Wallarah 2
COAL PROJECT

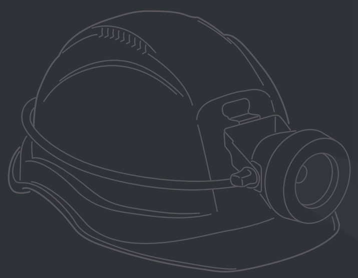
Wallarah 2 Coal Project

Environmental Impact Statement

April 2013

Appendix P

Aquatic Ecology
Impact Assessment



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ENVIRONMENTAL CONSULTANTS

WALLARAH 2 COAL PROJECT
ENVIRONMENTAL IMPACT STATEMENT

AQUATIC ECOLOGY IMPACT ASSESSMENT

Spring Creek Swamp Site SW1 – Autumn 2011

REPORT PREPARED FOR
WYONG COAL PTY LTD

MARINE POLLUTION RESEARCH PTY LTD
February 2013

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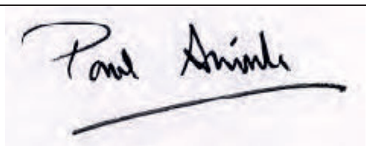
MPR APPROVAL: PAUL ANINK	 13 February 2013

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ACRONYMS

AusRivAS	Australian River Assessment System
DGRs	Director General's Requirements
DP&I	Department of Planning and Infrastructure
DPI	Department of Primary Industries
KFH	Key Fish Habitats
EEC	Endangered Ecological Communities
EIS	Environmental Impact Statement
EL	Exploration Licence
EMP	Environment Management Plan
EPBC	Environment Protection and Biodiversity Conservation Act 1999
EPT	Ephemeroptera, Plecoptera, and Trichoptera
FMA	Fisheries Management Act 1994
GDE	Groundwater Dependent Ecosystem
KTP	Key Threatening Process
LGA	Local Government Area
Mtpa	Million tonne per annum
NOW	NSW Office of Water
NPWS	National Parks and Wildlife Service
PAC	Planning Assessment Commission
RCE	River-Creek-Environment
SIGNAL	Stream Invertebrate Grade Number Average Level
TARP	Trigger Action Response Plan
TSC	Threatened Species Conservation ACT 1995
SCA	State Conservation Area
SEPP	State Environmental Protection Policy
WACJV	Wyong Areas Coal Joint Venture
WMP	Water Management Plan

EXECUTIVE SUMMARY

The Wyong Areas Coal Joint Venture (WACJV) seeks Development Consent under Division 4.1 in Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Wallarah 2 Coal Project (the Project). This Aquatic Ecology Impact Assessment supports 'The Wallarah 2 Coal Project Environmental Impact Statement' (Wallarah 2 EIS) prepared by Hansen Bailey Environmental Consultants to support the application.

The mine will be at a depth of between 350 m and 690 m below the surface within the underground longwall extraction area, located under the Jilliby Jilliby, Little Jilliby Jilliby and Hue Hue Creek catchments, with a small portion under the Wyong River catchment. A large proportion of the Project's underground coal extraction area is located beneath forested hills, comprising the Jilliby State Conservation Area (SCA) and the Wyong State Forest.

There are two proposed infrastructure areas; the Buttonderry site is located in the Buttonderry Creek catchment that drains to Porters Creek Wetland and the Tooheys Road site is located in the Wallarah Creek drainage, with part of the proposed rail loop in the Spring Creek drainage, both of which flow to Budgewoi Lake.

The aquatic ecology report assesses the potential impacts on aquatic ecology arising from the proposal and provides minimisation, mitigation and suggested offset measures for protection of the aquatic ecology of the development site. The assessment is based on review of relevant literature and on the results of biannual aquatic ecology surveys. The aquatic ecology baseline study endeavoured to answer the following questions:

- Where are the aquatic habitat resources in the study area?
- What are the ecological and riparian attributes of the aquatic habitats?
- Which of the aquatic resources provide suitable and sustained aquatic habitat for fish and other aquatic biota?
- Is there fish passage in the various streams within the project area?
- Are there any protected or threatened aquatic species or communities residing within the study area, or any mammals such as platypus and Australian water rat that may utilise the aquatic resources of the project area?
- Are there aquatic Groundwater Dependent Ecosystems (GDEs)?

The baseline study:

- Assessed the aquatic habitats and biota of in-line stream sites with an emphasis on sites within or draining directly to defined *Key Fish Habitats*.

- Included sequential habitat assessments of feeder creek sites, as access to these became possible.
- Sampled alluvial bore waters from the Dooralong Valley alluvium at the Jiliby Jilliby Creek, little Jilliby Jilliby Creek confluence to characterise the study area stygofauna.
- The baseline study is continuing to provide sufficient baseline data for future construction and operation management.

The adopted sampling methodology to achieve the study aims was as follows:

- Sampling the aquatic macroinvertebrate fauna twice a year (in autumn and spring 2011 and autumn 2012) using the AusRivAS sampling, sorting and identification protocols.
- Recording changes in site riparian and aquatic habitat condition and of aquatic plant distribution within the study areas at each sampling time.
- Estimation of fish occurrence where relevant by a combination of overnight or short-term bait-trapping, dip netting and observation, with all captured fish identified in-situ and immediately released wherever possible.
- Metered depth profiles of basic water quality parameters at each site.
- Platypus and Australian water rat habitat assessments and collection of turtle, reptile and aquatic bird observations during field sampling activities.
- Collection of alluvial bore waters from project Dooralong Valley alluvial bores to characterise the study area stygofauna.

Literature Review Results

The review concluded that there is a large, extended but fragmented surface water quality data base available for the project area that, combined with the more recent project data, is adequate for establishing long-term water quality goals for the relevant Wallarah Creek and Wyong River sub-catchments potentially impacted by proposed mining operations. This combined water quality database can be used as a basis for implementing future mine surface water protection measures and guidelines.

There are aquatic ecology data for the project area available from the late 1990s through to the present time that, combined, are adequate for establishing long-term stream-health goals for the relevant Wallarah Creek and Wyong River sub-catchments potentially impacted by proposed mining operations. The combined data indicate that the Wyong River and Wallarah Creek catchments provide suitable habitat to support diverse aquatic macroinvertebrate assemblages, a variety of native fish species plus animals dependent on aquatic habitats such as platypus and Australian water rat. The aquatic ecology database will incorporate results from on-going aquatic ecology surveys and will be used for establishing long-term stream-health and rehabilitation goals for the project.

There are no threatened aquatic plants, fish or macroinvertebrate species or populations, as listed under the threatened species provisions of the Commonwealth EPBC Act or under the threatened species provisions of the NSW Fisheries Management Act 1994 recorded from the Wyong River and Wallarah Creek catchments:

- Two fish species listed as “may be present’ under the EPBC Act (Australian grayling and Macquarie perch) are not reported from the varied fish surveys undertaken from the late 1990s to the present.
- The mountain creek habitats of the Jilliby Creek SCA are unlikely to support Adams emerald dragonfly by virtue of insufficient permanent and running water habitats to support this species over its extended (seven year) aquatic life stage.
- Giant dragonfly adults are reported from coastal locations around Tuggerah Lakes. Larvae for this species live in burrows under swampy/peaty lands and it is concluded that it is unlikely that there is suitable larval burrowing habitat in the mining subsidence area.

Baseline Study Results

This assessment is based on the first three biannual aquatic ecology surveys undertaken, in Autumn and Spring 2011 and Autumn 2012.

A total of seventeen macrophytes (aquatic plants) were recorded from the combined study area sites over the survey period. The diversity of macrophytes increased over consecutive surveys both as a result of the more favourable conditions for observing macrophytes and due to recolonisation following scouring by floods immediately prior to the commencement of the first sampling in Autumn 2011.

Over all sample seasons, the Wyong River sub-catchment sites recorded the highest aquatic macroinvertebrate Diversity, SIGNAL and EPT scores, and Porters Creek sub-catchment sites recorded the lowest SIGNAL scores. Wallarah Creek infrastructure area sites recorded the lowest Diversity scores. The present (2011 to 2012) seasonal results are in line with the original macroinvertebrate sampling in 1999 where the stream sites in Wyong River and Jilliby Jilliby Creeks also had higher taxa diversities and higher SIGNAL scores than the smaller creek sites in the infrastructure areas.

Whilst the Wyong River and Jilliby Jilliby Creek assessed habitats are known to support an abundance of native fish species plus aquatic mammals such as Australian water rat and platypus, only two native fish species have been caught or seen over the baseline study period, most likely due to the preponderance of flood or high flow conditions experienced over the study period. Regardless of flood and high flows, the streams all supported large populations of the introduced pest fish species plague minnow.

The low aquatic plant and invertebrate ratings, the physical evidence of repeated high flood scouring activity several times during the study period, the lack of native fish and aquatic mammals captures or sightings and the pattern of changes in macroinvertebarte assemblage indices over the three sampling periods following the first major flood in June 2011, are all consistent with and reflect the scouring induced habitat destruction impacts arising from the persistent flood activity over the study period.

There are a variety of native and introduced fish known from the Wyong River, lower Jilliby Jilliby Creek and the lower portion of Little Jilliby Jilliby Creek, and it is anticipated that more fish will be able to colonise the lower reaches of the study area over time as a result of the recent upgrade of the Wyong River weir fishway:

- The Wyong River and Jilliby Jilliby Creek floodplains are also drowned out regularly for some distance upstream during floods, further facilitating fish passage, particularly from the main streams to floodplain wetlands and dams.
- Natural obstacles plus the ephemeral nature of the majority of the forested ridge gully and foothill slope drainages preclude fish passage and colonisation.
- Whilst there are a number of natural and constructed obstacles that prevent fish passage from Tuggerah Lake to Wallarah and Spring Creeks during low to no flow periods, there would appear to be sufficient fish passage available to the lower portions of these creeks during medium to high flows and allow fish colonisation of the more permanent pools at the lower ends of the freshwater reaches of these creeks, located below the mine infrastructure area.

There are three main groundwater aquifers identified in the study area; the alluvial sediments of the valleys and floodplains, the upper shallow weathered zone of the Narrabeen Group in the forested areas and the Wallarah Great Northern coal seam:

- The shallow weathered rock aquifer provides limited baseflow to highland gullies or to foothill springs for short periods after rainfall with little expectation of there being any aquatic baseflow groundwater dependent ecosystems (GDEs).
- The aquatic biota within the main Jilliby Jilliby Creek channels are not considered highly dependent on baseflow as the proportion of base to total flow is relatively low and baseflow does not extend creek aquatic habitats for any significant time during prolonged drought periods. Isolated water bodies that intercept the water table may be of more importance as GDEs for aquatic biota, as these GDEs may provide better drought refuge than creek pools.
- The alluvial and underlying hard rock aquifers in Jilliby Jilliby Creek did not support stygofauna, in line with other studies of coastal sand aquifers.

Impact Assessment, Mitigation and Monitoring

Potential impacts are assessed as they relate to initial mine setup and construction, the longwall mining process and from operation of the surface facilities during mining.

Potential construction and operational impacts on the aquatic ecological values at, and downstream of the project infrastructure areas are to be managed by (i) appropriate siting of infrastructure away from aquatic habitats and the associated riparian corridors where possible, (ii) implementation of a Construction Water Management Plan (WMP) to ensure the protection of aquatic habitats during construction and (iii) an Operational WMP to ensure water quality and quantity and preserve and protect downstream aquatic habitats plus fish passage. The WMPs will also specify how site and associated rail, road and services corridor stormwater will be collected, treated and disposed of to ensure the integrity of the local waterways and wetlands.

Potential mining impacts on the aquatic ecology of the longwall mining area are to be avoided and minimised by appropriate siting and orientation of the longwalls, coupled with adaptive adjustments to the mining height, longwall lengths and widths, and by pillar collapse, to achieve a post subsidence topography that is no more variable over the Dooralong Valley floor than at present.

Adaptive management of mining parameters plus physical remediation works will also be used to ensure that there are no substantial during-mining changes to undermined aquatic ecology habitats (streamlines, lagoons, wetlands and dams) such that no large scale adjustments in aquatic and wetland habitat characteristics or in fish passage or connectivity would result. Where minor remediation works are required, these would be undertaken as part of an Environmental Management Plan (EMP) that will set out the manner in which any minor works are to be undertaken to ensure no additional environmental damage, and to provide appropriate monitoring to measure remediation success.

For the most part, the smaller low order gully drainages in the forested areas are steep V-shaped gullies with little bed-rock constrained structure and mostly boulder cascade constrained drainages with little water retention capability. The drainages are ephemeral with short tail flows (i.e., low local base flow and low shallow rock aquifer holding capacity) following rainfall, with short-lived pools. Accordingly, these gully drainages do not provide any significant permanent or semi-permanent aquatic ecology habitat but function to deliver catchment water to the important aquatic habitats downstream along the valley floors of Little Jilliby Jilliby Creek, Jilliby Jilliby Creek and Wyong River.

The nature and plasticity of the forested sub-catchment drainages means that many of the potential subsidence impacts associated with rock-constrained valleys will not occur, are not relevant or will not be exacerbated to any measurable degree. Whilst predicted tilts due to subsidence are not likely to result in any significant change in slope such that slope instability could increase, there are some residual risks of slope instability for some steep gullies due to modelled ground curvatures and strain. This residual impact is to be further assessed prior to mining in the area commences in or after year 12, with the view to modify the project where required, including adopting specific adaptive management measures.

All water within the mine water management system, including groundwater inflows to the underground mine and captured surface runoff, will be treated for use at the site to minimise impacts on streams. As the mine will have a water deficit in the early years, then provide surpluses for the life of the mine, surplus water will be saline and will require treatment prior to reuse or discharge. Treated water discharges to Wallarah Creek would be required for the life of the project and increase up to Year 7, remaining fairly consistent thereafter, ranging from 50 to 500 ML/a. Treated water will be of a similar quality to existing water quality in order to protect existing downstream aquatic ecosystems.

As Wallarah Creek is ephemeral, treated water discharges may occur at times when there is no natural flow in Wallarah Creek. However, based on the relatively low flow rate of treated water discharge and the good condition of bank vegetation, it is considered that these flows would not result in adverse impacts on aquatic habitat. Whilst the treated water discharge will alter the flow-duration relationship of Wallarah Creek, the creek will remain ephemeral and will still experience a similar frequency of zero to very low flow events plus similar flood flow events.

The success of aquatic ecology impact avoidance, minimisation, mitigation and remediation measures will also be determined by the application of the EMP that will include a comprehensive stream health monitoring program that utilises the on-going biannual stream health monitoring and will use a guiding set of criteria and protocols developed from the monitoring data to establish the circumstances under which additional mitigation measures would be required. These will be specified in the EMP and in associated Trigger Action Response Plans (TARPs).

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1 INTRODUCTION

Wyong Areas Coal Joint Venture (WACJV) proposes to develop an underground longwall mine known as the Wallarah 2 Coal Project (the Project) to the west of the F3 Freeway, northwest of Wyong, NSW. In early 2010 WACJV submitted an Environmental Assessment Report (EAR) to the NSW Dept of Planning and Infrastructure (DoPI). The Minister for Planning referred the proposal to a Planning Assessment Commission (PAC) and the PAC report recommended approval for the project contingent on a number of conditions relating to a need for more detailed information in the EAR. The Department of Planning assessment report to the Minister recommended that the project not be approved until a number of key issues, including an assessment of aquatic ecology impact for the project area, were addressed. The Minister subsequently did not approve the project in its present form.

The Wyong Areas Coal Joint Venture (WACJV) now seeks Development Consent under Division 4.1 in Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Wallarah 2 Coal Project (the Project). This Aquatic Ecology Impact Assessment supports 'The Wallarah 2 Coal Project Environmental Impact Statement' (Wallarah 2 EIS) prepared by Hansen Bailey Environmental Consultants to support the application.

This Aquatic Ecology Impact Assessment has been prepared in accordance with the Director-General's Environmental Assessment Requirements (DGRs) for the Project issued 12 January 2012 in accordance with the requirements in Part 2 in Schedule 2 to the *Environmental Planning & Assessment Regulation 2000* (EP&A Regs).

Development Consent is sought to mine coal within the Extraction Area for a period of 28 years. The majority of this resource lies beneath the Wyong State Forest and surrounding ranges (including the Jilliby State Conservation Area (SCA)) while a proportion, to be extracted first, lies beneath a section of the Dooralong Valley and the Hue Hue area. The location of the Project is shown on Figure 1 (below). Key features of the Project include:

- The construction and operation of an underground mining operation extracting up to 5.0 Mtpa of export quality thermal coal by longwall methods at a depth of between 350 m and 690 m below the surface within the underground Extraction Area;
- Mining and related activities will occur 24 hours a day 7 days a week for a Project period of 28 years;
- Tooheys Road Site surface facilities on company owned and third party land (subject to a mining lease) between the Motorway Link Road and the F3 Freeway which will include (at least) a rail loop and spur, stockpiles, water and gas management facilities, workshop and offices;

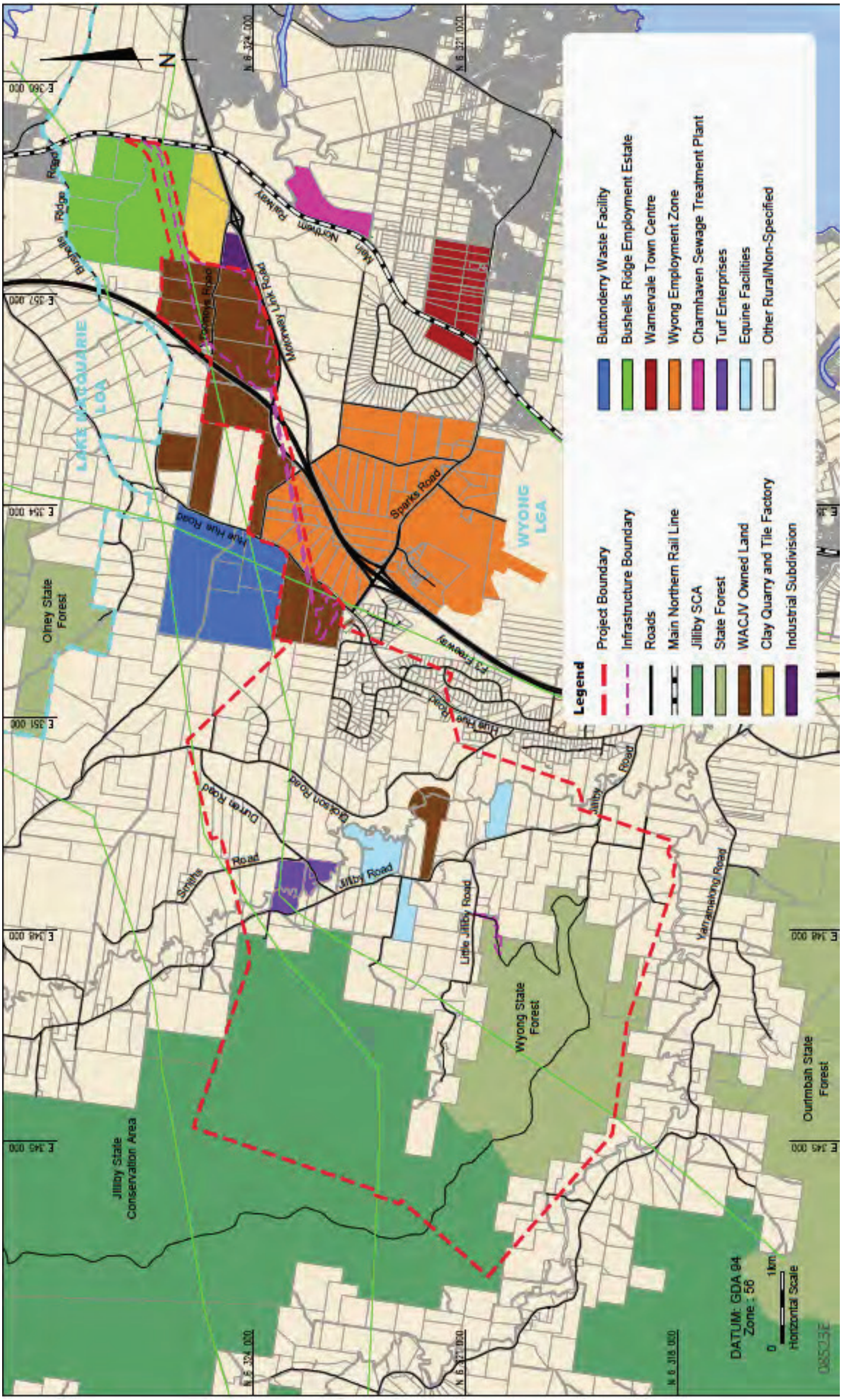


Figure 1 Location of the Project Application Area in relation to significant land use

- Buttonderry Site Surface Facilities on company owned land at Hue Hue Road between Sparks Road and the Wyong Shire Council's (WSC) Buttonderry Waste Management Facility. This facility will include (at least) the main personnel access to the mine, main ventilation facilities, offices and employee amenities;
- An inclined tunnel (or "drift") constructed from the coal seam beneath the Buttonderry Site to the surface at the Tooheys Road Site;
- Construction and use of various mining related infrastructure including water management structures, water treatment plant (reverse osmosis or similar), generator, second air intake ventilation shaft, boreholes, communications, water discharge point, powerlines, and easements to facilitate connection to the Central Coast Water Corporation water supply and sewerage system;
- Capture of methane for treatment initially involving flaring as practicable for greenhouse emission management and ultimately for beneficial use of methane such as electricity generation at the Tooheys Road Site;
- Transport of coal by rail to either the Newcastle port for export or to domestic power stations;
- A workforce of approximately 300 full-time company employees (plus an additional 30 contractors); and
- Rehabilitation and closure of the site at cessation of mining operations.

