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Prepared for **Department of the Environment**

Report

Water Quality Monitoring Plan

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1. Introduction

Condition 8 of the commonwealth EPBC approval for the Woleebee Creek to Glebe Weir Pipeline project (EPBC 2011/6181) directs the person taking the action to prepare and submit a Water Quality Monitoring Plan (WQMP) for the Minister's approval.

This document constitutes the WQMP.

The WQMP essentially mirrors the water quality component of the Receiving Environment Monitoring Program (REMP) required under State approvals. The REMP includes all aspects of aquatic environment monitoring (hydrology, geomorphology, water quality and biology) so amalgamates the Commonwealth Discharge Management Plan (relevant to hydrology) and WQMP. The REMP also addresses releases from the pipeline as distinct from release only to Glebe Weir, which is the sole subject of the WQMP.

The water quality and biology components of the REMP as they relate to the Dawson River have been extracted and modified slightly to better align with Commonwealth requirements for a WQMP. The REMP is included in full as Appendix 1 in order to show the extent of monitoring being undertaken and the basis of design of the full monitoring program.

Section 1.1 of this document specifically addresses the relevance of the Plan to MNES while Section 1.2 provides cross references to those parts of the Plan that relate directly to the conditions of approval.

The Woleebee Creek to Glebe Weir pipeline project is otherwise known as the Glebe Beneficial Use Scheme or GBUS and that is the terminology used in this document.

1.1 Relevance of the Plan to MNES

The Preliminary Documentation submitted 2 August 2012 included observations and predictions regarding potential water quality impacts on Matters of National Environmental Significance (MNES). The relevant MNES are Fitzroy River Turtle and the Great Barrier Reef World Heritage Area. With respect to Fitzroy River Turtle, direct impacts may relate to toxic components of the discharge, though none were predicted other than ammonia in exceptional circumstances. The Preliminary Documentation noted "Any risk of ammonia toxicity will be limited to Glebe Weir and immediately downstream, as ammonia is highly bioavailable and is likely to be assimilated by algal and plant communities". As Fitzroy River Turtle has never been recorded in or immediately downstream of Glebe Weir, this is considered a low risk.

A potential increase in the risk of algal blooms was also noted and was related to the low turbidity of the treated CSG water discharge and both the natural and potentially increased capacity of Glebe Weir to stratify. Naturally high turbidity in Glebe Weir was thought to currently limit algal and macrophyte growth in spite of high background nutrient levels. Increased macrophyte growth was recognised as having potentially positive impacts though in other areas excessive growth has been observed to block the turtle's access to nesting banks. There are no nesting banks in Glebe Weir or nearby with the nearest suspected to be in Theodore Weir.

Water quality changes which lead to an alteration of ecosystem functioning in general may also potentially indirectly impact on Fitzroy River Turtle.

Section 7 of the Preliminary Documentation noted "The parameters of concern (to the World Heritage Area) are identified as suspended solids and nutrients." Modelling predicted low levels of change, mainly related to increased agricultural production and runoff but the level of change would be immeasurable at the mouth of the Fitzroy River.

As a result, water quality parameters of concern to MNES are:

- Ammonia
- Temperature
- pH
- conductivity
- turbidity
- nutrients

and their effects on

- blue green algae, and
- macrophytes.

This plan also includes monitoring or various other parameters of relevance to the treated CSG water which, though predicted to be at levels which would not cause impacts, could lead to impacts if those predictions were to prove incorrect.

1.2 Cross reference to conditions of approval

The conditions of approval relevant to the WQMP are noted below, as extracted from SunWater's EPBC approval for the Woleebee Creek to Glebe Weir Pipeline project (EPBC 2011/6181), and cross referenced to sections of the document where information satisfying the condition can be found.

8. The person taking the action must prepare and submit a Water Quality Monitoring Plan (WQMP) for the Minister's approval (***this document***).

a. The WQMP must include, but not be limited to:

i. Measures to conduct **regular** environmental monitoring within the Dawson River, at a range of locations (***Section 5.2.1, Table 8 and Map 2***) including but not limited to:

1. upstream of the discharge point;
2. within Glebe Weir but downstream of the discharge point; and
3. downstream of Glebe Weir, at least as far as Theodore Weir.

ii. Details of parameters to be monitored (***Section 5.3***).

iii. For each parameter specified in Condition 8(a)(ii), the WQMP must stipulate a **threshold limit** (***Section 3.3 and Tables 5, 6 and 7***).

iv. The WQMP must specify the guideline, standard or relevant research for which both the background level within Glebe Weir and the threshold limit has been set, along with a discussion of why the particular guideline, standard or relevant research is appropriate (***Section 3.3.2 and 3.2***).

b. Within three months of **every six month** anniversary of commencement of discharge (and until two years after the cessation of discharge), the person taking the action must submit to the Minister an Environmental Performance Report (EPR). Each EPR must include, but not be limited to (***Section 6***):

i. The results of implementation of the Discharge Management Plan (DMP) required by Condition 7 (***Note: SunWater has separately developed and obtained approval of its DMP from the Department of Environment on 23 January 2015***),

ii. The results of the **regular** environmental monitoring required by the WQMP (***Section 5.3 and Table 9***),

iii. An independent evaluation of the results of the regular environmental monitoring required by the WQMP, and an assessment of any **new or increased impacts/likely impacts** to the environment identified.

c. If, upon review of an EPR, the Minister is not satisfied that **appropriate actions** have been taken or will be taken to mitigate any **new or increased impacts/likely impacts** to the environment identified during the regular monitoring required by this condition, the Minister may direct the person taking the action to reduce or cease discharge. The person taking the action must then undertake an evaluation in accordance with the recommendations of an independent evaluator and submit the report to the Department for approval.

The relevant definitions are:

Appropriate actions – Actions that result in the total rectification of the identified new or increased impact/likely impact (i.e. actions that return the quality of the water to the quality it was before the new or increased impact/likely impact was identified).

New or increased impacts/likely impacts – An impact not identified in the Preliminary Documentation, dated 2 August 2012. Also includes an increase in impact beyond that identified in the Preliminary Documentation, dated 2 August 2012.

Regular –

a) with respect to physico-chemical water quality parameters, a minimum of once per month for the first 12 months of operation, then at a frequency recommended by the Environmental Performance Report unless otherwise required by the Department,

b) with respect to biological parameters, twice per year (wherever possible this is to be once pre-wet season and once post-wet season) for the first three years of operation, then at a frequency recommended by the Environmental Performance Report unless otherwise required by the Department.

Threshold limit – The maximum limit or acceptable value range above the pre-existing background level within Glebe Weir which may be reached before impacts to Matters of National Environmental Significance are likely to occur.

2. Description of the Action

The GBUS is fully described in the EPBC Preliminary Documentation for the project (SunWater 2012c) and the application for a Beneficial Use Approval (BUA, SunWater 2012a). Those documents included risk assessments related to all relevant environmental features and they are relied upon to support this WQMP.

In summary, the GBUS will transfer treated coal seam gas water to customers along a transfer pipeline and within the DVWSS. The latter will involve authorised release of the treated CSG water to Cockatoo Creek at a point within the very downstream end of the storage area of Glebe Weir.

Once released to Glebe Weir the treated CSG water can be distributed within and extracted from the Dawson Valley Water Supply Scheme for a range of purposes.

2.1 Release Characteristics and Potential Risks

2.1.1 Water Quality

Release of the treated CSG water to Cockatoo Creek, within the weir pool of Glebe Weir, has been authorised at the limits shown in **Table 1**. The BUA specifies that the quality of the treated CSG water at discharge is based on measurement at the SunWater pump station which is located at the commencement of the pipeline.

Also shown are the WQO's that apply at the outlet from Glebe Weir. The WQO's are based on the *Dawson River Sub–basin Environmental Values and Water Quality Objectives* (EPP (Water) 2009 (EHP 2013a). Those guidelines separate water body types and locations and for simplicity that used below is only 'Lower Dawson main channel', which commences immediately below the Glebe Weir wall. In setting interim local WQO's SunWater (Report prepared for SunWater by frc Environmental, 2014g, "SunWater Glebe Beneficial Use Scheme, Interim Local Water Quality Objectives") has determined no difference between water body types within the receiving environment for water quality indicators so a single set of indicators for all sample sites is appropriate.

The WQO's below have not been adjusted to take account of the interim objectives so the discussion of risk is based on that presented in application documents. Changes to that assessment as a result of further information and the setting of interim guidelines is discussed in Section 3.3.2.

Table 1: Water quality limits for the treated CSG water and WQO's at Glebe Weir outlet

Parameter	Unit	Treated CSG Water	
		Limits[a] for treated CSG water at discharge	WQOs[b] for receiving water at Glebe Weir
pH	unit	6.5 – 8.5	6.8 – 8.5
electrical conductivity @ 25°C	µS/cm	445	340
turbidity	NTU	50	
Ammonia	mg/L	0.4	0.02
Boron	mg/L	1.0	0.37
Arsenic	mg/L	0.024	0.024

Parameter	Unit	Treated CSG Water	
		Limits[a] for treated CSG water at discharge	WQOs[b] for receiving water at Glebe Weir
Chromium	mg/L	0.001	0.001
Iron	mg/L	0.3	0.3
Lead	mg/L	0.0034	0.0034
Manganese	mg/L	1.9	1.9
Nickel	mg/L	0.011	0.011
Selenium	mg/L	0.005	0.005
Copper	mg/L	0.0014	0.0014
Zinc	mg/L	0.008	0.008

a Limits are maximums unless presented as a range.
b WQO's are medians

A comparison of the above shows the only indicators which have been licenced to have concentrations at the point of discharge in Glebe Weir (as measured at SunWater's pump station) which are greater than the prescribed WQO's are Boron, Ammonia and Electrical Conductivity. As such they are the only compliance parameters recognised as posing a potential risk to the environment. It is also assessed that the BUA limit for Electrical Conductivity, being a maximum value of 445 µS/cm, is equivalent to a median value of 340 µS/cm and therefore no worse than the WQO. All other indicators specified have maximum limits which are no greater than the corresponding WQOs which are median values based on the most stringent environmental value applicable (and hence by default will not cause environmental harm if compliant).

At 0.4 mg/L of ammonia, the CSG discharge would be toxic to some aquatic biota when pH was greater than 8.5, coinciding with water temperatures greater than 30°C, or at pH 9 when temperatures exceeded approximately 24°C. These conditions are very unlikely in Glebe Weir, even during summer and there will generally be a high level of dilution of the CSG water. QGC has since addressed this issue by proposing to use non-ammonia generating treatment methods at times when environmental conditions may favour ammonia toxicity. The background levels for ammonia in the Dawson River ranged from less than the Limit of Reporting (LOR) up to 6mg/L in the monitoring undertaken in the receiving environment between 2007 and January 2015. The water quality limit of 0.4mg/L for ammonia falls within this range, and considering risks and potential impact in association with temperature and pH as identified above.

The limit of 1.0 mg/L (maximum) for Boron is higher than the current WQO of 0.37 mg/L (national and state accepted aquatic ecosystem trigger value), in accordance with the amended BUA approval conditions and considering recent direct toxicity evaluations (Halcrow for Santos 2012 in the Dawson) that have recommended the local trigger could be adjusted to 1.0mg/L. The assessment was conducted using Dawson River from upstream of Taroom and is considered representative of the area of the scheme. As further support, similar studies in the Condamine River returned the same result (Acqua Della Vita, 2014). These studies were conducted in accordance with the ANZECC guidelines, validate the change to 1.0 mg/L and have been accepted by DEHP (Qld).

As the nominated metals are licenced to be no more than the guideline (WQO) levels in the discharge and this is often well below the ambient concentration in water at Glebe Weir, accumulation in the sediment would not be expected to represent a risk.

