Central Queensland Coal Project

Appendix 5b – Historical Surface Water Quality Results

Environmental Impact Statement

CIVIL

WATER

STRUCTURAL

INFRASTRUCTURE

PROJECT DELIVERY

URBAN DEVELOPMENT

YEATS
CONSULTING ENGINEERS

PRELIMINARY

Surface Water Resources Technical Report

STYX COAL PROJECT

STYX BASIN, QLD

FAIRWAY COAL PTY LTD

APRIL 2012

REVISION 1.0

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Terms and Abbreviations

SSCC	semi-soft coking coal
ROM	run of mine
The project	Styx Coal Project
CHPP	coal handling and preparation plant
MIA	mine industrial area
WRP	Water Resource Plans
ERAs	Environmentally Relevant Activities
EA	Environmental Authority
EVs	Environmental Values
MNES	Matters of National Environmental Significance
GBRMP	Great Barrier Reef Marina Park
QWQG	Queensland Water Quality Guidelines
ANZECC	Australia New Zealand Environment Conservation Council Guidelines
FBA	Fitzroy Basin Association
BOM	Bureau Of Meteorology
MHWS	Mean High Water Spring
ML	Mining Lease
RRC	Rockhampton Regional Council
LOR	Limit of Reporting
FRP	Bioavailable phosphorous
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
LTV	Long Term Value
AWBM	Australian Water Balance Model

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1 Introduction

1.1 Overview

This technical report has been prepared to provide an overview and summary of the results of the water resources assessment and monitoring program to date for the Styx Coal Project (the Project), located in Fairway Coal Pty Ltd's Exploration Permit for Coal 1029 (EPC 1029). The area is located in the Styx Basin, Queensland as shown in **Figure 1**, approximately halfway between Rockhampton and Mackay in the Styx Basin in Central Queensland.

The project involves development of a semi-soft coking coal (SSCC) mining operation, with a resource described as highly volatile, low sulphur, thermal coal and semi soft coking coal. The project will include the development of two open pit excavations to expose the coal resource with an anticipated rate of extraction up to 1.9 Mtpa of run of mine (ROM) coal. The ROM coal will be crushed and processed at an expected yield of around 75% with up to 1.5 Mtpa expected to be produced for export.

1.2 Scope

This report presents the current state of works with respect to the water resources component of the project, including:

- an assessment of the existing hydrological environment;
- analysis of historical, regional and project specific water quality and flow data;
- a conceptual water balance model;
- interim environmental values and water quality objectives; and
- a concept water management strategy.

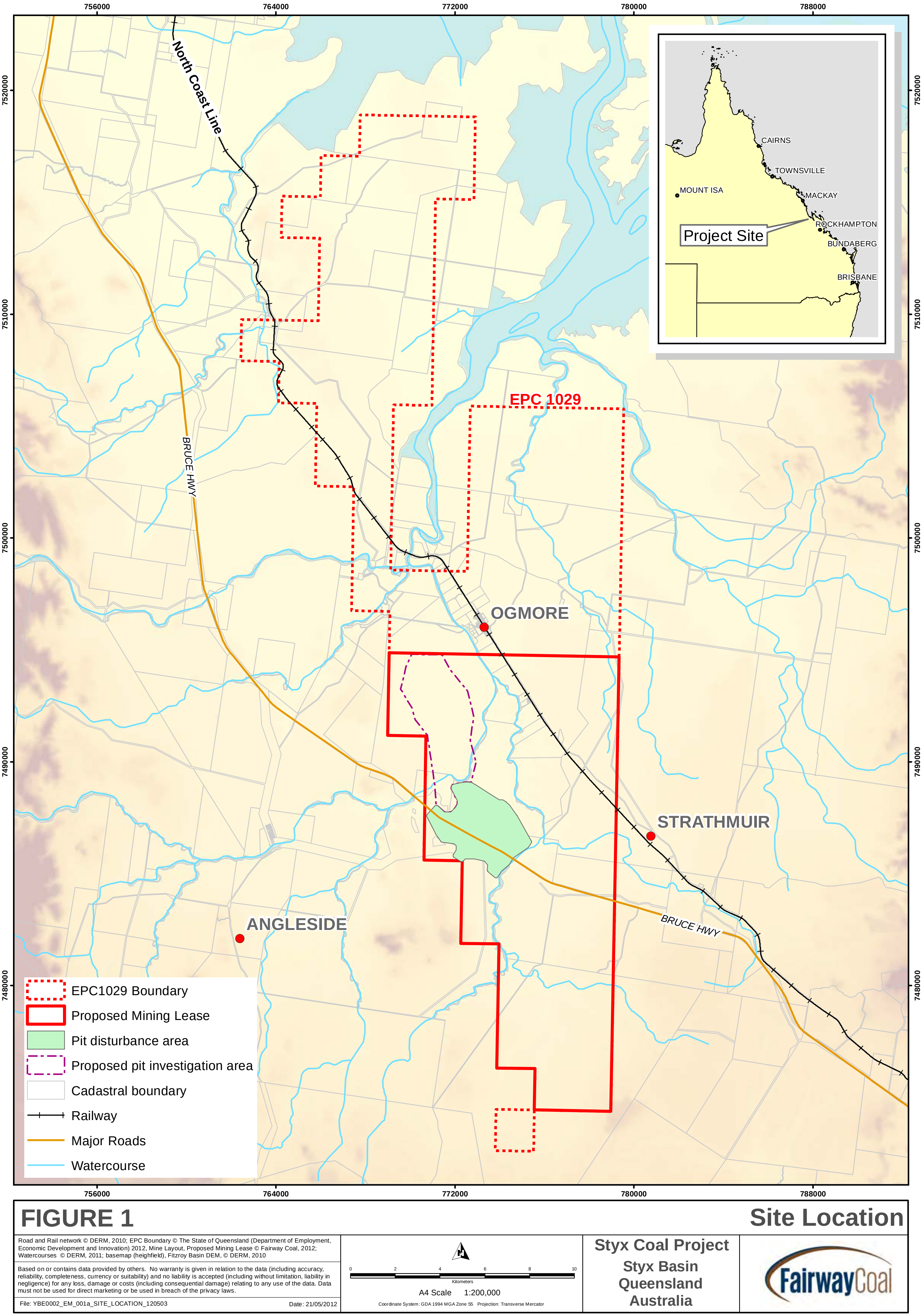

FIGURE 1

Site Location

Road and Rail network © DERM, 2010; EPC Boundary © The State of Queensland (Department of Employment, Economic Development and Innovation) 2012, Mine Layout, Proposed Mining Lease © Fairway Coal, 2012; Watercourses © DERM, 2011; basemap (heighfield), Fitzroy Basin DEM, © DERM, 2010

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File: YBE0002_EM_001a_SITE_LOCATION_120503

Date: 21/05/2012

Styx Coal Project

Styx Basin
Queensland
Australia

FairwayCoal

2 Project Description

2.1 The Project

As described above, the Project involves the development of a 1.95 Mtpa open cut coal mine in the Styx basin to produce up to 1.5 Mtpa product coal for export. The key components of the mine will include:

- two open pits;
- two out of pit overburden dumps;
- a ROM stockpile;
- a coal handling and preparation plant (CHPP);
- initial out of pit tailings storage dam;
- a haulage transportation route to the rail loop and train loading facility; and
- a balloon loop and spur for rail access from the project, along with signalling and other associated infrastructure.

The mine operation will consist of conventional open-cut mining techniques which include topsoil stripping, drill and blast, truck/shovel operations, dozer push waste removal, coal extraction and progressive rehabilitation.

The layout of the coal mine and associated infrastructure is shown on **Figure 2**: Mine Layout.

The expected total workforce required for mining, processing, technical support and management is initially 100 persons during construction and 120 persons during operation. Accommodation for employees will initially be located at the Marlborough Motel and Caravan Park, under agreement with the owner to provide the requisite accommodation. It is proposed that a dedicated mining camp will be established in a suitable location within the project site.

It is proposed that coal will be transported utilising the existing “North Coast Line” rail infrastructure that runs through the project boundaries. The coal will then be delivered to the Port of Townsville (POTL) or the Port of Gladstone, destined for the international markets.

2.1.1 Coal Handling and Preparation Plant (CHPP)

The project will purchase a modular plant with the capacity to produce 1.5 Mtpa of product coal. Coal from open cut excavations will either be fed directly into the dump hopper for direct feed into the CHPP, or transported from the ROM stockpile area to the CHPP via an overland conveying system. The various coal seams will have dedicated raw coal stockpiles immediately preceding the CHPP. A combination of a surge bin and reclaim conveyors beneath individual stockpiles will provide for some blending if required.

It is expected that the CHPP will operate at a feed rate of around 300 tph, operating on an average of 7000 hours per annum. Product coal will be conveyed to a train load-out station on the rail loop for loading onto the coal trains for transport to the port stockyard.

Currently the plant has not been specified, and so water usage and rates within this document have been estimated from statistical and standard rates of service in the mining industry.

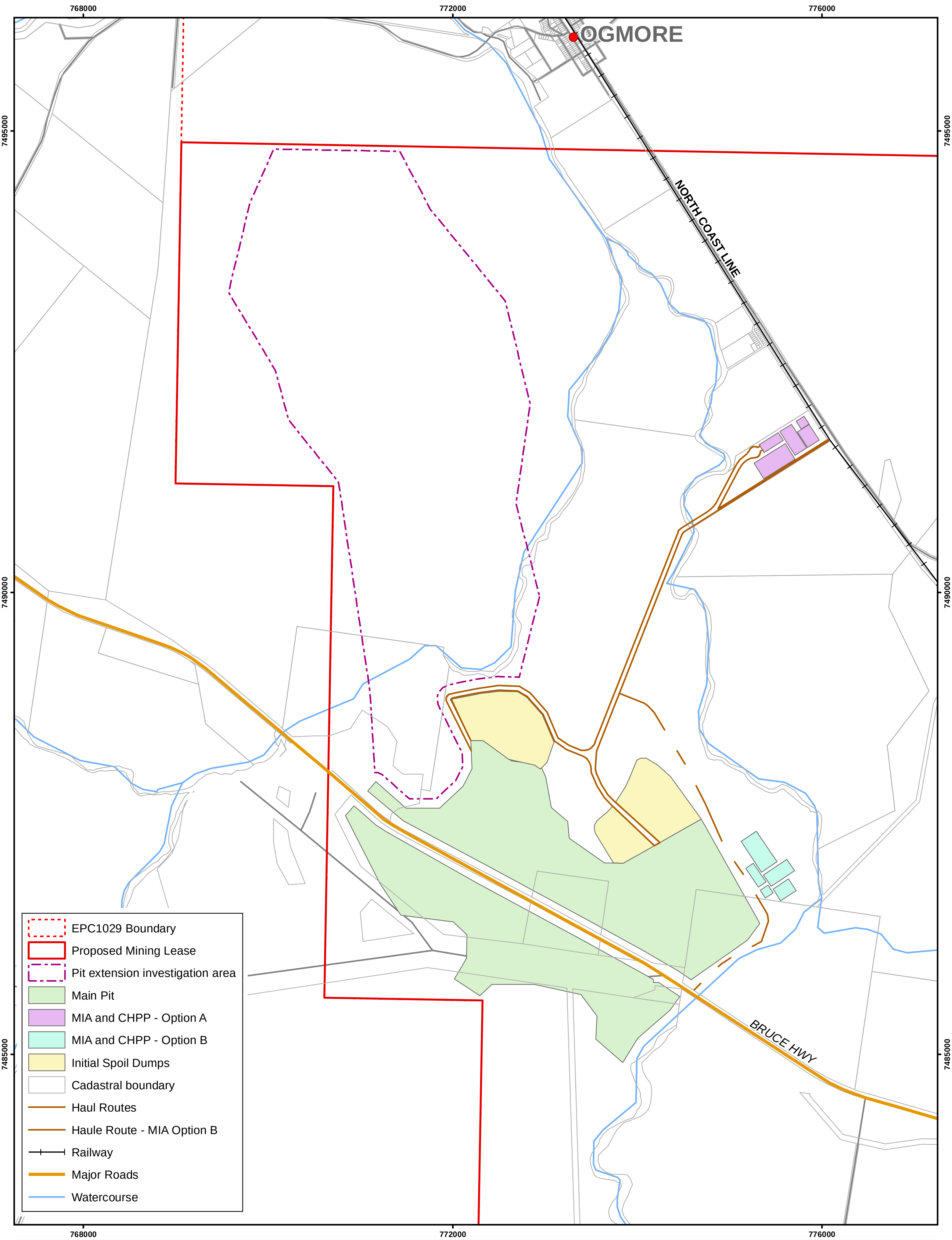

FIGURE 2

Mine Layout Plan

Road and Rail network © DERM, 2010; Proposed Mining Lease, Mine Layout © Fairway Coal, 2012; Watercourses © DERM, 2011; DCDB © DERM , 2012.

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File: YBE0002_SW_002a_MINE_LAYOUT_PLAN_120503 Date: 21/05/2012

0 1 2
Kilometers

A4 Scale 1:50,000

Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Styx Coal Project

Styx Basin
Queensland
Australia

FairwayCoal

2.2 **Water Management System**

Water is required for CHPP operation, dust suppression, fire protection, and for operation of the administration and accommodation camp facilities. Water for the project will be drawn from a number of sources including Tooloombah Creek, Deep Creek, bore field, dams, water harvesting, mine dewatering and catchment runoff.

The management system will generally be designed to capture, treat, reuse and, in extreme circumstances, to release surface water runoff from the mine area, as well as to manage dewatered groundwater from mine pits. The main types of water for the Project will be:

- Type 1: Clean water runoff from undisturbed catchment areas – this water will be diverted around the disturbed area or, in some circumstances, a portion may be collected to augment the water supply for the Project;
- Type 2: Raw water sourced to supply amenities, process water for CHPP and related operations – currently Tooloombah and Deep Creeks, and the local alluvial groundwater aquifers are being assessed for the sourcing of makeup water;
- Type 3: Dirty runoff water from areas subject to disturbance and management of topsoil, overburden, access roads etc. contaminated by sediment only – this water will be directed through sediment dam(s) prior to being reused on-site or released under controlled conditions in extreme rainfall events to local waterways;
- Type 4: Contaminated water from the mine industrial area (MIA), ROM pads, in-pit water and dewatered groundwater, tailings storage areas and tailings dams, and other areas subject to contamination from mining operations and coal dust or similar contaminants – this water will be contained on-site for reuse; and
- Type 5: Heavily contaminated waters and trade wastes from workshop areas, plant and infrastructure maintenance works, etc. containing contaminants such as oil and grease. The overall objective for management of these areas is to avoid any runoff being generated by undertaking these works in roofed and bunded areas, and using spill cleanup procedures to avoid runoff of these contaminants into the site water management system. Any runoff containing hydrocarbons will be contained on site until either treated and reused or removed from the site by a licensed contractor;
- Type 6: Sewage waste – wastewater derived from on-site amenities will be treated and discharged in accordance with an on-site sewerage management strategy, likely to include land application of treated recycled water. While not further discussed here, the quantity of recycled water is anticipated to be in the order of 90kL/day, requiring potentially a 4-5ha irrigation area.

The only waters that are proposed to be discharged are clean runoff waters (Type 2), treated (i.e. settled) sediment laden waters (Type 3) and recycled water applied to land (Type 6). The latter will be undertaken within the hydraulic capacity of the land application areas and will therefore not discharge to creeks or waterways.

Based on the above and consistent with similar projects in Queensland, the following types of dams and water containment facilities are expected to be required on the site:

- Tailings storage facility and associated return water dams;

- Environmental dams receiving water contaminated by mine operations (mine pit, ROM stockpile areas, etc.); and
- Sediment dams to contain and treat water from disturbed areas, subject only to sediment laden runoff.

3 Relevant Legislation and Guidelines

3.1 Legislation

The key pieces of legislation relating to water management in Queensland are the *Water Act 2000*, *Water Supply (Safety and Reliability) Act 2008*, *Environmental Protection Act 1994* and the *Sustainable Planning Act 2009*. In addition, due to the proximity of the project to the coast and the Great Barrier Reef Marine Park area, the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* is potentially relevant to the project in terms of water quality.

These are described in more detail below.

3.1.1 Water Act 2000

The Water Act provides a framework for the planning, allocation and use of non-tidal water in Queensland, including regulating both major water impoundments (dams, weirs and barrages), extraction by pumping and requirements for works requiring disturbance to the bed and banks of watercourses (i.e. stream diversions) and generally interfering with the flow of water. Non-tidal water includes in-stream (watercourses, lakes and springs) and overland flow water and groundwater.

The Act provides for the development of Water Resource Plans (WRP), Water Use Plans and Land and Water Management Plans:

- WRPs generally relate to specific catchments, intended to balance water allocations (human use) with environmental flows. Resource Operations Plans provide operational details of the implementation of a WRP under which Resource Operations Licenses and Water Permits may be granted. Two approvals are required for extraction of water from a watercourse and other matters regulated under the Act:
  - a resource entitlement or allocation which provides approval to extract or use a water resource
  - a development permit - which provides approval for the development associated with the use of water that is assessable under the Sustainable Planning Regulation 2009;
- Water Use Plans may be prepared for areas at risk of land or water degradation; and
- Land and Water Management Plans may be submitted by individual landowners applying to irrigate their lands.

Schedule 3 of the Sustainable Planning Regulation 2009 also defines a number of types of water related development as assessable or self-assessable development. Assessable development includes all work in a watercourse, lake or spring that involves taking or interfering with water (e.g. a pump, stream re-direction, weir or dam) and taking, or interfering with artesian bores, in conjunction with the *Water Act 2000*.

