults and juveniles and according to acclimatisation history.	0.1-16 Found in water of a range in clarity. Can be found in highly turbid waters.	p.214-216
Mogurnda adspersa	Purple-spotted	Found in a variety of lotic and	11.9-31.7	0.6-12.8	5.6-8.8	13.3-2,495	0.1-200	p.548-550

Taxon	Common Name	Habitat	Water Quality Range					Reference
			Water Temp (ºC)	DO ($mg.L^{-1}$)	pH	Conductivity (μScm^{-1})	Turbidity (NTU)	Pusey et al. (2004)
	gudgeon	lentic habitats including small coastal streams, rainforest streams, large rivers and in dune lake and river systems. Usually found in freshwater habitats however can be found in estuaries.	Appears tolerant to a wide range of temperatures.	Appears to tolerate low dissolved oxygen concentrations.	Tolerates moderately acidic to basic water conditions.	Most populations unlikely to tolerate elevated salinities	Prefers less turbid water (mean 5.8 NTU)	
Nemaralosa erebi	Bony bream	Wide range of habitats from salt lakes, lowland rivers, floodplain billabongs and lagoons, impoundments to rainforest streams. Habitats occupied are limited only be access and possibly by minimum water temperatures.	12-38 A maximum temperature of 38ºC is close to the upper limit for the species, whilst the minimum value that has been recorded as 12ºC.	0.1-12 Can tolerate a large range of dissolved oxygen concentrations from $0.1mg.L^{-1}$ to 12 $mg.L^{-1.}$	5.1-9.1 Occurs most frequently in neutral to slightly basic waters, however it has been recorded from water of a moderately large range of acidity: 5.1 to 9.1 pH units.	Tolerates a wide range of salinities, from salinities approaching sea water to very fresh water.	Found in a wide variety of water clarities, however is most common in waters of moderate turbidity.	p.94-96
Neosilurus hyrtlii	Hyrtl's tandan	Small permanent or intermittent tributary streams through to large lowland low gradient seasonal rivers. Makes use of virtually every aquatic habitiat available within a river with the exception of estuarine reaches.	12.8-36 Occupies predominately warm waters.	1-11.4 Found over a wide range of dissolved oxygen levels.	5.2-9.1 Recorded from a wide range of water acidity.	4-1,855 Should be considered a freshwater species, occurs over a wide range of water conductivity.	0.4-170 Occupies a substantial range in water clarity.	p.115-117
Oxyleotris lineatus	Sleepy cod	Widely distributed in rivers, lowland sandy pools, lowland backflow billabongs, corridor billabongs and upper floodplain billabongs. Most abundant in lowland backflow billabongs. Have a definite requirement for abundant cover in the form of submerged macrophytes, root masses or woody debris.	15-38 The temperatures at which sleepy cod have been collected reflect its northern tropical distribution.	1-11 Tolerant to hypoxia and appear able to tolerate low levels for an extended period of time.	4.8-9.2 Tend to avoid highly acidic habitats.	4-650 Very fresh water is required.	1-579 Found over a wide range of water turbidity.	p.482-483
Philypnodon grandiceps	Flathead gudgeon	Occurs in a variety of lotic and lentic habitats including small coastal streams, large rivers, floodplain habitats, inland saline lakes and coastal wetlands.	11-31	2.6-12 Tolerant of low dissolved oxygen levels.	6-8.6 Tolerates mildly acidic waters.	122.1-2,495 Tolerates high conductivities throughout much of its lifecycle.	0.7-36 Maximum turbidity has been recorded as 36 NTU, however it is likely that this species can tolerate much higher concentrations.	p.561-562

Source: Pusey *et al* 2004

APPENDIX C AQUABAMM PRIORITY AQUATIC FLORA AND FAUNA

C.1 Aquatic Flora

The ACA of the Burdekin and Fitzroy Catchments identified priority flora species in the riverine and non-riverine wetlands (Rollason and Howell, 2012). Priority flora is defined as flora which must exhibit one or more of the following:

- It forms significant macrophyte beds (in shallow or deep water).
- It is an important/critical food source.
- It is important/critical habitat.
- It is implicated in spawning or reproduction for other fauna and/or flora species.
- It is at its distributional limit or is a disjunct population.
- It provides stream bank or bed stabilisation or has soil-binding properties.
- It is a small population and subject to threatening processes.

Terrestrial flora species associated with riparian areas have been assessed in the terrestrial ecology report (Rollason and Howell, 2012). Given this, 35 priority macrophytes species that have potential to occur in the project area are detailed in Table C-1 below.