A number of constituents of the treated CSG water not included within BUA limits were identified as being of potential concern when discharged to Glebe Weir. They were:

- Alkalinity will be significantly lower than background levels and may have implications for the buffering capacity of the receiving water (i.e. may be more susceptible to changes in pH from acid sources). However as background levels are well above the minimum guideline levels, the lower levels in the treated CSG water will only be of concern when it constitutes nearly all of the available water.
- Major ions. Sodium will be higher and calcium lower than background levels while magnesium will be similar. These relative ion concentrations may cause dispersion of sediment in the water column (and increase turbidity) and possibly the release of bound nutrients and toxicants. Low calcium levels may affect the ability of some animals to form shells though natural levels provide ample supply and dissolved sources (such as in the treated CSG water) are usually not the only source.
- Turbidity and total suspended solids will be much lower than background levels. The high background turbidity and TSS loads in Glebe Weir are highly likely to be preventing algal growth. Therefore, there is a risk of increasing the likelihood of algal blooms in Glebe Weir (which have historically rarely been observed).
- Temperature, which could be a concern as it may be greater than 2°C higher than the background seasonal range, particularly in cooler seasons.

2.1.2 Water Quantity

The annual volume released to the pipeline must not exceed 36,500 megalitres (ML) and the maximum daily release to Glebe Weir must not exceed 100 ML. Release is expected to peak early in the life of the project before tailing off. Thus, the first three to five years of operation represent the highest risk of adverse environmental impacts.

The treated CSG water is allowed to be released for a maximum period of 26 years. Within the DVWSS the treated CSG water will be allocated via the existing announced allocation system, meaning most of the treated CSG water will be available for extraction and use from and upstream of Theodore Weir pool.

3. Description of Receiving Environment Attributes

3.1 Spatial Extent of the Receiving Environment

The receiving environment for GBUS includes the waters of Glebe Weir and the DVWSS (Map 3). The DVWSS extends from the upstream end of Glebe Weir pool (AMTD 356.5 km) to Boolburra Waterhole (AMTD 18.4 km) on the Dawson River, including the Theodore and Gibber Gunyah irrigation channels (Map 1).

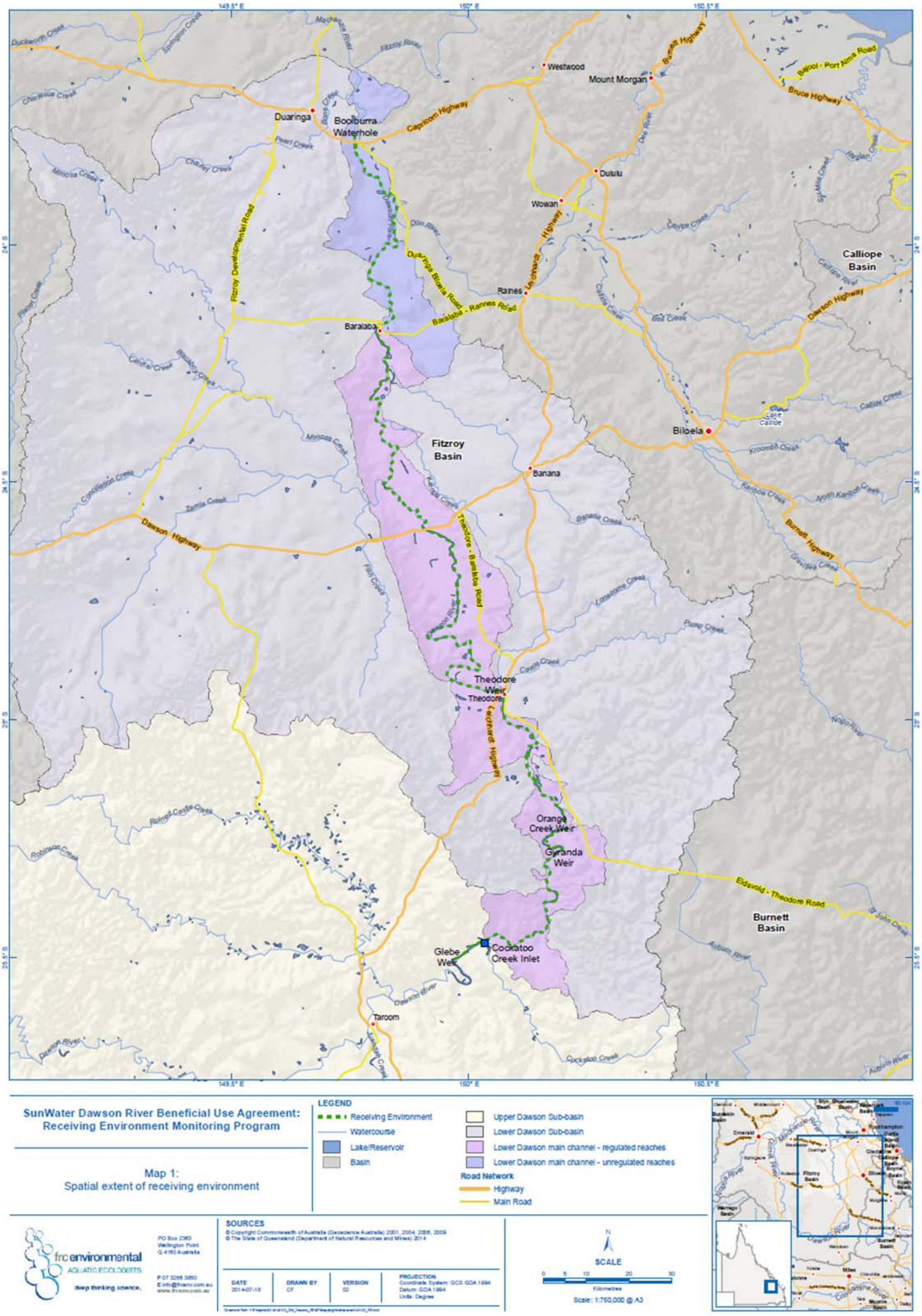
The DVWSS includes flowing reaches and a number of impounded reaches (i.e. weir pools). The weirs in the system from upstream to downstream are Glebe, Gyranda, Orange Creek, Theodore, Moura and Neville Hewitt (Map 1).

The receiving environment spans both the Upper and Lower Dawson River Sub-catchments, with waterways upstream of Glebe Weir (and including Glebe Weir) being within the Upper Dawson Sub-catchment, and waterways downstream of Glebe Weir being within the Lower Dawson Sub-catchment (Map 1). Designations are in accordance with *Dawson River Sub-basin Environmental Values and Water Quality Objectives* (EPP (Water) 2009 (EHP 2013a). Within that document weir pools are designated as a separate water body type; 'Freshwater lakes and reservoirs'.

3.1.1 Potentially Impacted Waterways

Previous studies have shown that any impacts to water quality and aquatic ecology are mostly likely to occur near the point of discharge at the lower end of Glebe Weir and within a short distance downstream of the weir. Sites upstream of the junction of Cockatoo Creek within the Dawson River are unlikely to be affected when the river is flowing either naturally or via releases from the Weir. It is possible that flow regime impacts may be measurable downstream of Theodore Weir, however it is expected that modified flows this far downstream will be minor compared to existing flow modification and are unlikely to have an adverse environmental impact. The majority of the additional water will be extracted upstream of Theodore Weir so locations downstream from this point are not regarded as at risk.

MAP 1 – Dawson River sub-catchments (upper and lower Dawson sub-basin)



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3.2 Current Condition of the Receiving Environment

3.2.1 Previous Surveys

A number of relevant studies were undertaken in the Dawson River as part of the Nathan Dam and Pipelines EIS (SunWater 2008, 2012b; frc environmental 2010; 2011). These studies considered the hydrology, geomorphology, water quality, aquatic flora and aquatic fauna of the Dawson River.

Baseline aquatic ecology and water quality surveys within the receiving environment (and upstream of the receiving environment) have been completed on a regular basis since February 2012, and are intended to form the basis of project specific local water quality guidelines. The baseline surveys have included quarterly water quality monitoring (**Table 2**) and twice-yearly surveys of aquatic ecology (including aquatic habitat, sediment quality, aquatic plants, macroinvertebrates and fish) since November 2012 (**Table 3**). The Dawson River was under base flow condition during the baseline surveys. This baseline data has been addressed, along with other historical data, as part of preparing this WQMP and the REMP and assisted in determination of suitable locations to undertake monitoring. The location of the baseline monitoring sites is presented in Map 2.

Table 2: Overview of baseline surveys of water quality that have been undertaken within the receiving environment

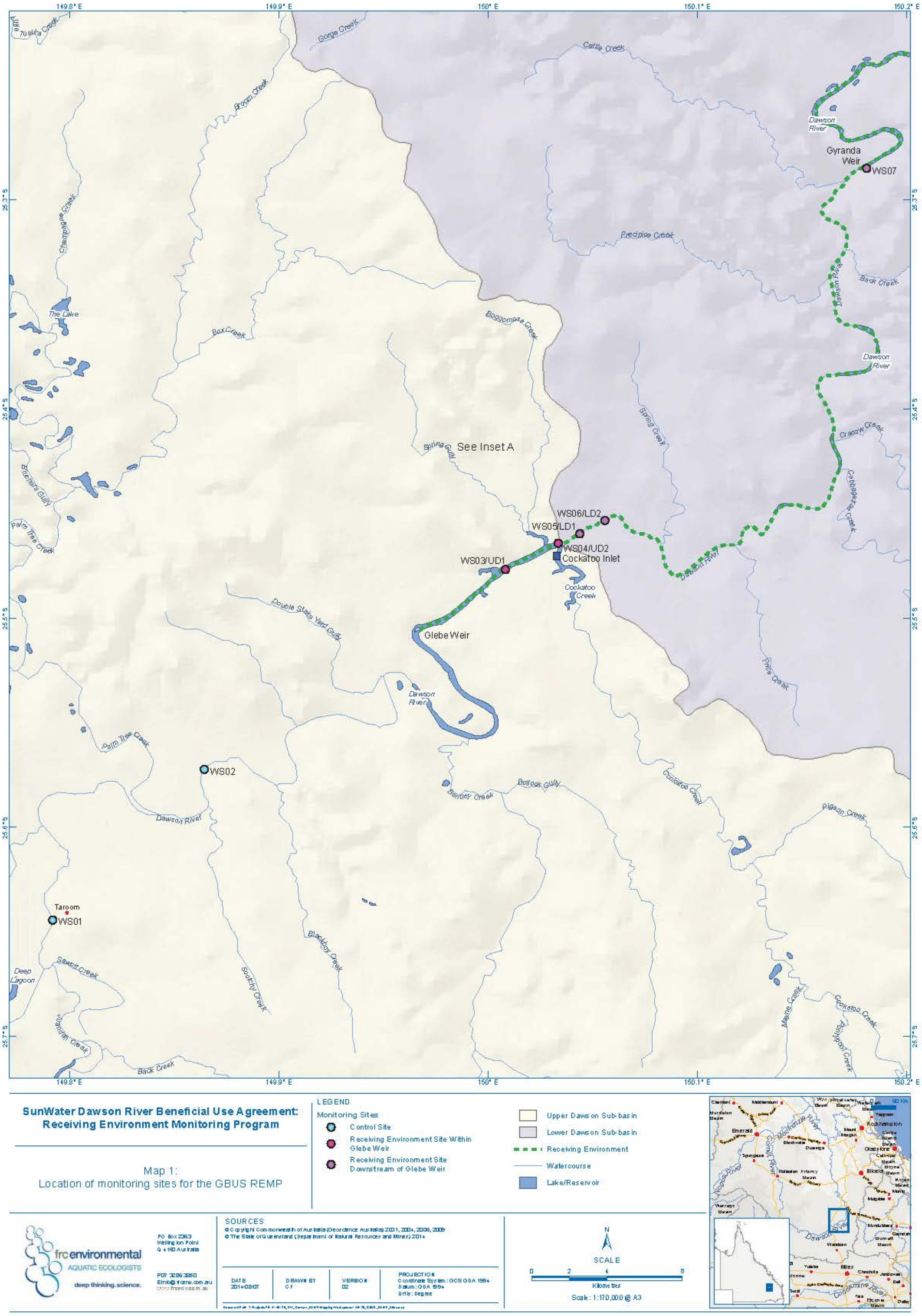
Study	Monitoring date and round	Sites assessed in survey round
ALS 2012	Water quality monitoring round 1, February 2012	Utopia Downs, WS01, WS02, WS04/UD2, WS05/LD1, WS07, WS08, WS09, Boolburra Waterhole
GHD 2012	Water quality monitoring round 2, August 2012	Tarana Crossing, WS01, WS02, WS04/UD2, WS05/LD1, WS07, WS08, WS09, Boolburra Waterhole
frc environmental 2013a	Water quality monitoring round 3, November 2012	Tarana Crossing, WS01, WS02, WS04/UD2, WS05/LD1, WS07, WS08, WS09, Boolburra Waterhole
frc environmental 2013b	Water quality monitoring round 4, April 2013	Tarana Crossing, WS01, WS02, WS03/UD1, WS04/UD2, WS05/LD1, WS06/LD2, WS07, WS08, WS09, Boolburra Waterhole
frc environmental 2013c	Water quality monitoring round 5, June 2013	WS01, WS02, WS03/UD1, WS04/UD2, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2013d	Water quality monitoring round 6, September 2013	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2013e	Water quality monitoring round 7, November 2013	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2014a	Water quality monitoring round 8, January 2014	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental	water quality	WS01, WS02, WS03/UD1, WS04/UD2, WS10,