Wyong Coal Pty Ltd commissioned Marine Pollution Research Pty Ltd (MPR) to undertake baseline aquatic ecology sampling with a view to assessing the potential impacts on aquatic ecology arising from the proposal and to provide minimisation, mitigation and if required, offset measures for protection of the aquatic ecology of the development site. Biannual aquatic ecology baseline surveys commenced in Autumn 2011 and are continuing, and the surveys from Autumn and Spring 2011 and Autumn 2012 form the basis for the Aquatic Ecology Impact Assessment report presented here. This aquatic ecology impact assessment report should be read in conjunction with the other related environmental studies for the project, including the following:

- Cumberland Ecology (2013) Ecological (Terrestrial) Impact Assessment, Wallarah 2 Coal Project;
- Environmental Earth Sciences (EES 2012) Soils and Land Capability Assessment, Wallarah 2 Coal Project;
- Mackie Environmental Research (MER 2013) Groundwater Management Studies, Wallarah 2 Coal Project;
- Mine Subsidence Engineering Consultants (MSEC 2013) Subsidence Predictions and Impact Assessments, Wallarah 2 Coal Project;
- WRM Water & Environment (WRM 2013) Surface Water Impact Assessment, Wallarah 2 Coal Project; and
- Wyong Areas Coal Joint Venture (WACJV 2012) Subsidence Modelling Study, Wallarah 2 Coal Project.

1.1 Regional Setting

The aquatic ecology study area comprises the combined drainages running through the infrastructure sites or located over the mining footprint and the receiving aquatic habitats downstream of the study area. The combined project drainages all eventually discharge to the Tuggerah Lakes estuary, which comprises three coastal lagoons, Tuggerah Lake, Budgewoi Lake and Lake Munmorah draining a total catchment area of around 700km^2 (see **Table 1**). The average depth of the lakes is approximately 3 metres, with bottom sediments composed of fine black mud, mostly sourced from catchment runoff and transported in suspension along tributaries during flood events (Roberts 2001). The estuary is classified as a barrier lagoon with an intermittently opening entrance. It is now mostly kept open to the sea by a sand dredge, which allows some limited flushing and mixing to occur, however, the overall effects of flushing are small when the size of the estuary is taken into account (Roberts and Dickinson 2005).

Roberts *et al.* (2006) noted that the major tributaries such as Wyong River and Ourimbah Creek contribute about 72% of the freshwater inflow and, together with Wallarah Creek, directly influence the hydrodynamics of the Tuggerah Lakes estuary, particularly via river inputs after large floods, which, combined with tidal motions and oceanic oscillations, assist in the flushing of the Tuggerah Lakes estuary.

Table 1 Tuggerah Lakes Catchment Statistics

Catchment & Sub-catchment	Area (km^2)	Length (km)
Tuggerah Lakes Catchment		
Total Lake Catchment	700	
Lake Water area	70	
Ourimbah Creek	153	31
Wyong River	441	69
Jilliby Jilliby Ck	101	22
Porters Ck	55	
Wallarah Ck		9
Tumbi and Saltwater Cks		

With a catchment area of 441 square kilometres, the Wyong River is the main tributary of the Tuggerah Lakes estuary, and a significant contributor to the flushing processes. However, under present conditions, river inputs are reduced as a result of agricultural and town water supply water extraction, particularly during drought conditions.

Figures 2 and 3 show the relationship of the proposal to the various river and creek drainage sub-catchments draining under or through it. These drainages can be grouped as follows:

- Drainages over the mining footprint discharge to Wyong River via thee different pathways;

  - via Wyong River direct (ridge sub-catchments west of Watagan Forest Drive ridge),
  - via Jilliby Jilliby Creek draining through the Dooralong Valley to Wyong River (ridge sub-catchments east of Watagan Forest Drive ridge and west of the foothill ridge line west of Dickson Road,
  - via Hue Hue Creek east of the Dickson Road ridge line which then drains to Wyong River via Porters Creek Wetland.
- The Jilliby Jilliby Creek and Wyong River catchments form part of the Wyong LGA potable water supply system with water take-off located at the Wyong Weir, some 3.2 km downstream of the Jilliby Jilliby Creek confluence.
- The Wyong River is brackish to estuarine and tidal from the weir to Tuggerah Lake.
- The Buttonderry infrastructure area drains to Buttonderry Creek and this creek plus Hue Hue Creek (partially located over a portion of the underground mine) drain to Porters Creek Wetland, a regionally important wetland protected under a State Environmental Protection Policy (SEPP14). Porters Creek drains to Wyong River
- The Tooheys Road infrastructure area is located in semi rural areas on small sub-catchments of Wallarah Creek discharging to Budgewoi Lake, which in turn drains to Budgewoi Lake.

1.1.1 Project Area land use

The region supports grazing, cropping, vineyards, hobby farms, small hamlets and larger urbanised or light industrial areas, mainly on the lower slopes or coastal plains of Tuggerah Lake. Elevated slopes and ridges are generally vegetated with much conserved in the Jilliby State Conservation Area and Wyong State Forest. The floodplains of Jilliby Jilliby Creek and Wyong River include numerous freshwater wetlands sustained by both flood waters and sub-surface flow from the extensive alluvial floodplain:

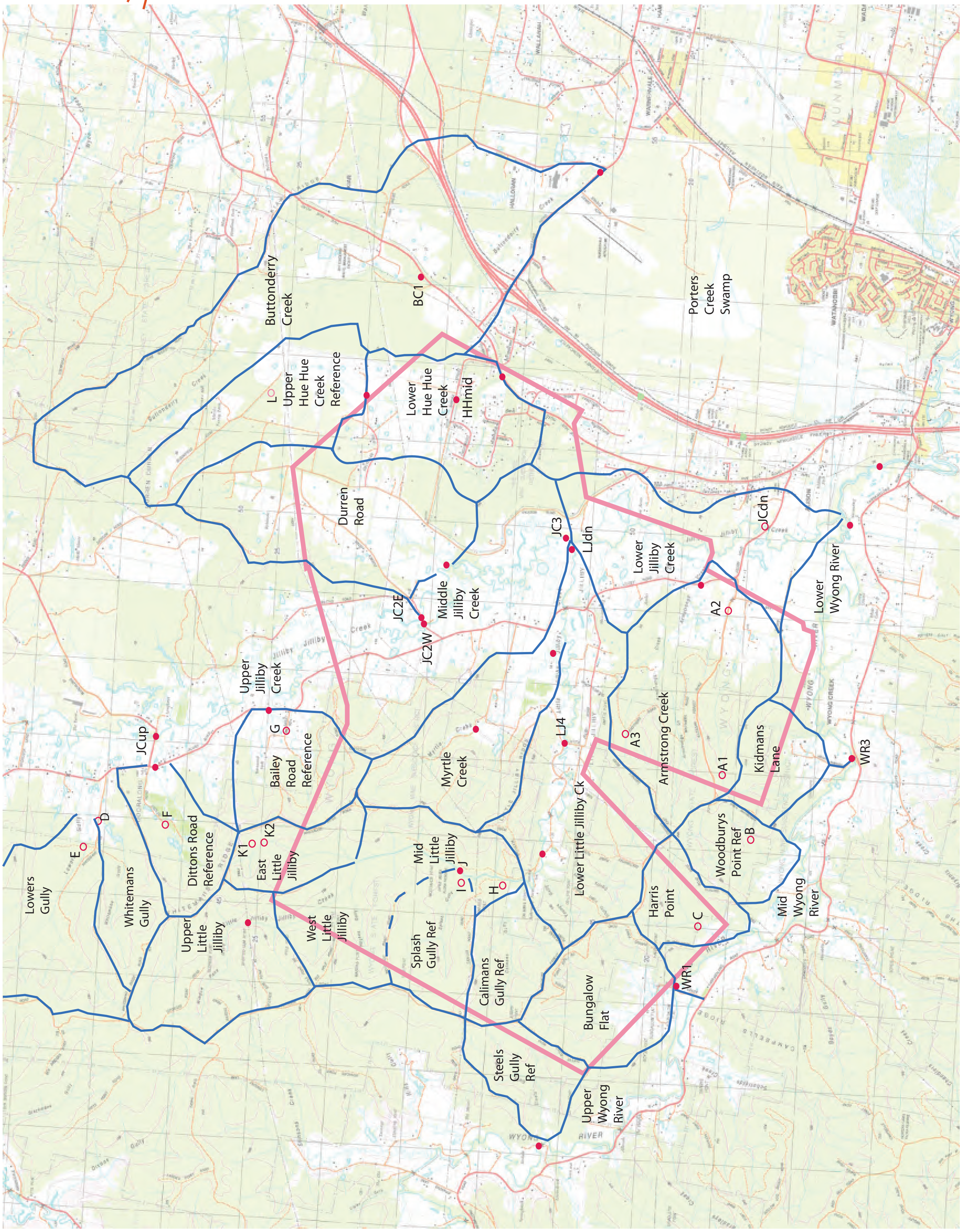
- A large proportion of the Project's underground coal extraction area is located beneath forested hills, comprising the Jilliby State Conservation Area (SCA) managed by the National Parks and Wildlife Service (NPWS) and the Wyong State Forest managed by Forests NSW (**Figure 1**).
- Jilliby SCA continues north into the Watagan Mountains (Olney and Watagans State Forests) and links to Watagans National Park. Jilliby SCA also extends south of the Wyong River to Ourimbah State Forest, located on the slopes of Somersby Plateau. Dharug and Yenco National Parks are located to the west of the Yarramalong Valley.
- About two thirds of Little Jilliby Jilliby Creek sub-catchment overlays the mining area with the upper half of the creek located in hilly forested land within the Jilliby SCA and the lower half of the creek flowing through freehold land.

FIGURE 4

W2CP PROPOSED LONGWALL MINING & BUTTONDERRY INFRASTRUCTURE AREA FOOTPRINT AND ASSOCIATED WYONG RIVER SUB-CATCHMENT TRIBUTARIES

Sub-catchment Aquatic Ecology Sampling Site Network

Outline of Proposed LOng Wall Mine



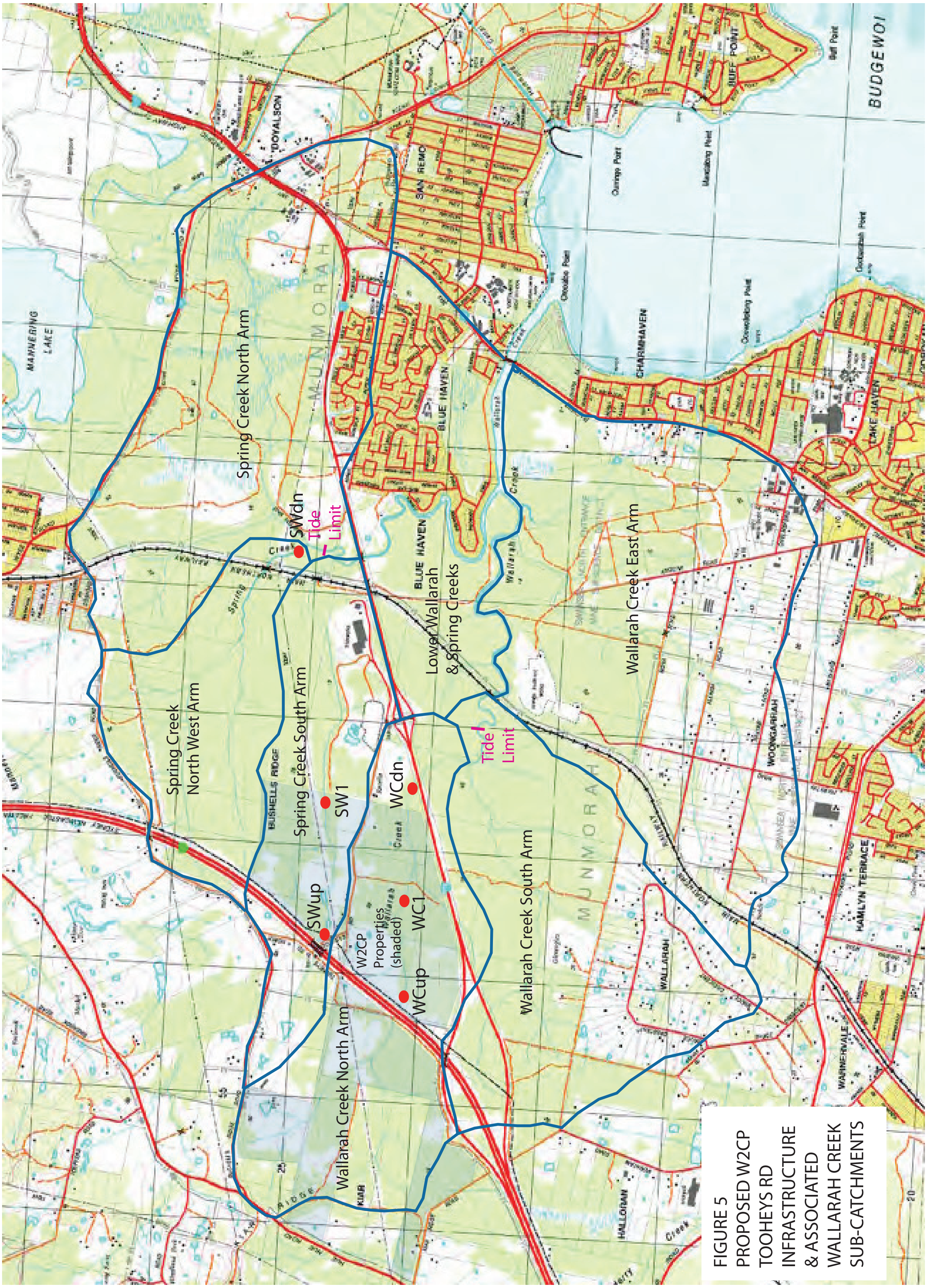


FIGURE 5
PROPOSED W2CP TOOHEYS RD INFRASTRUCTURE & ASSOCIATED WALLARAH CREEK SUB-CATCHMENTS

- Most of the land within the mining area through which Jilliby Jilliby and Hue Hue Creeks flow is freehold land.
- The dominant agricultural activity in these freehold lands is grazing, although turf farming also occurs in the more fertile floodplains near the Wyong River and Jilliby Jilliby Creek. Over the last 20 years, large holdings have been fragmented and converted to hobby farms, rural weekend retreats, market gardens, nurseries, and horse properties. As a result, the character is rural rather than agricultural. Scattered rural dwellings follow the river flats and the small localities of Yarramalong and Dooralong are at the head of their respective valleys.

1.2 Regional Climate

Table 2 below presents regional air temperature and rainfall data plus statistics for a coastal weather station at Norah Head and a coastal range weather station at the Narara Research Station (data from Hansen Bailey 2011). These data provide an indication of climatic conditions for the Tooheys Road infrastructure area and the project subsidence area respectively.

Table 2 Mean Daily Temperature and Monthly Rainfall for Wyong Region

	Mean Daily Temperatures (°C)				Mean Mo Rain (mm)		Mean Mo Rain Days	
Month	Norah Head		Narara		Norah Hd	Narara	Norah Hd	Narara
	Min	Max	Min	Max				
January	19.6	25.7	16.8	27.6	66.9	132.4	8.0	8.7
February	20.0	25.9	17.2	27.2	101.6	152.5	8.2	8.8
March	18.7	24.8	15.4	26.0	105.2	149.3	8.3	9.1
April	15.8	22.8	11.9	26.6	127.3	137.7	8.6	8.4
May	13.1	20.0	8.3	20.3	163.0	119.2	9.9	7.6
June	10.9	18.0	6.5	17.9	133.8	129.9	8.6	7.5
July	9.7	17.2	4.7	17.5	98.6	80.7	7.6	6.4
August	10.5	18.8	5.3	19.0	69.6	73.0	5.7	6.2
September	12.8	20.9	7.7	21.3	64.6	67.6	7.1	6.3
October	14.8	22.5	10.7	23.7	56.4	84.9	6.8	7.2
November	16.7	23.4	13.1	25.1	87.0	91.7	8.4	7.9
December	18.4	24.9	15.3	26.9	65.7	102.8	6.9	7.8
Minimum	9.7	17.2	4.7	17.5	56.4	67.6	5.7	6.2
Maximum	20.0	25.9	17.2	27.6	163.0	152.5	9.9	9.1
Median	15.3	22.7	11.3	24.4	92.8	111.0	8.1	7.7
Mean	15.1	22.1	11.1	23.3	95.0	110.1	7.8	7.7
Total					1140	1322	94	92

Coastal temperatures are generally milder than the foothills with overall higher minimum and lower maximum temperatures. The foothills are also generally wetter, with overall higher mean monthly rainfall in most months except May to July. This is not reflected in the mean rainfall days, which are similar for the coast and foothills, indicating that overall rainfall is generally more intense on the foothills compared to the coastal plain.

Winds are predominantly north-easterly in summer interspersed with southerly changes associated with fronts moving up the coast. Winds are variable for the rest of the year with overall greater bursts of westerly winds tending south westerly in the colder months and north westerly in the warmer months.

The net effect of this climate in regards to the aquatic study areas is that the lower Dooralong Valley and Hue Hue Creek plus the Watagan Forest Drive ridge sub-catchments draining to Jillliby Jilliby Creek and the coastal plains are more exposed to the drying warm climate winds thus aiding evapotranspiration, whilst the incised gullies draining the Watagan Forest Drive ridge to Little Jilliby Jilliby Creek and Wyong River on the southern flanks of the ridge are more sheltered with regard to evapotranspiration stress.

This is reflected to some degree in the overall native vegetation in these areas, with Mountain Blue Gum-Turpentine moist shrubby open forest generally found on the south facing or sheltered incised slopes of the ridge and it sub-catchments and Spotted Gum-Grey Ironbark open forest on the drier exposed slopes (see vegetation mapping in Cumberland Ecology 2012). The degree of shelter from drying winds and higher temperatures afforded in the deeply incised gullies on the ridges could also account in part for the presence of the coachwood-crabapple warm temperate rainforest within these gullies.

1.3 Compliance with DGRs

The Department of Planning and Infrastructure (DP&I) Director General's Requirements (DGRs) issued in January 2012, provide the overall requirements for preparation of the EIS. The DGRs set out general requirements plus key issues that must be addressed in the EIS. Table 3 below summarises compliance with the DGRs in relation to the aquatic ecology assessment.

Table 3 Compliance of Aquatic Ecology Report with DGRs			
Agency	Requirement	Response	Report Sections
DP&I General Requirements	Description of existing environment using sufficient baseline data.	Three seasonal surveys undertaken as per AusRivAS methods	3.1 methods 4 results
DP&I General Requirements	Assessment of potential impacts and cumulative impacts as per relevant guidelines.	Assessment against guidelines as listed in Section 1.3.1.	Section 5 Impact Assessment
DP&I General Requirements & Key Issue Biodiversity	Avoidance, minimisation, mitigation, offsets and contingency plans	Assessed against guidelines as listed in Section 1.3.1.	Section 5 Impact Assessment
DP&I Key Issue Biodiversity	Detailed assessment of potential impacts on aquatic threatened species or populations and habitats	Assessment against guidelines as listed in Section 1.3.1.	2 databases, 2.2, Section 4 Study Results
DP&I Key Issue Biodiversity	Impacts on Jilliby State Conservation Area conservation and recreational values	Assessment against guidelines as listed in Section 1.3.1.	Section 5 Impact Assessment
DP&I Key Issue Biodiversity	Comprehensive offset strategy to ensure maintenance or improvement of aquatic biodiversity values of the region, medium to long-term.	Offset strategy includes creek plus riparian restoration activities on the project streams to provide improved aquatic biodiversity and corridor connection values	Section 5.3
DP&I Key Issue: Rehabilitation	Proposed rehabilitation strategy including objectives, methodology, monitoring, performance standards and completion criteria.	Monitoring to derive performance standards and completion criteria for aquatic ecology provided.	Section 6

1.3.1 Relevant Legislation & Guidelines

With regard to the assessment of aquatic ecology impact, a prime task is to determine whether there are any listed aquatic species or endangered ecological communities (EECs) in the study area or in areas that could be impacted by the proposal. Freshwater aquatic species and EECs are listed under the NSW *Fisheries Management Act 1994* (FMA), and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC).

One of the objectives of the Fisheries Management Act 1994 is to 'conserve key fish habitats (KFH)'– those aquatic habitats that are important to the sustainability of the recreational and commercial fishing industries, the maintenance of fish populations generally and the survival and recovery of threatened aquatic species.
Accordingly, the aquatic ecology impact assessment needs to show how KFHs are to be conserved or, if they are to be impacted, how these impacts can be minimised, mitigated or offset as per Department of Primary Industries (DPI) Fisheries' Guidelines (NSW Fisheries 1999a,b). DPI (Fisheries) has produced a series of KFH maps based on LGA boundaries and two portions of the Wyong Regional KFH map are shown below as **Figures 4** and **5** below.

Figure 4 indicates that there are defined Key Fish Habitats in Wallarah and Spring Creeks downstream of the Tooheys Road infrastructure area and in the area of the proposed rail loop.

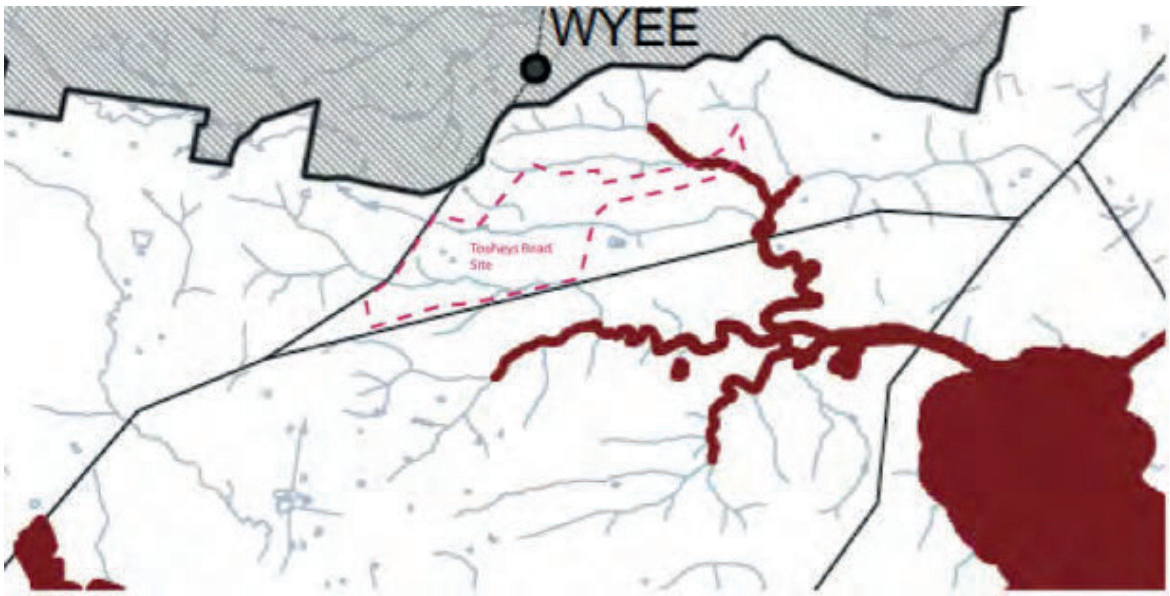


Figure 4 Portion of the DPI (Fisheries) Wyong LGA Key Fish Habitat Map (KFHs in red) showing the relationship of the Tooheys Road infrastructure area to defined Key Fish Habitats in Wallarah Creek, Spring Creek & Budgewoi Lake.