C.2 Aquatic Fauna

The ACA of the Burdekin and Fitzroy Catchments identified priority fauna species in the riverine and non-riverine wetlands (Rollason and Howell, 2012) including fish, mammal and reptile species. Given this, 26 priority aquatic fauna species that have potential to occur within the project area are detailed in Table C-2 below.

- It is endemic to the study area (>75 per cent of its distribution is in the study area/catchment).
- It has experienced, or is suspected of experiencing, a serious population decline.
- It has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area/catchment.
- It is currently a small population and threatened by loss of habitat.
- It is a significant disjunct population.
- It is a migratory species (other than birds).
- A significant proportion of the breeding population (>1 per cent for waterbirds, >75 per cent other species) occurs in the waterbody.

Terrestrial fauna species associated with riparian areas have been assessed in the terrestrial ecology report (Rollason and Howell, 2012).

Table C-1 Priority macrophytes within the Project area

Scientific Name	Common Name	Fitzroy	Burdekin	Comments
Baumea articulata	Jointed twigrush	x		Forms significant macrophyte beds
Baumea rubiginosa		x		Forms significant macrophyte beds
Ceratopteris thalictroides			x	Indicator of better water quality systems
Cyperus exaltatus		x		Forms significant macrophyte beds
Eleocharis dulcis		x	x	Forms significant macrophyte beds Forms large areas of monotypic sedgeland that is a key threatened wetland community in Burdekin Dry Tropics.
Eleocharis sphacelata		x	x	Forms significant macrophyte beds
Gahnia sieberiana	Sword grass	x		Forms significant macrophyte beds
Hydrilla verticillata			x	Small population subject to threatening processes
Hymenachne acutigluma			x	Key indicator of waterfowl habitat value
Leersia hexandra	Swamp rice grass	x	x	Forms significant macrophyte beds
Lepironia articulata		x		Forms significant macrophyte beds
Lomandra longifolia		x		
Marsilea drummondii	Common nardoo		x	This species forms a key threatened macrophyte community on the Burdekin floodplain.
Monochoria cyanea		x		Forms significant macrophyte beds
Muehlenbeckia florulenta	Lignum	x		Forms significant macrophyte beds
Myriophyllum simulans		x		Forms significant macrophyte beds
Myriophyllum verrucosum	Water milfoil	x		Forms significant macrophyte beds
Najas tenuifolia	Water nymph	x		Forms significant macrophyte beds
Nelumbo nucifera	Pink waterlily	x		Forms significant macrophyte beds
Nymphaea gigantea		x	x	Forms significant macrophyte beds
Nymphaea immutabilis			x	Important food source and habitat, at distributional limit in Burdekin Region.
Nymphoides exiliflora		x		Forms significant macrophyte beds

Scientific Name	Common Name	Fitzroy	Burdekin	Comments
Nymphoides indica	Water snowflake	x		Forms significant macrophyte beds
Oryza australiensis			x	Important food source and habitat, at distributional limit in Burdekin Region
Oryza meridionalis			x	Important food source and habitat, at distributional limit in Burdekin Region
Oryza rufipogon			x	Important food source for fish and vertebrates such as waterbirds particularly during winter
Ottelia alismoides		x	x	Forms significant macrophyte beds
Ottelia ovalifolia	Swamp lily		x	Important food source for fish, vertebrates and waterbirds especially during winter
Paspalum distichum	Water couch	x		Forms significant macrophyte beds
Phragmites australis	Common reed	x		Forms significant macrophyte beds
Pseudoraphis spinescens	Spiny mudgrass		x	Indicator of habitat integrity and provides good waterfowl habitat.
Schoenoplectus mucronatus		x		Forms significant macrophyte beds
Sphenoclea zeylanica			x	Forms significant macrophyte beds
Typha orientalis	Broad-leaved cumbungi	x		Forms significant macrophyte beds
Vallisneria nana		x	x	Forms significant macrophyte beds