Study	Monitoring date and round	Sites assessed in survey round
2014b	monitoring round 9, April 2014	WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2014d	water quality monitoring round 10, July 2014	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2014f	water quality monitoring round 11, October 2014	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09

Table 3: Overview of baseline surveys of aquatic ecology that have been undertaken within the receiving environment

Study	Monitoring date and round	Sites assessed in survey round
frc environmental 2013f	Aquatic ecology monitoring round 1, November 2012	Tarana Crossing, WS01, WS02, WS04/UD2, WS05/LD1, WS07, WS08, WS09, Boolburra Waterhole
frc environmental 2013g	Aquatic ecology monitoring round 2, June 2013	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2013h	Aquatic ecology monitoring round 3, November 2013	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2014c	Aquatic ecology monitoring round 4, April 2014	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09
frc environmental 2014e	Aquatic ecology monitoring round 5, October 2014	WS01, WS02, WS03/UD1, WS04/UD2, WS10, WS11, WS05/LD1, WS06/LD2, WS07, WS08, WS09

MAP 2 – Location of Baseline & WQMP Monitoring Sites



3.2.2 Catchment Area, Surrounding Land Use and Current Riverine Development

The Dawson River is a major tributary of the Fitzroy River. The Dawson River and its tributaries cover an area of approximately 50,776 km^2 (EHP 2013a).

Glebe Weir (the most upstream reach of the receiving environment) was constructed in 1971 and has a catchment area of 19,423 km^2. The surrounding land use is predominantly cattle grazing, with some cropping and recreation. The nearest town is Taroom, approximately 50 km upstream of the weir. The weir pool is a popular primary and secondary recreation area used for fishing and boating, and there is a designated and well used camping area and boat ramp on the left bank adjacent to the weir and opposite the mouth of Cockatoo Creek. Water is extracted or released from Glebe Weir to the DVWSS and used for cropping (mostly cotton), stock watering, industrial use and urban supplies (SunWater 2012a and b). Public access to Glebe Weir, in particular boating traffic on the weir pool, creates moderate disturbance of aquatic habitats. Aquatic habitats within the weir pool are restricted, mostly limited to deep pool habitat and large woody debris, which are the dominant aquatic habitats within impounded reaches of the Dawson River generally.

Gyranda Weir, Orange Creek Weir and Theodore Weir are also located within the receiving environment (**Table 4**) downstream from Glebe Weir. Similar to Glebe Weir, surrounding land use at Gyranda and Orange Creek is predominantly cattle grazing but they have no formal recreation areas or direct public access. Theodore Weir is adjacent the township of Theodore and the main irrigation area, which is both riparian and channel based. Aquatic habitat diversity at all weirs is low. There is over 15 km of flowing river between Glebe Weir and the upstream extent of Gyranda Weir pool, and 25 km of flowing river between Orange Creek Weir and Theodore Weir pool, although there is limited flowing river between Gyranda Weir and Orange Creek Weir pool (**Table 4**).

Table 4: Location of weirs within the receiving environment

Weir	Location (AMTD km)	Full Supply Volume	Length of river inundated (km)
Glebe	326.2	17,700	30.3
Gyranda	284.5	16,500	26.5
Orange Creek	270.7	6,140	13.8
Theodore	228.5	4,760	16.0

3.2.3 Hydrology

The flow regime of the Dawson River and its tributaries is dominated by ‘unpredictable, highly intermittent summer flow’ with some reaches having ‘variable, extremely intermittent summer flow’ (Kennard et al. 2010). Thus, the magnitude, duration and timing of summer flows can vary between years, although the majority of flows occur from December to April, with high flow events most likely to occur in late summer or early autumn (SunWater 2008). Long-term flow data recorded at the Nathan George gauging station show that the Dawson River is in low flow condition most of the time with intermittent flows generally occurring as large pulses (SunWater 2008). Median annual flow at Glebe Weir is 240,065 ML/a (to 2011). In unregulated reaches above Glebe Weir years of zero flow have been recorded.

The low flow regime within the DVWSS is regulated via releases from the weirs and determined by the Fitzroy Basin Water Treated CSG water Plan and Treated CSG water Operations Plan.

Low flow and zero flow periods are likely to be the most important ‘events’ for the WQMP, as during these times the discharge of treated CSG water may constitute a significant proportion of water within the Dawson River near the discharge location (i.e. Glebe Weir and immediately downstream).

3.2.4 Geomorphology

From upstream of Glebe Weir into the upstream parts of Nathan Gorge, the Dawson River is characterised by a broad low-level floodplain approximately 200 m to 350 m wide between banks from approximately 8 m to 15 m high. The clayey confined floodplain is dissected by a series of anastomosing channels with some isolated waterholes. Only one, or occasionally two, of these channels carry low flows and the nature and maturity of the vegetation adjacent to these channels and on the confined floodplain suggests that the channels are relatively permanent. The native vegetation cover in the river channel resists erosion during normal flood events but would be stripped during large floods.

Nathan Gorge, below Glebe Weir, is a well-known geomorphic feature in the Dawson River area. The Dawson River has eroded a deep channel through a landscape where the surface geology is dominated by the relatively resistant Precipice Sandstone, resulting in formation of the gorge landform. When full, Gyranda Weir pool backs up through the gorge.

The Preliminary Documentation (SunWater 2012c) concluded that potential impacts on fluvial geomorphology relating to flow velocity and height within the weir pool are likely to be minor. Impacts will be associated with the effects of releasing relatively clear treated water into a turbid water body at relatively high velocities. Impacts may include erosion of exposed surfaces immediately downstream of the discharge point in Cockatoo Creek, leading to entrainment and increased sediment delivery to the lower end of the weir. The design based slowing of the flow rate at the discharge point and armouring of the area surrounding the outfall will significantly limit impacts. The impact will be limited to the short reach from the discharge point to the weir wall and will initially relate to movement of sediment accumulated since construction of the weir. Increasing turbidity as a result of the scour will allow for more efficient mixing with the weir pool and will reduce the risk of downstream clear water scour. Sediment delivery from upstream areas of Cockatoo Creek during times of natural stream flow will replenish the sediment as will that from the Dawson catchment, which is orders of magnitude greater.

Impacts to geomorphology downstream of Glebe Weir relating to increased flow velocity and heights will be of a similar nature to those within the weir and include bed and bank scour and associated changes to channel geomorphology. However, given that hydrological modelling shows that impacts to flows other than very low flows will be insignificant in comparison with existing conditions, any geomorphic impacts would also be expected to be minor.

With respect to increased flow regulation, the following geomorphic impacts could be expected:

- Notch erosion, which is gradual scour of a bank at a particular height due to regulated flow. This is typical downstream of a regulated flow release where low flow releases are of a similar water level for the majority of the time. This is likely to occur particularly within the reaches immediately downstream of the weir and at those locations where erosion is currently active. This will be a gradual process which can be monitored; and
- Concomitant bar / bench and vegetation encroachment and resulting low-flow contraction. This impact is generally more associated with a reduction in intermediate flows and is already evident downstream of Glebe Weir.

Given the already highly regulated nature of flow in this river and the extent of existing weir pools within the DVWSS, impacts on geomorphology were predicted to be minor and restricted to the region immediately downstream of the discharge and of Glebe Weir.

3.2.5 Aquatic Habitat Features

There is a diverse range of aquatic habitats in the Dawson River within the receiving environment that provide favourable conditions for aquatic fauna and plants. Habitats include shallow and deep pools, riffle and run flowing habitats, large woody debris and variable substrate types. Perennial water holes and weir pools also provide dry-season refuge for aquatic fauna, including for conservation significant species of freshwater turtle (Section 3.2.11) several species of fish (Section 3.2.10) and invertebrates (Section 3.2.9) that are endemic to the Fitzroy River.

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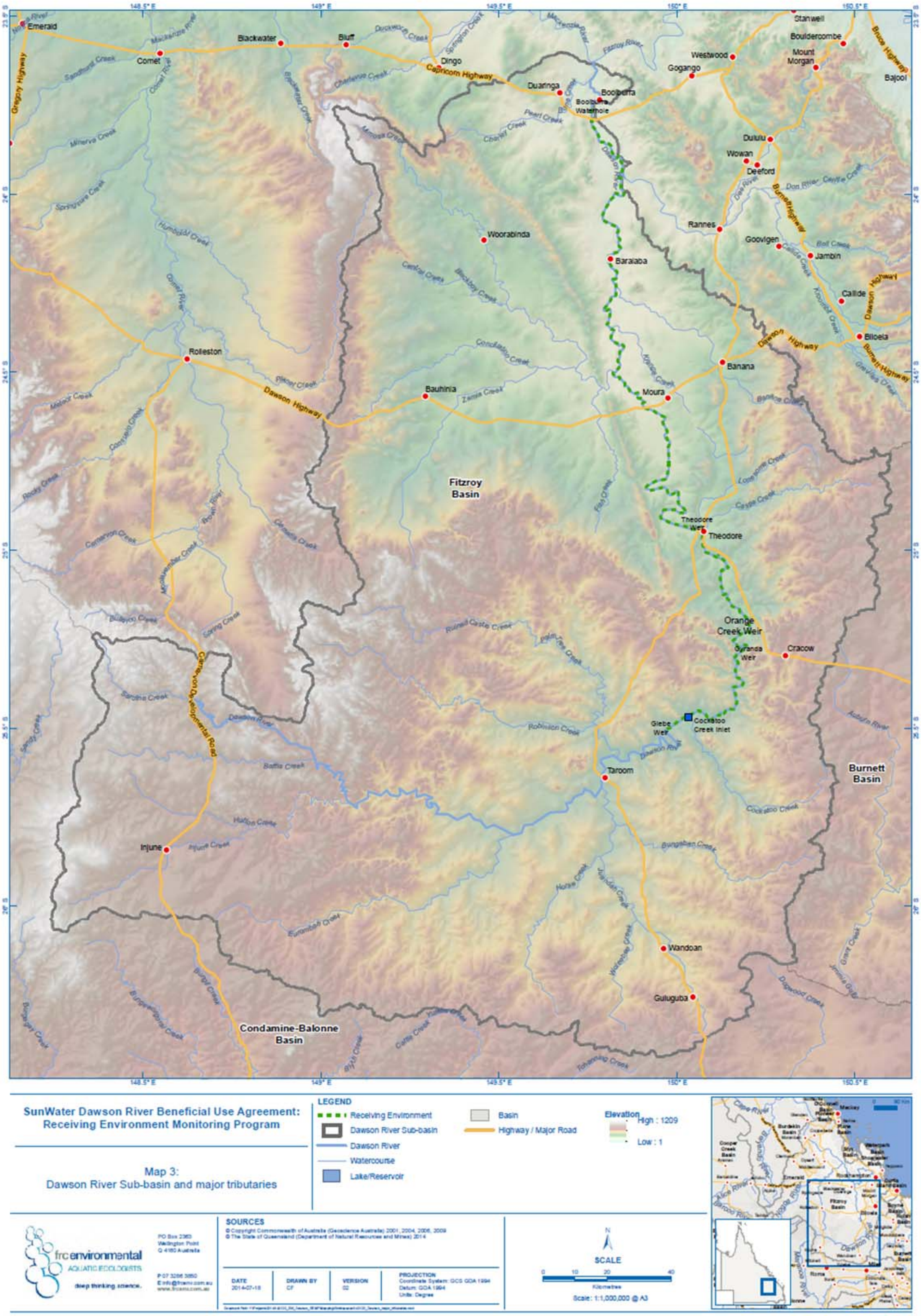
MAP 3 – Area of the Receiving Environment



3.2.6 Water Quality

Water quality data relevant for the WQMP was collected at baseline monitoring sites, and was compiled and summarised. Previously reported water quality data (e.g. SunWater 2008; 2012a,b,c) were also reviewed to provide an overview of the current condition of water quality within the receiving environment.