Figure 5 shows the relationship of the proposed longwall mining footprint and of the proposed Buttonderry infrastructure area to Wyong River, Jilliby Jilliby Creek, Little Jilliby Jilliby Creek and Porters Creek Swamp KFHs:

- Whilst the proposed mining area does not impinge directly on the Wyong River KFH, two sub-catchment creeks flowing to Wyong River from the south-west corner of the mining footprint at Bangalow Flat are defined as KFH.

- Hue Hue Creek within the proposed mining area and Buttonderry creek in the infrastructure area are not considered KFH but both drain to Porters Creek Swamp, which is a KFH.
- The whole Wyong River catchment drains to Tuggerah Lake KFH.

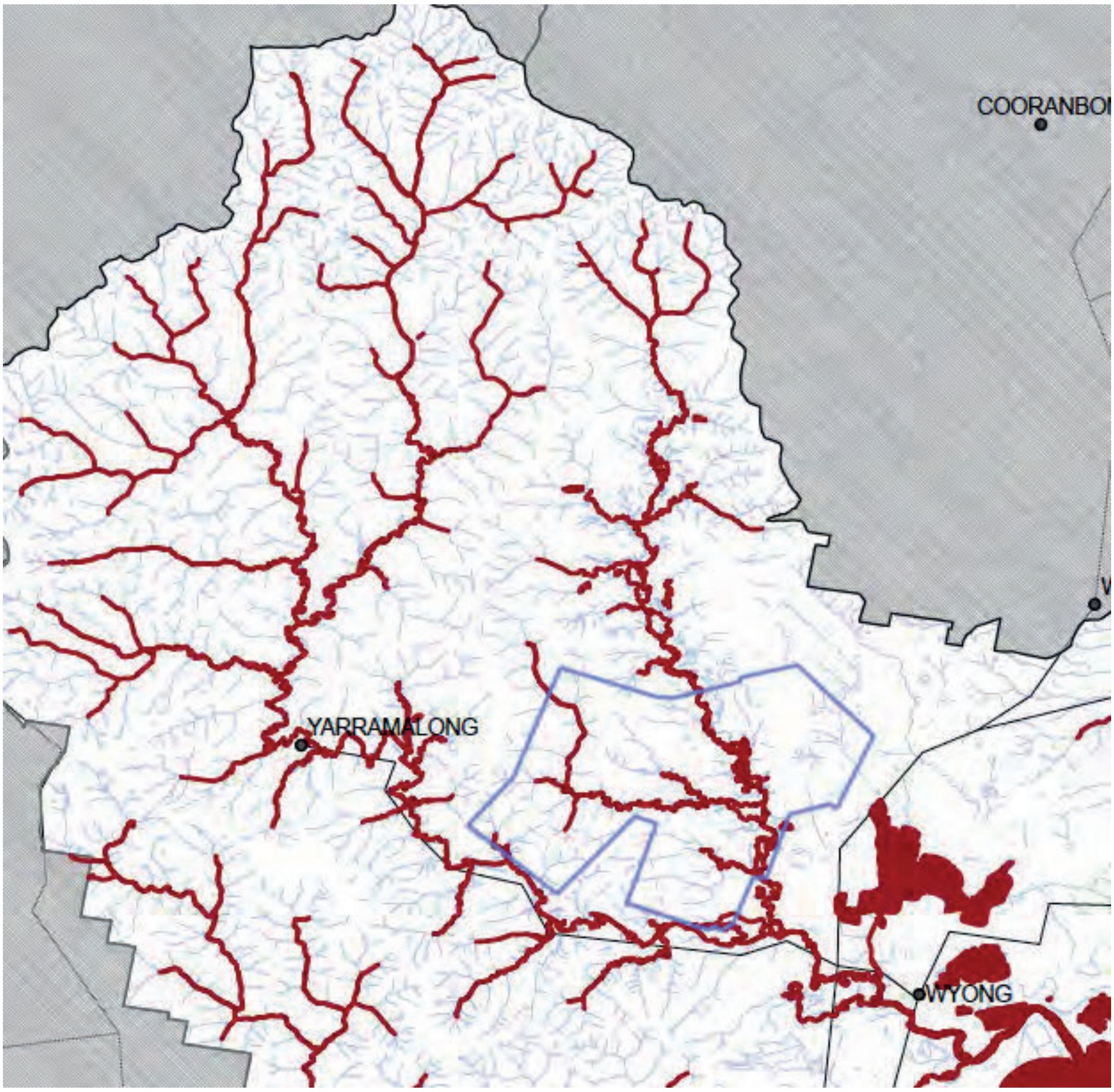


Figure 5 Portion of the DPI (Fisheries) Wyong LGA Key Fish Habitat Map (KFH- in red), showing the whole of the Wyong River, Jilliby Jilliby Creek and Porters Creek catchments draining to Tuggerah Lake in the south east corner. The proposed underground mine area boundary is shown in blue.

Aquatic ecosystems include those that are groundwater dependent, and protection of potential Groundwater Dependent Ecosystems (GDEs) is set out in the NSW State Groundwater Dependent Ecosystem Policy (2002). GDEs need to be identified using the eight-step rapid assessment (DLWC 2002), with specific potential aquatic GDEs including base-flow aquatic GDEs, aquifer & cave aquatic GDEs and submerged wetland GDEs. Terrestrial GDEs defined under the broad GDE classification include emergent vegetation wetlands, and these are considered separately in the Terrestrial Flora and Fauna report (Cumberland Ecology 2012).

Where relevant, the following guidelines have been taken into account when assessing the project impacts and mitigation for aquatic ecology:

- Threatened Biodiversity Survey and Assessment Guidelines for developments and Activities. Working Draft (DECC 2004).
- Guidelines for Threatened Species Assessment (DoP 2005).
- The Threatened Species Assessment Guideline – The Assessment of Significance (DECC 2007).
- Survey guidelines for Australia's threatened fish (AMBS).
- NSW State Groundwater Dependent Ecosystem Policy (DLWC 2002).
- NSW Wetlands Management Policy, (NSW State Government 1996).
- Policy & Guidelines - Aquatic Habitat Management and Fish Conservation (NSW Fisheries 1999a).
- Plan of Management for Jilliby SCA (DECCW 2010).
- Policy & Guidelines - Fish Friendly Waterway Crossings (DPI Fisheries 1999b).
- A Rehabilitation Manual for Australian Streams (LWRRDC and CRCCH).
- Mine Rehabilitation - Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia).
- Risk assessment guidelines for GDEs (DPI Office of Water May 2012)

1.4 Aquatic Study Aims and Objectives

In terms of overall study objectives, the aquatic ecology baseline study endeavours to answer the following questions:

- Where are the aquatic habitat resources in the project area?
- What are the ecological and riparian attributes of the project aquatic habitats?
- Which of the aquatic resources provide suitable and sustained aquatic habitat for fish and other aquatic biota?
- Is there fish passage in the various streams within the project area?
- Are there any protected or threatened aquatic species or communities residing within the study area, or any mammals such as platypus and Australian water rat that may utilise the aquatic resources of the project area?
- Are there aquatic Groundwater Dependent Ecosystems (GDEs)?

In terms of impact assessment for aquatic ecology, the study aims to provide an assessment that incorporates the objectives of the DECC 2005 guidelines for ecological assessments, namely to assess how the project can avoid ecological impact at the onset then, where impact cannot be avoided, how the impacts can be minimised and/or mitigated, and then provide suitable offset options for residual impacts.

2 LITERATURE REVIEW AND DATABASE SEARCHES

The following literature review surveys the literature and threatened species databases pertaining to aquatic biota, being plants and animals that are aquatic. Thus, some semi-aquatic species such as emergent riparian vegetation communities, fishing birds and amphibians are not considered in this review, as these species are considered under the terrestrial fauna and flora survey methods and assessment (Cumberland Ecology 2012). Platypus and Australian water rat are not listed as threatened but are nevertheless important water dependent species and these are included in this review.

2.1 Literature Review for Region and Locality

There have been a number of ecology and water quality surveys undertaken on behalf of proponents for the Project or more generally within the study area since the original exploration license was activated in the late 1990s. Literature review for this report has entailed a reappraisal of the earlier studies and/or reports, to provide some understanding of the available aquatic ecology data plus their value for the present study. These are addressed chronologically below. Where relevant, fish species' lists have been used to compile an expected fish list for the study area.

Cooper and Richardson (1982) – referenced in The Ecology Lab (2003), found six fish species in Wyong River above the weir and 3 species in Jilliby Jilliby Creek. The plague minnow *Gambusia holbrooki* was widespread, and an Australian bass *Macquaria novemaculaeta* was recorded from the middle reaches of Wyong River. This species migrates between freshwater and estuarine habitats. The Ecology Lab did not identify the other fish species.

Aitkins et al (1995) undertook aquatic flora and fauna surveys of the Tuggerah Wetland on behalf of Pacific Power. This site was also earmarked as a possible infrastructure site for the original mine proposal. The report provides the results of water quality, macroinvertebrate, fish, frog and aquatic plant surveys for the wetland and the creek draining to the wetland. There were 450 macroinvertebrate specimens identified from 38 families, and electrofishing yielded four fish species (long and short finned eels, a striped gudgeon *Gobiomorphus australis* and the plague minnow *Gambusia holbrooki*). Water quality indicated that the waters generally had variable dissolved oxygen levels ranging from 1.5mg/L to 6.6mg/L, acidic pH (3.8 to 6.7 pH units), elevated conductivity (340 to 1430 µS/cm) and low turbidity (2 to 28 NTU) – all characteristic of paperbark swamp forests in the region. The detailed macroinvertebrate species list provides a good background collection for comparison of similar paperbark swamp wetlands at the Tooheys Road infrastructure and rail loop site.

State Forests NSW undertook a fish survey in the Morrisset Forestry District EIS (referenced in ERM 2002) and recorded 8 fish species, all of which are likely to occur in the project study streams, especially the Wyong River catchment. ERM did not provide the fish list.

A progress report prepared for WACJV by ERM Mitchell McCotter (1998) refers to a number of estuarine studies undertaken in Tuggerah Lakes associated with the previous expanded mining proposal that included possible mining under Tuggerah lakes. These studies examined seagrass, benthic and estuarine fish communities of the Tuggerah Lakes, and are summarised in The Ecology Lab (1998). As there are no direct interactions of the present mining proposal with Tuggerah Lakes, no further assessment of these studies has been undertaken.

A further seagrass ecology study report was prepared by The Ecology Lab (2000) that provided a comparison of fish species in two locations in Tuggerah Lake (Tuggerah and Chittaway Bays), Lake Macquarie, and Brisbane Waters. The study listed a number of fish species that are also found in freshwaters and that could be expected in the Wallarah Creek and Wyong River catchments. These species were assessed against other freshwater fish studies to aid in compiling a potential fish list for the present study (see **Section 4.6**).

ERM Mitchell McCotter (1999) described various groundwater related studies initiated in 1998:

- A survey mapping wetlands within the proposed subsidence areas in the Doolalong and Yarramalong valleys indicated that many natural wetlands had been modified by dams to increase the water storage capacity in the wetland. A map showing the location and classification of the wetlands identified was developed but was not available in the report.
- A 'spring' survey based on questionnaires provided to land-owners provided information on location, flow rates and use of springs on private properties. The majority of springs were located near the base of hills and appeared to be accessing water from the shallow fractured rock aquifer. There were no data provide on the location or yields for these springs
- Field measurements of groundwater quality in 14 bores was undertaken in December 1998 and indicated that surface water levels ranged from 0 to 7.5m, pH varied between 4.8 and 6.8 pH units, conductivity (192 to 13310 µS/cm) and generally saline (11 of 14 bores >1000 µS/cm). Dissolved oxygen was uniformly low (range 0.2 to 3.13 mg/L) and turbidity was variable (0 to 1000 NTU).

Towell (1999) - referenced in The Ecology Lab (2003) - sampled water quality, fish and macroinvertebrates in five waterways draining to Tuggerah Lakes, including Wyong River and Jilliby Jilliby Creek. Towell recorded macroinvertebrate taxa from 63 families with high similarities between Ourimbah Creek and Wyong River assemblages. Nine fish species were recorded from five streams with Wyong River having the highest species diversity. The Ecology Lab report did not provide fish or macroinvertebrate details but used the results of the fish studies reviewed to compile an expected fish list for the Wyong River catchment. This fish list has been used for the present report (**Section 4.6**)

COAL (2001) provided an interim environment assessment report to the WACJV dated February 2001. This report made reference to aquatic ecology surveys undertaken in late 1999 as "*a pilot survey to determine the range of freshwater conditions within the study area and assess the health of the streams prior to the proposed development*" with sampling undertaken *"using the AusRivAS protocol*" (see **Section 3.2.1** of this report for details of this protocol). Sample locations "*included 24 sites across eight streams of surface facilities in the Wallarah Creek catchment and 18 sample sites within the subsidence area of the Wyong River catchment. Due to the large number of streams within the subsidence area, six streams were randomly selected…Sample site locations within a stream were determined using a stratified random design to ensure that 3 to 5 sample sites were obtained for sampling along upper, middle and lower reaches of each stream*". Water quality analysis using metered and laboratory analysis was also undertaken.

The COAL (2001) report provided observations that "*water quality was generally of medium to high quality*" and that a "*wide variety of freshwater invertebrate taxa were identified*" with the *"highest and similar diversity occurring within forested upland streams of the subsidence area and in the upper reaches of small streams within the surface facility area"*. The introduced plague minnow was said to be *"abundant in the lower reaches of all streams and absent from the upper ephemeral reaches of the surface facility streams"*. The COAL (2001) report did not include any reference to the aquatic ecology studies nor to any data.

ERM (2002) and The Ecology Lab October (2002) also made reference to the 1999 aquatic ecology study, and it was referenced as ERM (2001) *Wyong Areas Coal development Project. Surface facilities and potential subsidence areas Report No 106093.225RP1*. An extensive search of the WACJV report library and of their electronic database, and queries to ERM, have not produced a copy of this report. The database search did provide several draft reports entitled *Freshwater macroinvertebrate* *study for Wyong Coal Mine – Surface facilities and potential subsidence areas. Report prepared for COAL 99075RP3 in a later February draft),* and another ERM report dated March 2000 titled *Wyong Areas Coal Development Project Surface Facilities And Potential Subsidence Areas - Freshwater Ecosystems. Report prepared for COAL March 2000 Report Number 96093.09RP1.* Whilst none of these draft reports include detailed site location information (map grid references or location maps) detailed methods or results, the database search did provide the original macroinvertebate plus water quality data with some site location data. These data have been incorporated into this present aquatic ecology report (see **Sections 4.3 and 4.5**) with the caveat that the data were unable to be examined for quality control without further information on the original study.

ERM (2011) provides summary data of surface water monitoring results for the project area from 2005 to 2010 inclusive. This water quality monitoring program has continued, and data to March 2012 were available for this aquatic ecology assessment.

Umwelt (2008) provided aquatic macroinvertebrate survey data from potentially impacted creeks for the Austar Coal Extension Project south of Cessnock. It is considered that these survey results are of limited value for the present study owing to the distance between the two study areas.

SKM (2008a) prepared an REF for the upgrade of the Gosford-Wyong Wyong River Licences that included environmental flow studies leading to recommendations for the upgrade of the Wyong River weir fishway. This study formed part of the pre-feasibility studies for the Mardi to Mangrove Pipeline Project (reviewed below). Ancillary studies reviewed the effectiveness of the current weir (FCS 2008), provided an environmental flow literature review (TEL 2008), assessed the fish communities of the Wyong River, Ourimbah Creek, Wallarah Creek and Dora Creek (Cummings et al 2008), assessed aquatic macrophytes of the Wyong River (SKM 2008b) and assessed platypus usage of the Wyong River (Grant 2008).

SKM (2008b) recorded 12 aquatic plants species including one introduced species *Myriophyllum aquaticum* (Brazilian Water-milfoil). They noted that the actual distribution of aquatic plants was sparse and attributed this to extensive flooding in June 2007, evident in extensive erosion and channel scouring observed during the survey, which resulted in a reduction of suitable aquatic plant habitat and which would have resulted in a dramatic reduction in macrophytes from the river channel. The populations of macrophytes recorded in the 2008 study were either in a state of colonisation or regeneration from damaged stocks.

A number of other aquatic biota studies were undertaken for the Mardi to Mangrove Link Project assessing the environmental impacts of the proposed 21km long water transfer pipeline down the Yarramalong Valley, alongside the Wyong River:

- GHD (2008) described the results of the Grant (2008) platypus studies in the Wyong River. The report recorded platypus and suitable platypus habitat all along the river (including the river reach alongside the Project mine footprint). GHD also concluded that the river supported Australian water rats. Applying the attributes assessment protocol used to assess platypus habitat in the Wyong River to the Jilliby Jilliby Creek catchment, it can be demonstrated that there is additional platypus habitat in that catchment.
- GHD (2009) undertook two seasonal aquatic ecology surveys (aquatic habitat, macroinvertebrate and fish) in the Wyong River in Autumn and Spring 2008 and concluded the average of each of their biological indices for sites within the Wyong River were much higher than the averages for tributary sites, probably because the Wyong River provides better habitat conditions than the tributaries, by exhibiting a higher diversity of habitat types and satisfying a greater range of ecological requirements for more ‘sensitive’ macroinvertebrate taxa.
- GHD (2009) recorded ten freshwater fish species within the Wyong River over their two seasonal surveys, all of which are considered common to south-eastern Australia. Of these ten species the Mosquito Fish (*Gambusia holbrooki*), is introduced. The native freshwater fish fauna largely consists of species that have a marine dispersal stage or a high tolerance to salt. The Common Galaxias (*Galaxias maculatus*), Striped Gudgeon (*Gobiomorphus australis)*, Longfin Eel (*Anguilla reinhardtii*) and Australian Bass (*Macquaria novemaculeata*) are catadromous, i.e., they spawn in marine areas, and the resulting juveniles have an estuarine dispersal stage prior to re-entering freshwater. These species require free passage between the estuarine/marine environment and freshwater to complete successful life cycles. Construction on waterways has the potential to severely impact resident fish communities by preventing this migration.

SKM (2010) made an assessment and provided documentation of groundwater and surface water data for a portion of Wyong LGA that encompasses the project area.

Fletcher (2010) studied the platypus populations of the Wyong River catchment that included populations in the Jilliby Jilliby Creek sub-catchment.

NSW Office of Water reported on a state-wide riverine ecosystem monitoring program (NOW 2010) that includes aquatic macroinvertebrate and fish sampling from non-ephemeral (i.e., flowing) streams in selected catchments, including the Tuggerah Lake catchment. The project includes the OEH Monitoring Evaluation and Reporting (MER) program for aquatic macroinvertebrate sampling. Whilst internet searches have indicated that these data are not available on-line, OEH have provided Spring 2012 macroinvertebrate sampling results for two sites; in Wallarah and Ourimbah Creeks. The latitude and longitude information provided by OEH for the Wallarah Creek site places the sampling site in the Wallarah Creek south arm, about 1km south of the project north arm site (see **Figure 3**). Compared to the project Wallarah Creek study site, the OEH study site is on a higher order stream segment within a predominantly undisturbed native vegetated sub-catchment south of the Motorway Link Road. This site is an undisturbed reference aquatic ecology site in contrast to the disturbed sub-catchment study sites located within the Tooheys Road infrastructure area.

ERM (2011) undertook surface and bore-water quality monitoring for the Project and provides summary data of surface water monitoring results from 2005 to 2010 inclusive.

Hose et al (2012) undertook aquifer biodiversity studies in Gosford LGA that included fractured sandstone aquifers of the Kulnura Plateau and of alluvial and coastal sand aquifers. Stygofauna (groundwater dwelling fauna) were only found in parts of the fractured sandstone aquifer with presence limited by the porosity of the aquifer, which for the sand-dominated matrices of sand aquifers, was too small for stygofauna to inhabit.

2.2 Threatened Species and EEC Database Search Results

In 1999 the Fisheries Management (Amendment) Act inserted threatened species provisions into the Fisheries Management Act 1994 (FMA) for the protection of these biota and for aquatic habitat protection. The FMA is administered by the Department of Primary Industries (DPI Fisheries), and the conservation aspects of the FMA are set out in two NSW Fisheries Policy and Guideline Documents (NSW Fisheries 1999a, 1999b).

The following database searches were conducted for specific details on possible threatened species, ecological communities and key threatening processes; (i) Commonwealth DSEWPaC EPBC Protected Matters Report of a square area 37x37 km (1370km^2) to encompass the whole project area, (ii) NSW DPI (Fisheries) Records Viewer database (iii) Australian Museum Biomap database and (iv) OEH BioNet database/atlas search for the Wyong LGA:

- The search of the DPI (Fisheries) Records Viewer, the Australian Museum Biomaps Viewer for the Wyong LGA and for the Hunter and Central Rivers CMA and the OEH BioNet Atlas search for the Wyong LGA yielded no records for protected fish and there were no threatened aquatic species listed.