Table C-2 Priority aquatic fauna within the Fitzroy and Burdekin catchments

Scientific Name	Common Name	Fitzroy		Burdekin		Comments
		NR	R	NR	R	
Ambassis agrammus					x	
Anguilla obscura	Pacific shortfin eel			x	x	Presence of species indicates good habitat connectivity
Anguilla reinhardtii	Longfin eel			x	x	Presence of species indicates good habitat connectivity
Chanos chanos	Milkfish			x	x	Species is dependent on good connectivity with estuarine ecosystems and therefore provides a good indicator of hydrological and habitat connectivity with estuaries.
Elops hawaiensis	Giant herring			x	x	Species is dependent on good connectivity with estuarine ecosystems and therefore provides a good indicator of hydrological and habitat connectivity with estuaries
Elseya albagula	Southern snapping turtle		x			
Elseya irwini	Irwin's turtle				x	Endemic to Burdekin basin
Euastacus eungella	Freshwater crayfish		x			Endemic species with only a small population threatened by loss of habitat.
Euastacus monteithorum	Freshwater crayfish		x			Endemic species with only a small population threatened by loss of habitat
Giurus margaritacea	Snakehead gudgeon				x	Highly migratory catadromous species thought tobe an estuarine brackish breeder and therefore an indicator of coastal hydrological connectivity
Hephaestus fuliginosus	Sooty grunter	x	x			Threatened by loss of habitat
Kuhlia rupestris	Jungle perch		x		x	Species is suffering a decline in population and distribution as it is sensitive to water quality and riparian vegetation condition as well as being connectivity dependent
Lates calcarifer	Barramundi	x	x			Migratory species that has experience a significant reduction in its already naturally restricted distribution due to habitat modification
Macquaria ambigua	Yellowbelly		x			Endemic species that has experienced a significant reduction in its already naturally restricted distribution.
Megalops cyprinoides	Oxeye herring	x	x			Migratory species that has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area.
Mogurnda adspersa	Southern purple spotted gudgeon			x	x	Declining populations and local extinctions

Scientific Name	Common Name	Fitzroy		Burdekin		Comments
		NR	R	NR	R	
Mugil cephalus	Sea mullet	x	x			Migratory species that has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area
Myxus petardi	Pinkeye mullet	x	x			Migratory species that has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area
Neosilurus mollespiculum	Softspine catfish				x	Endemic to Burdekin region with a patchy distribution in the Burdekin River catchment.
Notaden melanoscaphus	Brown shovelfoot			x		Extremely geographically restricted species on the east coast with populations in the wider Burdekin catchment extremely isolated from other populations given current knowledge
Ophiocara porocephala	Spangled gudgeon	x	x	x	x	Largely a brackish species restricted in distribution and suffering from loss of habitat
Philypnodon grandiceps	Flathead gudgeon			x	x	Restricted in distribution.
Scleropages leichardti	Southern saratoga	x	x			Endemic to the study area this species' entire breeding population occurs within wetlands
Scortum hillii	Leathery grunter	x	x			Endemic to the study area this species' entire breeding population occurs within wetlands.
Scortum parviceps	Smallhead grunter				x	Endemic to the Burdekin River catchment, this species has a patchy distribution within the catchment because of specific habitat requirements for example below Burdekin falls
Strongylura krefftii	Freshwater longtom	x	x	x	x	Suffering declining populations and distribution.

C.2.1 *Migratory Fauna*

In addition to the priority aquatic fauna above, migratory species listed under the following agreements are also considered priority fauna species:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA); and
- Convention on the Conservation of Migratory Species of Wild Animals (CMS).

Migratory species that have potential to occur within Burdekin and Fitzroy catchments (and thus the project area) are detailed below in Table C-3

Table C-3 Priority migratory fauna species within the Fitzroy and Burdekin catchments

Scientific Name	Common Name	Fitzroy		Burdekin	
		NR	**R**	**NR**	**R**
Anas querquedula	Garganey			X	X
Ardea ibis	Cattle egret	x		X	
Ardea modesta	Great egret	x	x		
Arenaria interpres	Ruddy turnstone	x			
Calidris acuminata	Sharp-tailed sandpiper	x		x	
Calidris alba	Sanderling			x	
Caladris canutus	Red knot			x	
Calidris ferruginea	Curlew sandpiper			x	
Calidris melanotos	Pectoral sandpiper			x	
Calidris ruficollis	Red-necked stint			X	
Calidris subminuta	Long-toed stint			X	
Calidris tenuirostris	Great knot			X	
Ceyx azureus	Azure kingfisher			x	X
Charadrius bicinctus	Double-banded plover	x			
Chlidonias leucopterus	White-winged black tern	x	x	x	
Circus approximans	Swamp harrier			x	
Gallinago hardwickii	Latham's snipe	x	x	x	x
Glareola maldivarum	Oriental pratincole	x		x	
Limosa limosa	Black-tailed godwit	X		x	
Numenius minutus	Little curlew	X		x	
Philomachus pugnax	Ruff			x	
Plegadis falcinellus	Glossy Ibis	X			
Pluvialis fulva	Pacific golden plover	X			
Rostratula australis	Australian painted snipe	X	x		
Tringa glareola	Wood sandpiper			x	
Tringa nebularia	Common greenshank			X	
Tringa stagnatilis	Marsh sandpiper	X		x	
Xenus cinereus	Terek sandpiper	x			

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