Water quality in the receiving environment relative to the default WQO range was characterised by:

- High electrical conductivity (base flow conditions);
- High turbidity;
- Low dissolved oxygen;
- High nutrient levels;
- High ammonia; and
- High concentrations of some metals (e.g. aluminium, iron, manganese).

3.2.7 In-stream Sediment Quality

Sediment quality data was collected at sites within the receiving environment and was compiled and summarised.

Sediment quality in the receiving environment complied with the interim sediment quality guidelines (low trigger value) (ANZECC & ARMCANZ 2000a), noting that guideline values are not available for all parameters. The concentration of metals in sediment was varied, with some parameters, such as iron and manganese, having relatively high concentrations compared to other parameters.

3.2.8 Aquatic Plants

Aquatic plant abundance and diversity in the receiving environment is low. One submerged plant species, curly pondweed (*Potamogeton crispus*), four floating plants species (*Azolla pinnata, Ricciocarpus* sp., *Spirodela polyrhiza, Lemna* sp.) and one floating attached species (*Ludwigia peploides montevidensis*) have been recorded from baseline surveys (frc environmental 2013a; b; c). However, the total cover / abundance of aquatic plants in water was highly variable and generally very low. A number of emergent aquatic plants have also been recorded, mostly growing on the banks and along the edge of water, including *Juncus* spp., *Persicaria* spp., *Cyperus* spp., *Fimbristylis* spp. and *Lomandra* sp.; however, the total abundance and / or cover of these aquatic plant species is also low (frc environmental 2013d; e; f; 2014c).

3.2.9 Macroinvertebrates

From baseline surveys, macroinvertebrate communities in Glebe Weir generally have lower taxonomic richness, PET richness and SIGNAL-2 scores compared to the other weir pools. This may be related to Glebe Weir's role in the water supply scheme (i.e. it is the headwater storage so it is emptied first), meaning that it undergoes greater fluctuations in water level compared to weirs further downstream. Furthermore, downstream weirs on the Dawson River are mandated under the Treated CSG water Operations Plan to have relatively constant water levels, meaning that edge habitat in these weirs is less variable and more likely able to support more diverse macroinvertebrate communities.

Macroinvertebrate communities in the riverine areas of the receiving environment are in good condition, with taxonomic richness, PET richness and SIGNAL-2 scores within or above published biological water quality objectives. Macroinvertebrate communities are dominated by tolerant taxa, including Ceratopogonidae, Chironominae and Tanypodinae (non-biting midges) and Corixidae (waterboatmen) (frc environmental 2013d; e; f; 2014c). More sensitive taxa including Elmidae (riffle beetles), Scirtidae (marsh beetles), Leptophlebiidae (mayflies) and Calamoceratidae (sleeping-bag caddisflies) have been recorded in small numbers in both the riverine areas and weirs. A species of moon snail, *Larina strangei* (family Viviparidae), is known from the Dawson River in the vicinity of Isla Delusion (site WS08), and is considered to be endemic to the Dawson River, although it is not a listed threatened species.

3.2.10 Fish

Fifteen native species of fish have been recorded during baseline surveys within the receiving environment (frc environmental 2013e; f; 2014c):

1. Agassiz's glassfish (*Ambassis agassizii*)
2. barred grunter (Amniataba percoides)
3. blue catfish (Neoarius graeffei)
4. bony bream (*Nematalosa erebi*)
5. carp gudgeon (*Hypseleotris* spp.)
6. eastern rainbowfish (*Melanotaenia splendida splendida*)
7. flathead gudgeon (*Philypnodon grandiceps*)
8. flyspecked hardyhead (*Craterocephalus stercusmuscarum*)
9. freshwater catfish (Tandanus tandanus)
10. Hyrtl's catfish (*Neosilurus hyrtlii*)
11. leathery grunter (*Scortum hillii*)
12. sleepy cod (*Oxyeleotris lineolata*)
13. southern saratoga (*Scleropages leichardti*)
14. spangled perch (*Leiopotherapon unicolor*)
15. yellow belly (*Macquaria ambigua*)

The fish species recorded can tolerate a wide range of water quality conditions (Allen et al. 2002; Pusey et al. 2004). All species are common to the Fitzroy Basin and the Upper and Lower Dawson River and have been recorded in other surveys in the region (Platten 2011). Leathery grunter and southern saratoga are endemic to the Fitzroy River.

One exotic species of fish, mosquitofish (*Gambusia holbrooki*) has also been recorded in baseline surveys. This species is widespread throughout Queensland and is common in the region (Platten 2011). Two other exotic species are known to occur in the receiving environment, goldfish (*Carassius auratus*) and guppy (*Poecilia reticulate*). Both species have been recorded in other surveys in the area (Platten 2011).

3.2.11 Turtles

Five species of turtles have been recorded from the receiving environment (SunWater 2008; frc environmental 2010; 2011):

1. Krefft's river turtle (Emydura macquarii krefftii)
2. saw-shelled turtle (*Wollumbinia latisternum*)
3. broad-shelled turtle (*Chelodina expansa*)
4. Fitzroy River turtle (*Rheodytes leukops*)
5. white-throated snapping turtle (*Elseya albagula*)

All but Fitzroy River turtle have been recorded from Glebe Weir.

Krefft's river turtle, saw-shelled turtle and broad-shelled turtle species are common in the region and are not listed as species of conservation significance under Commonwealth or State legislation.

The Fitzroy River turtle is listed as vulnerable under the EPBC Act. The white-throated snapping turtle (*Elseya albagula*) is a priority species under Queensland's Back on Track species prioritisation framework. Turtles were not included in the baseline surveys as dedicated surveys had been undertaken in the Dawson for the Nathan Dam and Pipelines EIS (SunWater 2008; frc environmental 2010; 2011) and they are not recognised within the water quality objectives gazetted for the Dawson River.

3.3 Environment Values and Water Quality Objectives

3.3.1 Environmental Values

The receiving environment spans the Upper and Lower Dawson River Sub-catchments, with waterways upstream of Glebe Weir (and including Glebe Weir pool) being within the Upper Dawson Sub-catchment, and waterways downstream of Glebe Weir being within the Lower Dawson Sub-catchment. The *Dawson River Sub–basin Environmental Values and Water Quality Objectives*, EPP (Water) 2009 (EHP 2013a) identifies the following environmental values (EVs) for water within these sub-catchments for both regulated and un-regulated reaches:

- aquatic ecosystem (moderately disturbed waters);
- irrigation;
- farm water supply;
- stock water;
- aquaculture (only regulated reaches of the Lower Dawson River Sub-catchment);
- human consumers;
- primary recreation;
- secondary recreation;
- visual recreation;
- drinking water;
- industrial uses; and
- cultural and spiritual values.

However only the aquatic ecosystem value is relevant to MNES in the Dawson River, and will form the basis for identifying the current published water quality objectives and trigger levels as discussed in the follow section and as identified in Table 5.

3.3.2 Water Quality Objectives

Water quality objectives (WQOs) represent trigger levels for parameters that when achieved provide protection of the relevant EV. Where a WQO is not met, further investigation is required to determine if adverse environmental harm has been or may be caused. Thus, exceedence of the WQOs does not indicate adverse environmental harm in itself; only the need for further investigation. In this way they do not exactly meet the definition of a "threshold limit" which by definition represents a level above which impacts are "likely", but they are used here as a very conservative trigger as per the ANZECC and Queensland water quality guidelines.

The WQOs presented in this WQMP represent the water quality targets in the receiving environment to be achieved, but as noted do not represent the contaminant concentrations or levels indicating adverse environmental impacts. Where the WQOs are exceeded, further investigation would be triggered (Section 6.1).

WQOs to protect the identified environmental values have been published in the following documents:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000a), which specifies national and where possible regional WQOs for broad regions within Australia
- Queensland Water Quality Guidelines (QWQG) (EHP 2013c), which specifies WQOs for different regions within Queensland, but also encourages the development of local WQOs, and
- *Dawson River Sub–basin Environmental Values and Water Quality Objectives* EPP (Water) 2009 (EHP 2013a), which specifies sub–regional WQOs for different areas of the Dawson River Sub–basin.

With respect to the latter, at times it did not actually develop guidelines from local data but referred back to one of the other documents.

There are no WQO's that specifically relate to Fitzroy River turtle so the aquatic ecosystem objectives have been utilised as indicative. These include physico-chemical and biological components (fish and macroinvertebrates).

For the purposes of the WQMP, the parameters listed in Table 1 have been utilised as being of most relevance along with those acknowledged in Section 2.1.1 as potentially relevant at different times. The applicability of the default published WQOs was assessed using baseline and historical water quality data from the receiving environment and draft interim WQOs have been determined for those parameters (**Table 5**), though noting these draft interim values are for information only at this stage, and will be updated and formally revised and submitted (to DEHP and DoE) once a full complement of samples has been collected for those parameters for which it is assessed that local (project specific) WQOs will be developed. The development of these draft interim WQOs was in accordance with the work undertaken by SunWater's consultant frc environmental, and described in the Report prepared for SunWater by frc Environmental, 2014g, "SunWater Glebe Beneficial Use Scheme, Interim Local Water Quality Objectives". The process is in accordance with that described in both ANZECC and Queensland Water Quality Guidelines.

Also, the default WQO's were generally developed as maximums on the basis that contaminants generally increase concentrations above levels that may become toxic or harmful. However, the CSG discharge will sometimes have the opposite effect, it may reduce the concentration or measure to a level that may become indirectly harmful, for example by not providing sufficient calcium or magnesium for species that use it to manufacture a shell or exoskeleton or by providing clear water which may stimulate algal growth. In such cases a minimum trigger has also been developed. For turbidity and total suspended solids, as a percentile for the lower level trigger would essentially be meaningless in an environment where background is well above natural, the lower level trigger has been set at the default WQO.

To be clear, this assessment is for the purpose of updating the risk assessment presented in application documents. The list of parameters included is not indicative of those which would be included in monitoring because, as previously noted, most do not represent a risk to environmental values as their concentration in the discharge must meet the licenced criteria.