- The EPBC Act Protected Matters search provided two threatened fish species "that may be present", Australian Grayling *Prototroctes maraena* (vulnerable), and Macquarie perch *Macquaria australasica* (endangered).
- The DEH Atlas search provided records for the Giant dragonfly *Petalura gigantea*), listed under the TSC Act. Both records were from sites around Tuggerah Lake. Whilst this species is not considered an aquatic species, it spends most of its life in burrows under swamps.
- Adams emerald dragonfly *Archaeophya adamsi* is listed as 'vulnerable' under the FMA and whilst the database searches did not indicate this species occurring in the Wyong LGA it is recorded from Somersby Falls (17km south) and from Hungry Creek Way in Wollemi National Park to the west.
- A cross-check of the 2010 Wyong Shire State of the Environment report did not yield any further listings for threatened aquatic species or EECs.

Morris et al (2001) provides a review of threatened and potentially threatened freshwater fishes of coastal New South Wales and the Murray-Darling Basin. This report was also consulted to check whether there were any potentially threatened freshwater fishes which could occur in the study area. None were listed.

Previous aquatic ecological surveys for Wyong River and Wallarah Creek catchments (as reviewed in **Section 2.1**) were also inspected for threatened species information or occurrences and no aquatic species listed under the FMA or EPBC were reported or are expected. Finally, none were reported from the studies undertaken for this report.

2.2.1 Listed Aquatic Species that may be present

Australian Grayling *Prototroctes maraena*

The recovery plan for this species (Backhouse et al 2008) notes that the Australian grayling is endemic to south-eastern Australia, including Victoria, Tasmania and New South Wales, and is a diadromous species that inhabits estuarine waters and coastal seas as larvae/juveniles, and freshwater rivers and streams as adults. On the mainland it occurs from the Shoalhaven River (NSW) south and west to the Hopkins River system (Vic). Australian grayling spend most of their lives in freshwater, inhabiting rivers and streams, usually in cool, clear waters with a gravel substrate and alternating pool and riffle zones, but can also occur in turbid water. With its relatively short life span, most individuals spawn only once before they die, so populations are especially vulnerable to any disruption of spawning or recruitment.

Inspection of the available fish records for Tuggerah Lakes and its catchment streams indicates no occurrences of this species from the locality and it is concluded that it currently does not occur in this estuary or its coastal streams. Notwithstanding, there would appear to be suitable habitat at least in the Wyong River, and probably in Jilliby Jilliby Creek and its recolonisation, either naturally or by re-stocking cannot be discounted entirely. It is concluded that measures taken for the protection of fish habitats generally would be sufficient to protect potential habitat for this species if it were to recolonise the estuary.

Macquarie perch *Macquaria australasica*

As noted on the NSW Fisheries Scientific Committee's final determination, *Macquaria australasica* is endemic to the southern tributaries of the Murray-Darling River System, and is also found in the Hawkesbury-Nepean and Shoalhaven river systems. It is a relatively fecund, fast growing and early maturing species, which spawns in shallow upland streams or flowing parts of rivers and deposits adhesive eggs in stones and gravel in riffle areas. Macquarie perch are found in both river and lake habitats; especially the upper reaches of rivers and their tributaries. It is a popular angling species, and is highly regarded for its sporting and edible qualities.

Inspection of the available fish records for Tuggerah Lakes and its catchment streams (see review in **Section 2.1**) indicates no occurrences of this species from the locality and it is concluded that it currently does not occur in this estuary or its coastal streams and is unlikely to occur, other than by active stocking.

Adams emerald dragonfly *Archaeophya adamsi*

The Adams emerald dragonfly is listed as vulnerable under the FMA and is known from several sites in the greater Sydney region but is not recorded from the project area streams. However, as Adams emerald dragonfly is reported from Somersby Falls (17km south) and from Hungry Creek Way in Wollemi National Park to the west, there remained a possibility that they could reside in Jilliby SCA creeks.

Based on the stated habitat requirements for the larvae of this species, (i.e., that larvae live for up to 7 years in small creeks with gravel or sandy bottoms, in narrow, shaded riffle zones with moss and rich riparian vegetation), this possibility would only be valid if there are creeks and pools that hold clear water that are running often. Given the prolonged average wet weather cycle experienced over the study area for the duration of the aquatic studies undertaken for this EIS since July 2011, this possibility could not be discounted (or tested) until a suitable period of dry weather occurred, when a search for suitable habitat could be made.

Such a dry weather period became available in August 2012 and a targeted search of upland creeks draining from the Watagan Forest Drive ridge was undertaken on 17 and 21 August 2012. This survey provided sufficient evidence that creeks draining from the Jilliby SCA are ephemeral and it is unlikely that there would be suitable stream habitat in the study area to support Adams emerald dragonfly larvae for sufficiently long periods to complete its lifecycle (see **Section 4.4** for survey details and results). Notwithstanding this conclusion, the on-going aquatic ecology baseline surveys will continue to include targeted surveys for Adams emerald dragonfly habitat.

Giant dragonfly *Petalura gigantea*

The Giant dragonfly *Petalura gigantea* Leach is listed as *Endangered* under the TSC Act. Larvae are slow growing and may live for 10 years or more. The adults emerge from October/November to December and probably survive for a few months. They are poor flyers and do not readily disperse. The Giant dragonfly is most often reported in the adult stage as part of targeted terrestrial fauna surveys and its wetland habitats are generally described as part of terrestrial vegetation surveys (see the Terrestrial Flora and Fauna report for this EIS). Accordingly, the focus of consideration in this aquatic ecology report is on the semi-aquatic larval habitat availability within the study area.

Larvae live in long chambered burrows under permanent swamps and bogs. The burrows can contain numerous entrances to both aquatic and terrestrial habitats, from which the larvae are thought to emerge at night and in wet weather to feed on insects (including odonate dragonfly and damselfly larvae) and other invertebrates. Larvae are not known to swim, and avoid open water. They are distinguished from other species of dragonfly by this apparent inability to swim and by their use of terrestrial habits. Based on a consideration of the known larval habitats of this species (e.g., Wingecarribee Swamp, high swamps on the Newnes Plateau and coastal sedge wet heath in the northern rivers), it would appear that the preferred larval swamp habitat is generally mossy or peat-like swamp that is not frequently flooded.

There are no records of highland swamps in the gullies draining the Watagan Forest Drive ridge-line or from the ridge separating Dooralong Valley from Hue Hue Creek catchment, and swamps associated with the Dooralong Valley alluvium, are generally more sandy and subjected to reasonably frequent flooding. Accordingly the shallow surface alluvium can be expected to become saturated on a regular basis, which would likely cause flooding of burrows. It is therefore considered unlikely that there is suitable Giant dragonfly larval habitat available in the proposed mining subsidence area. Whilst there are freshwater wetlands in the Tooheys Road infrastructure area, there are no coastal heath swamps recorded from there (Cumberland Ecology 2012) and therefore it is considered unlikely that there is suitable Giant dragonfly larval habitat available in the Tooheys Road infrastructure area.

2.3 Literature Review Summary

The review of literature indicates that there is a large, extended but fragmented surface water quality database available for the project and for the Mardi-Mangrove Pipeline Link project that, combined with the more recent project data, is adequate for establishing long-term water quality goals for the relevant Wallarah Creek and Wyong River sub-catchments potentially impacted by proposed mining operations. The field and laboratory water quality results from at least 1997 through to 2002 are available electronically but not in any coherent form and the Mardi to Mangrove Link data are contained in reports not readily available. It is recommended that a combined water quality database be established as a basis for implementing future mine surface water protection measures and guidelines.

There are aquatic ecology data for the Tuggerah Lake catchments from the late 1990s through to the present time that, combined, are adequate for establishing long-term stream-health goals for the relevant Wallarah and Wyong River sub-catchments potentially impacted by proposed mining operations. The combined data indicate that the Wyong River and Wallarah Creek catchments provide suitable habitat to support diverse aquatic macroinvertebrate assemblages, a variety of native fish species plus animals dependent on aquatic habitats such as platypus and Australian water rat. As for the water quality data described above, the available project aquatic ecology data from the late 1990s are fragmented and incomplete and the Mardi-Mangrove Link project data are contained in reports not readily available. It is recommended that an aquatic ecology database be established as a basis for long-term stream-health goals for the project and that results from on-going aquatic ecology surveys be incorporated into this database.

The literature review noted that there has been previous work done to identify springs in the study area and to classify the various wetlands and dams in the Doolalong study area. These data should be retrieved and incorporated into a single database, then extended with targeted surveys as required for the combined flora, fauna and groundwater studies.

There are no threatened aquatic plants, fish or macroinvertebrate species or populations, as listed under the threatened species provisions of the Commonwealth EPBC Act or under the threatened species provisions of the NSW Fisheries Management Act 1994 recorded from the Wyong River and Wallarah Creek catchments:

- The two fish species listed under the EPBC Act (Australian grayling and Macquarie perch) are most likely not present and are not expected to be present.
- Whilst the mountain creek habitats of the Jilliby SCA have the potential to support Adams emerald dragonfly, it is concluded that they are unlikely to occur by virtue of insufficient permanent and running water habitats to support this species over its extended (seven year) aquatic life stage, i.e., by virtue of the intermittent nature of the streams and their potential to dry out completely over dry periods. Nevertheless, searches for possible suitable habitat for this species in the Little Jilliby Jilliby Creek upper and mid catchments will continue.
- Giant dragonfly is listed under the TSC Act and adults are reported from coastal locations around Tuggerah Lakes. Larvae for this species live in burrows under swampy lands and it is concluded that it is unlikely that there is suitable larval habitat in the mining subsidence area. It is recommended that additional targeted searches for this species and its habitats be continued.

3 AQUATIC BASELINE STUDY & ASSESSMENT METHODS

3.1 Study Design and Study Elements

The first step for study design was a desk-top assessment of the potential aquatic habitat values for the sub-catchments and streams, based on available topographic information. **Figures 2** and **3** in **Section 1** show the relationship of the proposed mine and infrastructure areas to the various river and creek drainage sub-catchments draining over or through the proposed mine footprint, and **Figure 6** provides an assessment of stream order for the streams and drainages above or near the mine footprint; derived from spreadsheet survey data provided by the proponent. The proponent used these data to produce stream longitudinal profiles (see e.g., **Figure 7** that shows longitudinal profiles of the three major streams in the mining area):

- There is one sixth-order stream – Wyong River, and one fifth-order stream - Jilliby Jilliby Creek. These are major waterways with the greatest potential for fish habitat, fish passage and permanent aquatic habitats. These streams require sampling.
- The floodplains of Jilliby Jilliby Creek (in particular) also provide numerous dams, billabongs, lagoons and other ponded waters, mostly in private lands. Given the flooding relationship of these habitats with the creek, these will need to be sampled for aquatic attributes opportunistically (i.e., as access becomes available).
- There is one fourth-order stream, the lower floodplain section of Little Jilliby Jilliby Creek, and most of the remaining Little Jilliby Jilliby Creek within the mining footprint is third-order. This is an important stream that is likely to provide fish passage at least for some of its lower length, and permanent aquatic habitats in the form of drought refuge pools and this system also needs to be sampled.
- There are three other third order streams in the mining area footprint Lower Myrtle Creek, Lower Armstrong Creek (north arm), and lower Boyds Lane Creek (draining to Wyong River). These are much shorter and drain smaller catchments than Little Jilliby Jilliby Creek and are unlikely to provide fish passage or primary fish habitat. These should be investigated for suitable aquatic habitat and aquatic sampling could be delayed for later pre-construction surveys. Further, inspection of the topographic information indicates that lower Myrtle Creek is completely in private lands and there may be access issues.
- There are 26 second-order streams and these are listed in **Table 4**. Seven drain south west to Wyong River, six drain to Little Jilliby Jilliby Creek direct and two drain to Little Jilliby Jilliby Creek via Myrtle Creek. Three are arms of

Armstrong Creek. A selection of these creeks should be inspected for suitable aquatic habitats with aquatic sampling staged over later pre-construction surveys.

- There are numerous first order drainages. These are relatively short and generally drain very small headwater catchments (**Figures 2** and **6**) and are likely to be ephemeral with little or no aquatic habitat available. Some are located in the mining footprint and drain into 2nd order streams outside the footprint (e.g., drainages to 2-22 (see **Figure 6**). A selection of these drainages should be inspected for determining their aquatic ecology attributes, with additional inspections of other first order drainages if necessary during later pre-construction surveys.

Table 4 Second Order Streams - Mining Area

W2CP Named Creek or Stream Description	*Stream Number	**Streams inspected for aquatic habitats and water quality sampling
"Maculata Road" Gully	2-01	
Myrtle Creek (western arm)	2-02	
Myrtle Creek (eastern arm)	2-03	Myrtle Ck East arm
"NoonaMeena - Smithys Road"	2-04	
"Goldsmiths Point"	2-05	
Youngs Gully	2-06	
Little Jilliby Creek (upper reaches - eastern arm)	2-07	K1 K2 East Little Jilliby Ck
Splash Gully	2-08	I Lower Splash Gully
Calmans Gully	2-09	
Bangalow Flat (upper eastern arm -Boyds Lane)	2-10	
Bangalow Flat (upper western arm - Boyds Lane)	2-11	
Bangalow Flat (lower eastern arm -Boyds Lane)	2-12	
"Harris Point"	2-13	C1-C3 Harris Point
"Woodburys Point (east branch)"	2-14	B Woodburys Point Ref
"Woodburys Point (west branch)"	2-15	
Armstrong Creek (northern arm)	2-16	A3 North Armstrong Creek
Armstrong Creek (central arm)	2-17	
Armstrong Creek (southern arm)	2-18	A1 A2 Upper South Armstrong
"Kidmans Lane (east)"	2-19	
"Kidmans Lane (west)"	2-20	
"Amber" Gully	2-21	
"Barnwood Park" Gully (south)	2-22	Bailys Road south
"Barnwood Park" Gully (north)	2-23	F Mid Dittons Rd Ck Crossing
"Unnamed"	2-24	D Lower Whitmans Gully
"Dittons Road" Gully	2-25	E Mid Lowers gully
"Dittons Road" Gully	2-26	G Low Sth Baileys Rd Ck

Notes: * See Figure 6 for W2CP Stream Locations; ** See Section 4.4

A selection of sites based on these determinations was made and priority for sampling distributed as per the above desktop review recommendations. Site selection also included sites from Hue Hue Creek mining footprint and from the two infrastructure sites. Eventually, owing to a combination of wet seasons, lack of forest access via flooding or no private land access, some sites could not be sampled in the three aquatic ecology sampling seasons reported for this assessment.

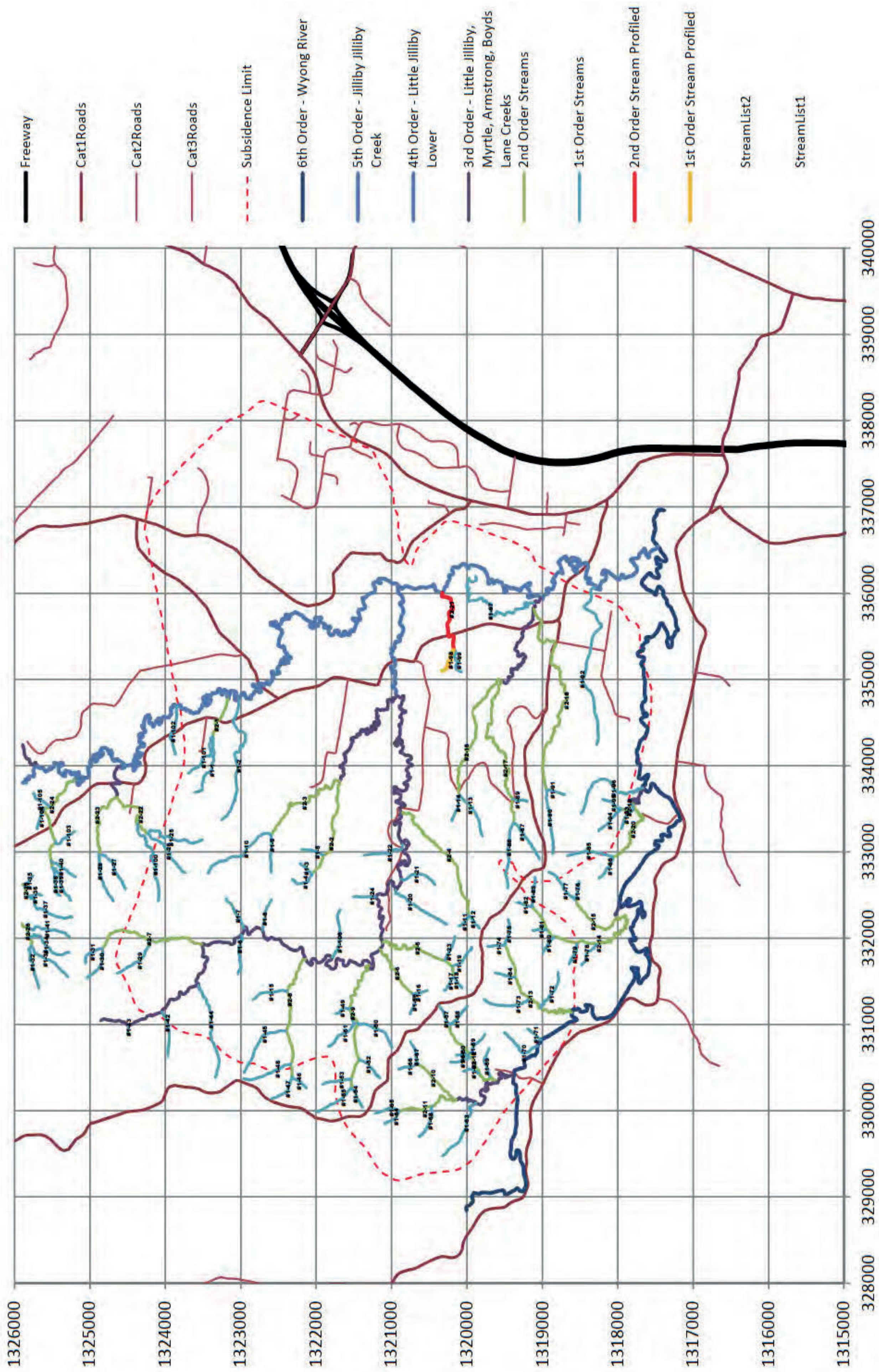


Figure 6 Project Stream Order Assessment for Streams over or near the mining footprint

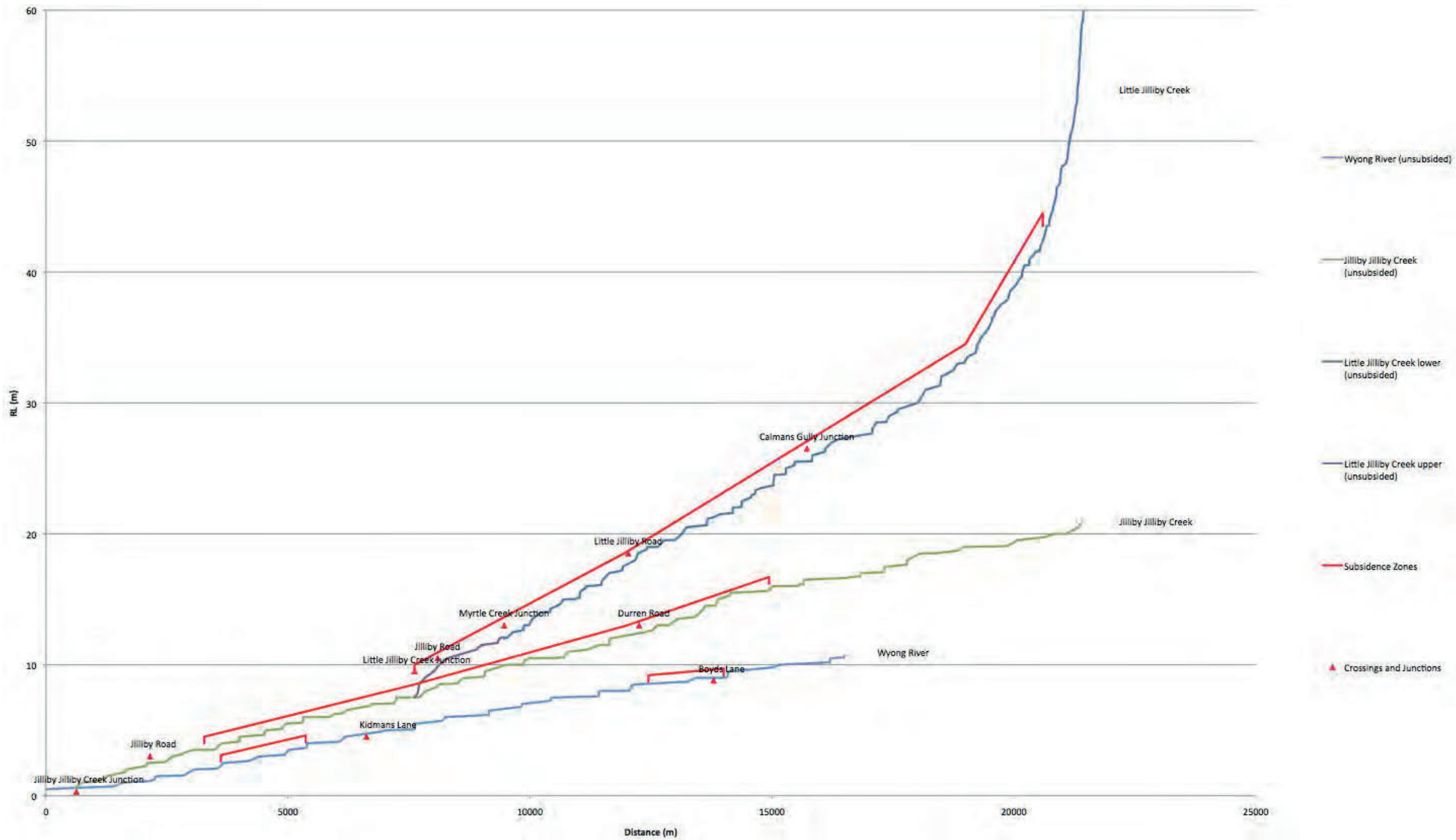


Figure 7 Stream Profiles for Wyong River, Jilliby Jilliby Creek and Little Jilliby Creek

Figures 2 and **3** provide locations of aquatic ecology survey sites that were assessed for this report. These sites form a sub-set of sites selected from an initial desk-top scoping study of sites that would be required to meet the combined approval, construction and operational monitoring needs for the project over the project life-time.