In addition to these planning controls, the destruction of vegetation, excavation or placing fill in a watercourse, lake or spring is regulated under Section 814 of the *Water Act 2000*.

DERM administers the Water Act in conjunction with the Queensland Water Commission, water authorities, and local governments.

Relevance to the Project

No Water Resource Plan is in operation for the Styx Catchment.

Licensing will be required for extraction of water from surface or groundwaters, though no license will be required for the installation and sampling of groundwater monitoring wells.

A person may take overland flow for any purpose unless there is a moratorium notice, a water resource plan or wild river declaration that limits or alters the water that may be taken (none of which apply). New works to take overland flow water associated with environmentally relevant activities or for diversion of overland flow water around a mine site are identified as self-assessable under the Sustainable Planning Act 2009. This means that the works can be built without prior approval from the department provided they are allowed for by the relevant water planning document, and comply with the *Code for self-assessable development for taking overland flow water to satisfy the requirements of an environmental authority or a development permit for carrying out an environmentally relevant activity*.

A Riverine Protection Permit will not be required to destroy vegetation, excavate or place fill in a watercourse, lake or spring, if it is undertaken in accordance the DERM guideline *Activities in a watercourse, lake or spring associated with mining operations* for holders of a mineral development licence or mining lease under the *Mineral Resources Act 1989 (Qld)*.

3.1.2 Water Supply (Safety and Reliability) Act 2008 (Qld)

This Act regulates the supply of recycled water (including recycled water from sewage, greywater and industrial wastewater) and drinking water from water service providers, and dam safety, including dam failure risk assessment. Water service providers are defined as:

- a local government that owns infrastructure for supplying water or sewerage services;
- a water authority that owns infrastructure for supplying water or sewerage services; and
- each person who is the owner (or a relevant nominated person of the owner) of 1 or more elements of infrastructure for supplying water or sewerage services for which a charge is intended to be made.

The above does not apply to a person who owns infrastructure that produces and supplies recycled water, or that supplies recycled water that is coal seam gas water, unless the person also owns other infrastructure for supplying a water or sewerage service. As such the Act does not apply.

This Act is administered by DERM.

3.1.3 Environmental Protection Act 1994

The Environmental Protection Act 1994 provides the key legislative framework for environmental management and protection in Queensland. The Act regulates and establishes tools for, amongst other things:

- Environmental Protection Policies (EPPs);
- the environmental impact statement process for mining activities;
- a system for development approvals integrated into the Sustainable Planning Act 2009 (Qld) for Environmentally Relevant Activities (ERAs);

- environmental authorities for mining activities (Chapter 5 of the Act) including the process for obtaining an Environmental Authority (EA) for mining activities;
- a general environmental duty and a duty to notify of environmental harm;
- environmental evaluations and audits;
- transitional environmental programs;
- environmental protection orders;
- financial assurances;
- a system for managing contaminated land; and
- environmental offences.

Four EPPs have been gazetted under the Act:

- Environmental Protection (Air) Policy 2008
- Environmental Protection (Noise) Policy 2008
- Environmental Protection (Waste Management) Regulation 2000
- Environmental Protection (Water) Policy 2009

The *Environmental Protection Regulation 2008 (Qld)* lists the ERAs in Schedule 2, including sewage treatment which may be relevant for the site. The regulations also provide a regulatory regime for minor issues involving environmental nuisance as well as for implementing National Environment Protection Measures for the National Pollutant Inventory and Used Packaging Material.

3.1.4 **Environmental Protection Policy (Water)**

The EPP (Water) establishes Environmental Values (EVs) and management goals for Queensland waters. Schedule 1 contains those areas for which EVs and water quality objectives have been set. The Styx Basin has not been scheduled as yet, though it has been timetabled for December 2013.

Generally management of waters on the site and discharges from the site in relation to environmental protection are administered via the EA conditions for the development.

The Act is administered by DERM.

3.1.5 **Fisheries Act 1994 (Qld)**

The *Fisheries Act 1994* is the key piece of legislation regulating fishing, development in fisheries habitat areas, and damage to marine plants in Queensland. It regulates land based activities that may damage declared fish habitat areas and marine plants such as mangroves, with technical detail for mechanisms created by the act outlined in the *Fisheries Regulation 1995 (Qld)*, including:

- Closed waters and protected areas (e.g. Green Zones in the Great Barrier Reef Marine Park);
- Protected species (e.g. dugongs).

The Act is administered by Fisheries Queensland and the Queensland Boating and Fisheries Patrol within DEEDI.

<u>Relevance to the Project</u>

The freshwaters in the region house habitat areas for some species of fish, including Barramundi and sea mullet, and a declared Fish Habitat Area is located downstream of the site, terminating at the Styx River bridge at Ogmore.

Marine plants are also located downstream of the site, within the declared Fish Habitat Area.

3.1.6 **Coastal Protection and Management Act 1995**

The Coastal Protection and Management Act 1995 establishes State and regional planning processes for coastal development. The Act is integrated into the *Sustainable Planning Act 2009 (Qld)* and provides for the regulation of dredging, quarrying, canal construction, tidal works and other activities in the coastal zone, in particular in coastal management districts and erosion prone areas.

The Queensland Coastal Plan has been prepared under the Coastal Protection and Management Act 1995, and includes a state planning policy under SPA - State Planning Policy 3/11: Coastal Protection. This replaces the previous policy—the State Coastal Management Plan, and no longer includes mining activities.

The Act is administered by DERM.

3.1.7 **Environment Protection and Biodiversity Conservation Act 1999 (Cwth)**

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) regulates:

- impacts on Matters of National Environmental Significance (MNES);
- impacts on the environment involving the Commonwealth or Commonwealth land;
- killing or interfering with listed marine species and cetaceans (e.g. whales); and
- international trade in wildlife.

Importantly, the Act administers the approval for actions with a significant impact on MNES. These, and actions by the Commonwealth or involving Commonwealth land with a significant impact on the environment are termed *controlled actions* and require approval under the Act. Under the Act, an *action* is a physical activity or series of activities such as the construction and operation of a mine, dam or factory, and a *significant impact* is impact that is important, notable or of consequence having regard to its context or intensity.

The current MNES are:

- the world heritage values of a declared World Heritage property;
- the National Heritage values of a declared National Heritage place;
- the ecological character of a declared Ramsar wetland;
- listed threatened species and ecological communities;
- listed migratory species;
- nuclear actions;
- Commonwealth marine areas; and
- the Great Barrier Reef Marine Park.

Relevance to the Project

In terms of water resources for the project, only the world heritage and Great Barrier Reef Marina Park (GBRMP) MNES are potentially triggered. Based on the proposed total reuse on-site, it is not anticipated that downstream waters will be affected by the mine to the extent that they can impact on the GBRMP and world heritage area.

3.2 Applicable guidelines

The National Water Quality Management Strategy presents the overarching national approach to improving and managing water quality in Australia's waterways, with a key technical component of the guidelines being the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (the ANZECC Guidelines, ANZECC & ARMCANZ, 2000). Schedule 1 to the *Environmental Protection (Water) Policy 2009* (EPP Water) contains environmental values and water quality objectives for certain waters. Where the waters are not listed in Schedule 1, the EPP Water describes the process to be undertaken for determining which guidelines should be used, being in order of priority:

- Site specific documents for the water;
- The Queensland Water Quality Guidelines (QWQG) (DERM, 2009a);
- The ANZECC Guidelines; or
- Other relevant documents published by the relevant entity (e.g. DERM).

Environmental Values and Water Quality Objectives have not been scheduled under the Environmental Protection (Water) Policy 2009 (EPP Water) for the Styx catchment, though they are due to be scheduled by December 2013 (the Boyne, Calliope, Curtis Island, Shoalwater, Styx and Waterpark basins and coastal waters).

Site specific documents do not exist, and therefore in the absence of scheduled WQOs and site specific documents, the QWQGs are appropriate for the Styx Catchment, based on the appropriate water types, and supplemented by the ANZECC Guidelines for parameters such as metals that are not addressed in the QWQGs. DERM's *Final Model Water Conditions for Coal Mines in the Fitzroy Basin* (DERM, 2009b) must also be considered since, while the site is not located within the Fitzroy basin, its proximity mean these will likely be the starting point for any license issued for mining activities.

In addition to the above guidelines the following documents are potentially relevant to the site and activities:

- the Fitzroy Basin Association (FBA) Interim Water Quality Guidelines for Freshwater Events (FBA, 2009c).

As stated in the QWQGs, water quality has a strong dependence on flow, with poor water quality generally under flood or high flow conditions, and during very low or nil flows, as is the case for the waters within the ML area. However, the existing QWQGs and ANZECC Guidelines are relevant generally to baseflow conditions only. As such, interpretation of the guidelines and criteria will need to take into account these seasonal low flow periods and flood events.

The key water quality guidelines are summarised in Table 1 and 2 below. Generally, these are based on 20^{th} and 80^{th} percentile ranges from reference waters, or for toxicants, from dose response studies or similar. The 75^{th} percentile value for conductivity was used to derive the stated preliminary guideline value.

Table 1. Water Quality Objectives, QWQGs, FBA (2009) and DERM (2009b)

Parameter[1]	Units	QWQGs (unless otherwise specified)[2]				Fitzroy basin freshwater events[4]	DERM Model Water Conditions[5]
		mid estuarine[3]	upper estuarine	lowland streams	upland streams		
Ammonia N	ug/L	10	30	20	10		900
Nitrate	ug/L	700[6]					1100
NOx	ug/L	10	15	60	15		
Org N	ug/L	260	400	420	225		
TN	ug/L	300	450	500	250	3400	
FRP	ug/L	8	10	20	15		
TP	ug/L	25	40	50	30	2000	
Chl a	ug/L	4	10	5	n/a		
DO[2]	% sat[3]	85 - 100	70 - 100	85 - 110	90 - 110		
Turbidity	ntu	8	25	50	25	6976	
TSS	mg/L	20	25	10	-	2000	
pH	units	7 - 8.4	7 - 8.4	6.5 - 8	6.5 - 7.5	7.46 - 6.78	6.5 – 9.0
Sulfate	ug/L						1000
Flouride	ug/L						2000
Conductivity	uS/cm			375	375	221.8	1000

Table notes:

1 NOx – Nitrate + Nitrite; Org N – Organic Nitrogen; TN – Total nitrogen; FRP – Filterable Reactive Phosphorous (i.e. bioavailable phosphorous); TP – Total Phosphorous; Chl a – Chlorophyll *a*; DO - Dissolved Oxygen; TSS – Total Suspended Solids; SO

2 Queensland Water Quality Guidelines (DERM, 2009a) Water types for Central Queensland Waters

3 full water type description is mid estuarine and tidal canals, constructed estuaries, marinas and boat harbours

3 % sat – percent saturation.

4 Fitzroy Basin Association Interim WQOs (FBA, 2009)

5 DERM's Final Model Water Conditions for Coal Mines in the Fitzroy Basin (DERM, 2009b)

6 Low reliability or ECL trigger value from ANZECC Guidelines, Section 8.3.7

Table 2. Water Quality Objectives for toxicants, ANZECC Guidelines, DERM (2009a)

Parameter	Units	Trigger values for freshwater		Trigger values for marine water		DERM Model Water Conditions[1]
		0.99	0.95	0.99	0.95	
Aluminium_mgL pH > 6.5	ug/L	27	55	0.5[2]		100
Aluminium_mgL pH < 6.5	ug/L	ID	ID	ID	ID	-
Antimony	ug/L	9[2]		270[2]		-
Arsenic (As III)	ug/L	1	24	270[2]		13
Arsenic (AsV)	ug/L	0.8	13	ID	ID	-
Beryllium	ug/L	0.13[2]		ID	ID	-
Boron	ug/L	90	370 C	5100[2]		370
Cadmium	ug/L	0.06	0.2	0.7 B	5.5 B, C	0.2
Chromium (Cr III)	ug/L	ID	ID	7.7	27.4	1
Chromium (CrVI)	ug/L	0.01	1 C	0.14	4.4	-
Cobalt	ug/L	1.4[2]		0.005	1	90
Copper	ug/L	1	1.4	0.3	1.3	2
Iron	ug/L	300[2]		ID	ID	300
Lead	ug/L	1	3.4	2.2	4.4	10
Manganese	ug/L	1200	1900C	80[2]		1900
Molybdenum	ug/L	34[2]		ID	ID	34
Nickel	ug/L	8	11	7	70 C	11
Selenium (Total)	ug/L	5	11	3[2]		10
Selenium (SeIV)	ug/L	ID	ID	ID	ID	-
Silver	ug/L	0.02	0.05	0.8	1.4	1
Thallium	ug/L	0.03[2]		17[2]		-
Tin	ug/L	3[2]		10[2]		-
Uranium	ug/L	0.5[2]		ID	ID	1
Vanadium	ug/L	6[2]		50	100	10
Zinc	ug/L	2.4	8 C	7	15 C	8
Mercury (inorganic)	ug/L	0.06	0.6	0.1	0.4 C	0.2
Mercury (methyl)	ug/L	ID	ID	ID	ID	-

Table notes:
ID Insufficient data to derive a reliable trigger value
1 DERM's Final Model Water Conditions for Coal Mines in the Fitzroy Basin (DERM, 2009b)
2 Low reliability or ECL trigger value from ANZECC Guidelines, Section 8.3.7

4 Existing Environment

4.1 Local Climate

Climatic conditions in the Styx catchment are typical of a seasonally dry subtropical region. Higher rainfall in the months of November through to March corresponds with the major climatic drivers in the region being intense low pressure influences and associated rain depressions. The overall annual rainfall is relatively low, and evaporation exceeds rainfall typically for all months.

Rainfall in the Styx catchment varies between 800 mm/year in the south to around 1,100 mm/year in the north. A number of rainfall recording stations are located within the Styx catchment, with two stations - Strathmuir and Tooloombah[1] - located close to the Project, and another two - St. Lawrence Post Office and Mystery Park[2] - located approximately 35km north.

Monthly rainfall statistics from Strathmuir (BOM station no. 033189) for the period from 1941 through to 2010 is shown in **Figure 3**. These statistics show that generally around 70% of the annual rainfall falls in the November to March period, however this can be highly variable, with January recording the largest variation (maximum recorded January rainfall was 1,002 mm in 1951).

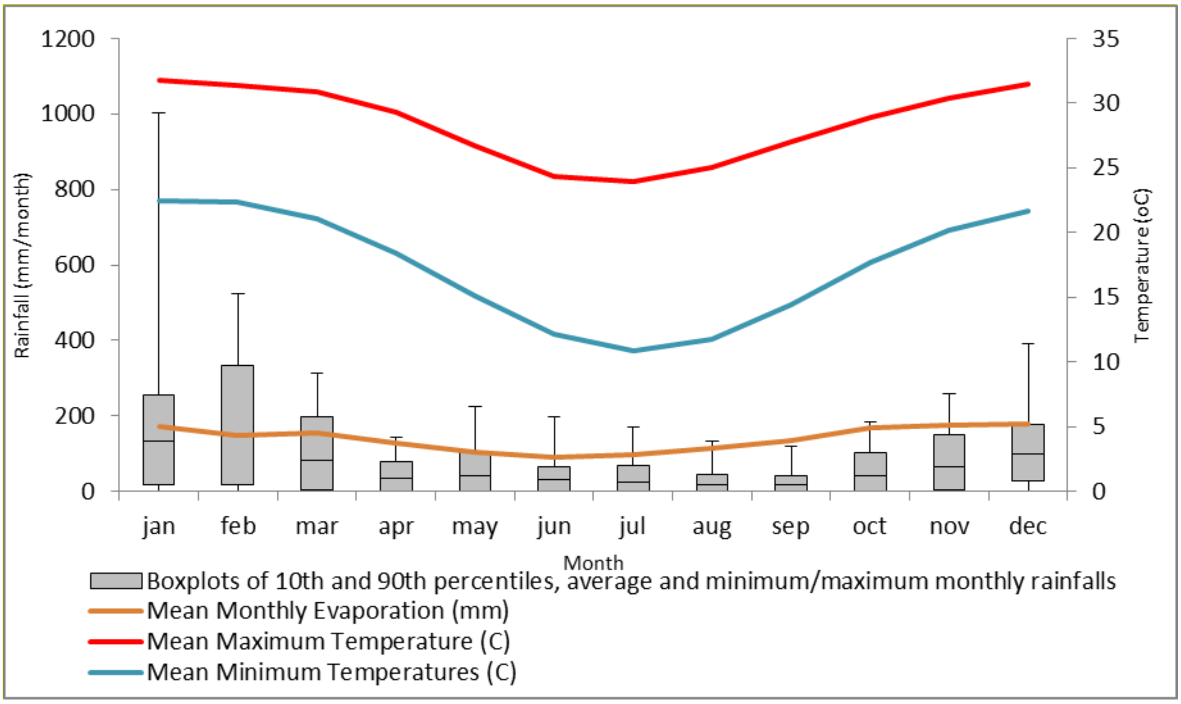

Figure 3. Rainfall, Evaporation and Temperature trends

Source: Rainfall from Strathmuir (BOM station no. 033189); Temperature and evaporation data from St. Lawrence Post Office (BOM station no. 033065)

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[1] Strathmuir (BOM station no. 033189), located approximately 8.5 km east of Mamelon and Tooloombah (BOM station no. 033211), located 11 km west of Mamelon with annual mean rainfalls of 756 and 820 mm/yr respectively.

2 St. Lawrence Post Office (BOM station no. 033065) and Mystery Park (BOM station no. 033170), with annual rainfalls of 1070 and 1020 mm/yr respectively.