Table 5: Interim local Water Quality Objectives for water chemistry

Parameter	Units	Published WQO	Observed Water Quality Range [a]
Parameters listed in Schedule B, Table 1 of the BUA			
Physical-Chemical			
pH	pH unit	6.0 – 8.5	6.5 – 8.5
electrical conductivity (base flow)	µS/cm	340	340
Nutrients			
ammonia as N	mg/L	0.01	0.16
Total Metals and Metalloids			
arsenic	µg/L	13	13
boron	µg/L	370	1000 [b]
chromium	µg/L	1	1.7
copper	µg/L	1.4	4.7
iron	µg/L	10	2936
lead	µg/L	3.4	3.4
manganese	µg/L	10	283
nickel	µg/L	11	11
selenium	µg/L	5	5
zinc	µg/L	5	13.7
Additional parameters			
Physical-Chemical			
temperature	°C	15 – 35	15 – 35
dissolved oxygen	mg/L	–	3.6 – 8.0
dissolved oxygen	% saturation	85 – 110	42 – 110
turbidity	NTU	20	20 - 241
total suspended solids	mg/L	10	10 - 89
Major Cations and Anions			
calcium	mg/L	1000	1000
magnesium	mg/L	15	15
potassium	mg/L	–	6.2 - 7.5
sodium	mg/L	115	115

Parameter	Units	Published WQO	Observed Water Quality Range [a]
chloride	mg/L	175	175
fluoride	mg/L	0.2	0.2
sulfate	mg/L	5	10.5
Alkalinity			
bicarbonate	mg/L	–	125
carbonate	mg/L	–	< LOR [e]
hydroxide	mg/L	–	< LOR [e]
residual alkalinity	meq/L	–	0.5 – 1.0
Total alkalinity	mg/L		20 - 125
Total Metals and Metalloids			
aluminium	µg/L	55	1767
barium	µg/L	1000	1000
beryllium	µg/L	0.13	0.24
cadmium	µg/L	0.2	0.2
cobalt	µg/L	2.8	2.8
mercury	µg/L	0.6	0.6
silver	µg/L	0.05	0.05
strontium	µg/L	–	381
tin	µg/L	3	3
vanadium	µg/L	6	10.7
Algae			
Chlorophyll-a	µg/L	5	8.6

- Grey shading denotes values that were calculated from baseline data and adopted as the interim local WQO.

a All single values represent a maximum value that should not be exceeded; where a range is presented then monitoring results should not be below or above this range

b Aquatic ecosystem WQO is 1000 based on direct toxicity assessments (in frc 2014g)

3.3.2.1 Macroinvertebrates

WQOs for macroinvertebrates for the region have been published in the *Dawson River Sub-basin Environmental Values and Water Quality Objectives* EPP Water (EHP 2013a). WQOs for macroinvertebrates relate to communities in flowing water habitats (i.e. riverine water type), and are not applicable to the weir pools (i.e. reservoir water type). While the published default WQOs for macroinvertebrates separate the lower and upper Dawson River catchments, the baseline data found no such difference but could differentiate between riverine and reservoir water types. Therefore, interim local WQOs for macroinvertebrate indices have been calculated separately for the riverine water type and the reservoir water type using data collected during baseline surveys (frc environmental 2014g), and are presented in **Table 6**. Current interim objectives are based on a relatively low number of samples so will be progressively modified.

Table 6: Summary of sample collection for each index

Parameter	Riverine		Reservoir	
	Published WQO	Interim local WQO	Published WQO	Interim local WQO
Edge				
taxonomic richness	23 – 33	23 – 33	–	17 – 24
PET richness	2 – 5	2 – 5	–	2 – 4
SIGNAL 2 Score	3.31 – 4.2	3.31 – 4.2	–	3.0 – 3.5
Riffle				
taxonomic richness	12–21	12 – 27	–	–
PET richness	2–5	2 – 6	–	–
SIGNAL 2 Score	3.33–3.85	3.33 – 4.31	–	–

Note: Grey shading denotes values that were calculated from baseline data and adopted as the interim local WQO.

3.3.2.2 Fish

Water quality guidelines for fish for the region (EHP 2013a) were developed using the approach presented in Platten (2011), and this approach was used to develop WQOs for fish for the GBUS (frc environmental 2014g). Using baseline data, local WQOs for fish are derived by calculating the probability of occurrence in the catchment (or within each water type; i.e. riverine / reservoir) for each species captured (excluding exotic species). All species with a probability of 0.5 or greater in a catchment or water type (i.e. those observed / caught in 50 per cent or more of baseline samples) are tallied, and the number of species with this probability is taken as the expected number of species, with the local WQO expressed as a ratio, as follows: observed number of species / expected number of species. Thus, the observed or caught number of native species in each monitoring survey must equal or be greater than the expected number of species, which was determined using the 0.5 probability of occurrence from the baseline data. The fish species which have a probability of occurrence of >0.5, as determined using baseline data, is presented in **Table 7**. Note that the WQO does not relate to which species are collected, only the number of species.

The published default WQOs for fish separate the lower and upper Dawson River catchments. The baseline data also found differences in the species caught between the Upper and Lower Dawson catchments, as well as between riverine and reservoir water types in each catchment. Therefore, interim local WQOs for fish have been calculated separately for the riverine water type and the reservoir water type in both the Upper and Lower Dawson catchments using data collected during baseline surveys (frc environmental 2014g); they are presented in **Table 7**.

For exotic species, the default WQO is that the number of exotic species does not increase from the numbers that are currently known from the waterway. Baseline studies found one exotic species, mosquito fish (*Gambusia holbrooki*); thus, the WQO in both riverine and reservoir water types in the

Upper and Lower Dawson River catchments is that no more than 1 exotic fish species is captured in the receiving environment. Despite this result, as noted above, three exotic species have historically been found in the area.

Table 7: Published default and interim local WQOs for fish in the receiving environment

Species Name	Common Name	Published WQO – Lower Dawson [a]	Published WQO – Upper Dawson [a]	Interim Local WQO – Lower Dawson (Reservoir)	Interim Local WQO – Lower Dawson (Riverine)	Interim Local WQO – Upper Dawson (Reservoir)	Interim Local WQO – Upper Dawson (Riverine)
Native Fish							
Ambassis agassizii	Agassiz's glassfish	✓	✓		✓	✓	
Amniataba percoides	barred grunter	✓			✓		
Arius graeffei	blue catfish	✓					
Craterocephalus stercusmuscarum	flyspecked hardyhead			✓			✓
Hypseleotris spp.	carp gudgeon	✓	✓	✓	✓	✓	✓
Leiopotherapon unicolor	spangled perch		✓		✓		✓
Macquaria ambigua	yellow belly	✓	✓	✓	✓		✓
Melanotaenia splendida splendida	eastern rainbowfish	✓	✓	✓	✓	✓	✓
Nematalosa erebi	bony bream	✓	✓	✓	✓	✓	✓
Oxyeleotris lineolata	sleepy cod	✓		✓	✓	✓	
Pseudomugil signifier	Pacific blue eye		✓				
Scleropages leichardti	southern saratoga	✓					
Scortum hillii	leathery grunter	✓			✓		✓
Tandanus tandanus	freshwater catfish	✓	✓		✓		
WQO for native fish	–	**11**	**8**	**6**	**10**	**5**	**7**

a EHP 2013a
✓ indicates the species expected in each water type in each catchment as they were present in 50% or more of the baseline surveys

4. Temporal Context of the WQMP

Three temporal considerations are important for the WQMP for GBUS:

- periods with different CSG water discharge rates;
- river flow status; and
- release rates from Glebe Weir.

These factors affect mixing and dilution of the CSG water and hence its ability to alter the existing environment. They constitute the very basis of risk and should be fundamental to the design of a WQMP.

4.1 Periods with Different Discharge Rates

The peak discharge of CSG water is predicted to be short-lived (a few years) then will decline to approximately half before slowly declining over an extended period.

The high rates of discharge represent an important temporal phase for the WQMP, as any adverse environmental impacts would be most likely at this time. Thus, the frequency of monitoring during peak discharge should be higher than during lower discharges. If no undesirable effects are observed during these higher discharge periods, they would not be expected at lower discharge rates and the need for monitoring or the extent of monitoring could be revised.

4.2 River Flow Status

Periods of flow afford greater mixing and minimise the risk of any impacts related to the discharge. As dilution is only required for Ammonia, the flow required to affect the necessary dilution is easily calculated. For ammonia, other criteria need to be simultaneously met for the discharge to be toxic, viz, high pH and high temperature.

Low and zero river flow periods are likely to be the most important ‘events’ or ‘times’ for the WQMP, as during these times the CSG water discharge may constitute a significant proportion of water within Glebe Weir or within the downstream Dawson River if it is released from Glebe Weir. When these periods coincide with high discharge rates of CSG water, the greatest extent of change from background conditions can be expected and the highest risk of water quality or ecological effects.

Risk assessments presented in the application documentation showed exceedance of guidelines as a result of low or zero flow events would occur only a few percent of the time (based on the historic flow record).

4.3 Release rates from Glebe Weir

SunWater routinely records releases from Glebe Weir (and their purpose) as part of requirements for reporting related to their Resource Operating Licence for the DVWSS. Releases are measured at the tailwater gauge (no.130345, site WS05) some 1.9 km downstream from the weir. Water is held in storage in Glebe Weir unless required to service orders from downstream customers or to meet environmental flow objectives of the WRP. The status of releases determines whether the discharge of the treated CSG water could be affecting just the weir pool environment of Glebe Weir or the river downstream as well.

5. Monitoring Program Design

5.1 Monitoring Program Components

Release of the treated CSG water to the Dawson River may:

- directly influence certain water quality parameters within the receiving waters;
- directly influence bank stability; and
- indirectly influence biological communities (i.e. fish and macroinvertebrates) within these waters.

Therefore the monitoring components of the GBUS REMP are:

- hydrology;
- physical environment or geomorphology;
- water quality
- biology (fish and macroinvertebrates).

For the WQMP, only water quality and biology (as a measure of the suitability of water quality) are relevant.

Monitoring of the quantity of the treated CSG water that is released to Glebe Weir is mandated by the BUA. Monitoring of the quality of the treated CSG water prior to discharge is also mandated. While this monitoring is not part of the WQMP, the data will be important to aid interpretation of the WQMP results and to trigger potential investigations.

SunWater also currently collects monthly meter-based depth stratified water quality (temp, pH, conductivity, turbidity) and Blue-green algae samples from all weirs within the DVWSS and this data will be available to the WQMP.

The Dawson River WQMP has two complementary approaches towards detecting adverse environmental impacts on the local environmental values:

Component 1: A regular monitoring program using water quality and biological indicators. This program will also provide data to support the Stage 2 investigations included within Component 2.

Component 2: Reactive assessment when a water quality trigger is exceeded. Exceedence will result in staged investigations being undertaken in accordance with ANZECC guidelines. The investigation stages are:

- **Stage 1**: water quality based 'Control Impact' (upstream / downstream) comparison. If downstream sites are shown to be impacted relative to upstream sites then move to Stage 2.
- **Stage 2**: is a biological investigation using the Decision Tree approach of ANZECC. This will include 'Before After' and 'Control Impact' (BACI) analysis of fish, macroinvertebrate and potentially blue-green (BG) algal communities, to statistically test for differences in community composition before and after the release and upstream / downstream of the release.

If Stage 2 show that a statistically relevant impact has occurred, appropriate actions will be initiated.

5.2 Monitoring Plan Design

5.2.1 Water Quality

Monitoring of water quality for Component 1 will utilise two sites on the Dawson River upstream of the discharge (WS02 and WS03), one site downstream but within Glebe Weir (WS04), two sites downstream of but close to Glebe Weir (WS05 and WS06) and two sites a more significant distance downstream of Glebe Weir (WS07- Gyranda weir and WS08 - Theodore Weir). This provides both weir pool and flowing water sites both upstream and downstream of the discharge (**Table 8**).

Table 8: Description of WQMP monitoring sites

Site	Description	WGS84	
		Latitude	Longitude
Upstream Monitoring Points within the Receiving Environment			
WS02	Dawson River at Bundalla Road Crossing; 35 km upstream of the confluence of Cockatoo Creek and Dawson River.	-25.572372	149.864464
WS03	Dawson River within Glebe Weir pool; 2.5 km upstream of the confluence of Cockatoo Creek and Dawson River.	-25.476944	150.008333
WS04	Dawson River within Glebe Weir pool; 100 m upstream of the confluence of Cockatoo Creek and Dawson River.	-25.464269	150.033529
Downstream Monitoring Points within the Receiving Environment			
WS05	Dawson River downstream of Glebe Weir; 1.9 km downstream of the discharge location.	-25.459722	150.043889
WS06	Dawson River downstream of Glebe Weir; 6.5 km downstream of the discharge location.	-25.453333	150.055833
WS07	Dawson River 42 km downstream of Glebe Weir in Gyranda Weir Pool	-25.284722	150.181389
WS08	Dawson River 60 km downstream of Glebe Weir to Isla Delusion Rd, upstream of Theodore Weir Pool	-25.188889	150.183611

Orange shading denotes sites within non-flowing waters (i.e. reservoir sites)

5.2.2 Biology

Samples for fish and macroinvertebrates will be collected from the same sites as water quality.