In regard to preliminary assessment for approval purposes, the sites provide a broad spectrum of aquatic sites over the study area, and were able to be visited during the study period. A sub-set was selected for the initial aquatic ecology baseline surveys (see **Table 5** below), to address the study aims for the EIS as set out in **Section 1.2** above.

Table 5 Project Baseline Aquatic Ecology Site Sample Schedule

Catchment	Site	Coordinates		Full sample	SDL	O/N Fish	RCE
		E	N				
Wyong River	WR1	344202	6319627	1		3	
	WR3	347325	6317535	1		2,4	
Jilliby Jilliby Ck	JCUp	347065	6326369	1			
	JC2E	348742	6323131	1			
	JC2W	348671	6323105		2,4		2
	JC3	349885	6321367		2		2
Little Jilliby Jilliby Ck	LJ4	347307	6321163	1			
	LJDn	349770	6321259	1		2,4	
Spring Ck	SWUp	356266	6324790				2
	SW1	357437	6324827	1		2,3	
	SCDn	359360	6324867				2
Wallarah Ck	WCUp	355830	6324108				2
	WC1	356608	6324188	1		2	
	WCDn	357507	6324128				2
Buttonderry Ck	BC1	353035	6323284	1		3	
Hue Hue Creek	HHMd	351545	6322809	1			

Note: 1- Sampled for all surveys
2- Sampled for Autumn 2011
3- Sampled for Spring 2011
4- Sampled for Autumn 2012
Full sample includes SDL, macroinvertebrate sampling and RCE
O/N fish represents overnight fish traps

Note that for much of the baseline survey period, and in particular for the initial two seasonal surveys (Autumn and Spring 2011 through to February 2012), the study area was predominantly wet with abundant river and creek flows plus localised flooding. From February to May 2012 there was monthly average rainfall preceding the Autumn 2012 'dry weather' seasonal sample. Accordingly the adopted set of baseline sites indicated in **Table 2** are sufficient to assess the aquatic ecology of the study area under wet and wet-to-dry transitional weather conditions.

The formal seasonal baseline surveys did not include sampling of farm dams, shallow lagoon sites in private lands or upslope forest and SCA sites, due to weather and property access restrictions. Given the intimate interrelationship between the shallow lagoons and many of the floodplain dams with the three main streams via floods over the study survey period, it is considered that these dams and lagoons would have yielded aquatic ecology results similar to those derived from adjacent stream sites. As the prevailing weather cycle becomes drier and the dams and lagoons remain isolated from the streams for longer periods, sampling of strategic and representative dams and lagoons, including those classified as KFH, will become more important (see also **Section 4.3** for details of additional dry weather water quality sampling undertaken in August 2012). These sites would be added to the study site inventory as they are located and sampled during the continuing pre-construction baseline surveys. That is, the intention of future studies is to augment existing sites by adding, re-locating and/or excising sites as more information regarding the study area becomes available from the continuing baseline surveys and as mine plans and infrastructure area layouts are refined.

The adopted sampling methodology to achieve the study aims incorporated the following tasks to be undertaken at each site:

- Sampling the aquatic macroinvertebrate fauna twice a year (in spring and autumn) using the Australian River Assessment System (AusRivAS) sampling, sorting and identification protocols (see **Section 1.2.2** below). Note that for AusRivAS sampling purposes 'autumn' is defined as March 15 to June 15 and 'spring' is defined as September 15 to December 15.
- Recording of changes in site riparian and aquatic habitat condition and of aquatic plant distribution within the study areas at each sampling time.
- Estimation of fish occurrence by a combination of overnight or short-term bait-trapping, dip netting and observation, with all captured fish identified in-situ and immediately released wherever possible. Given the flood conditions for much of the survey period, over-night trapping was generally not possible. Further, with mostly good fish passage connection between the major streams and the lower sections of many third and some second order streams, it was concluded that the fish fauna of the study area would be able to be inferred from the available combined Wyong River fish surveys, as reviewed in **Section 2**).
- Metered depth profiles of basic water quality parameters at each site.
- Platypus and Australian water rat habitat surveys and collection of turtle, reptile and aquatic bird observations during field sampling activities.
- Collection of alluvial bore waters from relevant sub-catchments to characterise the study area stygofauna.

3.2 Aquatic Macroinvertebrate Sampling

The aquatic macroinvertebrate assemblages are determined using the standardised Australian River Assessment System (AusRivAS) sampling protocol (Turak et al 1999, Turak et al 2004, Chessman 2003b), which provides a number of definitions of sites, and of habitats within sites, for selection of sampling locations. The following AusRivAS definitions are relevant and sampling has conformed to these definitions:

- A site is "a stream reach with a length of 100 m or 10 times the stream width, whichever is the greater"
- A riffle habitat is "an area of broken water with rapid current that has some cobble or boulder substratum". However, “sampling riffles where the substratum consists predominantly of large boulders may be difficult and may not produce reliable results".
- Edge habitat is "an area along the creek with little or no current".

3.2.1 AusRivAS sample protocol

Ideally, AusRivAS recommends that, wherever possible, two habitats (riffles and edges) be sampled at each site and that a particular reach within each of the sample locations is selected on the basis of it being (i) a reach with high drought resistance (generally based on pool size, depth and riparian cover) and (ii) a reach with high aquatic habitat diversity; ideally deep pools connected by gentle riffles, abundance of stream bed litter, presence of snags, presence of aquatic vegetation and good extent of cover of overhanging riparian vegetation.

In practice, given that over extended periods the creek sub-catchments are often dry and sometimes comprise isolated pools unconnected by any surface flow with limited riffle sections available for sampling, it was concluded that pool 'edge' samples would provide the optimum sampling unit, as riffle samples could not be guaranteed for all (or possibly even for many) sites at all sample times.

3.2.2 Field methods for macroinvertebrate sampling

Macroinvertebrate assemblages are sampled using a 250 µm mesh dip net over as many aquatic 'edge' habitat types as can be located within each of the pools along the defined stream reach. Net samples are then placed into white sorting trays for in situ live sorting. Live sorting (picking) is undertaken for up to 1 person-hour (with a minimum of 40 minutes), as per the AusRivAS protocol. Following cessation of live picking, further observations are made of the pool edge sample areas for surface aquatic macroinvertebrate taxa (e.g., water skaters and spiders) and any other taxa (such as freshwater crayfish) not collected by the dip netting process. Where possible (or necessary) representatives of these organisms are collected and added to the dip net samples.

Specimens for which positive identifications can be made in the field (especially the rarer specimens such as e.g., water scorpions), were generally released. That is, for protection of the pool macroinvertebrate integrity we adopt a 'sampling with replacement' method. Notwithstanding this procedure, for most taxa that can be positively identified in the field, at least one of each of the field identified taxa are retained as a representative of that taxa for that sampling event. For all other macroinvertebrate taxa where field identifications are not definitive, specimens are retained for later detailed taxonomic analysis in the laboratory. Notes are also kept of the presence of burrows and holes that are present in the site aquatic habitats (i.e., as indications of yabbies or burrowing dragonflies).

All retained specimens are placed in sample jars preserved in 70% ethanol for subsequent laboratory identification. Sample jars are labelled and paper laundry tags are inserted noting the sample site, sample date and sample collector/picker initials.

3.2.3 Laboratory methods for macroinvertebrate samples

In the laboratory, taxonomic identifications are generally facilitated using Maggy lights or binocular dissecting microscopes. The following taxonomic guides have been found to be the most useful; CSIRO, Land and Water Resources & Environment Australia (1999), Hawking & Smith (1997), Hawking & Theischinger (1999) and Williams (1980).

Organisms are identified (as a minimum) to the appropriate taxa level as per AusRivAS protocols. These are as follows; family level for all insect taxa except Chironomids which are taken to sub-family). Collembola arthropods (springtails) are classified as a single class and the arachnid arthropods (spiders and mites) are classified as two orders. For the mites (Order Acarina) we have taken them to sub-order classification level where possible. Crustaceans were taken to Family level where suitable keys are available. Ostracoda were left at Class level. The worm like taxa are shown at Phylum or Class level. For all taxa, where suitable keys were available, taxa were identified to lower levels of taxonomy.

The sorted specimens are then transferred to individual glass vials (one per family/sub-family) and paper laundry tags inserted into each glass vial with the sample site, sample date and initials of taxonomist noted on the tags. Glass vials are then topped up with 70 % alcohol, sealed with plastic lids and placed back into the original field sample jars. Where there are any individual specimens where the collected material is too indistinct or fragmented to assign a definitive identification, the samples are dispatched to relevant Australian Museum specialists or other specialists, as recommended by EPA. For all samples the following taxonomic QA/QC procedure is followed:

At least ten percent of the samples/sites are selected at random and the individual retained taxa are identified without reference to the original identifications. A table is then made of the original identifications verses the second identifications, indicating where there were any anomalies in identification (if any). If there are no anomalies, the QA/QC sample protocol is accepted and no further QA/QC checking is undertaken. If there are differences in identifications, all the samples containing the related taxa are re-examined to clear up the anomalies.

Following this procedure, and if there have been anomalies, an additional 10 percent of the remaining samples are chosen and the QA/QC procedure re-applied. This process continues until there are no differences between original identifications and QA/QC identifications.

3.2.4 Macroinvertebrate data evaluation

The aquatic invertebrate assemblage for each sample site is described in terms of the site Taxa Diversity (number of individual AusRivAS taxa) and in terms of a site SIGNAL score. SIGNAL (Stream Invertebrate Grade Number Average Level) is a pollution tolerance index for stream macroinvertebrates. The indices are derived by correlation analysis of macroinvertebrate occurrence against water chemical analysis (Chessman 1995). The water chemistry attributes generally used are temperature, turbidity, conductivity, alkalinity, pH, dissolved oxygen, total nitrogen and total phosphorus (Chessman 2003a). Site SIGNAL scores are graded into the following generalised categories (Chessman *et al.* 1997):

- SIGNAL Index > 6 = Healthy Unimpaired
- SIGNAL Index 5-6 = Mildly Impaired
- SIGNAL Index 4-5 = Moderately Impaired
- SIGNAL Index < 4 = Severely Impaired.

SIGNAL indices may be regionally specific (e.g. SIGNAL HU-97 developed for the Hunter Valley Catchment - Chessman 1997), or applicable Australia wide (e.g.

SIGNAL-2, Chessman 2003a). SIGNAL-2 was used for the GHD (2009) Wyong River surveys and for the present study SIGNAL-2 scores are also applied. Taxa with no published SIGNAL score are excluded from the site SIGNAL analysis.

Once individual taxa SIGNAL indices have been applied, site SIGNAL scores are calculated as the mean of the individual taxa SIGNAL indices. For coherent groups of sites (e.g., all sites within a stream/river or all dam sites within a catchment), combined stream or habitat type (dams) scores can be calculated in the same way from the combined taxa for the stream/habitat types. Site and stream/habitat SIGNAL scores can then be compared across each survey and between surveys.

The site taxon data are also used to derive site EPT scores where EPT refers to the sum of all families from three common insect orders Ephemeroptera, Plecoptera, and Trichoptera, that together provide a further indication of aquatic habitat health.

3.3 Field Sampling Methods for Fish and other Vertebrates

At each macroinvertebrate sampling site four fish bait traps (dimensions 250 mm by 250 mm by 400 mm, 4 - 5 mm mesh size and 50 mm diameter entrance) are set at suitable locations. These are left in the stream either overnight, or for the duration of the combined macroinvertebrate sampling and live picking survey (minimum 1.5 hours) and then retrieved. Captured fish are identified in situ and released. Any fish caught or observed as part of the macroinvertebrate dip net sampling are also identified, noted and released. Fish specimens that become deceased during the sample process are retained with macroinvertebrate samples, and identified using Allen et al (2002) and McDowall (1996). Any fish retained that are not positively identified are sent to the Australian Museum for confirmation of species identification. Following completion of the fish and macroinvertebrate sampling, any further observations of fish during the pool condition survey are also noted, with fish species-name only noted if positively identified.

For each survey, tadpoles (which are not macroinvertebrates but chordates) are noted in the results but are not kept or identified (see the Terrestrial Fauna report for details of the study area amphibians). Notes are also kept of the presence of reptiles, turtles, aquatic birds and bats that directly utilise the aquatic habitats. Spotlighting surveys for platypus and Australian water rat are undertaken at suitable river and creek locations within the hour before dark, and for a short period after dark to detect the emergence and activity of these aquatic animals. The reports of amphibians, reptiles, birds and mammals have been provided to the Terrestrial Fauna team for incorporation into their assessments where required.

3.4 Stream Condition, Aquatic Plants and Field Water Quality

A standardised description of aquatic and riparian site condition is used to compile a stream site condition index, based on a modified version of the River-Creek-Environment (RCE) method developed by Petersen (1992), as reported by Chessman *et al* (1997) for the greater Hunter River catchment. The index is compiled by rating each RCE descriptor (13 in total) a score between 0 and 4, and summing the scores to reach a maximum possible score of 52 (see Appendix Table A3 for complete RCE descriptors). Scores are then expressed as a percentage.

The aquatic edge sampling for macroinvertebrates includes assessment of aquatic plants (macrophytes) within the site length and more generally within the study area. Macrophytes are listed and an assessment of site cover is made which is then incorporated into RCE scores. Any macrophytes that cannot be identified in the field are sampled and if these cannot be identified in the lab, specimens are submitted to the Sydney Royal Botanic Gardens herbarium for identification.

A submersible Yeo-Kal 911 water quality data logger was used to record water depth, temperature, dissolved oxygen concentration and saturation, pH, conductivity and turbidity at all aquatic ecology sampling sites. Where possible, depth profiles of water quality are made to test for layering/mixing. Physical observations are also taken in the field to highlight any aquatic habitat variations (e.g. recent rain, subsequent infilling, detritus in water column or on benthos, scum or flocculates in or on water body etc.).

3.5 Aquatic Groundwater Dependent Ecosystems (GDEs)

Both the Terrestrial and Aquatic Ecology studies include inspections for Groundwater Dependent Ecosystems (GDEs) within the study area, as required under the DGRs Key Issue for *Biodiversity*, and this in turn requires the proponent to "take into account the relevant guidelines", in this case the *NSW State Groundwater Dependent Ecosystem Policy* (DLWC 2002).

Aquatic GDEs include all aquatic biota of aquatic habitats that are dependent on baseflow for their continued existence, and this definition does not include ephemeral aquatic habitats that depend on sporadic surface water flow.

Assessment for aquatic GDEs followed the Rapid Assessment Process specified in Appendix D in the GDE policy, and in the field searches for possible surface expressed aquatic GDEs were made at all sampling sites visited included looking for springs and seepages or any indications of emerging groundwater, such as the presence of macrophytes, semi-aquatic or salt tolerant plant species in isolated pools that may indicate potential GDEs.

The significance of GDEs is assessed against the GDE Policy, which details five *Management Principles*:

- Identifying the values of and threats to GDEs.
- Managing groundwater extraction so the GDEs are maintained.
- Giving priority to protecting GDEs identified as being under immediate or high degree of threat.
- Application of the precautionary principle.
- Developments to minimise adverse impacts on GDEs.

3.5.1 Stygofauna Sampling

Broadly, stygofauna are aquatic fauna living in groundwater systems (referred to as *hypogean* ecosystems in the NSW GDE Policy), comprising highly specialised species that have adapted to complete their entire life-histories in lightless, subterranean waters ranging from underground cave systems to alluvial and fractured hard rock groundwater systems. Most species spend their entire lives in groundwater and are found nowhere else. "Whilst they can play an important role in maintaining the physical structure of an aquifer by keeping the pore spaces free of fine organic matter and grazing on microbial biofilms" (p12 of State GDE Policy) this ecosystem benefit is proportional to stygofauna densities. The currently known groundwater invertebrate fauna of Australia includes many kinds of crustaceans, worms, snails, insects, mites and other invertebrate taxa and in some places fish.

The proposed longwall mine is located under Jilliby Jilliby Creek, which is an alluvial valley with a deep alluvial aquifer. An assessment of possible stygofaunal assemblages of the aquifer was made in February 2012, by sampling groundwater from a series of bores near the Jilliby Jilliby and Little Jilliby Jilliby Creek confluences. **Figure 8** shows the location of the bores and **Table 6** provides relevant bore information.

As indicated in **Table 6** there are five bore locations and at each location there are two to three separate bores with screens set to intercept the underlying rock aquifer, the middle or shallow alluvial aquifer. Sampling involved collection of bore waters using an inertia pump. For each bore up to 300 L was obtained where possible.

Figure 8 Location of the Honeysuckle Park Bore Field at the confluence of Little Jilliby Jilliby and Jilliby Jilliby Creeks

Table 6 Honeysuckle Park Experimental Bore Field - Bore Information

Bore HPBH...	Sub-bore No*	Date Drilled	Depth (mTOC)	Screen	Substratum	Mean Level	Mean pH	Mean ORP	Mean Bore EC	Mean EC Bore Groups
1	A	18.03.10	42	33.0 – 39.0	Rock	1.70	7.61	481	2955.2	
2	A	19.03.10	42	33.0 – 39.0	Rock	2.14	6.69	440	1790.4	
3	A	23.03.10	42	33.0 – 39.0	Rock	1.42	6.65	449	2628.8	
4	A	24.03.10	42	33.0 – 39.0	Rock	1.89	7.27	458	4956.6	
5	A	30.03.10	42	33.0 – 39.0	Rock	2.48	7.20	428	2282.0	2923
1	B		16.5	12.0 – 15.0	Deep alluv	1.72	6.43	475	1693.4	
2	B		24	19.0 – 21.0	Deep alluv	1.89	6.61	444	1723.4	
3	B		24	18.0 – 21.0	Deep alluv	1.27	6.62	447	2079.8	
4	B		30	24.0 – 27.0	Deep alluv	1.89	6.39	407	1944.2	
5	B		23	17.0 – 20.0	Deep alluv	1.68	7.39	383	663.0	1621
3	C		8	5.0 – 8.0	Shal alluv	0.36	6.40	443	798.8	
4	C		6	3.0 – 6.0	Shal alluv	0.55	6.11	404	289.4	
5	C		6	3.0 -6.0	Shal alluv	0.52	6.30	390	830.0	639

Means from 5 samples between 13 April 10 & 22 Jun 10.
Alluvium depths: Site 1; 20 m, site 2; 22.6m, site 3; 21m, site 4; 28m, site 5; 20m.
* Note HPBH 4 B & C were sabotaged with oil and results may reflect contamination impact.

Water was pumped into 20 L buckets and then filtered through a 53µm mesh plankton net. The retained net contents were placed into sample tubes, stained using Rose Bengal biological stain (which is only taken up by living biota), then preserved in 100% ethanol for later sorting and identification.

Sequential field water quality metering was undertaken periodically on sub-samples of the water obtained from each bore and, once the bore water was running clear, samples were collected for additional laboratory analysis (as part of the on-going groundwater investigations – see the Groundwater report for this EIS.

In the laboratory the retained contents of each bore replicate sample were systematically sub-sampled in small volumes of clear alcohol suitable for viewing under a dissecting microscope using x 20 and x 40 magnification to locate and collect specimens. This was repeated until each whole sample had been scanned and sorted. Specimens were collected and retained together in individual site/replicate specimen tubes. The remainder of the sample contents were retained in their original sample tubes for possible further sorting or analysis.

Retained specimens were submitted to Dr Grant Hose of Macquarie University for identification. The level of morphological identification was set to match the level of identification of Hunter Valley stygofauna as per Hancock and Boulton (2008).

4 BASELINE AQUATIC ECOLOGY STUDY RESULTS

For the project baseline aquatic ecological field investigations, there were three seasonal surveys undertaken, in Autumn and Spring 2011 and Autumn 2012. Results for the initial survey were reported in a stand-alone aquatic ecology report (MPR 2011) and the results of the Spring 2011 plus Autumn 2012 surveys have been incorporated directly into this EIS report. Annexure Table A1 provides field notes for all sites on each sampling season and seasonal site photographs are included in Annexures B to D. Note that for AusRivAS assessments, 'Autumn' sample season is defined as March 15 to June 15, and 'Spring' sample season is September 15 to December 15.

Figures 2 and **3** in Section 1 show the locations of the aquatic ecology sites sampled over the baseline survey period in relation to the project study area. **Table 5** in **Section 3.1** provides the seasonal site sample schedule and map coordinates for the study sites.

4.1 Sampling Periods, Weather, Rainfall & Stream Flow

Figure 9 below provides a graphical summary of daily discharge and stream water lever for Jilliby Jilliby Creek at the NSW Office of Water (NoW) stream gauge 211010, located just below the aquatic ecology sampling site JC3. **Table 7** summarises sampling dates and daily flow rates for the sampling days for each of the seasonal surveys. Daily flow rates in the Wyong River were obtained from NoW guage #211009 at Site WR3.

Table 7 Seasonal Flow Rates

Season	Date	Flow (ML/day	
		Wyong River	Jilliby Ck
Au11	27/06/11	155.6	16.3
Au11	28/06/11	147.3	15.4
Au11	29/06/11	179.7	30.8
Au11	30/06/11	202.4	57.5
Au11	1/07/11	217.6	38.5
Sp11	12/10/11	217.8	22.2
Sp11	13/10/11	175.3	18.5
Sp11	14/10/11	152.9	16.5
Au12	15/5/12	52.0	5.35
Au12	16/5/12	50.7	5.26
Au12	17/5/12	50.3	5.21

Autumn 2011

The Autumn 2011 baseline aquatic ecology field investigations and sampling were undertaken between the 27th June and 1st July 2011. This initial baseline study was delayed due to regional flooding throughout the study area catchments.