The evapotranspiration Climatic Atlas of Australia (BOM, 2001) shows average annual evapotranspiration (areal potential) between 1700 - 1800 mm/yr, matched by recorded evaporation data in the area of 1680 mm/yr (St. Lawrence Post Office, BOM station no. 033065). Average evaporation exceeds average rainfall for all months, however, as noted above, the large variation in rainfall means that 90th percentile rainfalls exceed evaporation during the January to March period.

Monthly mean rainfall, temperature and evaporation are shown in **Figure 3**.

Table 3: Monthly average Evaporation and rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Monthly Evaporation (mm)	174	147	155	129	105	90	96	115	140	162	183	174	1,680
Mean Monthly Rainfall (mm)	134	146	83	36	41	30	25	19	16	42	66	99	756
Evaporation – Rainfall (mm)	40	1.0	72	93	65	60	72	96	119	126	111	81	924

Source: Evaporation from St. Lawrence Post Office (BOM station no. 033065), rainfall from Strathmuir (BOM station no. 033189)

4.2 Water Resources

4.2.1 Styx Catchment

The ML area is located entirely within the Styx River Catchment (Queensland river basin 127), a small catchment forming part of the Fitzroy River Natural Resource Management region, which discharges into the Coral Sea adjacent to Rosewood Island (in the vicinity of the Project). The catchment is formed by the Connors and Broadsound Ranges to the west (Nogoa/Mackenzie system), and its main tributaries include Granite, Tooloombah, Stoodleigh, Deep, Waverley and Wellington Creeks. Other tributaries to the north include Clairview and St. Lawrence Creeks. The location of the ML in relation to the catchment and waterways is shown on **Figure 4**.

The catchment is located within the Brigalow Belt bioregion, in the Central Queensland Coast region, and abuts the Broadsound Fish Habitat Area, as well as the Great Barrier Reef Marine Park. No water resource plan is in force over the catchment.

The catchment covers some 302,000 ha, which is predominantly used for 'cattle grazing from relatively natural environments' (73%) (DNRM&W, 1999). Other major land uses in the catchment include:

- Remnant native vegetation cover (15%);
- freshwater or intertidal wetlands (8.1%);
- National Park and State forest (2.5%);
- Production forestry (1.7%);
- Residential (0.07%);
- Cropping for Hay and silage (0.06%);

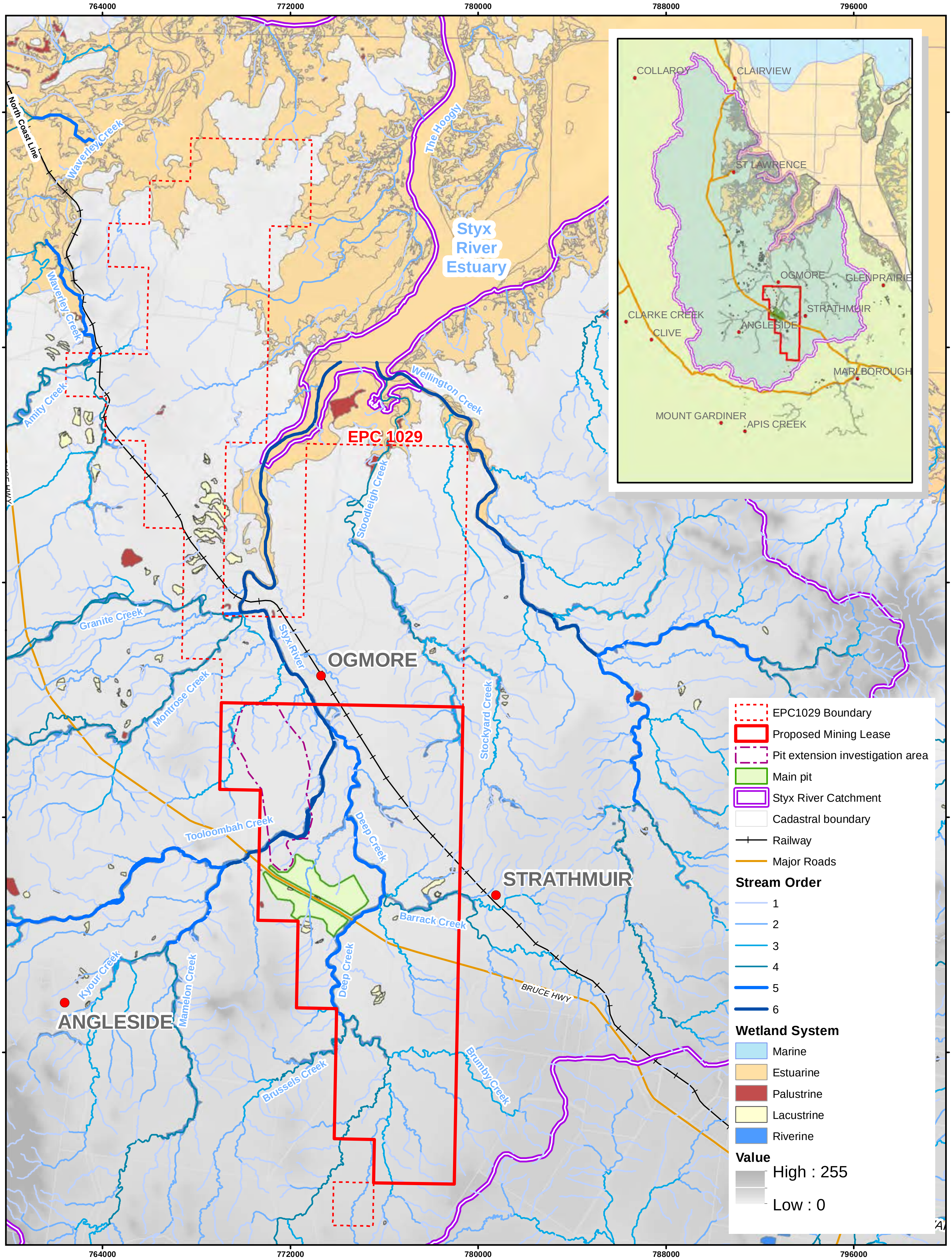

FIGURE 4

Styx Catchment and Water Types

Road and Rail network © DERM, 2010; Proposed Mining Lease Boundary, Mine Layout © Fairway Coal, 2012; Watercourses © DERM, 2011; basemap (heighfield), Fitzroy Basin DEM, © DERM, 2010, Catchment Boundary, Wetland Systems © DERM 2012

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File: YBE0002_SW_004a_CATCHMENT & WETLAND TYPES_120510 Date: 21/05/2012

0 2 4 6 8 10
Kilometers

A4 Scale 1:200,000

Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Styx Coal Project

Styx Basin
Queensland
Australia

FairwayCoal

- Irrigated and perennial horticulture (0.025%);
- Services (0.02%).

4.2.2 Catchment Condition

The Queensland river condition workshop expert panel (ANRA, 2009a) assessed the Styx River Basin as having little modification from natural. Water quality was rated highly by the panel, with high turbidity levels found in the basin attributed to the dispersive soils and variable rainfall, and considered natural. Overall, the basin was noted as:

- largely unmodified based on the hydrological disturbance index;
- moderately modified based on the catchment disturbance index;
- largely unmodified based on the habitat index; and
- substantially modified based on the nutrient and suspended load index.

A land condition survey conducted by Melzer et al (2008) also found the catchment to be degraded, noting that around 30% of the Styx catchment was in a high to very high disturbance class, generally represented by bare ground and eroded surfaces. Issues in the catchment, according to the Great Barrier Reef Marine Park Authority (GBRMPA, 2007) include:

- grazing in drier lands show signs of overgrazing and inappropriate land-clearing practices which has led to weed problems and sheet and gully erosion in some areas;
- approximately 41% of the Catchment is cleared mostly for grazing;
- less than 0.2% of the catchment is within protected areas;
- ponded pasture development may impact riverine and wetland habitats; and
- floodplains have been modified.

In addition, Melzer et al (2008) noted several points in the catchment where 'erosion and land degradation must be considered severe'. The land condition survey noted that these most likely represent significant point sources of sediment to the streams, and places threats to road infrastructure. Seven very severe and six severe cases were identified where there was direct discharge to streams.

Little quantitative information is available for the broader catchment. However, the Fitzroy Basin Association Inc. (FBA) has established a monitoring site on the Styx River at Ogmore (coincident with the present St1 monitoring site – refer Section 5). This event-based monitoring program has operated since January 2008 with the latest round of sampling undertaken in March 2012.

The FBA monitoring program established that most parameters were within expected levels according to the FBA Interim Guideline levels (FBA, 2009; 2010) and the QWQG. Higher sediment and nutrient concentrations were typically experienced in the early stages of flows, particularly at the end of the dry season representing the 'first flush' of the wet season.

4.2.3 Waterways within the ML

The key waterways within or potentially impacted by the ML area are the Tooloombah and Deep Creeks, the Styx River Estuary, and downstream coastal waters. Smaller creeks within the ML region include Barrack, Montrose and Granite Creeks, and a number of smaller creeks and gullies.

With reference to the QWQG, the river and creeks investigated fall into three categories:

- Lowland freshwater streams; and
- Upper Estuarine;

Freshwaters

Lowland freshwater streams are defined by the QWQG as freshwater streams below 150m or otherwise larger (third, fourth and fifth order or greater), slow-flowing and meandering streams and rivers. Their gradient is generally very slight, with substrates rarely cobble and gravel, and more often sand, silt or mud. All freshwater streams investigated during this study fall broadly into this designation.

Estuarine Waters

The Styx River is a tidally influenced river and estuary, approximately 35 km long (to the Broadsound estuary) and is subject to one of the largest tidal ranges in Queensland. It is known for its tidal bore, a wave or series of waves that propagate upstream in certain rivers subject to large tidal ranges.

Estuarine environments can be distinguished by a mixture of fresh and salt water, usually bounded by the Mean High Water Spring (MHWS) in the upstream direction, and the mouth or inlet into the marine environment (i.e. the ocean) in the downstream direction. No information on the MHWS for the Styx River was found, and the large tidal range (and tidal bore) make it difficult to determine the upper extent of the saline influence (and therefore of the 'estuary').

According to DERM's wetland mapping program, the estuarine portion of the Styx River terminates 2.9km downstream of the bridge at Ogmore. However, anecdotal evidence and visual observation of the water level changes with tide at the Ogmore bridge indicates the tidal influence extends upstream past Ogmore. Monitoring indicates that the upstream limit of tidal influence is the confluence of the Tooloombah and Deep Creeks into the Styx River (at site St1- refer to Section 5), with generally higher conductivity (around 2,400 μS/cm) than found in either creek (around 760 μS/cm).

Using the decision tree from the QWQG (Figure B.1: Decision tree to determine presence/absence of an upper estuarine zone), no upper estuary can be defined for the Styx River Estuary. The middle estuary begins below the freshwater/estuarine cut-off (if there is no upper estuarine zone) and extends downstream to near the mouth of the estuary at the coast. It excludes the small section just upstream from and including the mouth that is well flushed each tide with incoming marine waters. From this and the monitoring results it may be concluded that the St1 site would be mid-estuary or freshwater, with the St2 site mid-estuary. However, Since the St1 site is so heavily influenced by upstream flows, it is considered more appropriate to adopt the lowland streams water type.

Combined with the results of the Aquatic Ecology survey, visual observations and the condition assessments, a preliminary classification of the waterways within the ML (as defined in the QWQG) is as follows:

- Deep Creek – lowland freshwater, slightly – moderately disturbed ephemeral creek;
- Tooloombah Creek – lowland freshwater, slightly disturbed semi-permanent creek;
- Granite Creek – lowland freshwater, slightly – moderately disturbed ephemeral creek;
- Barrack Creek - lowland freshwater, moderately disturbed highly ephemeral creek;

- Styx River at St1 - lowland freshwater, slightly – moderately disturbed river;
- Styx River at St2 – slightly - moderately disturbed mid estuary.

4.3 Regional and Historical Water Quality Data

Little historical data is available for the catchment, with the exception of monitoring by the Fitzroy Basin Association Inc (FBA), who have established a monitoring site on the Styx River at Ogmore (at the St1 monitoring site – refer Section 5). This event-based program has operated for the past five years with around 19 distinct events captured between January 2008 and March 2012 (some of which were rainfall events, some individual monitoring events during low flow).

Findings from FBA (2009; 2010) established that for the rounds prior to and including February 2009, most parameters were within expected levels according to the FBA Interim Guideline levels (FBA, 2009) and the QWQG. Higher sediment and nutrient concentrations were typically experienced in the early stages of flows, particularly at the end of the dry season representing the 'first flush' of the wet season.

Electrical conductivity varied with some results exceeding guidelines, noted as likely due to saline groundwater interaction (FBA, 2008).

5 Water Quality Sampling Program

5.1 Methodology

5.1.1 Program objectives

The study was intended to both identify constituents of the natural water environment that may be problematic for Fairway Coal in terms of compliance with DERM's standard water quality limits in the region, or the QWQG / FBA Interim Guidelines that may be generically applied, and to aid in characterising waterways in the region, due to the lack of existing baseline data.

The program was also undertaken alongside the aquatic ecology assessments for the Project in order to correlate AUSRIVAS sampling with water quality.

5.1.2 Parameters and analytical methods

DERM's *Final Model Water Conditions for Coal Mines in the Fitzroy Basin* (DERM, 2009b) include a number of parameters for monitoring of site discharges and/or background waters. Using this document and a standard suite of additional analytes, a number of parameters were chosen. Some analytes were subject to low range testing where the criteria from DERM (2009b) was below the high range test Limit of Reporting (LOR).

A standard suite of *in-situ* tests were undertaken at each site visited, namely:

- dissolved Oxygen (% saturation);
- pH;
- temperature (^{0}C);
- conductivity @25C (mS/cm or µS/cm);
- turbidity (NTU); and
- Redox potential (mV).

Laboratory analysis was undertaken by ALS Laboratory Group, a NATA accredited laboratory. The parameters chosen to be sampled / analysed, and their respective methods and LOR are shown in **Table 4** below.

Table 4. Monitoring Program Parameters

Analyte	Unit	ALS Method	LOR
Phys-chem			
Total Dissolved Solids @180°C	mg/L	EA015	5
Suspended Solids	mg/L	EA025	5
Alkalinity (Hydroxide, Carbonate, Bicarbonate and Total) as CaCO3	mg/L	ED037P	1
Cations and Anions			
Sulfate as $SO4^{2-}$ (Turbidimetric) by DA	mg/L	ED041G	1
Chloride by Discrete analyser	mg/L	ED045G	1
Calcium	mg/L	ED093F	1
Magnesium	mg/L		1
Sodium	mg/L		1

Analyte	Unit	ALS Method	LOR
Potassium	mg/L		1
Fluoride by PC Titrator	mg/L	EK040P	0.1
Total Anions	meq/L	EN055	0.01
Total Cations	meq/L		0.01
Ionic Balance	%		0.01
Dissolved Metals by ICP-AES			
Aluminium		EG005F	0.10
Antimony			0.01
Arsenic			0.01
Barium			0.1
Beryllium			0.01
Boron			0.1
Cadmium			0.005
Calcium			1
Chromium			0.01
Cobalt			0.01
Copper			0.01
Iron			0.05
Lead			0.01
Magnesium			1
Manganese			0.01
Molybdenum			0.01
Nickel			0.01
Phosphorus			1
Potassium			1
Selenium			0.01
Silver			0.01
Sodium			1
Strontium			0.1
Thallium			0.01
Tin			0.01
Titanium			0.01
Vanadium			0.01
Zinc			0.01
Dissolved Metals by ICP-MS			
Cadmium		EG020F	0.0001
Chromium			0.001
Copper			0.001
Silver			0.001
Uranium			0.001
Zinc			0.005
Dissolved Mercury by FIMS			
Mercury		EG035F	0.0001

Analyte	Unit	ALS Method	LOR
Nutrients by Discrete Analyser			
Nitrogen (as N) and Phosphorous (as P) – Ammonia, Nitrate, Nitrite, Nitrate + Nitrite (NO_x), Total Phosphorous, Reactive Phosphorus		EK055G, EK058G, EK057G, EK059G, EK067G, EK071G	0.01
Nitrogen (as N) - Total Kjeldahl Nitrogen (TKN), Total Nitrogen (TKN + NO_x)		EK061G, EK062G	0.1
Bacteriological			
Escherichia coli by MF	cfu/100ml	MW006	1

5.1.3 Monitoring Sites

Figure 5 shows the location of the monitoring points across the region, being:

- De1 – Deep Creek 1 – upstream of proposed southern resource area
- De2 – Deep Creek 2 - downstream of Bruce Highway
- De3 – Deep Creek 3 – just before confluence with Tooloombah Creek / Styx River
- Ba1 – Barrack Creek 1 – just before confluence with Deep Creek (not sampled due to no flow in areas)
- To1 - Tooloombah Creek 1 – bridge on Bruce Highway
- To2 - Tooloombah Creek 2 – upstream of confluence with Deep Creek prior to flow into Styx River
- Mo1 – Montrose Creek - bridge on Bruce Highway
- Gr1 – Granite Creek - upstream of Ogmore, prior to flow into Styx River
- St1 – Styx River 1 – just after confluence between Deep Creek and Tooloombah Creek into the Styx River (corresponds to Fitzroy Basin Association Inc. monitoring point); and
- St2 – Styx River at the bridge at Ogmore.

Generally, most of the sites were accessable during all rounds. However, particularly wet conditions hampered access to some of the sites, namely De1, De3, To2 and St1.

While all sites visited were subject to *in-situ* analysis, generally site De1 was not included in laboratory analysis.

Table 5 shows the sites visited and samples submitted for laboratory analysis during each sample round.