5.3 Indicators to be Monitored and Frequency of Monitoring

A detailed explanation of the methods to be used for each monitoring component is provided in Appendix A ("SunWater Glebe Beneficial Use Scheme: Procedures for Receiving Environment Monitoring Program Sampling and Reporting" (frc environmental 2014)).

The program may be adjusted depending on results.

Monitoring frequency is as determined in the EPBC Conditions for an initial period (refer to Section 1.2 above, including definition of "Regular" monitoring), and then as recommended by SunWater's Environmental Performance Report (EPBC Condition 8.b) unless otherwise required by the Department of Environment (commonwealth). This is as detailed in Table 9 below.

Table 9: WQMP design and monitoring for initial period of operation

Monitoring Component	Parameter	Monitoring Site	Monitoring Frequency
Water Quality Components			
Physico-chemical	As listed	Control Sites: • WS02 and WS03 Receiving Environment Sites: • WS04, WS05, WS06, WS07 and WS08	Monthly for the first 12 months of operation, then: • at a frequency recommended by SunWater's Environmental Performance Report; • unless otherwise as required by the Department of Environment
Biological Components			
Macroinvertebrates	Aquatic macroinvertebrates identified to the lowest practical taxonomic level Density of exoskeleton of crustaceans and molluscs by observation	Control Sites: • WS02 and WS03 Receiving Environment Sites: • WS04, WS05, WS06, WS07 and WS08	Twice per year for the first 3 years of operation – where possible being: • Pre-wet season (notionally November), and Post-wet season (i.e. April), then: • at a frequency recommended by SunWater's Environmental Performance Report; • unless otherwise as required by the Department of Environment
Fish	Richness of species	As above (for Macroinvertebrates)	As above (for Macroinvertebrates)
Physical habitat	Description as per reference documents	As above (for Macroinvertebrates)	Annually, with changes otherwise noted

5.3.1 Water quality

Routine water quality monitoring will be conducted at monthly intervals depending on flow (sampling will not be undertaken in unsafe conditions).

As noted above the characteristics of the treated CSG water itself, prior to release to Glebe Weir are monitored at continuous or weekly frequency.

The indicators to be monitored are:

- pH;
- electrical conductivity;
- temperature;
- dissolved oxygen;
- turbidity;
- ammonia;
- Dissolved Metals and Metalloids (arsenic, barium, boron, chromium VI, copper, iron, lead, manganese, nickel, selenium, zinc);

- Major Cations and Anions (calcium, magnesium, potassium, sodium, chloride);
- Alkalinity (bicarbonate);
- Total alkalinity;
- Hardness;
- BG Algae (cell count); and
- Chlorophyll-a.

With respect to Component 2, if the measurement of any parameter in the treated CSG water is above a trigger level, the ratio of the volume of CSG water discharge to the volume of river flow is calculated and this dilution factor applied to the concentration of the “at risk” parameter. If the resultant calculated concentration is above an ambient trigger level in the receiving environment then sampling in order to undertake the upstream / downstream comparison is undertaken. The validity of the calculation could be checked through initial measurements.

5.3.2 Biology

Biological monitoring of fish and macroinvertebrates will occur at approximately 6 monthly intervals coinciding with approximately April and November and depending on river flow (targeting pre-wet season and post-wet season periods), for at least the first 3 years of operation, and otherwise as noted in Table 9 above for “Biological Components”.

5.4 Quality Assurance and Quality Control

The monitoring, analysis and reporting, will have regard to the procedures and quality assurance / quality control (QA/QC) requirements set out in the following documents:

- Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC & ARMCANZ 2000b);
- Monitoring and Sampling Manual 2009, Environmental Protection (Water) Policy 2009 (EHP 2013b);
- AS 3778.3.1 Measurement of Flow in Open Channels;
- Sustainable Rivers Audit physical habitat methodology (MDBC 2004);
- Australian / New Zealand Standard AS5667.1 Water Quality – Sampling;
- Queensland Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual (DNRM 2001); and
- SunWater Glebe Beneficial Use Scheme: Procedures for Receiving Environment Monitoring Program Sampling and Reporting (frc environmental 2014) – attached as Appendix A.

Further details of the QA/QC procedures for each parameter to be monitored are provided in the latter.

5.5 Assumptions and Qualifications

The proposed monitoring locations have been determined based on the location of baseline monitoring sites to allow for comparisons with baseline / current condition.

Sites at road crossings are likely to be impacted by the presence of the road, and this will be taken into account when analysing the data. However, locating sites at public road crossings is necessary to ensure that they can be safely and easily accessible at almost all times of the year; and also so that access to private property is not required. Sites located away from public roads or well-established tracks may not be accessible during wet conditions.

It is possible that some sites may be dry during some survey events, depending on factors such as low antecedent rainfall.

Some sites may become unsafe to sample in conditions of elevated flow or local rainfall causing unsafe road conditions. The sampling schedule must include sufficient flexibility to accommodate the necessary adjustments.

6. Data Analysis, Reporting and Review

6.1 Derivation of Final Local WQOs

The ‘interim local WQOs’ for water quality will be finalised as ‘local WQOs’ upon completion of the required number of baseline monitoring events, which varies depending on the parameter (frc environmental 2014c).

6.2 Interim Analysis and Reporting

Brief interim reports will be completed after each sampling event in order to notify SunWater of any potential impacts to the receiving environment that have been identified and which are potentially related to the discharge. All data analyses and statistical procedures that will be used to assess monitoring data for each interim report are detailed in Appendix A (“SunWater Glebe Beneficial Use Scheme: Procedures for Receiving Environment Monitoring Program Sampling and Reporting” (frc environmental 2014)).

6.3 Six Monthly Analysis for the Environmental Performance Report

A report that synthesises the results of all monitoring events in the previous period will be prepared in time for submission in accordance with the schedule nominated in Condition of 8b of the EPBC approval. The report will assess if any impacts have occurred due to the release on the water quality, and biology of the receiving environment, based on a comparison to the relevant WQOs and, where appropriate (e.g. where WQOs have been exceeded) statistical tests based on the before-after control-impact (BACI) principle. Data analyses and statistical procedures that will be used to assess monitoring data for each report are detailed in Appendix A.

Any actions taken to rectify impacts or circumstances which could have resulted in likely impacts will be described and results assessing the success of their implementation presented. An independent evaluation of the results will assess any new or increased impacts/likely impacts on MNES.

6.4 WQMP review

In accordance with the definition of “Regular”, the water quality component of the WQMP will be reviewed after 12 months and the biological component after 3 years and potentially adjusted based on the results.

7. References

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APPENDIX A:

SunWater Glebe Beneficial Use Scheme: Procedures for Receiving Environment Monitoring Program Sampling and Reporting (frc environmental 2014)

SunWater Glebe Beneficial Use Scheme

Procedures for Receiving Environment Monitoring Program Sampling and Reporting

Prepared for:

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freshwater estuarine marine

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Contents

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Maps

1 Introduction

SunWater has obtained a Beneficial Use Approval (BUA; approval number ENB404254412) to supply up to 36 500 megalitres (ML) per year of treated CSG water (the resource) to customers along a transfer pipeline and within the Dawson Valley Water Supply Scheme (DVWSS). This project is referred to as the Glebe Beneficial Use Scheme (GBUS). The preparation and implementation of a receiving environment monitoring program (REMP) is required by conditions B21 – B23 of the BUA.

1.1 Purpose and Scope

The purpose of this report is to specify the procedures for sampling and reporting of water quality and aquatic ecology for REMP for the GBUS, as required under the BUA. The REMP design, including thresholds for water quality and aquatic ecology indicators and the monitoring schedule, is presented in the accompanying document – SunWater Dawson River Beneficial Use Agreement: Receiving Environment Monitoring Program (frc environmental 2014).

Specifically this report presents:

- Details of the sampling and laboratory processing methods and quality assurance and quality controls to be used for monitoring each indicator
- Methods for the data analyses, including statistical analyses, to be used for interpreting monitoring results, and
- Details of all reporting requirements to satisfy the REMP requirements of the GBUS.

1.2 Roles and Responsibilities

The roles and responsibilities relating to the development and implementation of the REMP are described fully in the BUA, which includes the following conditions:

- Condition A18 – all REMP monitoring is undertaken by suitable qualified persons
- Condition A20 – this REMP design document must be reviewed not less than once every three years
- Condition A26 - the REMP design document must be certified by a suitably qualified person, and
- Condition A27 - the REMP must be implemented.

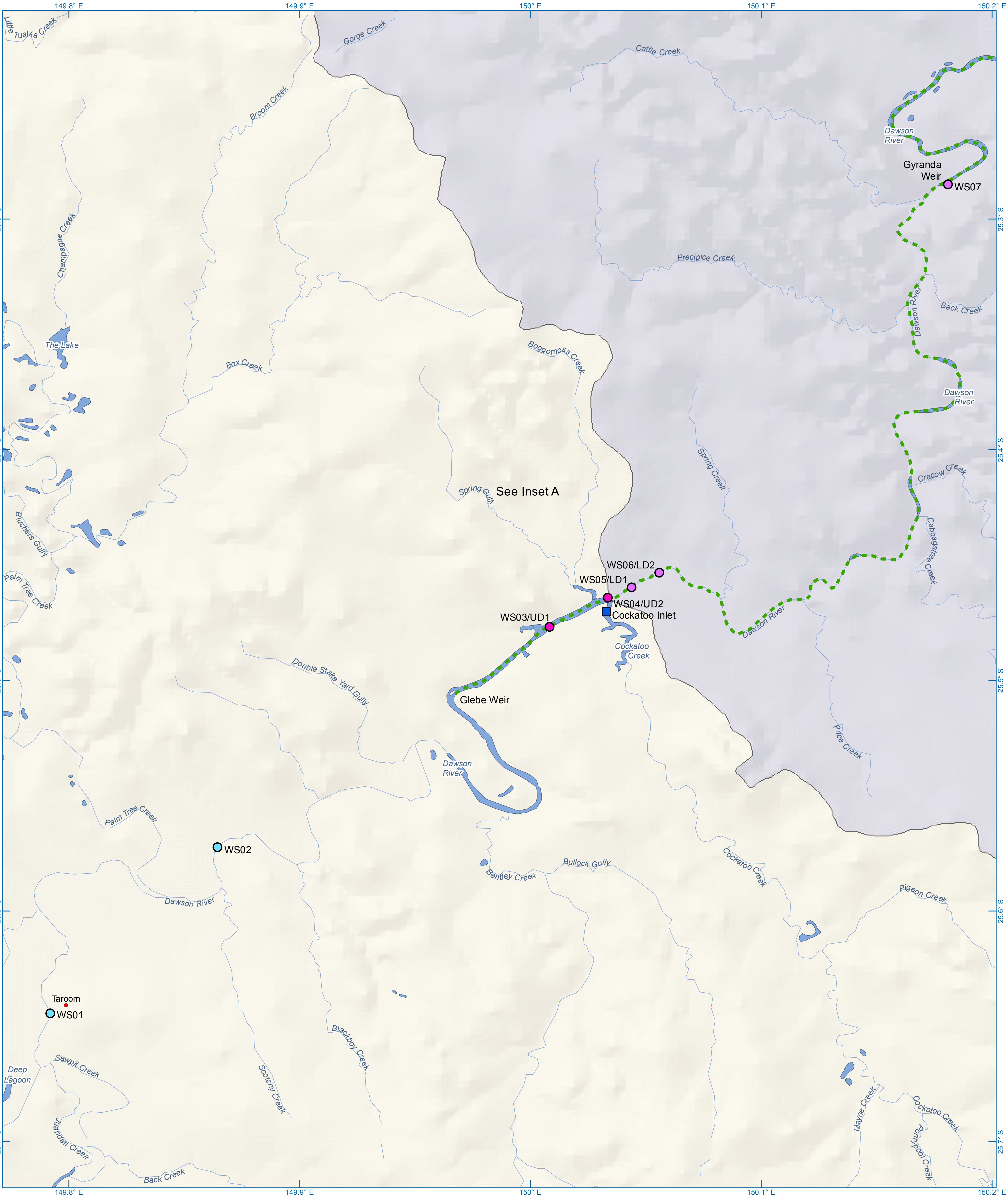
2 REMP Monitoring Sites

Eleven sites have been surveyed within the scope of baseline monitoring for the GBUS, and seven of these sites will become the monitoring sites for the REMP after the discharge has commenced (Table 2.1 and Map 1).