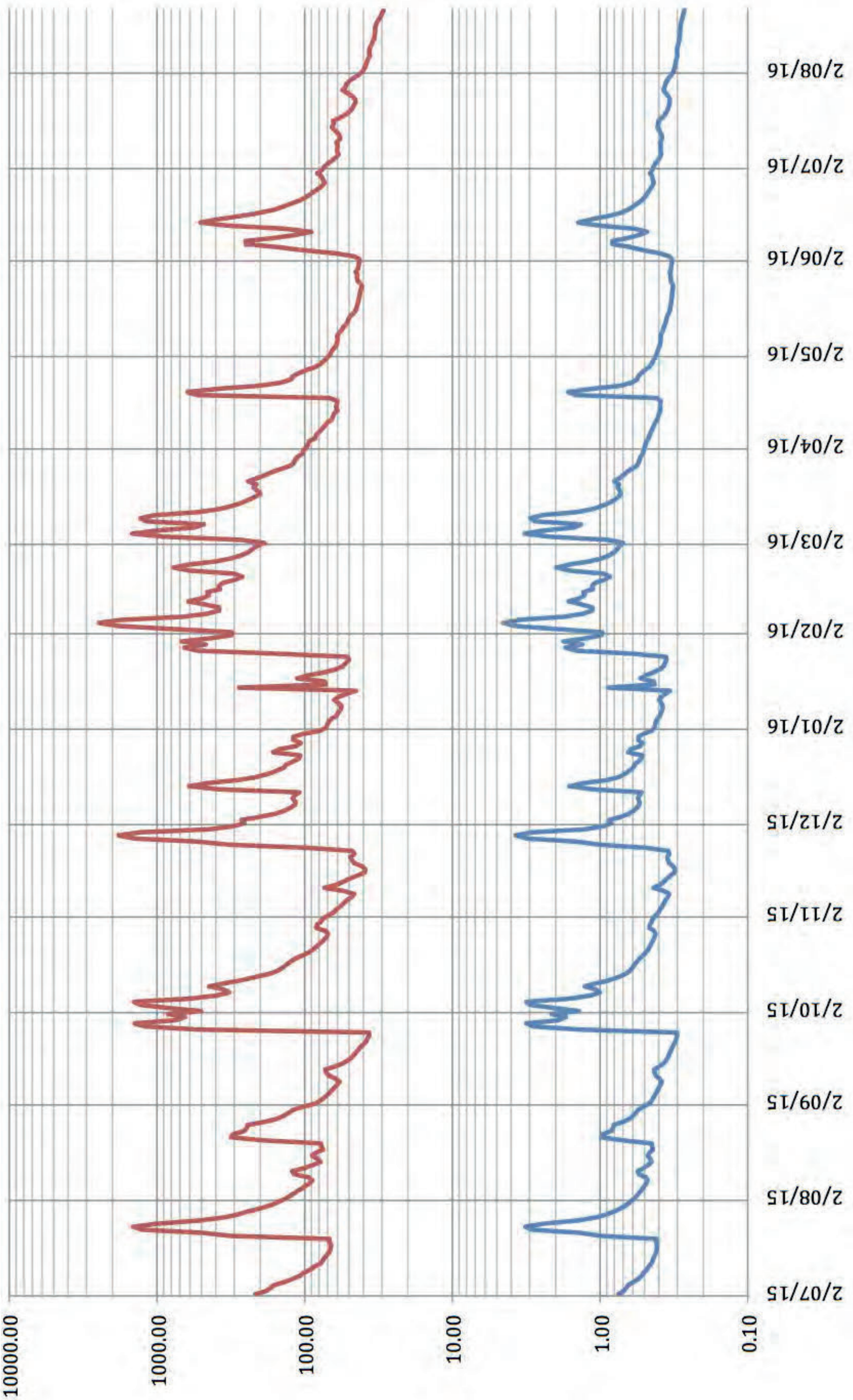


Figure 9 Jilliby Jilliby Creek Flow (ML/day) and Water Level (m) at NoW Gauge 211010 July 2011 to August 2012. Flow is red trace.

In the months leading up to the Autumn 2011 survey, the study area had been receiving above average rainfalls (as measured at Bureau of Meteorology Jilliby rain gauge, and compared with Wyong Golf Club gauge data for mean totals):

- Rainfall totals of 148mm and 187mm were recorded during the months of March and April respectively - considerably more than the monthly mean totals of 133.1mm and 110.3mm for the same two months.
- Although there was no rainfall recorded during the first three weeks of May 2011, 158mm fell over two weeks between May 23rd and June 5th.
- A significant rainfall event occurred in mid June with 234mm rain falling over six days between June 11th and 16th.
- 31mm of rain fell over the sample period between June 28th and 1st July.

In the month prior to the commencement of sampling there were two flood events associated with the aforementioned heavy rainfall periods. The first extended rainfall occurred in late May to early June in which 158mm fell over two weeks and caused the creek and river levels to rise to 2.1m in Jilliby Jilliby Creek and 2.3m in Wyong River. The larger rainfall event during mid June in which 234mm of rain fell over six days resulted in water levels rises to 4.4m in Jilliby Jilliby Creek and 5.8m in Wyong River. At all sites there was evidence of recent high flows, with debris lines in trees and fences, fallen trees, eroded and slumping banks and scouring of bank vegetation (**Figure 10**).

Figure 10 Wyong River flood 14 June 11 showing inundated road bridge at site WR2

As **Table 7** shows, the flow volumes in the Wyong River were considerably higher than that in Jilliby Jilliby Creek, with mean daily flow rates, indicating a general increase in stream flow for both river/creek systems over the course of the Autumn 2011 survey and there was surface flow present in all of the sites inspected for the survey.

The maximum site pool depths reached 2m in Jilliby Jilliby Creek site JC2E, with the majority of sites supporting maximum depths of between 1.2m and 1.5m. Spring Creek site SW1 and Hue Hue Creek site HHMd were both situated in swamps and were the shallowest sites at 1.0m and 0.9m respectively.

Spring 2011

The Spring 2011 aquatic ecology field survey was undertaken between the 12th and 14th October 2011. Since the Autumn 2011 survey, the study area had been experiencing well above average rainfalls, with some flooding occurring a fortnight prior to sampling for the Spring 2011 survey;

- Rainfall over the period of July to September totalled 489mm, which is significantly higher than the combined monthly total of 217.3mm for the same three months.
- 145mm of rain fell over a four day period between the 20th and 23rd July.
- A total of 282mm of rain fell over nine days between the 25th September and 3rd October, including a single days which recorded 175mm of rainfall.
- 15mm of rain fell between the 7th and 9th October just before sampling began.

Both of these rainfall events caused creek and river water levels to rise. The July event resulted in a rise from baseflow levels of 0.4m to a peak of 3.2m in the Wyong River and from 0.1m to 2.5m in Jilliby Jilliby Creek. For the larger rainfall event in September, creek water levels in Jilliby Jilliby Creek rose from 0.1m to 4.1m. Despite the 155mm rainfall spike on 26th September, Wyong River levels only rose from 0.3m to 3.1m.

At a number of sites there were indications that water levels had breached the channels onto the floodplain banks. In contrast to the Autumn 2011 survey there were not as many flood related impacts observed that could be directly attributable to the September high flow event, such as bank erosion or tree slumping (see **Figure 11**).

The mean daily flow rates were similar to the Autumn 2011 survey, although flows were decreasing instead of increasing over the study period. There was surface flow at all sites except JC2E and HHMd at which there was no observable movement of water. Flow at sites WC1 and SW1 had reduced to a trickle throughout the site lengths.

Figure 11 Bank erosion from flood-induced tree slumping in Jilliby Jilliby Creek.

For all of the creek and river sites, water levels for the Spring 2011 sample period were similar to those encountered during the Autumn 2011 survey. At the swamp sites HHMd and SW1, although the water levels were 0.2m and 0.1m lower (respectively), the widths of the waterbodies had contracted significantly. During the Autumn 2011 survey the broad, sheet flow at SW1 had ranged between 60 and 80m, however for the Spring survey water levels had receded and constricted the area of surface flow to the main channel (maximum width of 3m). Similarly at HHMd, the broad shallow flow that had spanned 20 to 50m during the Autumn 2011 survey was restricted to a maximum of 12m in width for the Spring survey. At both of the swamp sites there were a number of shallow isolated puddles scattered over the broader channel area adjacent to the main (flowing) channel, remnants of the receding high water levels.

Autumn 2012

The Autumn 2012 aquatic ecology field sampling was undertaken between the 15th and 17th May 2012. Since the Spring 2011 survey (undertaken in October 2011) the study area had been subjected to fluctuating rainfall patterns, with well above average rainfall between October 2011 and February 2012, followed by average rainfall with some dry periods for the months leading up to the Autumn 2012 survey and a storm event one month prior to sampling:

- A total of 796.0mm rainfall fell in the five months between October 2011 and

February 2012, much higher than the combined monthly averages of 476.1mm.
- The combined monthly total for March and April 2012 (247mm) was similar to the average for the same two months (243.4mm).
- There was a prolonged storm event over 4 days, four weeks prior to sampling.
- The three weeks leading up to the Autumn 2012 survey were dry, with a total of only 2mm falling over two rainfall days.

The most significant rainfall events over the inter-survey period occurred in November 2011 and February 2012. During mid to late November a total of 177mm fell over an eleven day period which caused creek and river levels to rise from 0.1m to 2.7m in Jilliby Jilliby Creek and 0.3m to 3.7m in the Wyong River. Prolonged rainfalls of 168mm over a two week period in late January to February caused water levels to rise from 0.1m to 2.7m in Jilliby Jilliby Creek and from 0.4m to 4.5m in the Wyong River. One month prior to the commencement of sampling a storm event in which 120mm of rain fell over a four day period, caused Jilliby Jilliby Creek to rise from the background level of 0.1m to 1.4 over two days (see **Figure 7**), and from 0.4m to 1.7m in the Wyong River. Over the following three weeks leading into the Autumn 2011 survey, creek and river water levels throughout the study area receded back to pre-storm levels.

Stream flow rates for the Autumn 2012 survey were much reduced compared to flow rates encountered during both former surveys. The mean daily flow rates indicate the flows were gradually receding over the course of the Autumn 2012 survey period, from 52.0 ML/day to 50.3 ML/day in the Wyong River and from 5.4 ML/day to 5.2 ML/day in Jilliby Jilliby Creek.

At most of the sites the water levels were considerably lower than the former Autumn and Spring 2011 surveys, with reductions in depths ranging from 10cm to 40cm. There was surface flow at the Wyong River sites, Jilliby Jilliby Creek site JC2W and the Little Jilliby Jilliby Creek sites, plus Buttonderry Creek site BC1 (albeit reduced to a trickle). There was no surface flow at SW1, Wallarah Creek site WC1, or at JC2E. Although the water levels had receded since the Spring 2011 survey, the general pool dimensions and available remained relatively unchanged at most of the sites, apart from Wyong River site WR3 in which the maximum width of the stream had decreased from 20m to 12-15m.

Maximum depths in the Wyong River and the Jilliby Jilliby Creek catchment sites ranged between 1.0m at JCUp and 1.2m to 1.5m for the remainder of sites. Sites WC1 and BC1 recorded maximum depths of 1.4m, whereas the swamp sites SW1 and HHMd were the shallowest at 0.7m and 0.5m respectively.

4.2 Aquatic Habitat and Aquatic Plant Assessments

Ten sites were sampled for fish and macroinvertebrates for all the baseline surveys; two in the Wyong River, two in Jilliby Jilliby Creek, two in Little Jilliby Jilliby Creek, and one site each in Wallarah Creek, Spring Creek (western tributary to Spring Creek), Buttonderry Creek and Hue Hue Creek. Additional field water quality readings, overnight fish trapping and RCE descriptions were undertaken at six sites in Jilliby Jilliby Creek, Spring Creek and Wallarah Creek for the Autumn 2011 survey. Scheduled aquatic habitat inspection surveys of lower order creeks including water quality sampling was undertaken in ten western forested streams and at seven additional upper Little Jilliby Jilliby Creek sites during the first available dry period in August 2012 (see **Table 13** site notes).

4.2.1 Aquatic plants

Annexure Table A2 details the occurrence of aquatic macrophytes for the seasonal surveys and the results are summarised in **Table 8**.

Table 8 Combined Seasonal Aquatic Macrophyte Distribution

Site	Azolla *Azolla sp*	Marsh Clubrush *Bolboschoenus fluviatilis*	Starwort *Callitriche sp*	*Giant sedge* *Cyperus exaltatu*	Tall Spikerush *Eleocharis sphacelata*	Spikerush *Eleocharis ?gracilis*	Swamp Lily *Ottelia ovalifolia*	Slender Knotweed *Persicaria decipens*	Frogsmouth *Philydrum lanuginosum*	Common Reed *Phragmites australis*	River Buttercup *Ranunculus inundatus*	Sagittaria *Sagittaria platyphylla*	Rush *Schoenoplectus mucronatus*	River Clubrush *Schoenoplectus validus*	Duck Weed *Spirodela sp*	Water Ribbons *Triglochin sp*	Cumbungi *Typha spp*	Charophytes
SKM 2008b				√	√									√	√		√	
WR1																		
WR3																		
JCUp																		
JC2W													√					
JC2E	√							√						√	√	√	√	
JC3																		
LJ4			√		√		√	√				√		√		√		√
LJDn																		
SWUp				√				√		√			√	√			√	
SW1																√		√
SWDn																		
WCUp							√											
WC1					√	√	√									√		
WCDn																		
BC1								√								√		
HHMd		√				√	√	√	√		√						√	

Note: SKM (2008a) recorded 12 macrophytes from Wyong River site in a flood recovery stage.

There were seventeen macrophytes recorded from the study area sites over the three surveys, of which five were recorded previously in Wyong River (SKM 2008b). There were no macrophytes recorded from the Wyong River sites WR1 and WR3, Jilliby Jilliby Creek sites JCUp and JC3, downstream Little Jilliby Jilliby Creek site LJDn, Spring Creek site SWDn and Wallarah Creek site WCDn and the overall study macrophyte diversity increased marginally over consecutive surveys for Autumn 2011, Spring 2011 and Autumn 2012 at 10 species, 11 species and 14 species respectively.

Seven other macrophytes recorded by SKM (2008b) from Wyong River sites were not found at all in the present study; *Elatine gratioloides* (Waterwort), Hydrilla verticillata (Water Thyme), *Juncus usitatus*, *Ludwigia peploides* subsp. *montevidensis* (Water Primrose), *Persicaria lapathifolia* (Pale Knotweed), *Persicaria strigosa* (Bristly Knotweed), and the introduced *Myriophyllum aquaticum* (Brazilian Water-milfoil).

The initial paucity is attributed to the scouring impacts of the major flood preceding the first seasonal survey in June 2011 and the slow recovery due to successive floods over the study period.

Site LJDn and Hue Hue Creek site HHMd supported the highest diversity of macrophytes, with 7 taxa being recorded, and Spring Creek (western tributary) upper site SWUp and Jilliby Jilliby Creek site JC2E also recorded high diversities with 6 taxa from each site. Each of the sites supported a combination of floating and emergent macrophyte species. Water ribbons and slender knotweed (*Persicaria decipens*) were the most common macrophytes throughout the study area, being found at five sites.

At Wallarah Creek site WC1 there were healthy beds of all the following macrophytes; tall spikerush (*Eleocharis sphacelata*), a spike rush presumed to be *Eleocharis gracilis* (specimens sent to the Royal Botanical Gardens Sydney were unconfirmed), water ribbons (*Triglochin* sp) and swamp lily (*Ottelia ovalifolia*).

Charophytes, which are a type of algae and not true flowering plants, were recorded at SW1 on all three survey occasions, and in small amounts at LJ4 for the most recent Autumn 2012 survey.

4.2.2.Aquatic habitat condition assessment

Full seasonal and site aquatic habitat assessment RCE scores are provided in Annexure Table A3 and **Table 9** below provides the initial category RCE scores for all sites visited during the first survey in Autumn 2011. **Table 10** provides a summary of the overall changes in site scores over subsequent seasons.

The RCE results in **Table 10** are expressed as percentages, with higher percentages indicating better aquatic habitat condition.

Table 9 Initial Autumn 11 Stream Site Aquatic Habitat Condition (RCE Index)

Category	WR1	WR3	JCUp	JC2W	JC2E	JC3	LJ4	LJDn	SWUp	SW1	SWDn	WCUp	WC1	WCDn	BC1	HHMd
Land-use pattern beyond immediate riparian zone	3	3	2.5	2	2	3	3	3	3	4	4	**4**	**4**	**4**	3.5	3
Width of riparian strip-of woody vegetation	4	3.5	3.5	4	3.5	3.5	3.5	3.5	3	4	4	**4**	**4**	**4**	4	4
Completeness of riparian strip of woody vegetation	4	4	4	3.5	4	4	4	4	2	4	4	**4**	**4**	**4**	4	4
Vegetation of riparian zone within 10 m of channel	3	3.5	3	2.5	3	3.5	3	3.5	3	4	4	**4**	**4**	**4**	3.5	3
Stream bank structure	4	4	3.5	4	3.5	3.5	3.5	3.5	3	4	4	**3.5**	**4**	**4**	4	4
Bank undercutting	2	2	2.5	2.5	3	2	2.5	2	3	4	2	**2**	**2**	**2**	2	4
Channel form	4	3.5	4	3.5	3	4	4	4	3	2	4	**4**	**4**	**4**	4	2
Riffle/pool sequence	3	2.5	2.5	2	2	3	2	3	1.5	2	3	**3.5**	**3.5**	**3.5**	3	2
Retention devices in stream	3	3	2	3	2	3	2.5	2	1	3	2	**3**	**3.5**	**3.5**	1	2
Channel sediment accumulations	1.5	1.5	2	2.5	2	2	2.5	2	1	4	2	**2.5**	**3.5**	**3.5**	3.5	1
Stream bottom	1	1	1.5	3	2	2	2	1	0.5	1	1.5	**2**	**3**	**3**	2	2
Stream detritus	2	2	3	3	3	3	3	1	2	4	3	**3**	**4**	**4**	2	2
Aquatic vegetation	4	4	4	3.5	2	4	4	4	2	4	4	**4**	**3.5**	**3.5**	4	3.5
Autumn 2011 RCE Score %:	74	72	73	75	67	78	76	70	54	85	80	**84**	**90**	**90**	78	70

The overall RCE results may be summarised as follows:

- The site RCE scores indicate that the site riparian and channel environments were generally in good condition (above 70%) across most sites, with two site scores below 70% (54% at Spring Creek SWUp and 65-67% at Jilliby Jilliby Creek site JC2E).
- For the Autumn 2011 to Spring 2011 survey period there was one variation in site RCE scores for sites that were visited on both surveys. Little Jilliby Jilliby Creek Site LJ4 recorded a lower category score for 'aquatic vegetation' as a result of increased levels of algae.
- For the Spring 2011 to Autumn 2012 survey period there were two variations in RCE scores. At JC2E and WC1 lower category scores were recorded for aquatic vegetation' as a result of increased levels of algae.

Wyong River and Jilliby Jilliby Creek catchment site RCE scores were generally similar (67 to 79%) owing to shared RCE attributes:

- Most of the higher category scores were attributable to the completeness and composition of well established riparian corridors.

- Lower RCE scores for these sites included channels sediment accumulations, bank undercutting, and lack of riffle-pool sequences.

Table 10 Seasonal Variation in Stream Site Aquatic Habitat Condition (RCE Index)

	WR1	WR3	JCUp	JC2W	JC2E	JC3	LJ4	LJDn	SWUp	SW1	SWDn	WCUp	WC1	WCDn	BC1	HHMd
Au 11	74.0	72.1	73.1	75.0	67.3	78.8	76.0	70.2	53.8	84.6	79.8	83.7	90.4	90.4	77.9	70.2
Sp 11	74.0	72.1	73.1		67.3		75.0	70.2		84.6			90.4		77.9	70.2
Au 12	74.0	72.1	73.1		65.4		75.0	70.2		84.6			89.4		77.9	70.2

In Spring Creek there was a considerable difference between the upper site SWUp (54%), and the lower sites SW1 (85%) and SWDn (80%). Sites SW1 and SWDn recorded high scores for the condition and quality of the riparian corridors, which were continuous along the site length and composed mostly of native vegetation. Although SWUp did support native vegetation on the northern bank, the southern bank was partially cleared with a number of weeds in the site length. Inferior channel form, substrates and aquatic vegetation also contributed to the overall lower site RCE score at site SWUp.

All of the Wallarah Creek sites recorded comparatively high RCE scores, generally owing to the completeness and composition of the riparian corridors, which were continuous between upper site WCUp and downstream site WCDn. In addition, the Wallarah Creek sites returned good scores for factors relating to stream bank structure, channel form, retention devices and riffle-pool sequences, owing to the meandering, incised channel which supports consistent alternation between pool shapes throughout the site lengths, as a result of log jams and debris build-up. The lowest scores were for bank undercutting and stream bottom condition.

Buttonderry Creek site BC1 returned an RCE score of 78%. The category scores relating to the riparian environment were high as the riparian corridor at BC1 is native woodland and is continuous along the site length. Also, the channel is well formed, with a frequent alternation of pools and pseudo-riffle zones, and there were very few accumulations of loose sediments. The lowest scores at BC1 were for bank undercutting, which was prevalent along the whole site length, lack of retention devices, lack of detritus and inferior stream bottom characteristics.

The RCE score for site HHMd was 70%. This reflected the status of the riparian environment, which was continuous and complete, though there were a number of weed species at the site. As the site is located in a Melaleuca swamp there were categories that returned low stream scores; channel sediment accumulations due to the sluggish nature of water movement, lack of channel structure and riffle-pool sequences, stream bottom and stream detritus.