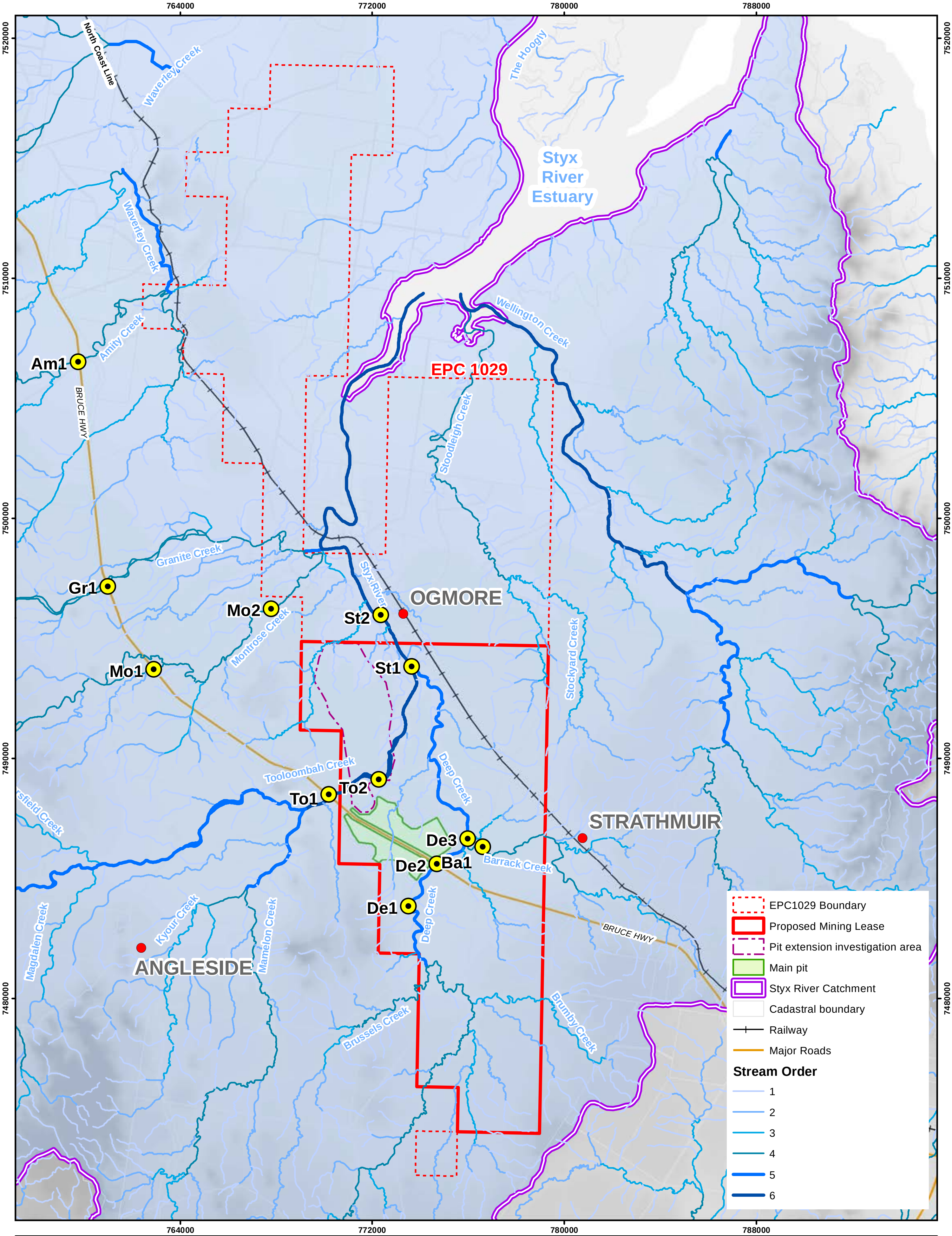

FIGURE 5

Water Quality Monitoring Locations

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File: YBE0002_SW005a_WATER_QUALITY_MONITORING_LOCATIONS_120510 Date: 21/05/2012

0 2 4 6 8 10
Kilometers

A4 Scale 1:200,000

Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Styx Coal Project

Styx Basin
Queensland
Australia

FairwayCoal

Table 5. Monitoring conducted (V = site visited, L = lab analysed)

		Deep Creek			Tooloombah Creek		Montrose Creek		Granite Creek	Styx River		Amity Creek
Round	**Dates**	**De1**	**De2**	**De3**	**To1**	**To2**	**Mo1**	**Mo2**	**Gr1**	**St1**	**St2**	**Am1**
1	1 – 5/6/11	V, L	V, L	V, L	V, L	V, L			V, L	V, L	V, L	
2	27 – 29/9/11	V	V, L	V, L	V	V, L	V, L	V, L	V, L	V, L	V, L	V
3	25 – 26/10/11	V	V, L	V	V, L	V, L	V, L	V, L	V, L	V, L	V, L	
4	21 – 22/11/11	V	V, L	V, L	V, L	V, L	V, L	V, L	V, L	V, L	V, L	
5	13-14/12/11	V	V, L	V, L	V, L	V, L	V, L	V, L	V, L	V, L	V, L	
6	31/1/12	V, L	V, L		V, L		V, L	V, L	V, L	V, L	V, L	V
7	21 – 22/2/12	V, L	V, L		V, L		V, L	V, L	V, L		V, L	
8	20/3/12	V, L			V, L		V, L	V, L	V, L		V, L	

5.1.4 Sampling and Sample Handling

Sampling was undertaken with reference to DERMs *Monitoring and Sampling Manual 2009* (DERM, 2010). Unless access was unsafe, *in-situ* measurements were made by lowering the sensors directly into the waters and logging the results once readings stabilised. In-situ measurements were made using a 90FL-T TPS water quality meter, with the following sensors:

- k = 1 Conductivity / Temperature Sensor
- YSI 5739 Dissolved Oxygen Sensor; and
- pH, ORP and Turbidity sensors.

Sample collection for laboratory analysis was undertaken using a 2 – 5m extendible sampling pole with replaceable sample cup. Prior to sampling at each site, the cup was inspected for obvious contamination (weeds, etc.) and pre-washed with water from the sample site at least three times prior to sample collection (with waste disposed of downstream or on land). Samples were collected from between 20 – 30 cm below the surface (by first upending the sample container, and turning up when underwater to avoid sampling the surface).

Water was decanted directly into pre-labelled and appropriately preserved sample containers supplied by ALS Laboratory suitable for each analyte.

For dissolved metals analysis, samples were pre-filtered through a 0.45 µm disposable filter connected to a disposable, sterile and hand operated syringe.

Samples were placed immediately into an esky on ice, and maintained between sampling days in a refrigerator at or below 4^{0}C. Eskies were labelled, and fitted with security seals and taped prior to transport to the laboratory with appropriate chain of custody documentation.

5.1.5 **Quality Assurance / Quality Control**

The program aimed to include a minimum 10% field QA/QC samples, being generally duplicates for metals analysis to test the repeatability of sampling and analysis techniques. One duplicate sample was included in the analytical batch (ALS Brisbane), and another sent to a different laboratory (ALS Sydney).

5.2 Monitoring Results

5.2.1 **Stream Conditions**

Table 6 below shows the stream / waterway conditions during each sampling event. Based on the timing of rainfall prior to sampling, and observations during sampling, the sample events represent a range of events from no flow or baseflow periods to storm flows from recent rains over the catchment, with February and March containing flows likely to largely represent storm flows more than baseflow events. However, it is considered unlikely that any of the sampling rounds coincided with the peak storm discharge.

5.2.2 **General Water Quality**

Water quality monitoring results are shown in Appendix A, and summarised for each creek / river system in the sections below.

Deep Creek

The three Deep Creek monitoring sites were relatively similar in water quality, though the De1 and De2 sites were more similar to each other than to the De3 site, even though the De3 and De2 sites were closer (1.6km compared to 2km between De1 and De2).

Based on observations and rainfall records, the following changes were generally noted as a response to rainfall and dry periods:

- During the dry/no flow periods from September to December 2011, results were generally more variable, especially between sites, with the only generally consistent pattern an increase in conductivity;
- During the December monitoring round, which recorded a rainfall in the previous week of 46 mm (and 33mm in 24hrs recorded 2 days previous), spikes in nutrients, TDS, suspended solids, turbidity and for redox at De1 (only) were noted, and falls in pH (to below 5.6), conductivity, alkalinity, chloride, and other cations;
- Following this initial ‘first flush’, increases were noted in dissolved oxygen, bioavailable phosphorous (FRP), redox potential at De2 (to match De1), and a continued rise in ammonia (though other nutrient species dropped to January 2011. Results varied somewhat after January with drops in dissolved oxygen, redox, ammonia, FRP phosphorous, and a rise in pH (to above 7.2).

Table 6. Waterway conditions and sites sampled per round

Sample round	Dates	Rainfall in previous		Deep Creek	Tooloombah Creek	Montrose Creek	Granite Creek	Styx River[1]	Amity Creek
		week	month						
1	1 – 5/6/11	0	18	Baseflow	Baseflow	n/a	Baseflow	45mins after high	n/a
2	27 – 29/9/11	0	7.4	No flow	Baseflow	Baseflow	Baseflow	0.5hr after low, outgoing	Baseflow
3	25 – 26/10/11	0	43	No flow	Baseflow	Baseflow	No flow	1hr before low, outgoing	n/a
4	21 – 22/11/11	0	0.2	No flow	Baseflow	Baseflow	No flow	Low, nil	n/a
5	13-14/12/11	46	79	No flow	Baseflow	Baseflow	Baseflow	2hr after high, Nil	n/a
6	31/1/12	55	137	Storm / base flow	Storm / base flow	Storm / base flow	Storm / base flow	1hr before high, outgoing	storm / base flow
7	21 – 22/2/12	78	211	Storm flow	Storm flow	Baseflow	No flow	mid tide, coming in, outgoing	n/a
8	20/3/12	139	298	Storm flow	Storm flow	Storm flow	Storm flow	1.5hrs after low, outgoing	n/a

Table notes:

1 tides taken from Hay Point tidal predictions, using McEwan Inlet, 24 mins after Hay Point (25km north of Styx bridge approximately). Flow (outgoing, incoming, nil) based on observations at the St1 site at the time of sampling.

Granite Creek

Granite Creek is similar in many ways to Deep Creek, with an overall similar pattern although not as pronounced except for turbidity and suspended solids. Generally when compared to Deep Creek, Granite Creek:

- had generally a higher dissolved oxygen concentration, higher temperature during the dry post flood period from July to October, higher turbidity and suspended solids spikes following the December rainfall event, lower conductivity and TDS (with no December spike noted), lower pH, sulfate, lower nutrients, and no FRP phosphorous detected; and
- had a similar level and pattern for calcium and magnesium, while total alkalinity, and chloride and sodium were lower, with no potassium was detected. Total anions and cations were both lower.

Based on aerial imagery for the catchment, the Granite Creek sub-catchment appears to be smaller, and comprises a larger proportion of vegetated areas than Deep Creek.

Tooloombah Creek

The two Tooloombah Creek sites were quite similar, more so than was found between the Deep Creek sites, with the latter likely due to the no flow periods and isolated pools that formed whereas Tooloombah Creek was flowing for the entire period (albeit slowly during low flow periods). The exception to this was dissolved oxygen, with a large increase at the To2 site during the lower flow October round, which was not matched at To1. Broadly, the pattern of responses to rainfall and prolonged lack of rainfall were similar between the creeks, though Tooloombah Creek displayed a less ‘flashy’ response than the two previous (and smaller) creeks.

Tooloombah Creek recorded the highest salinity (conductivity and total dissolved solids) of the three freshwater lowland streams prior to December, without the peak in TDS seen in Deep and Granite Creeks in December 2011, and dropping to a lower salinity from January to March 2012. Tooloombah Creek represents the largest of the three freshwater catchments included in the monitoring program, with cleared and eroded lands comparable to the Deep Creek catchment. The elevated salinity during dry periods is likely due to groundwater influences during baseflow periods, especially considering the high salinity found in groundwater wells in the region. With the larger catchment size, salinity levels were reduced compared to the Deep and Granite Creeks due likely to enhanced levels of runoff.

Generally, Tooloombah Creek displayed the following characteristics:

- Dissolved oxygen showed two patterns for the two sites, with a peak at To2 in the October – November low flow period (not seen at To1), and a peak at To1 in January (site To2 was inaccessible and may have been similar). Otherwise dissolved oxygen remained generally within the 70 – 100% saturation range;
- Conductivity, pH and chloride rose gradually to December 2011, followed by a large fall to January and smaller continued drops to March. pH varied from a high of 8.4 to a low of 5.9, conductivity 1,407 to 193.7 µS/cm, and chloride from 366 to 21 mg/L;
- Total dissolved solids, alkalinity, magnesium, sodium and anions and cations showed a gradual decrease to December 2011, and afterwards a similar pattern as seen for conductivity, pH and chloride as a result of the rains. Potassium did not show any particular pattern of results, varying only over a relatively narrow range (2 – 4 mg/L);

- Nutrients were relatively low or falling prior to the December rainfall event, with rises noted in Ammonia, TKN, TP, and FRP, and Nitrite at To2, during the December to January wet period;

Again, the disturbed areas and grazing pressure is reflected in the higher nutrient levels found in this creek.

Montrose Creek

Montrose Creek again showed generally similar patterns to the Deep and Granite Creek systems. Generally:

- The rainfall event in December resulted in an increase in dissolved oxygen which was mostly sustained afterwards (during subsequent wet periods), and drops in conductivity, pH, TDS, Alkalinity, chlorine, calcium, magnesium, sodium, and total anions and cations;
- As was found for Deep Creek, a peak in turbidity / suspended solids was observed in December, though this was of a smaller magnitude than for Deep Creek;

Amity Creek

Amity creek was only sampled for *in-situ* parameters on two occasions – September 2011 and January 2012. Generally, it was more similar to Granite and Montrose Creeks on those occasions than the other sites, with conductivity similar to Granite Creek. pH varied between 8.2 (September 2011) and 7.6 (January 2012).

Styx River

The two Styx River monitoring sites (St1 and St2) were divided by water quality into the Ogmore Bridge site (St2) and the St1 site located at the confluence of Tooloombah and Deep Creeks. The St1 site was more heavily influenced by runoff from the two creeks, whereas the St2 site showed a larger influence from saline waters (i.e. the estuarine influence).

Water quality at the St1 site showed the interplay between the freshwater runoff from Deep and Tooloombah Creeks, and the influence from the Styx Estuary (i.e. St2). Conductivity was generally seen to increase over the dry period, to a much greater extent than was seen in either Deep or Tooloombah Creeks, while for the other parameters the results were generally a mix of the three sources (i.e. Deep, Tooloombah and Styx Estuary).

When examining the key physical-chemical parameters for the Deep and Tooloombah Creeks with St1 (pH, conductivity, anions and cations), the St1 site was found to be more similar to Tooloombah Creek than to Deep Creek generally (visually from the data), and more similar to the freshwater creeks overall, which is consistent with the relative sizes of the two catchments (and therefore flows). A multivariate similarity assessment showed similarity of about 71%, compared to the St2 site (with a similarity to all other sites of only 44%).

Generally, the St1 site displayed similar levels and overall patterns to the upstream creeks, with some slight delays evident and also reduced flood peak concentrations (from examination of the Fitzroy Basin Association storm flow monitoring). This may be due in part to mixing and influence with the salt wedge from the estuary, evident in the higher salinity levels at this site (especially at depth during low flow periods). A fairly high peak in bioavailable phosphorous (FRP) was seen in December, though this was not observed in the Deep or Tooloombah creek sites (located futher upstream).

For phys-chem properties:

- Dissolved oxygen varied from around 70 to 95% prior to October, rising to very high levels during October to December, dropping again during the post December rain period;
- Conductivity, TDS and alkalinity reflected the overall influence of the estuary during the low flow period, with a gradual rise (especially at depth for conductivity) to December, followed by a rapid fall with levels matching the upstream creeks during the January to March 2012 period;
- pH remained relatively stable, possibly indicative of the stronger buffering capacity of the more saline waters
- turbidity and suspended solids show the flashy behaviour of the river at this point, strongly influenced by rainfall runoff from the Deep and Tooloombah Creeks.

The St2 site was very similar to the St1 site, except that the saline influence was much more pronounced during the low flow period. In flood / stormflow periods, water quality was very similar between the two sites.

Observations were made of flow direction and tide levels during the monitoring period. On all occasions other than one (September 2011), flow direction was seawards (i.e. outgoing), and the tidal bore was not observed, even though the site was visited on several occasions when the regional tide was predicted to be incoming. Based on the flow observed from the Deep and Tooloombah Creeks on many of the occasions during the low flow period, it is quite possible that outgoing flows prior to December 2011 were the result of tide return, and that in fact incoming tides were missed by the sampling team.

5.2.3 **Comparison of results with Guidelines**

5.2.3.1 Protection of Aquatic Ecosystems

Table 7 below summarises compliance with the guideline levels outlined in Section 3.2.

Other than conductivity, which exceeded the guideline values in all freshwater streams, median statistics for phys-chem parameters largely met the QWQGs. The exceptions were dissolved oxygen in Deep Creek and suspended solids in Deep and Tooloombah Creeks, and the Styx River.

All waterways showed exceedances for ammonia at virtually all times (dry or flood), with organic nitrogen and total nitrogen almost always above the guidelines at Deep and Tooloombah Creeks, total phosphorous at Deep Creek and the St2 Styx River site, and oxidized nitrogen at the St2 Styx River site.

During rainfall periods, exceedances were also encountered for organic nitrogen, total nitrogen, total phosphorous and bioavailable phosphorous (FRP) at all sites other than Granite Creek which did not record any FRP phosphorous. The St2 Styx River site also recorded exceedances for NOx during rainfall.