Table 2.1 Description of REMP monitoring sites.

Site	Description	WGS84	
		Latitude	Longitude
Upstream Monitoring Points within the Receiving Environment			
WS03/UD1	Dawson River within Glebe Weir pool; 2.5 km upstream of the confluence of Cockatoo Creek and Dawson River.	-25.476944	150.008333
WS04/UD2	Dawson River within of Glebe Weir pool; 100 m upstream of the confluence of Cockatoo Creek and Dawson River.	-25.464269	150.033529
Downstream Monitoring Points within the Receiving Environment			
WS05/LD1	Dawson River downstream of Glebe Weir; 1.9 km downstream of the discharge location.	-25.459722	150.043889
WS06/LD2	Dawson River downstream of Glebe Weir; 6.5 km downstream of the discharge location.	-25.453333	150.055833
WS07	Dawson River 42 km downstream of Glebe Weir in Gyranda Weir Pool	-25.284722	150.181389
Control Sites Upstream of the Receiving Environment			
WS01	Dawson River at Leichhardt Highway; 38 km upstream of the confluence of Cockatoo Creek and Dawson River.	-25.644476°	149.791877°
WS02	Dawson River at Bundalla Road Crossing; 35 km upstream of the confluence of Cockatoo Creek and Dawson River.	-25.572372	149.864464

Grey shading denotes sites within non-flowing waters (i.e. reservoir sites)



SunWater Dawson River Beneficial Use Agreement: Receiving Environment Monitoring Program

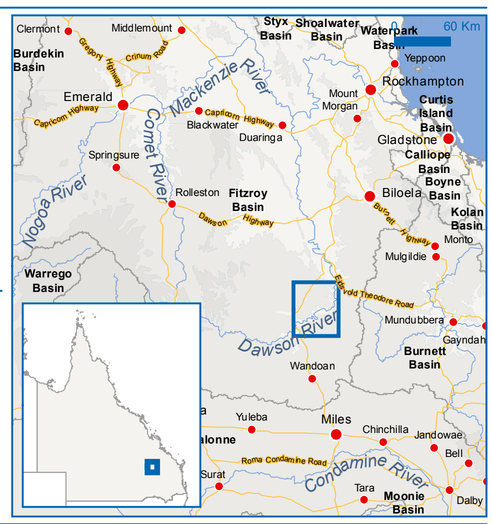
Map 1:
Location of monitoring sites for the GBUS REMP

LEGEND

Monitoring Sites

- Control Site
- Receiving Environment Site Within Glebe Weir
- Receiving Environment Site Downstream of Glebe Weir

- Upper Dawson Sub-basin
- Lower Dawson Sub-basin
- Receiving Environment
- Watercourse
- Lake/Reservoir



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SOURCES

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3 Monitoring Procedures

3.1 Flow

3.1.1 Survey Method

Stream flow [i.e. discharge in megalitres / day (ML/day)] will be measured daily at automated gauging stations:

- DNRM's station 130302A Dawson River and Taroom, and
- Sunwater's station 130345 at Glebe tailwaters.

While stream flow will be measured daily, the data will be accessed and analysed as needed, such as when interpreting biological or water quality data collected for the REMP

3.1.2 Quality Assurance and Quality Control

Flow data that is collected at the gauging stations has associated meta-data that describes the reliability or accuracy of the readings. Where the metadata indicates that readings are of an unacceptable standard, then this data will be discarded.

3.1.3 Data Analysis and Reporting

Hydrographs presenting monthly flow data for the reporting year compared to median flow data for each month for all years, will be presented.

Interim Reporting

A description of discharge volumes recorded at the gauging stations for the period preceding and during monitoring events will be provided.

Annual Reporting

Hydrographs of stream flow data recorded at the gauging stations will be produced for the entire year.

3.2 Bank Geomorphology and Stability Monitoring

3.2.1 Survey Method

Bank geomorphology and stability will be monitored twice yearly using the Sustainable Rivers Audit physical habitat methodology (MDBC 2004b), which is consistent with the methodology used in the Project EIS and in baseline monitoring. The assessment will include characterisation of the following parameters along a transect at each site:

- bank shape
- bank stability, including slumping or under-cutting, and
- areas of erosion, including formation of eroded notches in the bank

A visual record of the left and right banks at each site will be made using photographs, with left and right banks determined while facing downstream.

3.2.2 Quality Assurance and Quality Control

Suitably qualified and trained personnel will undertake the bank geomorphology and stability monitoring, analysis and reporting.

3.2.3 Data Analysis and Reporting

Interim Reporting

Field observations of bank geomorphology and stability made during the corresponding monitoring event will be tabulated for each site. Photographs of banks at each site will be taken and included in applicable reports.

Annual Reporting

Field observations of bank geomorphology and stability made across all surveys for the will be tabulated for each site, noting any factors influencing bank stability and any changes to bank stability over time. Photographs of banks at each site will be taken and included in applicable reports.

3.3 Water Quality

The BUA specifies the water quality parameters to be monitored for the REMP, and these are also specified in Table 3.4 of .the accompanying document – SunWater Dawson River Beneficial Use Agreement: Receiving Environment Monitoring Program (frc environmental 2014).

3.3.1 Survey Method

Water quality will be measured weekly at sites WS03, WS04, WS05 and WS06, as specified in the BUA. Water quality will be measured quarterly at sites WS01, WS02 and WS07.

Physical water quality will be measured in-situ for the following parameters:

- temperature
- pH
- electrical conductivity
- turbidity, and
- dissolved oxygen (mg/L and % saturation).

In situ measurements will be taken using a hand-held water quality meter at 30 cm below the surface of the water (or as deep as practical if the water level is less than 30 cm). Depth profiles for these parameters will also be taken at 1 m intervals, or at 0.5 m intervals if the total water depth is 2 m or less.

Water samples will be collected for laboratory analysis of other parameters listed in Table 3.4 of the accompanying document – SunWater Dawson River Beneficial Use Agreement: Receiving Environment Monitoring Program (frc environmental 2014). Water samples will be collected into pre-labelled bottles supplied by a NATA accredited laboratory. Samples will be taken at 30 cm below the surface of the water (or as deep as practical if the water level is less than 30 cm), and collected by hand or using a sampling pole with clamp if required for safety reasons.

Two samples will be collected for analysis of nutrients and metals and metalloids. The first sample will be un-filtered and will be used for analysis of total nutrients and total metals. The second sample will be filtered in the field through a 0.45 µm filter, and will be used for the analysis of dissolved nutrients and dissolved metals. If field filtering is not possible (due to high turbidity) the sample bottles will be rinsed thoroughly (flushed with water three times) to remove all traces of preservative and filled with unfiltered water. The bottle will be marked as unfiltered and the sample will be lab filtered before being processed.

3.3.2 Quality Assurance and Quality Control

Field sampling will be undertaken by a suitably trained and competent person in accordance with the *Monitoring and Sampling Manual 2009* (EHP 2009) and Australian / New Zealand Standard AS5667.1 Water Quality - Sampling. In summary:

- Hand-held water quality meters will be calibrated before the commencement of sampling, and checked regularly while in the field (and recalibrated if necessary). A calibration record will be kept.
- Hand-held water quality meters will be cleaned at the end of each field day.
- Powderless gloves will be used when collecting all water samples, and care will be taken not to touch the inside of any sampling containers, or to place open bottles / jars or their lids onto the ground or other potentially contaminated surfaces.
- Water samples will be collected straight into the sample bottle wherever possible.
- If the sample bottle contains a preservative the bottle will not be rinsed prior to sample collection. If the sample bottle does not contain a preservative the bottle will be rinsed with ambient site water three times to remove all contaminants before collecting the sample.
- If the sample cannot be collected straight into the sample bottle, the container it is collected in (such as a stainless steel bucket or other form of sampler) will be thoroughly rinsed with ambient site water to ensure it is not contaminated.
- A field blank will be collected from one site during each sampling event using laboratory-grade deionised water, to assess sample handling procedures.
- A field duplicate will be collected from one site during each sampling event, to assess within site variation.
- Filtering of water samples for nutrients and metals will be done on site in the field, where possible.
- Samples will be stored under the appropriate holding conditions for each parameter (e.g. chilled or refrigerated) and delivered to the laboratory within the appropriate holding times (as specified by the laboratory), in accordance with the security and transport protocols outlined in the *Monitoring and Sampling Manual 2009* (EHP 2009).

- A chain of custody form will be completed for all samples sent to the laboratory for analysis.
- Samples will be analysed by a NATA-accredited laboratory, and laboratory duplicates and blanks will be analysed in accordance with NATA-accredited protocols.

3.3.3 Data Analysis and Reporting

Interim Reporting

Water quality data will be tabulated and / or graphed, as appropriate, and compared to the WQOs specified in the REMP design document (frc environmental 2014).

Potential impacts to water quality in the receiving environment as a result of the releases will be noted, for example if receiving environment sites exceed the specified WQO but the control sites (i.e. WS01 and WS02) do not.

Annual Reporting

Water quality data from all surveys will be compiled and summary statistics for each site will be calculated. The median values for physical and chemical properties will be calculated and compared to the WQOs specified in the REMP design document (frc environmental 2014). The 95th percentile values for toxicants (e.g. metals and metalloids, and fluoride) will be calculated and compared to the WQOs specified in the REMP design document (frc environmental 2014) in accordance with the methods outlined in ANZECC & ARMCANZ (2000), except where the WQO has been calculated based on the 80th percentile (or 75th percentile) of background data, in which case the median value will be used for comparison.

If the results for any parameters at receiving environment sites exceed the WQO, the results will be compared to the results of comparative sites. If the results of receiving environment sites are outside the range of comparative sites, further investigation may be required.

Water quality will also be related to flows measured at the gauging stations, and a discussion of water quality under various flow conditions will be provided.

3.4 In-stream Sediment Quality

3.4.1 Survey Method

Sediment samples will be collected twice yearly from four sites in the receiving environment (WS04/UD2, WS03/UD1, WS05/LD1 and WS06/LD2) and both control sites (to allow for comparative data). Each sample will be analysis for total metals and metalloids (As, B, Cr, Cu, Fe, Mn, Ni, Pb, Se, Zn).

Sediment samples will be collected from the top 0.30 m of sediment on the bed using a stainless steel trowel. Samples will be transferred directly into sampling jars provided by a NATA accredited laboratory.

3.4.2 Quality Assurance and Quality Control

Field sampling will be undertaken by a suitably trained and competent person in accordance with Australian / New Zealand Standard AS/NZ5667.12 Guidance on Sampling of Bottom Sediments, and the Handbook for Sediment Quality Assessment (Simpson et al. 2005). In summary:

- Powderless gloves will be used when collecting all sediment samples, and care will be taken not to touch the inside of any sampling containers, or to place open bottles / jars or their lids onto the ground or other potentially contaminated surfaces.
- Sediment samples will be collected straight into the sample bottle wherever possible, and the bottles will not be rinsed prior to sample collection.
- If the sample cannot be collected straight into the sample bottle, the container it is collected in (such as a stainless steel bucket or other form of sampler) will be thoroughly rinsed with ambient site water to ensure is not contaminated.
- A field duplicate will be collected from one site during each sampling event, to assess within site variation.
- Samples will be placed into an esky with ice bricks and kept chilled until delivered to the laboratory within the appropriate holding time (as advised by the analytical laboratory).
- A chain of custody form will be completed for all samples sent to the laboratory for analysis.
- Samples will be analysed by a NATA-accredited laboratory, and laboratory duplicates will be analysed in accordance with NATA-accredited protocols.