4.3 Surface Water Quality

As noted in the Literature Review (**Section 2.1**) there has been a number of surface water quality monitoring programs undertaken within the various study catchments over an extended period, between 1996 and the present. These are summarised in various water quality reports (see ERM 2011 and WRM 2013) and are not considered further here.

Water quality data relating to the original 1999 aquatic ecology sampling program are summarised in **Table 11** below and field water quality data associated with the present aquatic ecology investigation are presented in Annexure Table A4 and summarised in **Table 12**.

Table 11 Mean Field and Laboratory Water Quality Results for River and Creek sampling in the Subsidence Areas December 1999

Location*	Site	Temp (°C)	Cond (uS/cm)	Turb (NTU)	DO (mg/L)	DO % sat	pH units	OPR mV
WR	9	21.5	303.3	30.3	5.9	66.3	7.6	94.0
JJ	10	20.3	550.3	12.5	4.1	43.8	7.7	104.7
AC	11	18.8	707.3	29.1	0.5	5.3	7.2	7.7
LJdn	12	20.3	641.7	28.4	2.7	28.3	7.3	83.7
LJup	13	18.6	395.7	13.0	4.6	50.2	7.7	35.0
MC	14	17.4	990.7	16.9	3.5	38.0	6.9	3.7

Laboratory Analysis Results

Location	Site	Total Phos (mg/L)	NOx (mg/L)	TKN (mg/L)	TN (mg/L)	Total Alkal (mg/L)
ANZECC (2000) Limits		0.05	0.04		0.50	
WR	9	<0.025	0.1	1.2	1.4	62.3
JJ	10	0.1	<0.1	1.1	1.1	69.3
AC	11	0.0	<0.1	0.9	0.9	49.1
LJdn	12	0.1	<0.1	0.8	0.8	91.7
LJup	13	<0.025	<0.1	1.3	1.3	51.4
MC	14	<0.025	<0.1	0.3	0.3	57.3

Notes *WR = Wyong River, JJ = Jilliby Jilliby Ck, LJ = Little Jilliby Jilliby Ck, MC = Myrtle Ck and AC = Armstrong Ck.

Table 12 Project Baseline Survey Field Surface Water Quality Readings

Site	Date	Time	Depth m	Temp °C	Cond µS/cm	Sal ppt	DO %sat	DO mg/l	pH Units	Turb NTU
WR1	28/06/11	14:25	0.2	10.95	236	0.10	77.9	7.8	6.25	18.6
WR3	28/06/11	10:51	0.2	10.95	234	0.10	85.1	8.5	6.21	15.2
JCUp	1/07/11	12:07	0.1	12.19	349	0.16	83.9	8.2	6.25	45.2
JC2E	30/06/11	15:35	0.1	13.23	286	0.13	69.0	6.6	6.35	38.1
JC2W	29/06/11	15:42	0.2	11.69	422	0.19	88.1	8.7	6.56	30.4
JC3	1/07/11	13:39	0.2	12.21	327	0.15	72.2	7.0	6.30	36.3
LJ4	1/07/11	10:32	0.2	12.22	394	0.18	76.8	7.5	6.31	22.1
LJDn	30/06/11	14:16	0.2	12.65	399	0.19	83.3	8.0	6.55	44.6
SW1	29/06/11	12:55	0.1	12.85	282	0.13	99.4	9.5	5.24	48.8
WC1	30/06/11	11:03	0.2	12.88	256	0.11	63.8	6.1	5.52	37.9
BC1	27/06/11	14:41	0.1	10.59	291	0.13	59.6	6.0	6.73	139.6
HHMd	30/06/11	12:21	0.2	14.53	233	0.10	65.0	6.0	5.63	54.7
WR1	12/10/11	13:28	0.1	14.52	233	0.11	117.1	10.8	6.38	19.8
WR3	12/10/11	12:08	0.1	14.58	251	0.11	188.2	17.4	6.04	26.6
JCUp	13/10/11	11:04	0.1	14.48	412	0.20	139.1	12.9	6.35	23.8
JC2E	13/10/11	9:47	0.1	17.18	253	0.11	98.0	8.6	6.25	33.2
LJ4	13/10/11	8:29	0.1	14.18	397	0.19	168.6	15.7	6.25	15.2
SW1	13/10/11	15:20	0.1	15.36	413	0.19	98.4	8.9	5.21	15.2
WC1	14/10/11	8:23	0.1	15.10	640	0.33	50.6	4.6	5.53	22.4
BC1	13/10/11	14:03	0.1	15.73	287	0.13	116.2	10.5	6.88	76.4
HHMd	13/10/11	12:56	0.1	17.88	387	0.19	94.0	8.1	5.69	27.3
WR1	15/05/12	13:32	0.1	10.86	353	0.19	103.9	10.1	6.19	17.0
WR3	16/05/12	9:43	0.1	10.80	290	0.16	101.9	9.9	6.12	12.5
JCUp	16/05/12	15:02	0.1	11.39	521	0.28	90.8	8.7	6.34	18.4
JC2E	16/05/12	13:29	0.1	13.05	441	0.24	43.3	4.0	6.22	23.5
JC2W	16/05/12	13:20	0.1	12.09	505	0.27	93.4	8.8	6.50	22.5
LJ4	15/05/12	10:42	0.1	11.67	601	0.31	74.4	7.1	6.31	36.5
LJDn	16/05/12	11:32	0.1	12.29	610	0.31	97.6	9.2	6.47	34.7
SW1	17/05/12	14:36	0.1	11.28	534	0.29	63.7	6.1	4.92	12.8
WC1	17/05/12	13:12	0.1	12.62	1145	0.59	25.3	2.4	5.54	56.5
BC1	17/05/12	11:26	0.1	11.83	935	0.49	24.0	2.3	6.64	16.3
HHMd	17/05/12	10:09	0.1	11.47	514	0.27	89.0	8.5	5.85	114.8
			Min	10.59	233	0.1	23.8	2.3	4.88	12.5
			Max	17.88	1145	0.59	188.2	17.4	6.88	139.6
			Mean	12.8	465.7	0.2	83.2	7.9	6.1	35.3
			SE	0.29	36.05	0.02	5.09	0.47	0.07	4.08

Note: The water quality reading for LJDn in Spring 2011 was lost due to sensor malfunction.

Mean stream water quality results for the 1999 aquatic ecology sampling (**Table 11**) are summarised as follows:

- Mean stream water conductivity ranged from 303 µS/cm in Wyong River to 990 µS/cm in Myrtle Creek.
- Turbidity was not high and ranged from 12 to 30 NTU.
- Dissolved oxygen values were poor and ranged from 5 % saturation at sites in Armstrong Creek to 66 % in Wyong River. Waters were generally slightly alkaline (7.2 to 7.70 with mean pH slightly acid in Myrtle Creek (6.9 pH units).
- ORP was variable ranging from 3.7 mV in Myrtle Creek to 105 mV in Jilliby Jilliby Creek.
- Nutrient levels were generally above recommended ANZECC (2000) concentrations for protection of aquatic ecosystems.

Stream site water quality results for the present study over the three seasonal surveys from Autumn 2011 to Autumn 2012 (**Table 12**) are summarised as follows:

- There was good mixing at most of the sites and as a result there was no significant depth stratification for any water quality parameters at any sites.
- The temperature of surface waters ranged between 10.6°C and 18°C with values reflecting seasonal variation.
- Surface water conductivity showed a more or less consistent increase at each site over time. This is most likely related to the influence of flood flows over base flow with overall higher flood water flows in Autumn 2011, only moderate flood waters in Spring 2011 and relatively low flows in Autumn 2012. Increases in conductivity were most dramatic in the smaller streams WC1 and BC1 (around 250 to 1100µS/cm) and were lowest in Wyong River (230 to 350µS/cm). The results indicate that base flows throughout the study area (i.e., in both subsidence and infrastructure areas) are saline.
- The Dissolved Oxygen (DO) values of surface waters varied over all sites with a study range of 51 to 188 % saturation and a mean of 95% saturation. Two sites (BC1 and JC2E) both had low DO values in Autumn 2012; 24 and 43 % saturation respectively.
- Water pH was acidic at all sites, and ranged from 4.9 to 6.9 pH units. All sites except HHMd showed decreasing pH over the study period.
- Site BC1 had consistently higher pH values followed by the Wyong River catchment sites (WR, JJ and LJ sites) then the Hue Hue Creek site and the Wallarah Creek sites (WC and SC) were the most acid.
- Water turbidity was generally higher at all sites during the Autumn 2011 survey with most sites showing a decrease over time.

4.4 Characterisation of Western Forested Upper Catchment Aquatic Habitats

Following a dry spell after the completion of the Autumn 2012 aquatic ecology survey, access to the upper forested sub-catchments became possible and the scheduled upper catchment aquatic habitat surveys were undertaken in mid August 2012. **Table 13** provides a list of the sites inspected during the survey and **Table 14** provides water quality results obtained from available upper creek sites. Additional water quality sampling was undertaken in higher order creeks to provide some indication of dry weather water quality to contrast against the three wet seasonal aquatic ecology surveys.

Table 13 Site Location Notes for Section 4.4 and Table 14

Site	Location.
A1	Upper South Armstorng Ck
A2	Mid South Armstrong Ck
A3	North Armstrong Ck at track crossing - upstream culvert pool
B	Wooburys Point Ref Ck
C1	Harris Point Mid Braided Ck
C2	Harris Point East Braided Ck
C3	Harris Point West Seep upstream of Braided Ck
D	Lower Whitemans Gully
E	Mid Lowers Gully
F	Mid Dittons Rd Ck Crossing
G	Lower South Baileys Road Ck
LJ4	Mid Lower Little Jilliby Jilliby Ck (0.3 m deep)
JJdn	Jilliby Jilliby Ck Down (0.4 m deep)
H	Little Jilliby Jilliby Ox-bow lagoon d/s of Splash Gully (at road crossing)
I	Splash Gully 20 m upstream of Little Jilliby confluence
J	Little Jilliby Jilliby Creek 35 m upstream of Splash Gully confluence
K1	East Little Jilliby Jilliby Ck - upper sample
K2	East Little Jilliby Jilliby Ck – lower sample
L	Upper Hue Hue Creek off Bloomfields Lane
JCup	Jilliby Jilliby Ck upstream at Mandalong Rd crossing (0.4 m deep)
HHmd	Hue Hue Ck midstream on lower side of Sandra St crossing
WC1	Wallarah Ck midstream site
SW1	Spring Creek tributary
BC1	Buttonderry Ck upstream side of Hue Hue Rd Crossing

In the main, the upper first-order drainage sections comprised broad V shaped gullies with exposed broken rock and no aquatic habitats. As these first order drainages come together the drainage lines become cascade rock lined with no exposed basement rock, and pockets of sediment or vegetation/litter infill. These upper second-order drainages show evidence of ephemeral flows but there are no indications of any semi-permanent aquatic habitats of long-tail seepages. These features are illustrated in **Figures 12** and **13** that show the first-order and upper second-order sections of Little Jilliby Jilliby Creek (east) to around 400 m downstream.

Figure 12 View of Little Jilliby Jilliby Creek (East Arm) headwaters showing broad V shaped gully with exposed broken rock in the gully (looking upstream 250 m down slope of headwaters)

Figure 13 Little Jilliby Jilliby Creek (East Arm) 400m down slope from headwaters. The creek has a cascade rock lined form with no exposed basement rock, sediment infill and occasional sediment and litter confined pools

The middle sections of the second-order drainages become progressively more defined. They are generally steeper and take on the cascade rock lined form with some residual pools confined by sediments and vegetation. There are sections of exposed basement rock. These features are illustrated in **Figures 14** and **15** the show Little Jilliby Jilliby Creek (East) further downstream to around 620 m downstream of the headwaters.

Figure 14 Little Jilliby Jilliby Creek (East Arm) 600m down slope from headwaters. The creek has a steeper slope, a more defined cascade rock lined form with some exposed basement rock and sediment infill. Pools are still confined by sediment and litter banks (see **Figure 15** below).

Figure 15 Little Jilliby Jilliby Creek (East Arm) 620m down slope from headwaters showing cascade rock plus sediment confined ephemeral pool. Note that there is no iron staining at this elevation (some 120m AHD).

The second-order section of Myrtle Creek shows a similar form to Little Jilliby Jilliby Creeek East but the slope is less and the cascade gullies are wider and flatter with more exposed basement rock (see **Figures 16** and **17**).

Figure 16 Upper Myrtle Creek showing wide cascade rock bed

Figure 17 Upper Myrtle Creek showing exposed basement rock with seepage along the side of the creek line and a sediment constrained pool in the creek bed.

Second order drainages that are lower in the catchment (e.g., the drainages south-west to Wyong River and north-east to Little Jilliby Creek) have similar forms (cascade rock gullies) with some exposed basement rock and in addition exhibit distinct iron staining (see **Figures 18** and **19**). There is still no permanent surface water ponding.

Figure 18 Woodburys Point Reference Creek Site B GPS 262

Figure 19 Creek east of Harris Point Road, Site C3 West arm of creek upstream.

As the various second-order creeks start to level out the creek lines become wider with more accumulated sediment and there may be sufficient water to provide shallow pools. This can be seen in **Figures 20** and **21** for Creek C east of Harris Point Road where several first order drainages come together as a braided second-order creek and in **Figure 22** (Splash Gully) draining to Little Jilliby Jilliby Creek.

Figure 20 Creek C east of Harris Point Road, Middle Arm at confluence of the braided creek area.

Figure 21 Creek C east of Harris Point Road Detail of iron staining and iron bacteria in the braided creek.

Figure 22 Splash Gully 20 m upstream of confluence with Little Jilliby Jilliby Creek.

These smaller second-order creeks do provide ephemeral aquatic habitats following rainfall but they do dry out as tail seepage waters that have been released slowly from the weathered surface rock dries out (see also **Figures 23** and **24**).

Figure 23 Armstrong Creek (north arm) looking upstream from Brothers Road crossing, 1050m downstream of headwaters. The creek line is a shallow U shaped valley with sediment and litter infill. There is no incised low flow channel.

Figure 24 Armstrong Creek (north arm) showing shallow pooled iron stained water upstream of road crossing.

Second order creeks with larger catchments (such as Armstrong Creek south arm and several of the creeks draining to Jilliby Creek) start to show more permanent aquatic habitat availability by virtue of catchment size that allows the long tail seepage waters more residence time in lower creek pools (**Figures 25** to **27**).

Figure 25 Armstrong Creek Site A1 Upper South Arm at Watagan Forest Road Bridge

Figure 26 Lower Whitmans Gully Site D

Figure 27 Mid Dittons Rd Creek upstream of road crossing, Site F

The third-order Little Jilliby Jilliby Creek collects the combined drainage from some seven second-order creeks and the creek line has a relatively shallow gradient. The creek is characterised by having a wide and shallow rectangular form with high earthen banks and generally coarse sands in the creek bed. The creek is probably ephemeral but does provide relatively long-term flows after rain and there are larger sediment confined pools that may provide a measure of drought protection (see **Figures 28** and **29**).

Figure 28 Little Jilliby Jilliby Creek 100 m upstream of Splash Gully (looking upstream)

Figure 29 Little Jilliby Jilliby Creek upstream of Daniels Point Road crossing.

Little Jilliby Jilliby Creek within the forested lands also has an oxbow lagoon that appears to be created by infill sediment derived from road crossings from electricity high-tension wire service roads. The lagoon is characterised by having very silty turbid waters characteristic of runoff from disturbed lands (see **Figure 30**).

Figure 30 Little Jilliby Jilliby Creek oxbow lagoon at Daniels Point Road Crossing

Whilst fish passage from lower Little Jilliby Jilliby Creek to the middle reaches of the creek is possible it is by no means guaranteed for similar creeks that flow through private lands. There are obstructions to fish passage for Armstrong Creek, Boyds Lane Creek and possibly for the lower Myrtle Creek. A number of the drainages flowing north-east to Jilliby Creek also have barriers to fish passage (see e.g., **Figure 31**).

Figure 31 Baileys Road Creek Lower Crossing downstream connection to Jilliby Jilliby Creek

In regard to the possibility of aquatic groundwater dependent ecosystems occurring in the western forested drainages, only one boggy area was observed during the survey, at the base of the braided creek system in Creek C east of Harris Point Road (**Figure 32**). This boggy area did not have any surface water expression and no indication of ponded water. It is concluded that the 'base flow' responsible for the iron staining in the upper creeks is a short-duration shallow rock flow that occurs for a little time after rainfall and after surface runoff ceases. These flows are not sufficient to sustain pools and therefore there are no significant surface water aquatic GDEs.

Figure 32 Creek C Overflow Sedge Swamp

4.4.1 Dry weather sampling field water quality

The results of the field water quality sampling program undertaken during the western forested creek characterisation program in mid August 2012 are presented in **Table 14** below.

The trends noted in the seasonal field water quality surveys (**Table 12**) indicated that there was a fairly uniform saline and slightly acidic base flow component underlying the flood and post-flood flows experienced during the seasonal aquatic ecology studies, so the opportunity was taken to measure stream water quality at a number of sites throughout the study area in August 2012, when there had been a longer dry spell than for the previous seasonal (Autumn 2012) sampling in June/July 2012.

Table 14 Project Field Metered Water Quality - Dry Weather 17 to 23 August 2012

Date & Site*	Time	Depth m	Temp °C	Cond µS/cm	Sal ppt	DO %sat	DO mg/l	pH Units	ORP mv	Turb ntu
17-Aug										
A1	9:41	0.1	10.69	3503	1.87	36	3.5	4.34	371	13.3
A2	13:39	0.1	10.93	541	0.29	52	5.1	6.75	388	26.9
A2	13:40	0.4	10.25	566	0.29	52.1	5.1	6.74	388	26.2
B	10:58	0.1	9.35	2633	1.39	72	7.2	5.84	400	10
C1	12:32	0.1	9.05	1122	0.58	49.6	5	6.35	369	15.9
C1	12:32	0.5	8.74	1173	0.61	48.8	5	6.35	369	16.4
C2	12:35	0.1	8.28	981	0.51	62.2	6.4	5.94	368	15.7
C2	12:35	0.5	8.12	980	0.5	61.8	6.4	5.93	369	15.6
C3	12:56	0.1	9.1	997	0.52	64.3	6.5	6.12	385	19.8
D	16:04	0.1	11	115	0.08	30.9	3	6.26	380	37.4
D	16:04	0.1	11	115	0.08	30.9	3	6.22	380	37.3
E	16:11	0.1	10.28	971	0.51	79.4	7.8	6.63	378	18.6
F	16:26	0.1	10.82	430	0.23	71.5	7	7.02	362	56.2
G	16:39	0.1	12.46	726	0.38	80.2	7.5	7.1	338	21
G	16:39	0.5	12.43	750	0.4	79.8	7.5	7.07	341	20.5
LJ4	17:18	0.1	10.9	609	0.32	72.4	7	6.8	363	20.3
JJdn	17:31	0.1	10.5	533	0.28	89.7	8.8	7.27	364	23
JJdn	17:31	0.3	10.49	539	0.28	89.6	8.8	7.2	366	26.9
21-Aug										
H	11:26	0.3	8.27	234	0.14	44.7	4.6	6.59	372	127.9
H	12:07	0.3	8.27	234	0.14	44.8	4.6	6.59	372	130.8
I	12:11	0.1	10.09	1155	0.6	56.8	5.6	6.31	367	7.3
I	12:12	0.2	10.09	1153	0.59	56.5	5.6	6.27	367	6.9
J	12:18	0.3	9.29	863	0.44	85.1	8.6	6.67	364	8.6
K1	14:15	0.2	10.18	981	0.51	85.6	8.5	6.46	372	8.1
K1	14:15	0.3	10.18	985	0.51	85.5	8.4	6.45	373	8
K2	14:32	0.2	10.7	949	0.49	79.2	7.7	6.29	382	5.8
A3	15:57	0.1	10.88	551	0.29	42.7	4.2	6.41	383	113.8
23-Aug										
L	12:37	0.1	13.89	247	0.14	47.3	4.3	5.72	395	135.3
JCup	13:04	0.2	12.2	468	0.25	77.3	7.3	6.64	402	21.2
HHmd	13:27	0.1	17.39	1271	0.67	94.6	8	5.33	413	25.3
WC1	13:51	0.1	13.33	1251	0.65	27.4	2.5	5.74	416	46.9
SW1	14:13	0.2	12.46	753	0.4	62	5.8	4.8	435	17.7
BC1	14:33	0.1	13.46	688	0.36	29.3	2.7	7.04	430	62

Note: *Site locations and descriptions are presented in **Table 13**. Site locations are shown on **Figures 2** and **3**.

Five of the sites sampled in August 2012 were also sampled during the three seasonal surveys, and results are summarised as follows:

- Sites HHmid, SW1 and WC1 all had increased conductivity (515 to 1271µS/cm at HHmid, 530 to 753µS/cm at SW1 and 1150 to 1251µS/cm at WC1).

The remaining results group in the following way:

- Sites in the upper parts of the gullies draining from the two ridge lines either side of Little Jilliby Jilliby Creek (A, B, C, E, I and K) generally had elevated conductivity (from 980 µS/cm at site K (Little Jilliby Jilliby East Ck) to 3500 µS/cm at site A (upper Armstrong Creek).
- Conductivity then reflected overall location with respect to feeder waters. That is valley floor creek sites had comparatively low conductivity (115 to 234 µS/cm, sites D and L respectively) and mid valley sites had mid value conductivity from 430µS/cm at site F to 883µS/cm at site K (Little Jilliby Jilliby Ck Mid).
- The trend in pH values generally followed the conductivity trend, with slightly lower pH values for the high conductivity sites and more neutral pH values for valley floor sites.
- All sites showed abundant evidence of iron staining with staining more pronounced at upper gully creek sites and least pronounced at the valley floor sites. (see Annexure A for photos of the sites).

4.5 Aquatic Macroinvertebrate Survey Results

Table 15 summarises the original macroinvertebrte data obtained from the ERM Mitchell McCotter 1999 survey data. The SIGNAL calculations were re-done as SIGNAL-2 scores to allow comparisons with the more recent data.