The toxicants data show a large number of exceedances across the sites, with the most common being for iron (though based on a low reliability trigger value), aluminium, copper, selenium (except at St1) and zinc (except at Tooloombah). Antimony and vanadium exceeded the guideline value at Deep, Montrose and Tooloombah Creeks.

Other exceedances were recorded for Lead (Deep), Chromium (Deep, Tooloombah, Styx at St1), Silver (Deep, Tooloombah) Tin (Montrose, Tooloombah) and Uranium (Tooloombah - 1 occurance only).

The water quality confirms the disturbed nature of the catchment due to catchment disturbance and nutrient inputs, which are consistent with impacts from land clearing, erosion and cattle grazing and the nature of the soils.

5.2.3.2 Livestock and Irrigation

Comparison with the ANZECC Guidelines water quality guidelines for irrigation indicate that all freshwaters (i.e. all sites other than St2) were suitable with the following caveats

- Chloride levels – water in Tooloombah Creek recorded chloride levels unsuitable for sensitive crops, and the Styx River St1 site was unsuitable for sensitive or moderately sensitive crops, all generally at times other than the recorded flood periods. This also means that there may be a risk of cadmium toxicity from using this irrigation water (particularly at St1);
- Sodium levels –the Styx River sites recorded sodium at levels unsuitable for sensitive or moderately sensitive crops with the St2 site suitable at best for tolerant crops;
- Aluminium and iron recorded levels above the recommended Long Term Value (LTV) in irrigation water (from Table 4.2.10 of the ANZECC Guidelines) during wet periods;
- Manganese was variously above the LTV;
- Phosphorous was above the LTV, though this was noted as intended to minimise bio-clogging of irrigation equipment only.

The ANZECC Guidelines for livestock watering indicated TDS levels encountered in the streams were generally in the range regarded by the ANZECC Guidelines as 'no adverse effects on animals expected'. Of the toxicants:

- Aluminium was above the recommended low risk range during wet periods; and
- Selenium was marginally over at the Mo2 site in Montrose Creek in March 2012.

5.2.3.3 Drinking Water

When compared to Table 7.3.1 - *Guidelines for drinking water supply in the vicinity of storage off-takes or in groundwater supplies, before treatment* in the QWQG, the recommended water quality objectives were exceeded for manganese and iron, and during rainfall events turbidity and, to a lesser degree, suspended solids. Dissolved oxygen was below the target in Deep Creek but generally above in the other creeks (including the Styx River St1 site).

Based on the *Australian Drinking Water Guidelines 2011* (NHMRC and NRMMC, 2011), salinity (as total dissolved solids) can be regarded as of good quality in Granite, Montrose and Deep (except during December flows), fair quality in Tooloombah Creek, and poor to unacceptable at the St1 site (and unacceptable at the St2 site).

Several of the toxic metals did breach the ADWG's and would require removal prior to use in potable water supplies. The key elements included iron and manganese (as mentioned above) and aluminium for aesthetic reasons; and antimony and/or arsenic at the other Creek sites, plus lead at Deep Creek. Exceedances were found during the December to March (wet) period only, with the exception of antimony at Montrose and Tooloombah Creeks in November 2011 (10 μg/L).

Table 7. Summary of compliance with WQOs

Creek System	Phys-chem			Turbidity/SS			Nutrients			Metals[6]		
	Param	median	WQO[1]	Param	median	WQO[1]	Param	median	WQO[1]	Param	95th %ile	WQO
Deep Creek	DO	69.75	85 - 110	Turbidity	11.35	50	Ammonia	40	20[1]/900[2]	Al	8713.5	55[5]
	EC	571.8	375[1]/1000[2]	SS	13	10	Nitrate	20	1100[2]	Fe	4173.5	300[4]
	pH	7.6	6.5 - 8				NO_x	20	60	Pb	10	3.4
							Org N	640	420	Se	20	11
							TN	700	500/3400[3]	Vn	20	10[2]/6[4]
							TP	60	50/2000[3]	Zn	16	8
							FRP	<10	20	Cu	3.35	1.4/2[2]
	DO moderately below QWQG except during flow periods Conductivity above QWQG (below DERM except Nov-11 at De1) pH generally good, but elevated during late dry, and low after wet (Jan-11)			Turbidity above QWQG during wet periods			Nutrients showed exceedances for NH_4, Org N, TN, TP generally at all times, but more pronounced during the wet post December period. FRP exceeded the guidelines post December only.			Metals detected above the trigger levels were Al, Sb, Fe, Pb, Se, V, Zn, Cr, Cu and Ag. As, Ba, Bo, Mn, Sr and Ti were also detected, but without any exceedances.		

Table notes:

1 Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2 DERM (2009b) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin
3 FBA Interim guidelines (FBA, 2009)
4 ANZECC Guidelines low reliability value (for marine waters for St2)
5 for pH >6.5.
6 Al - Aluminium, Sb - Antimony, Fe - Iron, Pb - Lead, Se - Selenium, V - Vanadium, Zn - Zinc, Cr - Chromium, Cu - Cooper, Ag - Silver, As - Arsenic, Ba - Barium, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 8. Summary of compliance with WQOs

Creek System	Phys-chem			Turbidity/SS			Nutrients			Metals[6]		
Montrose Creek	Param	median	WQO[1]	Param	median	WQO[1]	Param	median	WQO[1]	Param	80th %ile	WQO
	DO	87.7	85 - 110	Turbidity	4.7	50	Ammonia	50	20[1]/900[2]	Al	6264	55[5]
	EC	532	375[1]/1000[2]	SS	13	10	Nitrate	10	1100[2]	An	10	9[4]
	pH	7.5	6.5 - 8				NO_x	10	60	Fe	2858	300[4]
							Org N	260	420	Se	24	11
							TN	300	500/3400[3]	Th	14	0.03[4]
							TP	70	50/2000[3]	Zn	14	8
							FRP	20	20	Cu	2	1.4/2[2]
										Sn	7	3[4]
										Vn	7	10[2]/6[4]
	Exceedances were seen for dissolved oxygen (too low in the dry, and too high in the wet), conductivity (too high in the dry).			Turbidity and suspended solids peaks were observed during wet periods.			Ammonia was always above the QWQG, with Org N, TN, TP and FRP above during rainfall periods.			Metals detected above the trigger levels were Al, Sb, Fe, Se, Th, Sn, V, Zn and Cu. As, Mn, Sr, and Ti were also detected, but without any exceedances.		

Table notes:

1 Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.

2 DERM (2009b) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin

3 FBA Interim guidelines (FBA, 2009)

4 ANZECC Guidelines low reliability value (for marine waters for St2)

5 for pH >6.5

6 Al - Aluminium, Sb - Antimony, Fe - Iron, Pb - Lead, Se - Selenium, Th - Thorium, Sn - Tin, V - Vanadium, Zn - Zinc, Cu - Cooper,As - Arsenic, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 9. Summary of compliance with WQOs

Creek System	Phys-chem			Turbidity/SS			Nutrients			Metals[6]		
Granite Creek	Param	median	WQO[1]	Param	median	WQO[1]	Param	median	WQO[1]	Param	80th %ile	WQO
	DO	91.5	85 - 110	Turbidity	6.0	50	Ammonia	50.0	20[1]/900[2]	Al	5177.0	55[5]
	EC	398.0	375[1]/1000[2]	SS	8.0	10	Nitrate	20.0	1100[2]	Fe	2056.0	300[4]
	pH	7.0	6.5 - 8				NO_x	20.0	60	Se	17.0	11
							Org N	202.5	420	Cu	2.0	1.4/2[2]
							TN	300.0	500/3400[3]	Zn	10.6	8
							TP	40.0	50/2000[3]			
							FRP	<10	20			
	Dissolved oxygen was mostly below the QWQG, except during rains when it was above. EC was generally above the WQO, though less so during rains pH was generally below the QWQG			Turbidity and suspended solids were above the QWQG during rainfall peaks			Exceedances were observed for Ammonia at virtually all times, and for TN, Org N, and TP during the December flow period (and March for TP).			Metals detected above the trigger levels were Al, Fe, Se, Cu and Zn. As, Mn, Sr and Ti were also detected, but without any exceedances.		

Table notes:

1 Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.

2 DERM (2009b) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin

3 FBA Interim guidelines (FBA, 2009)

4 ANZECC Guidelines low reliability value (for marine waters for St2)

5 for pH >6.5

6 Al - Aluminium, Fe - Iron, Se - Selenium, Cu - Cooper, Zn - Zinc, As - Arsenic, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 10. Summary of compliance with WQOs

Creek System	Phys-chem			Turbidity/SS			Nutrients			Metals[6]		
Tooloombah Creek	Param	median	WQO[1]	Param	median	WQO[1]	Param	median	WQO[1]	Param	80^{th} %ile	WQO
	DO	93.4	85 - 110	Turbidity	10.55	50	Ammonia	40	20[1]/900[2]	Al	5180	55[5]
	EC	1041.5	375[1]/1000[2]	SS	10	10	Nitrate	20	1100[2]	Fe	2400	300[4]
	pH	7.8	6.5 - 8				NO_x	20	60	Se	15	11
							Org N	460	420	Sn	8	3[4]
							TN	600	500/3400[3]	Vn	7.5	10[2]/6[4]
							TP	40	50/2000[3]	Cr	1.5	1
							FRP	<10	20	Cu	2	1.4/2[2]
										Ag	0.75	0.05/1[2]
										Ur	1	1[2]
	Dissolved oxygen showed exceedances above and below the QWQG, with EC generally above. pH was slightly above during Oct/Nov-11 and very low (5.9) in Jan-12.			Turbidity was above the QWQG during the Jan-12 and Mar-12 rainfall peaks. SS remained above from December onwards (wet period).			Ammonia, Org N, and TN were always above the QWQG, with TP and FRP above during rainfall periods.			Metals detected above the trigger levels were Al, Sb, Fe, Se, Sn, V, Cr, Cu, Ag and U. As, Ba, Mn, Sr and Ti were also detected, but without any exceedances.		

Table notes:

1 Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2 DERM (2009b) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin
3 FBA Interim guidelines (FBA, 2009)
4 ANZECC Guidelines low reliability value (for marine waters for St2)
5 for pH >6.5
6 Al - Aluminium, Sb - Antimony, Fe - Iron, Se - Selenium, Sn - Tin, V - Vanadium, Cr - Chromium, Cu - Cooper, Ag - Silver, U - Uranium, As - Arsenic, Ba - Barium, Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 11. Summary of compliance with WQOs

Creek System	Phys-chem			Turbidity/SS			Nutrients			Metals[6]		
Styx River (St1)	Param	median	WQO[1]	Param	median	WQO[1]	Param	median	WQO[1]	Param	80^{th} %ile	WQO
	DO	90.6	85 - 110	Turbidity	7.6	50	Ammonia	30	20[1]/900[2]	Al	7070	55[5]
	EC	1942	375[1]/1000[2]	SS	13	10	Nitrate	25	1100[2]	Fe	3261.25	300[4]
	pH	7.6	6.5 - 8				NO_x	25	60	Zn	9.5	8
							Org N	450	420	Cu	5	1.4/2[2]
							TN	500	500/3400[3]	Vn	16.25	10[2]/6[4]
							TP	120	50/2000[3]	Cr	1.625	1
							FRP	<10	20			
	Dissolved oxygen was above the QWQG from October onwards. Conductivity remained above at all times. pH was very high in June but within the QWQG on other occasions.			Turbidity was elevated from December onwards, and suspended solids from November onwards.			Ammonia was above the QWQG on all occasions, with Org N, TN, TP and FRP above during rainfall periods.			Metals detected above the trigger levels were Al, Fe, V, Zn, Cr, Cu and Zn. Ba, Bo, Mn, Sr and Ti were also detected, but without any exceedances.		

Table notes:

1 Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.
2 DERM (2009b) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin
3 FBA Interim guidelines (FBA, 2009)
4 ANZECC Guidelines low reliability value (for marine waters for St2)
5 for pH >6.5
6 Al - Aluminium, Fe - Iron, V - Vanadium, Cr - Chromium, Cu - Cooper, Zn - Zinc, Ba - Barium, Bo - Mn - Manganese, Sr - Strontium, Ti - Titanium.

Table 12. Summary of compliance with WQOs

Creek System	Phys-chem			Turbidity/SS			Nutrients			Metals[6]		
Styx River (St2)	Param	median	WQO[1]	Param	median	WQO[1]	Param	median	WQO[1]	Param	80^{th} %ile	WQO
	DO	75.28	70 - 100	Turbidity	14.3	25	Ammonia	50	30	Al	7448	0.5[4]
	EC	1417.5	-	SS	27	25	Nitrate	20	700[4]	Mn	392	80[4]
	pH	7.715	7 - 8.4				NO_x	20	15	Se	22	3[4]
							Org N	480	400	Zn	18	15
							TN	400	450	Cu	3	1.3
							TP	190	40			
							FRP	<10	10			
	Dissolved oxygen was variable, being mostly above the QWQG, though some (Sep-11, Nov-11) below (dry periods). Two low pH readings were found, during Sep-11 and Mar-12.			Turbidity and suspended solids exceeded the QWQG during rainfall events.			Ammonia, NO_x and TP were generally above the guidelines (though less so for TP during the dry), with Org N, TN and FRP above during rainfall periods (Dec-11 onwards).			Metals detected above the trigger levels were Al, Mn, Se, Zn and Cu. Sb, As, Ba, Bo, Fe, Sr, Ti, V, Cr and U were also detected, but without any exceedances.		

Table notes:

1 Water Quality Objectives from QWQG unless otherwise noted. Guideline values are for lowland streams in Central Queensland for all sites other than St2, which used upper estuary values for central Queensland.

2 DERM (2009b) – Final Model Water Conditions for Coal Mines in the Fitzroy Basin

3 FBA Interim guidelines (FBA, 2009)

4 ANZECC Guidelines low reliability value (for marine waters for St2)

5 for pH >6.5

6 Al - Aluminium, Mn - Manganese, Se - Selenium, Zn - Zinc, Cu - Cooper, Sb - Antimony, As - Arsenic, Ba - Barium, Bo - , Fe- Iron, Sr - Strontium, Ti - Titanium, V - Vanadium, Cr - Chromium, U - Uranium

6 Preliminary Site Water Management System

6.1 Overview

A preliminary water balance model, based on the present understanding of the site hydrology and operation, was devised as described in the following sections. Further detailed work will be required to determine final storage volumes, storage/release and internal cycling dynamics and strategies.

6.2 Climate Data

Two rainfall stations, Tooloombah (033211) and Strathmuir (033189), operated by the Bureau Of Meteorology (BOM) are located within the study location's catchment area. Although the Tooloombah station has been operating for a longer period of time (1890 - present) compared to the Strathmuir station (1941 - present), rainfall data from the Strathmuir station was utilised in the water balance modelling due to the completeness of the data. The BOM states that the daily rainfall data for Strathmuir is 90% complete, whereas the same data is only 34% complete for the Tooloombah station. A summary of the rainfall statistics for the Strathmuir rainfall station are presented in Table 13 below.

Table 13. Strathmuir Rainfall Station Statistics Summary

Statistic	Annual Rainfall (mm)
Mean	743.1
Minimum	304.9
5th Percentile	384.1
10th Percentile	476.7
Median	682.6
90th Percentile	1124.1
95th Percentile	1262.8
Maximum	1344.4

Evaporation data from the Rockhampton Aero (039083) rainfall station, once again operated by the BOM, was utilised in the water balance modelling. The mean daily evaporation (mm) for each month, calculated from a stated record period of 59 years (1959-2012), was utilised and is presented in Table 14 below.

Table 14. Rockhampton Aero Rainfall Station Mean Daily Evaporation

Month	Mean Daily Evaporation (mm)
January	7.3
February	6.5
March	6.2
April	5.3
May	4.1

Month	Mean Daily Evaporation (mm)
June	3.5
July	3.6
August	4.4
September	5.7
October	6.8
November	7.6
December	7.6

6.3 Surface Runoff

The depth of surface water runoff utilised in the water balance modelling has been estimated utilising the Australian Water Balance Model (AWBM). As there are no Stream gauging stations within the Styx River Catchment, the AWBM was calibrated using the methods described in the following two papers:

- *Calibrations of the AWBM for use on ungauged catchments* (Boughton and Chiew, 2003); and
- *Estimating runoff in ungauged catchments from rainfall, PET and the AWBM model* (Boughton and Chiew, 2006).

The following sections describe the steps taken as part of the rainfall-runoff modelling stage of the water balance modelling.

6.3.1 Australian Water Balance Model

The AWBM rainfall-runoff model has been used extensively throughout Australia since its development in the early 1990's. It utilises three partial surface storage areas to determine runoff within a catchment during a rainfall event. At each time step, either daily or hourly, the water balance of each storage area is calculated independently of the others, with runoff from the storage area occurring when the calculated value of moisture within the storage exceeds its storage capacity. This runoff can then be routed to simulate the delay associated with runoff within a medium to large catchment. Part of the runoff can also be utilised to recharge the base flow store. A schematic layout of the AWBM is provided in **Figure 6** below.