3.4.3 Data Analysis and Reporting

Interim Reporting

Sediment quality data will be tabulated and compared to the sediment quality limits and trigger levels as specified in the REMP design document (frc environmental 2014).

Annual Reporting

Sediment quality data from all surveys will be compiled and summary statistics for each site will be calculated. The 95th percentile values for each toxicant (i.e. metal and metalloid) will be calculated and compared to sediment quality limits and trigger levels.

If the results for any toxicants at receiving environment sites exceed the limit values, the results will be compared to the results of control sites. If the results of receiving environment sites are outside the range of control sites, further investigation may be required.

3.5 Aquatic Ecology

3.5.1 Aquatic Habitat

Each site will be assessed twice yearly for habitat attributes using State of the Rivers survey methodology (specifically sheets 3, 5, 9 and 10; Anderson 1993a; b), and a River Bioassessment Score will be calculated for each site (DNRM 2001). A photographic record of each site will be established using standard locations.

3.5.2 Macroinvertebrates

Survey Method

Macroinvertebrate communities will be sampled twice yearly using a Surber sampler and dip net.

At each site, five replicate Surber samples will be collected from:

- edge habitat, and
- riffle or glide habitat where available (this habitat normally only exists at two sites).

Each sample will be collected using a surber sampler that has a square 0.3 m x 0.3 m frame and 250 µm mesh size. Samples will be collected with one edge of the surber sampler parallel to and within a few centimetres of the water's edge. The substrate within the surber sampler frame will be disturbed (large rocks will be cleaned or organisms inside the surber net and finer substrates will be gently disturbed by hand or with a tool) and the sample will be collected by sweeping the net up through the disturbed area. The sample will be transferred into a screw-top jar, preserved using ethanol and transported back to the laboratory. Specimens within each sample will be identified in the laboratory to the lowest practical taxonomic level (family in most cases).

Diversity will be further assessed qualitatively by timed dip net samples (no longer than 30 seconds per habitat) within areas of identifiable discrete habitat where they exist. These habitats may include aquatic plants (macrophytes), tree roots, leaf litter or a clearly different substrate type not sampled by surber sampling. Dip net samples will be collected by disturbing the substrate within a 30 x 30 cm area for a period of five seconds, and each sample will then be collected by sweeping a standard triangular-framed macroinvertebrate sampling net (250 µm mesh) through the disturbed area five times. A single sample of one such discrete habitat per site will be taken.

After collection, all samples will be transferred into a screw-top jar and preserved using ethanol to be transported back to the laboratory and identified to the lowest practical taxonomic level (family in most cases).

Exoskeleton Density of Macrocrustaceans

Macrocrustaceans will be caught using the sampling methods used for the fish survey. Individuals from two of the commonly occurring macrocrustacean taxa (i.e. long-armed river prawns, *Macrobrachium australiense*; and glass shrimp; *Caridina* spp.) will be examined for signs of potential calcium and magnesium deficiencies. The strength, apparent thickness and colour of the exoskeletons will be recorded, and it will also be noted if any individuals are breeding at the time of survey. Macrocrustaceans caught using box traps and electrofishing will be returned to the environment once observations of exoskeleton condition have been made.

Quality Assurance and Quality Control

Suitably qualified and trained personnel will undertake the macroinvertebrate monitoring, analysis and reporting.

Sampling will be completed in accordance with the Smartrivers methodology (Smart Rivers 2013), and macroinvertebrate samples will be processed in accordance with the National River Health Program protocols outlined in *Monitoring and Sampling Manual 2009* (EHP 2009). Enumeration and identification of samples will be done by trained and accredited ecologists. Sorting, enumeration and data entry will be cross-checked by a second ecologist for 10% of the samples. An error rate of > 10% will be considered unacceptable and will result in a further 10% of samples being checked by a second ecologist, until an error rate of < 10% is achieved.

Data Analysis and Reporting

The following indices will be calculated for macroinvertebrate communities at each site:

- abundance
- taxonomic richness
- PET richness, and
- SIGNAL-2 scores.

Statistical techniques, such as analysis of similarities (ANOSIM) or permutational analysis of variance (PERMANOVA) will be used where appropriate and only if initial analysis indicates a potential impact form the discharge. Sediment data and water quality data will also be related to biological data using multivariate statistical techniques (e.g. BIOENV) if a potential impact from the discharge is identified.

Abundance

Abundance is the total number of individuals in a sample. The abundance of each family, and the overall abundance of macroinvertebrates, will be calculated for each site.

Taxonomic Richness

Taxonomic richness is the number of taxa (in this assessment, generally families). Taxonomic richness is a basic, unambiguous and effective diversity measure. However, it is affected by arbitrary choice of sample size. Where all samples are of equal size, taxonomic richness is a useful tool when used in conjunction with other indices. Richness does not take into account the relative abundance of each taxon, so rare and common taxa are considered equally.

PET Richness

While some groups of macroinvertebrates are tolerant to pollution and environmental degradation, others are sensitive to these stressors (Chessman 2003). Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies) are referred to as PET taxa, and they are particularly sensitive to disturbance. There are typically more PET families within sites of good habitat condition and water quality than in sites of degraded condition. PET taxa are often the first to disappear when water quality or environmental degradation occurs (EHMP 2007). The lower the PET score (i.e. number of families within the Plecoptera, Trichoptera and Ephemeroptera orders), the greater the inferred degradation.

SIGNAL-2 Scores

SIGNAL (**S**tream **I**nvertebrate **G**rade **N**umber — **A**verage **L**evel) (Chessman 2003) scores are also based on the sensitivity of each macroinvertebrate family to pollution or habitat degradation. The SIGNAL system has been under continual development for over 10 years, with the current version is known as SIGNAL-2. Each macroinvertebrate family has been assigned a grade number between 1 and 10 based on their sensitivity to various pollutants. A low number means that the macroinvertebrate is tolerant of a range of environmental conditions, including common forms of water pollution (e.g. suspended sediments and nutrient enrichment).

SIGNAL-2 scores are weighted for abundance. The scores take the relative abundance of tolerant or sensitive taxa into account (instead of only the presence or absence of these taxa). The overall SIGNAL-2 score for a site is based on:

- the total of the SIGNAL grade
- multiplied by the weight factor for each taxon, and
- divided by the total of the weight factors for each taxon.

Multivariate Analyses

Differences in the composition of macroinvertebrate communities between sites will be examined for each survey using a one-way analysis of similarity (ANOSIM). The abundance of each macroinvertebrate taxon will be log-transformed and converted to a Bray-Curtis similarity matrix prior to the analysis.

ANOSIM is limited to detecting differences between more than two factors, so differences in the community composition (the taxa present and their abundance) among the locations before and after discharges commence will be examined using a before-after control-impact (BACI) approach. This will be completed using PERMANOVA with the following factors:

- before vs. after releases commenced
- control (comparative) vs. impact (receiving environment) locations
- time period (nested in before vs. after and treated as a random factor)
- locations (nested in control vs. impact and treated as a random factor), and
- sites (nested in control vs. impact locations and treated as a random factor).

The homogeneity of multivariate dispersions will be checked using the permutational multivariate dispersion (PERMDISP) routine, which examines whether the spread of points around a centroid are tightly clustered; or are more widely dispersed, which can be indicative of an impact (Anderson 2004; Anderson et al. 2008).

Differences in the communities between sites will be displayed visually, using non-metric multi-dimensional scaling (nMDS) ordinations. Ordinations are maps of samples, in which the placement of samples on the map reflects the similarly of the community to the communities in other samples (Clarke & Warwick 2001). Distances between samples on an ordination attempt to match the similarities in community structure: nearby points represent communities with very few differences; points far apart have very few attributes in common (Clarke & Warwick 2001). Ordinations do not have scales and the axes are arbitrary; in fact data points can be flipped and rotated within the ordination to provide the best visual representation of the data.

Individual taxa that contributed most to the differences between sites will be identified using the similarity percentages (SIMPER) species contributions routine (Clarke 1993).

RELATE analyses (including BIOENV) will be used to correlate sediment and water quality data with the macroinvertebrate data, to determine which water and sediment quality parameters are having the greatest influence on macroinvertebrate community structure, and whether the discharges appear to have impacted on macroinvertebrate communities downstream.

Interim Reporting

Macroinvertebrate data will be entered at the completion of laboratory processing and indices (abundance, taxonomic richness, PET richness and SIGNAL 2 scores) will be calculated for each site. Results for each site will be compared to the relevant biological

WQOs as specified in the REMP design document (frc environmental 2014), to assess compliance at sites.

Annual Reporting

Results for macroinvertebrate indices at all sites for all monitoring events will be pooled and the minimum, maximum and median will be calculated for each index for each site. The median for each site will be compared to the relevant biological WQOs as specified in the REMP design document (frc environmental 2014), to assess compliance at sites. If the results of receiving environment sites do not comply with the relevant WQO, data will be compared to the results at control sites. If the results of receiving environment sites are outside the range of comparative sites, further investigation may be required.

Statistical analyses will be completed to determine whether there have been any likely impacts to macroinvertebrate communities due to the discharge. Multivariate data analyses, including ANOSIM, PERMANOVA, nMDS, SIMPER and BIOENV (implemented using PRIMER 6 software) will be used to:

- provide information on any changes to macroinvertebrate community structure in the receiving environment
- determine differences in macroinvertebrate community structure at different sites and between sampling events, and
- assess temporal changes in assemblages.

3.5.3 Fish

Survey Method

Each site will be assessed for fish assemblages twice each year. All available habitats (e.g. pool, riffle, run, bend, large wood debris) will be fished at each site using a combination of backpack and / or boat electrofishing (depending on the nature of the waterway being sampled), and baited box traps. Electrofishing and trapping are the preferred methods for targeting fish and macrocrustaceans; however, fyke and / or seine nets will be used at sites where electrofishing is not considered possible or appropriate due to site conditions or safety considerations.

Electrofishing will be conducted in accordance with the *Australian Code of Electrofishing Practice 1997* and DERM (2011) using a Smith-Root LR-24 backpack electrofisher and / or a Smith-Root 2.5 GPP boat electrofishing unit, depending on the dimensions of the waterway.

To supplement electrofishing efforts, fish caught in the baited traps used for macrocrustacean surveys will also be recorded.

If electrofishing at a site is not possible, then fyke and / or seine nets will be used. Seine nets of ~10 mm mesh size and 10 m long, will be used by completing at least three hauls through a variety of habitats. Two fyke nets of varying mesh sizes will be set overnight.

At each site, the species present and the abundance of each species will be recorded and the apparent health of individuals will be noted. Standard condition factors such as lesions, parasites and fin damage will be recorded.

Quality Assurance and Quality Control

The sampling of fishes will be conducted under appropriate General Fisheries Permits and Animal Ethics Approvals. Fishing will be performed by suitably trained and competent persons in accordance with the *Australian Code of Electrofishing Practice 1997*, with at least one member of the field team being a certified Senior Operator of electrofishing apparatus. Identifications of fish will be made in the field by experienced ecologists. Specimens that cannot be identified in the field will be euthanised and returned to the laboratory for identification and if necessary they will be sent to the Queensland Museum for a confirmed identification.

Data Analysis and Reporting

Interim Reporting

The richness and abundance of native and exotic fish species will be compared between sites and sampling events, including comparisons of results with baseline results for each monitoring site.

The observed number of fish that were caught within each water type will be compared to the WQO for that water type as a ratio – observed / expected number of fish. Where this ratio is less than one, then it will be determined that the fish community has been impacted compared to baseline condition. Comment will be made on whether this is likely to be due to the GBUS based on the results for other indicators, such as flow and water quality.

Annual Reporting

The richness and abundance of native and exotic fish species will be compared between sites and sampling events, including comparisons of results with baseline results for each monitoring site.

The observed number of fish that were caught within each water type will be compared to the WQO for that water type as a ratio – observed / expected number of fish. Where this ratio is less than one for both fish surveys in a year, then it will be determined that the fish community has been impacted compared to baseline condition. Comment will be made on whether this is likely to be due to the GBUS based on the results for other indicators, such as flow and water quality.

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