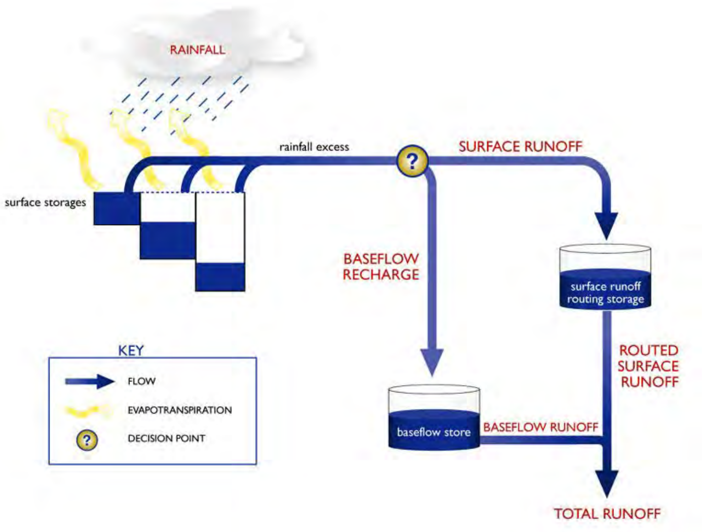

Figure 6. AWBM Model - Schematic Layout (Source: CRC for Catchment Hydrology, 2004)

The depth of surface water runoff produced by the AWBM is influenced by the following parameters:

- C1 to C3 - Surface storage capacities;
- A1 to A3 - Partial areas represented by surface storages;
- BFI - Baseflow index;
- K_{base} - Daily baseflow recession constant;
- BS - Current volume in baseflow store;
- KS - Daily surface flow recession constant; and
- SS - Current volume in surface routing store.

6.3.2 Calibration of AWBM

Although the AWBM allows for the surface water runoff to be calibrated against recorded stream flow data, this was not possible for this project as there are no currently, or previously, operating stream gauging stations within the Styx River catchment. Therefore manual calibration of the surface water runoff has been undertaken.

Boughton & Chiew (2006) developed a set of regression equations to estimate average annual runoff from a catchment through a study of 213 unimpaired gauged catchments from across Australia. Equations for each Drainage Division within Australia are presented with the equation for Drainage Division 1, where the Styx River catchment is located, being:

$$Q = 0.544P - 350$$

Where Q = average annual runoff (mm); P = average annual rainfall (mm).

Based on an average annual rainfall of 743.1mm, from the Strathmuir rainfall station, the estimated average annual runoff for the Styx River Catchment is 54mm/yr. This figure was then set as a target for calibrating the surface water runoff produced by the AWBM.

Boughton & Chiew (2003 and 2006) describe methods for calibrating the AWBM where no stream flow data is available. A range of values of the baseflow parameters BFI and K_{base}, determined from calibrations of the AWBM to gauged catchments in each drainage division are presented for each drainage division. The values of the partial areas (A_1 to A_3), and a relationship between the capacity of the three storage areas (C_1 to C_3) and an average surface storage capacity (Ave) are also provided. Therefore utilising this relationship and the recommended values for the parameters BFI and K_{base}, surface runoff produced by the AWBM can be altered by changing the average storage capacity. The values of each parameter utilised in this study are presented in Table ??.?? below:

Table 15. AWBM Calibration Parameters

Parameter	Value
A1	0.134
A2	0.433
A3	0.433
C1	0.075 x Ave
C2	0.762 x Ave
C3	1.524 x Ave
BFI	0.170
Kbase	0.950

Utilising the above values for the calibration parameters, the average surface storage capacity (Ave) was adjusted until the average annual runoff produced by the AWBM was equal to the value estimated by the regression equation described earlier. Through this process it was found that a value of 340mm for the Ave parameter resulted in an average annual runoff of 54.68mm/yr, which compares well to the 54mm/yr estimated by the regression equation described above.

6.4 Water Management System

In accordance with the Water Management System described in Section 2.2, a schematic of the Water Management System has been developed for use in the water balance modelling. This details graphically the various features of the Water Management System, how they interact with each other and the volumes of water expected to be generated/consumed. At this stage of the project only industry standard and annual estimates have been used. More detailed daily water balance modelling will be required to determine the final size of flows and therefore of storage, treatment and drainage infrastructure.

The main components of the Water Management System are:

- Water sources;
- Storage areas;
- Water consumption; and
- Release/disposal areas.

The Water Management System schematic is presented in **Figure 7** below.

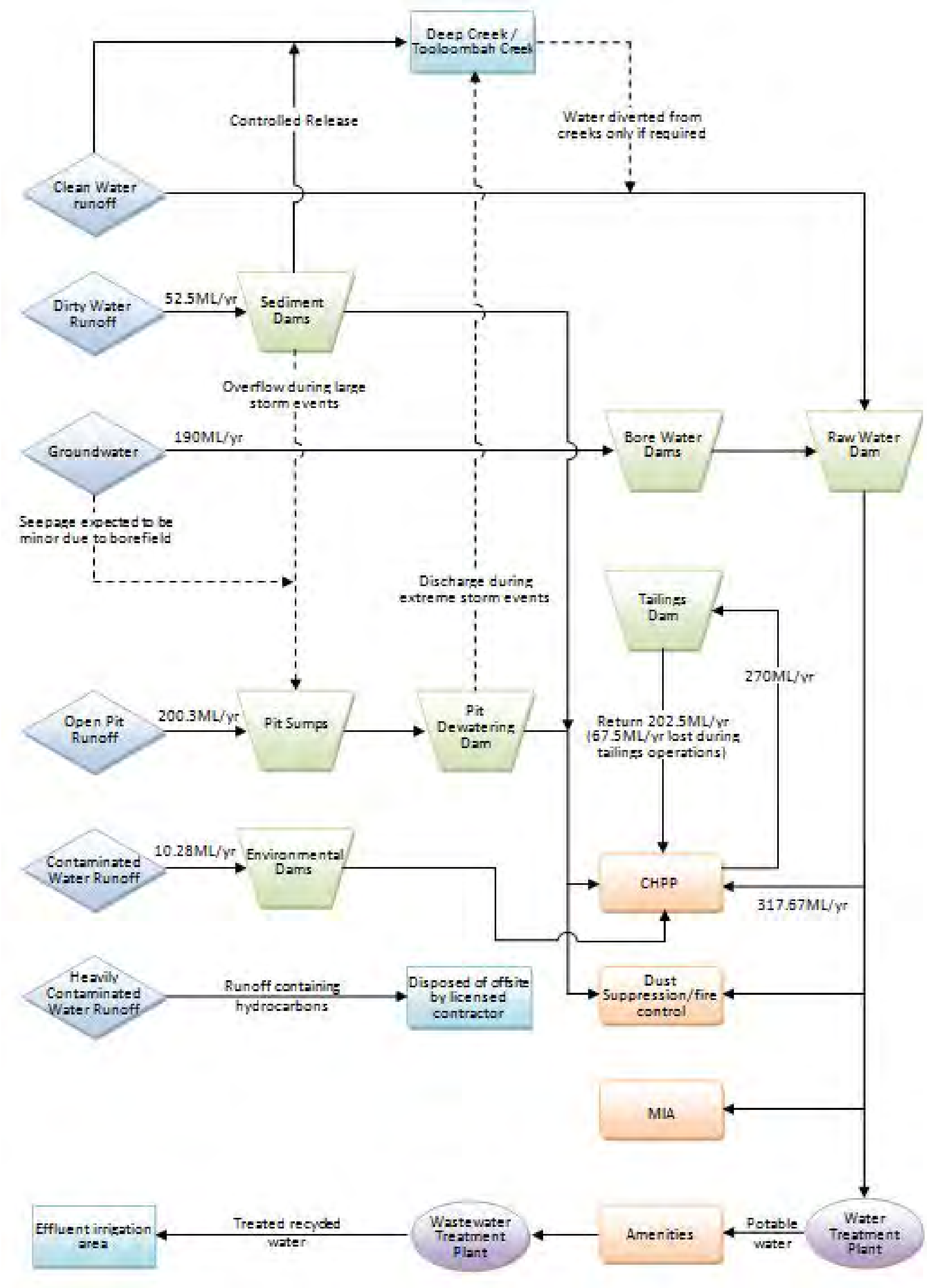

Figure 7. Water Management System Schematic

6.4.1 Water Sources

It is proposed to source water required for mining operations either from within the site in the form of runoff and bore water, or from the adjacent Tooloombah and Deep Creeks. As described in Section 2.2 water will be sourced from the following areas:

- Type 1: Clean water runoff from undisturbed catchment areas – this water will be diverted around the disturbed area or, in some circumstances, a portion may be collected to augment the water supply for the Project;
- Type 2: Raw water sourced to supply amenities, process water for CHPP and related operations – currently Tooloombah and Deep Creeks, and the local alluvial groundwater aquifers are being assessed for the sourcing of makeup water;
- Type 3: Dirty runoff water from areas subject to disturbance and management of topsoil, overburden, access roads etc. contaminated by sediment only - this water will be directed through sediment dam(s) prior to being reused on-site or released under controlled conditions to local waterways;
- Type 5: Contaminated water from the mine industrial area (MIA), ROM pads, in-pit water and dewatered groundwater, tailings storage areas and tailings dams, and other areas subject to contamination from mining operations and coal dust or similar contaminants - this water will be contained on-site in environmental dams for reuse; and
- Type 6: Heavily contaminated waters and trade wastes from workshop areas, plant and infrastructure maintenance works, etc. containing contaminants such as oil and grease – the overall objective for management of these areas is to avoid any runoff being generated by undertaking these works in roofed and bunded areas, and using spill cleanup procedures to avoid runoff of these contaminants into the site water management system. Any runoff containing hydrocarbons will be contained on site until either treated and reused or removed from the site by a licensed contractor;

6.4.2 Storage Areas

Various dams will be utilised across the site to store water for use/reuse depending on the source and quality of the water. This will ensure that contaminated or sediment laden runoff will not find its way into the local waterways. The following dams were considered as part of the water balance modelling:

- A raw water dam to supply water to the CHPP, dust suppression/fire control and to a water treatment plant to produce potable water. Water will be supplied to the raw water dam from the bore water dams, sediment dams, clean water runoff and if required water from the local waterways;
- Bore water dams (if necessary) for storage of ground water pumped from the borefield. This water will be supplied to the raw water dam;
- Sediment dams to contain and treat dirty water runoff. This water will be supplied to the pit dewatering dam;
- Pit sumps and pit dewatering dam will be utilised to collect and store runoff from the open pit areas. This water will be utilised in the CHPP and for dust suppression/fire control;
- Environmental dams will collect contaminated runoff from the MIA and ROM pads. This water will be utilised in the CHPP; and

- A tailings dam will collect and store water utilised in the tailings operations. This water will be returned to the CHPP for re-use.

6.4.3 **Water Consumption**

Whether it be for dust suppression, in the CHPP to process the ROM coal or potable water for the amenities, water will be consumed in all areas of the site during operation. The following water consumption nodes have been considered as part of the water balance modelling:

- Water will be required for the CHPP to process the ROM coal into product coal;
- It has been assumed that the tailings operations will utilise a wet slurry method of disposal from the CHPP. This water will be returned to the CHPP, however approximately 25% of it will be lost during the process;
- A water treatment plant will be required for potable water applications (amenities, administration area etc.);
- The MIA will require water for use in the workshop, truck washes etc.; and
- Dust suppression along haul roads, spoil sites, disturbed areas etc. This demand is assumed to be reduced on days when total rainfall exceeds 5mm and not required when total rainfall exceeds 10mm in a single day. Water will also be required for fire control of ROM and product coal stockpiles.

6.4.4 **Release/Disposal Areas**

Although it is proposed to reuse as much water within the site as possible, releases or disposal of water may be unavoidable. The following release or disposal scenarios are proposed:

- A portion of the clean water runoff from upstream catchments will be diverted around the site and into local waterways. As this water will be from undisturbed areas and will simply be diverted, no treatment before it is reaches the local waterways is proposed;
- When there is a surplus of water within the sediment dams and water quality meets the relevant guidelines/criteria for release from a sediment dam, water will be released into local waterways under controlled conditions. This will be carried out to minimise the risk of an uncontrolled release during extended periods of rainfall;
- Heavily contaminated runoff from the MIA containing hydrocarbons will be disposed of offsite by a licensed contractor; and
- Wastewater derived from on-site amenities will be treated and discharged in accordance with an on-site sewerage management strategy, likely to include land application of treated recycled water.

7 Interim Environmental Values

No information regarding Environmental Values (EVs) has been identified for the catchment, though DERM notes that they are timetabled under the Environmental Protection (Water) Policy 2009 (EPP Water) for December 2013.

However, the Aquatic Ecosystems Protection value will apply. From informal discussions with landholders, and experience with similar systems, the following environmental values are considered likely to be relevant for the waterways included in this study are shown in Table 16 below.

The key waterways of relevance to the site are the Deep and Tooloombah Creeks, the Styx River freshwater site (St1) and downstream estuarine areas.

Table 16. Interim Environmental Values

Water	Aquatic Ecosystems	Seagrass	Irrigation	Farm Supply / use	Stock Water	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Drinking Water	Industrial Use	Cultural and Spiritual Values
Deep Creek	SMD		✓	✓	✓	✓		✓	✓	✓		✓
Tooloombah Creek	HEV		✓	✓	✓	✓		✓	✓	✓		✓
Upper Styx River	SMD		✓	✓	✓	✓		✓	✓			✓
Styx River Estuary	✓					✓		✓	✓			✓
Coastal Waters	✓	?				✓		✓	✓			✓

Table notes:

HEV - High ecological/conservation value

SMD - Slightly–moderately disturbed

7.1 Explanatory notes

The interim environmental values are based on the assessments carried out during this study, and the related aquatic ecology surveys by ALS Water Resources Group. The following notes related to the chosen EVs or level of EV in Table 13 above:

- Aquatic ecosystems – Tooloombah Creek was identified as potentially a HEV waterway by ALS and was generally of good quality as found by this study, whereas Deep Creek showed the effects of land clearing processes, which have carried onto the Styx River as shown by the highly turbid peaks during flood events. As such, the designations have been given as shown;

- It is not known if seagrass are a potential value of coastal waters as affected by this project. Current marine ecology studies are underway to determine possible impacts;
- Irrigation, Farm supply/use and Stock water uses are not known to widely occur, though it appears the creeks can potentially sustain this type of use, and therefore the value has been chosen to be upheld (in the interim), particularly since primary industries are situated along these creeks downstream of the mine area;
- No primary recreation activities have been observed in the area, and the threat of crocodiles is expected to negate such activities;
- It is not known if Deep or Tooloombah creeks are used for drinking water supplies, though it is understood that dam water or cartage supplies are generally used for homesteads and Ogmore respectively rather than offtakes from the creeks. However, it is possible that this may be a value for some users in close proximity to the mine and has been accepted in the interim; and
- No industrial uses are known to occur in the region.

8 Interim Water Quality Objectives

8.1 Interim Receiving Water Quality Objectives

Table 17 below outlines the proposed interim water quality objectives for creeks affected by the proposed mining operation. Importantly, interim WQOs are based on the suggested criteria in the relevant guidelines (refer Section 3.2) unless they are considered inappropriate to the site. In this case, interim WQOs are set based on the available site specific data following the QWQG and ANZECC Guidelines where appropriate to the class of constituent considered.

Currently, only 3-4 monitoring points are available for any one flow type (flood, baseflow, nil flow). As such, the following must be amended following receipt of further data prior to the issue of the EA for the project as statistics are based on the entire dataset to date (8 or more monitoring points across flow and non-flow events).

Due to a lack of sufficient data, all WQOs are considered to relate to baseflow conditions and considered sufficient to be used as outlined in the QWQG and ANZECC guidelines – i.e. comparison of the median result against the WQOs. During rainfall periods, or periods when flow ceases, exceedances of the WQOs are expected for a range of parameters.

Table 17. Interim water quality objectives – phys-chem and nutrients

Parameter[1]	Units	Deep Creek	Tooloombah Creek	Styx River (St1)
Ammonia N	ug/L	136	182	64
NOx	ug/L	53	60	60
Org N	ug/L	1,059	540	947
TN	ug/L	1,240	960	1,800
FRP	ug/L	20	20	20
TP	ug/L	220	50	600
DO	% sat[3]	80 - 110	85 - 110	85 - 110
Turbidity	ntu	50	50	600
TSS	mg/L	142	17.8	392
pH	units	6.5 - 8	6.5 - 8	6.5 - 8
Sulfate	mg/L	500/250	40	-
Flouride	mg/L	-	0.2	-
Conductivity	uS/cm	775	1,220	766
TDS	mg/L	600	-	
Metals	To be derived for metals following further baseline monitoring data collection for event and non-event rounds.			

Table notes:

☐ QWQG values for lowland streams, central Queensland region

☐ based on 80th (or for pH and DO, 20th and 80th) percentile statistics from on-site measurements. n ≤ 8

☐ based on 80th (or for pH and DO, 20th and 80th) percentile statistics from on-site measurements. n > 30 (individual, non-correlated events – values from correlated events averaged and included in percentile estimate as single value)

☐ Drinking water extraction guidelines (QWQG) for good quality water and Australian Drinking Water Guidelines.

1 NOx – Nitrate + Nitrite; Org N – Organic Nitrogen; TN – Total nitrogen; FRP – Filterable Reactive Phosphorous; TP – Total Phosphorous; DO - Dissolved Oxygen; TSS – Total Suspended Solids

2 % sat – percent saturation.

8.2 Interim Release Quality Objectives

8.3 Ephemerality

As stated in the QWQG, the effect of ephemerality on WQOs or trigger values may differ depending on the type of constituent.

For toxicants, the QWQG state it is appropriate to apply normal guideline values, as the effects on the biota under stagnant conditions will be similar to those during flowing conditions. As such, WQOs for toxicants for receiving waters will be derived from the existing guidelines and, where appropriate, from the statistical characteristics of background monitoring datasets once sufficient data has been obtained.

The QWQG note that application of normal guidelines for phys-chem parameters such as pH and dissolved oxygen and nutrients to small waterholes in nonflow conditions is inappropriate. This is relevant for all waterways, but particularly so for Deep Creek. The interim WQOs shown in **Table 17** will need to be updated once sufficient data is available to apply to flow and potentially non-flow periods. WQOs for pH should relate to the statistical distribution of background and/or reference streams, but with reference to lower desirable levels for pH in these types of streams.

9 References

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Appendix A

Water Quality Data Results

Table A1. Water quality data – physical-chemical characteristics, Deep Creek

Site	Date	Flow type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb. Alk	SO_4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	µS/cm		NTU	°C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
De1	01-Jun-11	Baseflow	80.4	461	6.92	13.1	15.71	-	536	6	89	29	116	<0.1	20	16	72	3	5.65	5.52
De2	02-Jun-11	Baseflow	83.4	476	7.06	12.9	16.68	-	562	6	88	28	119	0.1	20	16	73	3	5.7	5.57
De3	03-Jun-11	Baseflow	85.8	447	7.21	17.2	14.79	-	508	6	100	24	118	0.1	17	16	82	3	5.83	5.81
De3	05-Jun-11	Baseflow	85.8	447	7.21	17.2	14.79	-	508	6	100	24	118	0.1	17	16	82	3	5.83	5.81
De1	29-Sep-11	No flow	58.4	849	8	7.6	20.7	185	-	-	-	-	-	-	-	-	-	-	-	-
De2	29-Sep-11	No flow	34.7	795	8.1	7.5	20.6	194	593	13	102	42	171	0.1	28	25	92	4	7.74	7.56
De3	29-Sep-11	No flow	30	754	7.9	9.8	21.5	242	445	11	173	14	144	0.1	26	22	100	3	7.81	7.53
De3	25-Oct-11	No flow	78.3	619	8.4	44	25.2	171	341	20	121	6	112	0.3	17	16	80	3	5.7	5.72
De1	26-Oct-11	No flow	73.5	918	7.1	6.5	22	135	-	-	-	-	-	-	-	-	-	-	-	-
De2	26-Oct-11	No flow	26.6	767	7.7	9.2	23.1	190	493	13	100	27	184	0.1	29	25	90	6	7.75	7.57
De1	21-Nov-11	No flow	63.6	1254	8	7.6	29.2	99	-	-	-	-	-	-	-	-	-	-	-	-
De2	21-Nov-11	No flow	66	925	8.1	6	26.4	141	545	9	132	16	218	-	30	30	108	6	9.12	8.82
De3	21-Nov-11	No flow	100.6	727	8.3	27.8	26.6	131	465	25	181	4	160	-	25	22	111	4	8.21	7.99
De1	13-Dec-11	No flow	34.4	355	8.2	too turbid	29.5	215	-	-	-	-	-	-	-	-	-	-	-	-
De2	13-Dec-11	No flow	57.1	397	8	959	28.3	125	10600	668	55	26	78	-	<1	<1	89	<1	3.84	3.87
De3	13-Dec-11	No flow	58.8	523.6	7.5	too turbid	27.7	134	3020	472	75	4	84	0.1	5	8	70	2	3.95	4
De1	31-Jan-12	Storm / baseflow	120.3	262	4.96	180.5	26.4	214	302	98	44	13	40	<0.1	9	7	29	4	2.28	2.39
De2	31-Jan-12	Storm / baseflow	156.6	465	5.53	166.5	29.4	222	307	99	44	14	39	<0.1	9	7	29	4	2.27	2.39
De1	21-Feb-12	Storm flow	90.1	0.07	7.2	5	29.1	160	388	<5	114	34	152	0.1	27	21	90	6	7.27	7.14
De2	21-Feb-12	Storm flow	81.3	683	7.3	6.8	28.3	144	351	5	92	31	139	0.1	24	19	77	6	6.4	6.26
De2	20-Mar-12	Storm flow	95.3	268	7.5	179.5	28.5	134	267	170	40	<1	44	<0.1	8	6	28	3	2.04	2.19

Table A2. Water quality data – nutrients and biological characteristics, Deep Creek

Site	Date	Flow type	Ammonia	Nitrite	Nitrate	NO_x	TKN	TN	TP	FRP	E.coli
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
De1	01-Jun-11	Baseflow	0.03	<0.01	0.03	0.03	0.7	0.7	0.04	<0.01	~90
De2	02-Jun-11	Baseflow	0.03	<0.01	0.03	0.03	0.4	0.4	<0.01	<0.01	~30
De3	03-Jun-11	Baseflow	0.02	<0.01	0.12	0.12	0.5	0.6	0.1	-	-
De3	05-Jun-11	Baseflow	0.02	<0.01	0.12	0.12	0.5	0.6	0.1	-	-
De2	29-Sep-11	No flow	0.03	<0.01	0.02	0.02	0.4	0.4	0.04	0.02	-
De3	29-Sep-11	No flow	0.02	<0.01	0.02	0.02	0.4	0.4	0.04	<0.01	-
De3	25-Oct-11	No flow	0.01	<0.01	0.02	0.02	0.4	0.4	0.01	<0.01	-
De2	26-Oct-11	No flow	0.03	<0.01	0.02	0.02	0.6	0.6	0.04	<0.01	-
De2	21-Nov-11	No flow	0.04	<0.01	0.01	0.01	1	1	0.08	<0.01	-
De3	21-Nov-11	No flow	0.01	<0.01	<0.01	<0.01	0.7	0.7	0.02	<0.01	-
De2	13-Dec-11	No flow	0.12	0.03	0.16	0.19	6.2	6.4	2.2	<0.01	-
De3	13-Dec-11	No flow	0.14	<0.01	<0.01	<0.01	2.8	2.8	0.58	<0.01	-
De1	31-Jan-12	Storm / baseflow	0.06	<0.01	0.01	0.01	1.2	1.2	0.26	0.11	-
De2	31-Jan-12	Storm / baseflow	0.31	<0.01	0.01	0.01	1.6	1.6	0.26	0.11	-
De1	21-Feb-12	Storm flow	0.07	<0.01	<0.01	<0.01	0.5	0.5	0.03	0.02	-
De2	21-Feb-12	Storm flow	0.08	<0.01	<0.01	<0.01	0.4	0.4	0.04	0.02	-
De2	20-Mar-12	Storm flow	0.14	<0.01	0.02	0.02	1	1	0.16	0.07	-

Table A3. Water quality data – dissolved metals, Deep Creek

Site	Date	Flow type	Al	An	As	Ba	Bo	Cr	Cu	Fe	Pb	Mn	Se	Sr	Ti	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
De1	01-Jun-11	Baseflow	<0.10	-	<0.01	<0.1	-	<0.001	0.002	<0.05	<0.01	0.08	<0.01	-	-	<0.01	0.029
De2	02-Jun-11	Baseflow	<0.10	-	<0.01	<0.1	-	<0.001	<0.001	<0.05	<0.01	0.04	<0.01	-	-	<0.01	0.006
De3	03-Jun-11	Baseflow	<0.10	-	<0.01	<0.1	-	<0.001	<0.001	<0.05	<0.01	0.04	<0.01	-	-	<0.01	<0.005
De3	05-Jun-11	Baseflow	<0.10	-	<0.01	<0.1	-	<0.001	<0.001	<0.05	<0.01	0.04	<0.01	-	-	<0.01	<0.005
De2	29-Sep-11	No flow	<0.10	<0.01	<0.01	<0.1	<0.1	<0.001	0.001	0.06	<0.01	0.89	<0.01	0.4	<0.01	<0.01	0.03
De3	29-Sep-11	No flow	<0.10	<0.01	0.01	0.1	<0.1	<0.001	<0.001	0.09	<0.01	0.82	<0.01	0.4	<0.01	<0.01	<0.005
De3	25-Oct-11	No flow	<0.10	<0.01	<0.01	<0.1	<0.1	<0.001	<0.001	<0.05	<0.01	0.08	<0.01	<0.1	<0.01	<0.01	<0.005
De2	26-Oct-11	No flow	<0.10	<0.01	<0.01	<0.1	<0.1	<0.001	<0.001	<0.05	<0.01	1.28	<0.01	0.4	<0.01	<0.01	<0.005
De2	21-Nov-11	No flow	<0.10	<0.01	<0.01	0.1	<0.1	<0.001	<0.001	0.14	<0.01	0.43	<0.01	0.5	<0.01	<0.01	<0.005
De3	21-Nov-11	No flow	<0.10	<0.01	<0.01	<0.1	0.1	<0.001	<0.001	<0.05	<0.01	0.34	<0.01	0.4	<0.01	<0.01	<0.005
De3	13-Dec-11	No flow	<0.10	<0.10	<0.10	<0.1	<0.1	<0.001	0.004	<0.10	<0.10	0.2	<0.10	<1.0	<0.10	<0.10	0.009
De1	31-Jan-12	Storm / baseflow	8.72	<0.01	<0.01	<0.1	<0.1	<0.001	0.003	4.17	<0.01	0.04	<0.01	0.1	0.2	0.02	<0.005
De2	31-Jan-12	Storm / baseflow	8.71	<0.01	<0.01	<0.1	<0.1	<0.001	0.003	4.18	<0.01	0.04	<0.01	0.1	0.2	0.02	<0.005
De1	21-Feb-12	Storm flow	<0.1	<0.01	<0.01	<0.1	0.1	<0.001	0.001	<0.05	0.01	0.06	0.02	0.4	<0.01	<0.01	<0.005
De2	21-Feb-12	Storm flow	<0.10	<0.01	<0.01	<0.1	<0.1	<0.001	0.001	<0.05	0.01	<0.01	0.02	0.4	<0.01	<0.01	<0.005
De2	20-Mar-12	Storm flow	1.96	0.01	<0.01	<0.1	<0.1	0.002	0.003	1.62	<0.01	0.03	<0.01	0.1	0.07	<0.01	<0.005

Table A4. Water quality data – physical-chemical characteristics, Montrose Creek

Site	Date	Flow type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb. Alk	SO4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	µS/cm		NTU	0C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
Mo1	28-Sep-11	Baseflow	74.1	719	6.9	1.5	21.9	147	475	6	157	19	140	0.2	42	28	64	1	7.48	7.21
Mo2	28-Sep-11	Baseflow	87.7	779	8	1.8	21.9	253	584	5	157	26	153	0.1	42	30	76	2	7.99	7.92
Mo1	25-Oct-11	Baseflow	83.4	737	7.7	3.3	24.4	166	414	<5	133	12	145	0.2	39	27	64	2	7	7
Mo2	25-Oct-11	Baseflow	58.3	742	8.5	4.7	23.8	200	406	<5	131	14	142	0.2	36	26	65	2	6.91	6.81
Mo1	22-Nov-11	Baseflow	66.1	761	7.8	2.7	24.7	202	411	6	154	8	162	-	41	29	71	1	7.81	7.55
Mo2	22-Nov-11	Baseflow	60.3	769	7.9	3.6	25.9	194	404	<5	160	10	159	-	37	30	76	2	7.89	7.67
Mo1	13-Dec-11	Baseflow	85.6	440	6.8	282	27.5	207	274	199	56	2	80	0.1	13	11	40	3	3.42	3.37
Mo2	13-Dec-11	Baseflow	130.9	444	7.5	142.9	31.7	176	-	-	-	-	-	-	-	-	-	-	-	-
Mo1	31-Jan-12	Storm / baseflow	123.1	225.7	6.99	46.2	26.7	143	239	15	59	6	28	<0.1	10	7	22	2	2.09	2.08
Mo2	31-Jan-12	Storm / baseflow	112	181	7.21	79.2	26.7	165	228	30	48	4	23	0.1	7	6	18	2	1.69	1.68
Mo1	21-Feb-12	Baseflow	114.4	532	7.7	3	27.7	163	278	<5	136	8	84	0.2	28	19	51	1	5.25	5.2
Mo2	21-Feb-12	Baseflow	-	-	-	-	-	-	274	<5	136	8	82	0.2	27	19	51	2	5.2	5.18
Mo1	20-Mar-12	Storm flow	100.6	131	6.4	67.7	28.8	134	179	11	45	<1	19	<0.1	7	5	18	1	1.44	1.57
Mo2	20-Mar-12	Storm flow	126.7	156.1	7.4	88.7	27.9	168	183	23	38	<1	15	<0.1	5	4	16	1	1.18	1.3

Table A5. Water quality data – nutrients and biological characteristics, Montrose Creek

Site	Date	Flow type	Ammonia	Nitrite	Nitrate	NO_x	TKN	TN	TP	FRP	E.coli
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
Mo1	28-Sep-11	Baseflow	0.03	<0.01	0.02	0.02	0.3	0.3	0.05	<0.01	-
Mo2	28-Sep-11	Baseflow	0.03	<0.01	0.01	0.01	0.3	0.3	0.07	<0.01	-
Mo1	25-Oct-11	Baseflow	0.05	<0.01	0.02	0.02	0.2	0.2	0.01	<0.01	-
Mo2	25-Oct-11	Baseflow	0.01	<0.01	0.02	0.02	0.3	0.3	<0.01	<0.01	-
Mo1	22-Nov-11	Baseflow	0.08	<0.01	0.02	0.02	0.2	0.2	0.02	<0.01	-
Mo2	22-Nov-11	Baseflow	0.03	<0.01	0.01	0.01	0.3	0.3	0.05	<0.01	-
Mo1	13-Dec-11	Baseflow	0.1	<0.01	<0.01	<0.01	1.2	1.2	0.16	0.03	-
Mo1	31-Jan-12	Storm / baseflow	0.07	<0.01	0.01	0.01	0.6	0.6	0.07	0.02	-
Mo2	31-Jan-12	Storm / baseflow	0.07	<0.01	<0.01	<0.01	0.9	0.9	0.1	0.04	-
Mo1	21-Feb-12	Baseflow	0.05	<0.01	<0.01	<0.01	0.2	0.2	<0.01	<0.01	-
Mo2	21-Feb-12	Baseflow	0.04	<0.01	<0.01	<0.01	0.3	0.3	<0.01	<0.01	-
Mo1	20-Mar-12	Storm flow	0.06	<0.01	0.02	0.02	0.4	0.4	0.1	0.01	-
Mo2	20-Mar-12	Storm flow	0.05	<0.01	0.02	0.02	0.5	0.5	0.12	0.02	-

Table A6. Water quality data – dissolved metals, Montrose Creek

Site	Date	Flow type	Al	An	As	Cr	Cu	Fe	Mn	Se	Sr	Th	Sn	Ti	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Mo1	28-Sep-11	Baseflow	<0.10	<0.01	<0.01	<0.001	0.001	0.08	0.19	<0.01	0.3	<0.01	<0.01	<0.01	<0.01	0.01
Mo2	28-Sep-11	Baseflow	<0.10	<0.01	<0.01	<0.001	<0.001	<0.05	0.01	<0.01	0.3	<0.01	<0.01	<0.01	<0.01	0.02
Mo1	25-Oct-11	Baseflow	<0.10	<0.01	<0.01	<0.001	<0.001	0.1	0.2	<0.01	0.3	<0.01	<0.01	<0.01	<0.01	<0.005
Mo2	25-Oct-11	Baseflow	<0.10	<0.01	<0.01	<0.001	<0.001	<0.05	<0.01	<0.01	0.3	<0.01	<0.01	<0.01	<0.01	<0.005
Mo1	22-Nov-11	Baseflow	<0.10	0.01	<0.01	<0.001	<0.001	0.08	0.4	<0.01	0.3	<0.01	<0.01	<0.01	<0.01	<0.005
Mo2	22-Nov-11	Baseflow	<0.10	<0.01	<0.01	<0.001	<0.001	<0.05	0.01	<0.01	0.3	<0.01	<0.01	<0.01	<0.01	<0.005
Mo1	13-Dec-11	Baseflow	<0.10	<0.10	<0.10	<0.001	<0.001	<0.10	0.28	<0.10	<1.0	<0.10	<0.10	<0.10	<0.10	<0.005
Mo1	31-Jan-12	Storm / baseflow	6.12	<0.01	<0.01	<0.001	0.002	2.63	0.03	<0.01	<0.1	<0.01	<0.01	0.16	<0.01	<0.005
Mo2	31-Jan-12	Storm / baseflow	6.48	<0.01	<0.01	<0.001	0.002	3.2	0.03	<0.01	<0.1	<0.01	<0.01	0.18	0.01	<0.005
Mo1	21-Feb-12	Baseflow	<0.10	<0.01	<0.01	<0.001	<0.001	<0.05	<0.01	0.01	0.2	<0.01	<0.01	<0.01	<0.01	<0.005
Mo2	21-Feb-12	Baseflow	<0.1	0.01	<0.01	<0.001	<0.001	<0.05	0.02	<0.01	0.2	<0.01	<0.01	<0.01	<0.01	<0.005
Mo1	20-Mar-12	Storm flow	2.62	0.01	0.01	<0.001	0.002	1.32	<0.01	0.02	<0.1	0.01	0.01	0.07	<0.01	<0.005
Mo2	20-Mar-12	Storm flow	2.63	0.01	<0.01	0.001	0.002	1.44	0.02	0.03	<0.1	0.02	<0.01	0.07	<0.01	<0.005

Table A7. Water quality data – physical-chemical characteristics, Tooloombah Creek

Site	Date	Flow type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb. Alk	SO4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	µS/cm		NTU	0C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
To1	03-Jun-11	Baseflow	94.7	866	7.59	5.93	16.05	-	740	<5	212	42	232	0.2	65	47	104	2	11.6	11.7
To2	04-Jun-11	Baseflow	92.11	848	7.4	1.67	15.64	-	778	<5	209	41	228	0.2	63	46	104	2	11.5	11.5
To1	29-Sep-11	Baseflow	70.1	951	8	5.6	22.3	192	-	-	-	-	-	-	-	-	-	-	-	-
To2	29-Sep-11	Baseflow	88.9	965	7.9	3	23.7	227	676	9	178	39	223	0.2	52	38	91	2	10.7	9.73
To1	25-Oct-11	Baseflow	76.1	1132	8.1	5.4	24.2	166	669	5	162	40	254	0.2	54	45	105	3	11.2	11
To2	25-Oct-11	Baseflow	136.6	1146	8.4	7.2	27.1	166	674	8	153	38	250	0.2	53	44	104	3	10.9	10.9
To2	21-Nov-11	Baseflow	127.5	1407	8.3	4.7	28.8	144	820	9	168	33	366	-	50	52	155	3	14.4	13.6
To1	22-Nov-11	Baseflow	74.5	1276	8.2	1.2	28.4	180	718	<5	183	39	313	-	53	48	129	2	13.3	12.3
To1	14-Dec-11	Baseflow	87.7	1225	7.7	15	27.7	148	608	<5	140	24	243	0.2	43	37	98	3	10.2	9.53
To2	14-Dec-11	Baseflow	108	1320	7.8	18.8	30.1	159	657	12	151	23	270	0.2	45	42	108	3	11.1	10.5
To1	31-Jan-12	Storm / baseflow	143.4	392	5.86	119.8	29.6	225	247	51	40	10	28	<0.1	9	6	20	3	1.8	1.89
To1	21-Feb-12	Storm flow	90.1	463	7.8	13.9	28.6	163	240	10	91	10	80	0.1	21	15	43	2	4.28	4.2
To1	20-Mar-12	Storm flow	98.8	193.7	7.5	125	28.6	139	235	23	41	<1	21	0.2	6	4	18	2	1.41	1.46

Table A8. Water quality data – nutrients and biological characteristics, Tooloombah Creek

Site	Date	Flow type	Ammonia	Nitrite	Nitrate	NO_x	TKN	TN	TP	FRP	E.coli
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
To1	03-Jun-11	Baseflow	0.02	<0.01	0.03	0.03	0.4	0.4	0.03	-	-
To2	04-Jun-11	Baseflow	0.02	<0.01	0.02	0.02	0.6	0.6	0.02	-	-
To2	29-Sep-11	Baseflow	0.03	<0.01	0.01	0.01	0.4	0.4	0.07	<0.01	-
To1	25-Oct-11	Baseflow	0.02	<0.01	0.02	0.02	0.4	0.4	0.01	<0.01	-
To2	25-Oct-11	Baseflow	0.02	<0.01	0.02	0.02	0.4	0.4	<0.01	<0.01	-
To2	21-Nov-11	Baseflow	0.04	<0.01	0.01	0.01	0.7	0.7	0.03	<0.01	-
To1	22-Nov-11	Baseflow	0.02	<0.01	0.02	0.02	0.5	0.5	0.05	<0.01	-
To1	14-Dec-11	Baseflow	0.1	<0.01	<0.01	<0.01	0.6	0.6	0.04	<0.01	-
To2	14-Dec-11	Baseflow	0.06	<0.01	<0.01	<0.01	0.6	0.6	0.08	0.02	-
To1	31-Jan-12	Storm / baseflow	0.25	<0.01	0.01	0.01	1.2	1.2	0.17	0.06	-
To1	21-Feb-12	Storm flow	0.06	<0.01	0.02	0.02	0.4	0.4	0.04	0.01	-
To1	20-Mar-12	Storm flow	0.69	<0.01	0.02	0.02	1.2	1.2	0.15	0.02	-

Table A9. Water quality data – dissolved metals, Tooloombah Creek

Site	Date	Flow type	Al	An	As	Ba	Cr	Cu	Fe	Mn	Se	Sr	Sn	Ti	Ur	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
To1	03-Jun-11	Baseflow	<0.10	-	<0.01	<0.1	<0.001	<0.001	<0.05	0.01	<0.01	-	-	-	0.001	<0.01	<0.005
To2	04-Jun-11	Baseflow	<0.10	-	<0.01	<0.1	<0.001	<0.001	<0.05	0.03	<0.01	-	-	-	0.001	<0.01	<0.005
To2	29-Sep-11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.04	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	0.01
To1	25-Oct-11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.02	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To2	25-Oct-11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.02	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To2	21-Nov-11	Baseflow	<0.10	<0.01	0.01	0.1	<0.001	<0.001	<0.05	0.04	0.02	0.6	<0.01	<0.01	<0.001	<0.01	<0.005
To1	22-Nov-11	Baseflow	<0.10	0.01	<0.01	<0.1	<0.001	<0.001	<0.05	0.29	<0.01	0.6	<0.01	<0.01	<0.001	<0.01	<0.005
To1	14-Dec-11	Baseflow	<0.10	<0.01	<0.01	<0.1	0.002	0.001	<0.05	0.05	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To2	14-Dec-11	Baseflow	<0.10	<0.01	<0.01	<0.1	<0.0001	0.001	<0.05	0.12	<0.01	0.5	<0.01	<0.01	<0.001	<0.01	<0.005
To1	31-Jan-12	Storm / baseflow	7.47	<0.01	<0.01	<0.1	<0.001	0.002	3.18	0.03	<0.01	0.1	<0.01	0.18	<0.001	0.01	<0.005
To1	21-Feb-12	Storm flow	<0.1	<0.01	<0.01	<0.1	<0.001	<0.001	0.05	0.01	0.01	0.2	<0.01	<0.01	<0.001	<0.01	<0.005
To1	20-Mar-12	Storm flow	2.89	<0.01	<0.01	<0.1	0.001	0.002	1.62	0.01	<0.01	<0.1	0.01	0.08	<0.001	<0.01	<0.005

Table A10. Water quality data – physical-chemical characteristics, Granite Creek

Site	Date	Flow type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb. Alk	SO4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	µS/cm		NTU	0C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
Gr1	05-Jun-11	Baseflow	83.7	324	6.6	7.44	18.3	-	182	6	75	2	73	<0.1	18	16	33	1	3.6	3.68
Gr1	29-Sep-11	Baseflow	82.8	472	6.1	2.4	23.7	149	325	7	88	2	93	<0.1	23	19	37	1	4.42	4.35
Gr1	25-Oct-11	No flow	99.3	511	8.1	4.6	26.1	181	300	<5	79	2	109	<0.1	24	20	40	1	4.69	4.61
Gr1	22-Nov-11	No flow	74.5	562	7.7	2.8	25.1	197	307	<5	93	1	135	-	28	23	50	1	5.69	5.49
Gr1	13-Dec-11	Baseflow	77.2	229.1	7.3	2084	28.6	175	486	810	38	2	38	0.1	6	6	22	1	1.87	1.78
Gr1	31-Jan-12	Storm / baseflow	115.6	149.8	6.58	45	26.3	149	192	9	45	<1	19	<0.1	6	5	14	2	1.44	1.37
Gr1	21-Feb-12	No flow	105.8	542	7.4	2.3	28.6	139	166	<5	88	2	48	<0.1	15	13	30	1	3.15	3.15
Gr1	20-Mar-12	Storm flow	99.3	121	4.9	62.8	28.8	204	138	<5	35	<1	11	<0.1	4	4	12	1	1.01	1.08

Table A11. Water quality data – nutrients and biological characteristics, Granite Creek

Site	Date	Flow type	Ammonia	Nitrite	Nitrate	NO_x	TKN	TN	TP	FRP	E.coli
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
Gr1	05-Jun-11	Baseflow	<0.01	<0.01	0.05	0.05	0.5	0.6	0.04	-	-
Gr1	29-Sep-11	Baseflow	0.03	<0.01	0.02	0.02	<0.1	<0.1	0.05	<0.01	-
Gr1	25-Oct-11	No flow	0.02	<0.01	0.03	0.03	0.2	0.2	0.01	<0.01	-
Gr1	22-Nov-11	No flow	<0.01	<0.01	0.02	0.02	0.2	0.2	0.02	<0.01	-
Gr1	13-Dec-11	Baseflow	0.1	<0.01	<0.01	<0.01	1.8	1.8	0.31	<0.01	-
Gr1	31-Jan-12	Storm / baseflow	0.07	<0.01	0.02	0.02	0.5	0.5	0.04	<0.01	-
Gr1	21-Feb-12	No flow	0.05	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.01	-
Gr1	20-Mar-12	Storm flow	0.05	<0.01	0.02	0.02	0.3	0.3	0.07	<0.01	-

Table A12. Water quality data – dissolved metals, Granite Creek

Site	Date	Flow type	Al	As	Cu	Fe	Mn	Se	Sr	Ti	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Gr1	05-Jun-11	Baseflow	<0.10	<0.01	<0.001	0.12	0.02	<0.01	-	-	0.014
Gr1	29-Sep-11	Baseflow	<0.10	<0.01	<0.001	0.1	0.07	<0.01	0.2	<0.01	<0.005
Gr1	25-Oct-11	No flow	<0.10	<0.01	<0.001	0.05	0.05	<0.01	0.2	<0.01	<0.005
Gr1	22-Nov-11	No flow	<0.10	<0.01	<0.001	<0.05	<0.01	<0.01	0.2	<0.01	<0.005
Gr1	13-Dec-11	Baseflow	<0.10	<0.10	0.002	<0.10	<0.10	<0.10	<1.0	<0.10	<0.005
Gr1	31-Jan-12	Storm / baseflow	6.23	<0.01	0.002	2.38	0.02	<0.01	<0.1	0.16	<0.005
Gr1	21-Feb-12	No flow	<0.1	<0.01	0.002	0.12	0.01	0.02	0.1	<0.01	<0.005
Gr1	20-Mar-12	Storm flow	2.72	0.01	0.002	1.3	0.01	0.01	<0.1	0.09	<0.005

Table A13. Water quality data – physical-chemical characteristics, Styx River

Site	Date	Flow type	DO	EC	pH	Turbidity	Temp	Redox	TDS	TSS	Bicarb. Alk	SO4	Cl	Fl	Ca	Mg	Na	K	Anions	Cations
			%sat	µS/cm		NTU	0C	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L
St2	04-Jun-11	Baseflow	114.6	1390	7.63	5.41	18.49	-	1080	<5	306	68	422	0.4	64	55	227	6	19.4	17.8
St1	05-Jun-11	Baseflow	90.9	987	9.19	5.63	16.74	-	850	<5	190	42	291	0.2	58	45	139	2	12.9	12.7
St1	27-Sep-11	Baseflow	-	1942	6.9	-	23.3	-	-	-	-	-	-	-	-	-	-	-	-	-
St2	27-Sep-11	Baseflow	-	5450	6.8	11.8	23.9	125	-	-	-	-	-	-	-	-	-	-	-	-
St1	29-Sep-11	Baseflow	87.3	1874	7.8	5.9	22.8	244	1260	9	192	60	531	0.2	64	58	252	3	20.1	19
St2	29-Sep-11	Baseflow	49.8	8200	6.9	9.7	22.4	203	6400	21	266	379	2800	0.4	124	192	1490	47	92.2	88
St1	25-Oct-11	Baseflow	113.6	2562	6.8	8.4	28.7	104	1510	9	177	69	646	0.2	76	74	333	4	23.2	24.5
St2	25-Oct-11	Baseflow	158.4	5100	8	12.7	27.1	145	3120	13	208	187	1340	0.3	85	123	780	25	45.8	48.9
St1	21-Nov-11	Baseflow	116.4	3830	7.6	6.8	29.9	98	2270	13	226	106	998	-	111	107	487	4	34.9	35.6
St2	21-Nov-11	Baseflow	177.4	5600	8.2	7.9	28.7	118	4440	18	214	240	1650	-	85	147	969	26	56.2	59.2
St1	13-Dec-11	Baseflow	161	2264	7.7	67.7	32.3	186	1050	27	103	37	487	0.1	38	44	224	4	16.6	15.4
St2	13-Dec-11	Baseflow	163.2	1445	8.1	109.9	32.2	198	736	33	103	24	324	0.2	27	29	154	7	11.7	10.6
St1	31-Jan-12	Storm / baseflow	90.6	231.5	7.12	201.4	27.2	196	268	84	44	9	30	<0.1	8	6	21	3	1.91	1.88
St2	31-Jan-12	Storm / baseflow	125.5	206	7.32	162.1	27.2	213	303	103	41	10	35	<0.1	7	6	26	4	2.01	2.08
St2	22-Feb-12	Storm flow	81.4	189.9	8.1	1772	24.3	176	1110	548	44	4	28	<0.1	6	5	22	2	1.75	1.72
St2	20-Mar-12	Storm flow	91.9	1953	6.4	157.2	28.4	140	242	52	40	<1	22	<0.1	6	4	20	2	1.42	1.55

Table A14. Water quality data – nutrients and biological characteristics, Styx River

Site	Date	Flow type	Ammonia	Nitrite	Nitrate	NO_x	TKN	TN	TP	FRP	E.coli
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Cfu/100ml
St2	04-Jun-11	Baseflow	0.03	<0.01	0.04	0.04	0.4	0.4	<0.01	<0.01	17
St1	05-Jun-11	Baseflow	0.02	<0.01	0.04	0.04	0.5	0.5	0.12	<0.01	10
St1	29-Sep-11	Baseflow	0.02	<0.01	0.03	0.03	0.5	0.5	0.12	<0.01	-
St2	29-Sep-11	Baseflow	0.03	<0.01	0.02	0.02	0.2	0.2	0.06	<0.01	-
St1	25-Oct-11	Baseflow	<0.01	<0.01	0.02	0.02	0.3	0.3	<0.01	<0.01	-
St2	25-Oct-11	Baseflow	0.04	<0.01	0.01	0.01	0.3	0.3	<0.01	<0.01	-
St1	21-Nov-11	Baseflow	0.04	<0.01	0.03	0.03	0.3	0.3	<0.01	<0.01	-
St2	21-Nov-11	Baseflow	0.02	<0.01	0.02	0.02	0.3	0.3	0.4	<0.01	-
St1	13-Dec-11	Baseflow	0.08	<0.01	<0.01	<0.01	1.1	1.1	0.33	0.21	-
St2	13-Dec-11	Baseflow	0.12	<0.01	<0.01	<0.01	0.9	0.9	0.28	0.2	-
St1	31-Jan-12	Storm / baseflow	0.06	<0.01	0.01	0.01	1	1	0.2	0.07	-
St2	31-Jan-12	Storm / baseflow	0.07	<0.01	<0.01	<0.01	1.4	1.4	0.3	0.09	-
St2	22-Feb-12	Storm flow	0.05	<0.01	0.02	0.02	1.9	1.9	0.41	<0.01	-
St2	20-Mar-12	Storm flow	0.08	<0.01	0.02	0.02	0.8	0.8	0.19	0.05	-

Table A15. Water quality data – dissolved metals, Styx River

Site	Date	Flow type	Al	As	Ba	Bo	Cd	Cr	Cu	Fe	Mn	Se	Sr	Ti	Ur	Vn	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
St2	04-Jun-11	Baseflow	<0.10	<0.01	<0.1	-	0.0001	<0.001	0.001	<0.05	0.08	<0.01	-	-	<0.001	<0.01	0.026
St1	05-Jun-11	Baseflow	<0.10	<0.01	<0.1	-	<0.0001	<0.001	<0.001	<0.05	0.19	<0.01	-	-	<0.001	<0.01	0.005
St1	29-Sep-11	Baseflow	<0.10	<0.01	0.1	<0.1	<0.0001	<0.001	<0.001	<0.05	0.28	<0.01	0.8	<0.01	<0.001	<0.01	0.03
St2	29-Sep-11	Baseflow	<0.10	0.01	0.2	0.7	<0.0001	<0.001	<0.001	<0.05	0.38	<0.01	1.9	<0.01	0.001	<0.01	0.02
St1	25-Oct-11	Baseflow	<0.10	<0.01	0.2	0.1	<0.0001	<0.001	<0.001	<0.05	0.55	<0.01	1	<0.01	<0.001	<0.01	<0.005
St2	25-Oct-11	Baseflow	<0.10	<0.01	0.1	0.4	<0.0001	<0.001	<0.001	<0.05	0.03	0.01	1.2	<0.01	<0.001	<0.01	<0.005
St1	21-Nov-11	Baseflow	<0.10	<0.01	0.3	0.2	<0.0001	<0.001	<0.001	<0.05	0.2	<0.01	1.6	<0.01	<0.001	<0.01	<0.005
St2	21-Nov-11	Baseflow	<0.10	<0.01	0.1	0.6	<0.0001	<0.001	0.002	<0.05	<0.01	<0.01	1.5	<0.01	<0.001	<0.01	<0.005
St1	13-Dec-11	Baseflow	<0.10	<0.01	0.1	<0.1	<0.0001	0.002	0.006	<0.05	0.13	<0.01	0.6	<0.01	<0.001	<0.01	0.011
St2	13-Dec-11	Baseflow	<0.10	<0.01	<0.1	0.1	<0.0001	<0.001	0.002	<0.05	0.18	<0.01	0.4	<0.01	<0.001	<0.01	<0.005
St1	31-Jan-12	Storm / baseflow	9.41	<0.01	<0.1	<0.1	<0.0001	<0.001	0.002	4.34	0.06	<0.01	0.1	0.26	<0.001	0.02	<0.005
St2	31-Jan-12	Storm / baseflow	10.8	<0.01	<0.1	<0.1	<0.0001	<0.001	0.003	5.3	0.06	<0.01	0.1	0.3	<0.001	0.02	<0.005
St2	22-Feb-12	Storm flow	0.51	<0.01	<0.1	<0.1	<0.0001	<0.001	0.002	0.44	0.02	<0.01	<0.1	0.02	<0.001	<0.01	0.006
St2	20-Mar-12	Storm flow	2.42	<0.01	<0.1	<0.1	<0.0001	0.002	0.003	1.58	0.02	0.03	<0.1	0.07	<0.001	<0.01	<0.005

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