Table 15 Summary Statistics of ERM December 1999 Macroinvertebrate Survey

	Wallarah Creek Infrastructure Area							
Stream	**WCD**	**CS1**	**S4**	**S3**	**S5**	S1	**S2**	**CS2**
Site Code	1	2	3	4	5	6	7	8
N	**4**	**8**	**6**	**8**	**6**	8	**8**	**4**
Total number of taxa:	15	23	23	21	11	22	18	10
SIGNAL 2:	3.53	3.71	3.86	4.20	4.18	3.86	3.39	4.11
EPT	2	4	5	4	2	5	2	2
	Subsidence Area							
Stream	**WR**	**JJC**	**AC**	**LJJ-l**	**LJJ-u**	**MC**		
Site Code	9	10	11	12	13	14		
N	**4**	**3**	**3**	**4**	**3**	**3**		
Total number of taxa:	24	20	18	24	25	22		
SIGNAL 2:	4.46	3.75	3.82	3.78	3.96	3.90		
EPT	6	5	3	4	5	5		

Whilst precise location information is not available for the 1999 Wallarah Surface Infrastructure sites, the Subsidence site data included stream names and thus can be compared to the more recent data:

- There were 54 taxa identified from the 1999 surveys of which 39 were insects, 6 crustaceans and 4 molluscs.
- The overall comparison of the Subsidence Area Sites to the Surface infrastructure sites indicates that the river sites had higher diversity, higher SIGNAL scores and higher EPT scores.

Annexure Table A5 shows the results of taxonomic identifications to the levels required by AusRivAS, plus occurrence data for all aquatic macroinvertebrates and fish over the three baseline surveys (Autumn 2011, Spring 2011 and Autumn 2012), and site statistics are summarised in **Table 16**.

Table 16 Summary of Aquatic Macroinvertebrate Diversity, EPT & SIGNAL Indices

Season	**Index**	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd
Au11	Div	30	26	26	22	21	21	12	8	14	25
Sp11	Div	26	24	22	19	25	20	15	9	15	23
Au12	Div	22	24	23	17	27	19	13	15	15	22
Au11	EPT	8	7	3	1	2	2	2	2	2	3
Sp11	EPT	7	7	2	4	2	3	3	2	2	4
Au12	EPT	8	9	4	3	5	6	4	2	2	2
Au11	SIG-2	4.48	4.92	3.81	3.05	3.55	3.53	4.00	4.71	3.15	3.30
Sp11	SIG-2	4.91	4.96	4.19	3.31	3.91	4.11	4.07	4.44	4.15	3.30
Au12	SIG-2	4.95	5.04	4.13	3.64	4.00	4.95	3.92	3.79	3.85	3.26
	Mean Div	26.0	24.7	23.7	19.3	24.3	20.0	13.3	10.7	14.7	23.3
	Mean EPT	8	8	3	3	3	4	3	2	2	3
	Mean SIG	4.78	4.97	4.04	3.34	3.82	4.19	4.00	4.31	3.72	3.29

The aquatic macroinvertebrate sampling results for the baseline survey may be summarised as follows:

- To date a total of 77 macroinvertebrate taxa have been identified from the study area over all three surveys.
- The majority of the macroinvertebrate fauna (57 taxa) were insects. Other taxa present include crustaceans (9 taxa), molluscs (3 gastropods and one bivalve), springtails, water mites, seed shrimps, freshwater worms and leeches, temnocephalans and flatworms, and freshwater sponges.
- Comparison of the 1999 taxa lists with the most recent survey results indicate that 45 of the 54 taxa from the 1999 survey have been reported for the present surveys.

- Individual site diversity ranged from 8 taxa at WC1 (Autumn 2011) to 30 taxa at WR1 (Autumn 2011). Mean number of taxa per site were similar between seasons at 20.5 ± 2.2 taxa for Autumn 2011, 19.8 ± 1.7 taxa for Spring 2011 and 19.7 ± 1.5 for Autumn 2012.
- On a creek/ river system basis the Wyong River and Little Jilliby Jilliby Creek were the most diverse, with 45 macroinvertebrate taxa being recorded from each system over all surveys, followed by Little Jilliby Jilliby Creek with 43 taxa.
- Hue Hue Creek site HHMd supported a relatively high diversity, with a combined total of 37 taxa being recorded from the surveys.
- Wallarah Creek site WC1 and Spring Creek site SW1 recorded the least number of taxa, with combined totals of 19 and 20 taxa respectively.
- Site SIGNAL scores were highest in the Wyong River and ranged between 4.48 and 5.04, compared to Jilliby Jilliby Creek where values ranged between 3.05 and 4.19. SIGNAL scores for Little Jilliby Jilliby Creek sites were generally low (between 3.53 and 4.11), however LJDn recorded a comparatively high score for Autumn 2012 of 4.95.

The poor Wallarah and Spring Creek diversity results contrast with the results obtained by OEH from their reference site in Wallarah Creek (south arm) for their 1999 and Spring 2012 surveys, where they recorded increasing taxa diversities - from 23 taxa in 1999 to 31 taxa in 2012 (data supplied directly by OEH. See **Section 2.1** for discussion regarding the OEH study program). However the sites were more similar on the basis of SIGNAL comparisons, with OEH recording decreasing SIGNAL scores (from 4.17 in Autumn 1999 to 3.74 for the recent Spring 2012 survey at Wallarah Creek south). These results are similar to the decreasing scores recorded for Wallarah Creek north arm (site WC1) over the flood period (4.71 to 3.79). On the EPT score comparison, OEH recorded decreasing scores from 5 EPT taxa in 1999 to 2 EPT taxa in Spring 2012, and the Wallarah Creek north site WC1 supported 2 EPT taxa over all surveys.

There were distinct trends in the site statistics over the three surveys:

- Overall site diversity decreased over the survey period at all the Wyong River catchment sites and at HHMd. The two Wallarah Ck sites were almost steady and there was a slight increase in diversity at site BC1.
- The highest EPT scores were also recorded during the Autumn 2012 survey at five of the six Wyong River catchment sites but not at Wallarah Creek or Porters Creek catchment sites.
- Site SIGNAL scores for five of the six Wyong River catchment sites showed increased scores over time whilst SIGNAL scores fell for Wallarah Creek sites.

Comparison of the averages for the recent macronvertebrate data to the original 1999 data indicates similar trends when comparing the Wyong River catchment data to other site data. Thus there were overall higher SIGNAL scores, higher diversities and higher EPT scores at Wyong River catchment sites compared to the combined Wallarah and Porters Creek catchment sites.

4.6 Fish and Other Aquatic Fauna

Table 17 below provides a listing of the fish expected from the Wyong River catchment. The list compares the literature review results of TEL (2008) with the field surveys of Cummings et al 2008, and includes the fish caught or indentified for the present study.

Owing to the elevated flows and general flood conditions during the three seasonal surveys for the present study, there were few fish species actually caught or observed. To date three confirmed species of fish have been recorded from the study area over the three surveys, including two native and one introduced species. The native fish species were the firetail gudgeon (*Hypseleotris galii*) recorded from WR3 in Spring 2011 and the flathead gudgeon (*Philypnodon grandiceps*) which was recorded from JCUp (in Autumn and Spring 2011), LJ4 (Autumn 2011) and LJDn (Spring 2011).

A number of unconfirmed juvenile gudgeons (most likely to be flathead gudgeons) were recorded from the Wyong River and Jilliby Jilliby Creek catchment sites over the course of the baseline survey period. The introduced pest species plague minnow (*Gambusia holbrooki*) was the most widespread fish recorded from within the study area, being found at least once from every site over the baseline survey period.

With regard to water dependent mammals, platypus and water rat are both reported from the Wyong River catchment (see **Section 2.1**). For the present study whilst there were no individuals observed, there are abundant sections along Wyong River and Jilliby Jilliby Creek within the study area and in the lower floodplain section of Little Jilliby Jilliby Creek that provide suitable burrowing, feeding and pool habitats for platypus.

For each survey there were Australian water rat tracks observed on exposed sand banks within the stream sites in Wyong River and Little Jilliby Jilliby Creek, with a feeding station containing freshwater mussel shells (family Hyriidae) found at WR1 in Spring 2011 and Autumn 2012 (see Plates 4 and 5 in Annexure A).

Table 17 Fish Species from the Wyong River Catchment

		Above Weir		MPR	Below Weir	
		TEL Review	Cumming et al	This Study	TEL Review	Cumming et al
Acanthopagrus australis	Yellowfin bream				√	√
Anguilla australis	Short-finned eel	√			√	√
Anguilla reinhardtii	Long-finned eel	√	√			
Ambassis jacksoniensis	Glass perchelt	√			√	√
Carassius auratus	Goldfish*	√				
Cyprinus carpio	Common carp*	√				
Galaxias brevipinius	Climbing galaxia	√				√
Galaxiasmaculatus	Common jollytail	√				√
Galaxias olidus	Mountain galaxias	√				
Gambusia holbrooki	Plague minnow*			√		√
Gerres subfasciatus	Common silverbelly					√
Girella tricuspidata	Blackfish	√				√
Gobiomorphus australis	Striped gudgeon	√	√			√
Gobiomorphus coxii	Cox's gidgeon	√				
Macquaria colonorum	Estuary perch		√		√	√
Herklotsichthys castelinaui	Souther herring				√	√
Hyporhamphu regulariss	River garfish					√
Hypseleotris compressa	Empire gudgeon	√	√		√	√
Hypseleotris galii	Firetail gudgeon	√		√		
Liza argentea	Flat tailed mullet				√	√
Macquaria novemaculeata	Australian bass	√	√		√	√
Mugil cepalus	Sea mullet		√			√
Myxus petardi	Freshwater mullet	√				
Notesthes robusta	Bullrout					√
Paratya australiensis	Glass shrimp**	√	√			
Philypnodon garndiceps	Flat head gudgeon	√	√	√	√	√
Philypnodon sp.	Dwarf Flat head gudgeon	√	√			√
Pomatomus saltatrix	Tailor				√	√
Potamolosa richmondia	Freshwater herring	√				
Pseudomugil signifer	Southern blue eye					√
Redigobius macrostoma	Largemouth goby					√
Retropinna semoni	Australian smelt	√	√			
Tandanus tandanus	Freshwater catfish	√				

Notes: * Introduced species, ** crustacean

4.7 Aquatic Groundwater Dependent Ecosystems (GDEs)

Application of the NSW GDE assessment process requires listing of the groundwater systems and types of likely GDEs within the defined geographical area (steps 1 and 2) with assessment of vulnerability and value of the identified GDEs (steps 3 and 4). This is done in the following sub-sections. The remainder of the assessment process deals and management plus monitoring actions (steps 5 to 8). These are considered in **Section 5** below.

4.7.1 Inferred aquatic baseflow GDEs

Ecological investigations for aquatic GDEs have been hampered by the prolonged wet weather conditions prevalent over the study period that have extended from the start of the study in late Autumn 2011 to mid June in 2012. This limited access to many parts of the forested hillsides, and the general surface runoff masked any possibility of inferring base or spring flows at accessible sites. The following inferred aquatic GDE distribution is based on information in SKM (2010) and the MER (2013) groundwater report, supplemented with some preliminary dry weather environmental observations obtained in mid August 2012, some two months since the last minor storm (on 13 June 2012).

The study area lies within the Newcastle Coalfield, which is located in the north-eastern part of the Sydney Basin. Unconsolidated Quaternary age sediments occur at the surface within the Dooralong and Yarramalong valleys and dune sands and estuarine deposits dominate the coastal areas to the east. The alluvial sediment depths range from10 m to 30 m (MER 2013).

The alluvial sediments are flanked by Triassic sandstones and claystones of the Narrabeen Group in the Coastal Highlands and the hard rock geology comprises south-westerly dipping sedimentary strata with the main units of the Narrabeen Group being (from top/youngest to bottom/oldest); Terrigal Formation, Patonga Claystone, Tuggerah Formation, Munmorah Conglomerate and Dooralong Shale. The Newcastle Coal Measures occur beneath the Narrabeen Group sandstones and shales and typically occur at a depth of around 400 m below natural surface.

There are three main aquifers identified in the study area:

- The alluvial sediments of the coastal valleys (i.e. the Yarramalong and Dooralong Valleys) and floodplains, and the coastal sediments to the east.
- The underlying Narrabeen Group which is only regarded as an aquifer in the

upper shallow weathered zones or where secondary permeability occurs due to jointing and stress relief, at shallow depths. It is regarded as an aquatard where it is overlain by the alluvial sediments.

- The Wallarah Great Northern coal seam is an aquifer given that the presence of cleating (fracturing) offers enhanced aquifer storage and transmissivity.

The alluvial unconsolidated deposits form heterogeneous aquifers with variable storage and transmissivity ranging from 0.1 to 5 m/day (MER 2013). Groundwater levels within the alluvial aquifers indicate that the typical saturated thickness of the Quaternary sediments ranges from 2 m to greater than 30 m. Some of the wetlands in the valleys may have windows to the alluvial groundwater and some dams are most probably constructed to intercept the alluvial groundwater.

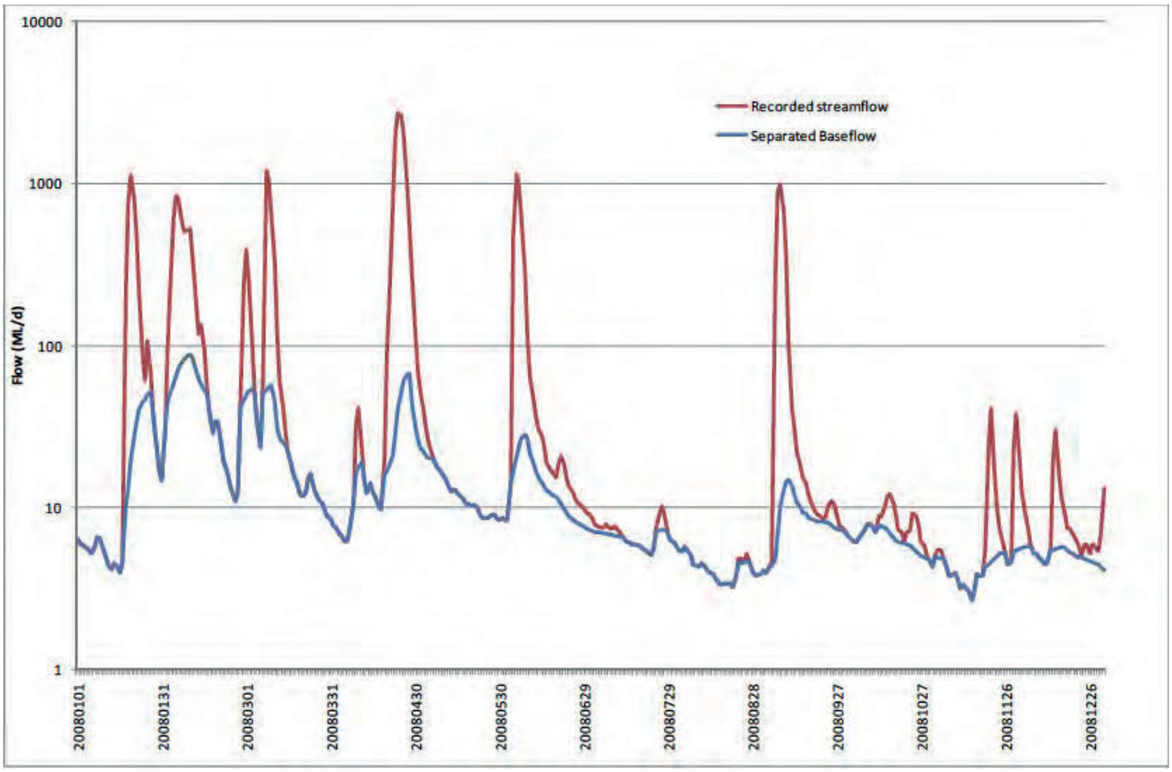


Figure 33 Modelled baseflow estimates for Jilliby Jilliby Creek at Stream Gauge 211010 for 2008 (from SKM 2010).

The alluvial aquifers are recharged via rainfall and eventually discharge groundwater to the river or creeks as base flow. SKM (2010) estimated that the baseflow component of Jilliby Jilliby Creek is between 14 and 17% total flow and between 25 to 28% in the Wyong River. **Figure 33** provides a modelled estimate of the baseflow component of the total Jilliby Jilliby Creek flow at gauge 211010 for 2008 (from Fig 4.6 in SKM 2010). SKM (2010) noted that during prolonged dry periods (such as 2006) there was generally some flow in Wyong River but for Jilliby Jilliby Creek there were instances of zero flow for days at a time.

The Narrabeen Group shallow groundwater sources are recharged via direct rainfall infiltration through the shallow weathered zone into the underlying clastic rocks. In the topographically high areas, the watertable elevation is high and where it is intersected by drainages, groundwater seeps down slope to the Wyong River and Jilliby Jilliby Creek, or it is lost from the system via evapotranspiration by the vegetation that lines the drainages. This means that the water tables reflect topography, with flow paths that begin in the elevated areas and end at the major drainages (i.e. the Yarramalong and Dooralong Valleys).

With regard to aquatic ecological implications of the groundwater-surface water interactions described above, it is inferred that riparian vegetation along the main drainages (Wyong River and Jilliby Jilliby Creek) are most likely groundwater dependant during drought (see also Cumberland Ecology 2012) but the aquatic biota within the main channels are less so, particularly in Jilliby Jilliby Creek where the proportion of base to total flow is relatively low and consequently during prolonged drought periods, the creek would rapidly shrink to a series of isolated pools with little extended duration provided from baseflow.

Given the generally low topographical variation across the valley floors, the multiplicity of dams, billabongs and wetlands scattered through the Dooralong Valley are frequently recharged following minor storms, as floodwaters overtop the main drainage channel. Consequently, during low flow and drought periods these wetlands and associated vegetation within the valley alluviums are most probably groundwater dependent and any aquatic plants plus biota within the wetlands would also be groundwater dependent, but with the degree of dependency related to the relative depths of the standing water to the alluvial water-table. That is, if the wetland holds water via base flow interaction or direct interception of the alluvial water-table for significant times after surface flow has ceased, the wetland pool may be an important drought refuge as the main channel dries down to smaller isolated pools.

The creeks draining from the highlands to the Wyong River, Litle Jilliby Jilliby Creek and to Jilliby Jilliby Creek are ephemeral, with any base flow component rapidly decreasing after surface flows cease. That is, it is inferred that the majority of the first and second order drainage lines will not hold water for any significant time after rainfall ceases and therefore would not provide any meaningful aquatic ecological habitat (or GDE) function. Further, the small amount of base flow emanating from the weathered Narrrabeen Group rocks includes elevated salts and minerals including iron, as evidenced by many observations of iron staining in these creeks (see **Section 4.4**), resulting in decreased water quality for the remaining ponded rainwaters.

The first and second order creeks draining to Wallarah and Spring Creeks from the coastal foothills (Bushells Ridge) are also ephemeral and are unlikely to have any significant baseflow component to provide extended drought refuge pools. However as these streams level out on the coastal plain there would appear to be sufficient available groundwater to support wetland communities, with ponded surface water that would appear to have good drought tolerance. These wetlands are therefore most likely groundwater dependent whilst the aquatic biota of the ponded surface waters in these wetlands may or may not be, again dependant on their drought tolerance, which has yet to be observed.

4.7.2 Alluvial GDEs

Jilliby Jilliby Creek, the lower Little Jilliby Jilliby Creek and Wyong River have well developed alluvial groundwater systems that may provide suitable habitat to support stygofauna. Accordingly, a pilot study for stygofauna diversity and abundance was undertaken in February 2012 (see methods in **Section 3.5.1**).

Water samples were obtained during the study for laboratory analysis and field metered water quality results were also obtained from sub-samples of the groundwater as it was collected. **Tables 18** and **19** show the combined water quality results.

Water quality results are summarised as follows:

- Groundwater temperature decreased with depths from a shallow alluvium mean of 22°C to a rock mean of 20.2°C.
- Conductivity increased with depth from a mean of 985µS/cm in shallow alluvial to 4322µS/cm in rock. Deep alluvial mean conductivity was 2422µS/cm.
- Dissolved oxygen values were low and decreased with depth from mean of 31% saturation in shallow alluvial to 22% saturation in the rock aquifer.
- pH values increased with depth, with a mean of 5.5 pH units in the shallow alluvium and 7.2 pH units in rock.
- ORP decreased with depth from 329 mV in shallow alluvium to 129 mV in deep alluvium and 84 mV in rock.

Table 18 Honeysuckle Park Stygofauna Sampling - Bore Sample Water Quality 6 to 7 February 2012

Site*	Bore Group	Bore Depth	Water Sample	Date	Time	Sample Volume (L)	Tenp °C	Cond µS/cm	DO %sat	DO mg/l	pH units	ORP mv	Turb NTU
3C1	3	C	1	6/02/12	15:43	134-156	21.77	958	34.6	2.7	5.56	318	200.5
3C2	3	C	2	7/02/12	11:34	56-78	22.26	1012	26.9	2.1	5.47	340	363.7
1B1	1	B	1	6/02/12	10:08	5-6	20.28	1603	28.4	2.3	6.08	133	366.9
1B2	1	B	2	6/02/12	10:31	134-156	19.95	1687	41.0	3.4	6.07	176	32.2
1B3	1	B	3	6/02/12	10:44	256-278	20.13	1729	32.6	2.7	6.03	161	16.7
2B1	2	B	1	6/02/12	12:15	0-22	21.71	2728	22.2	1.8	6.29	5	366.9
2B2	2	B	2	6/02/12	12:30	144-166	20.21	2345	21.3	1.7	5.73	138	44.1
2B3	2	B	3	6/02/12	12:40	267-289	20.18	2333	17.5	1.4	5.67	66	17.6
3B1	3	B	1	6/02/12	14:29	112-134	19.97	2619	23.0	1.9	5.53	151	366.9
3B2	3	B	2	6/02/12	14:48	234-256	20.24	2633	21.8	1.8	5.56	236	87.5
4B1	4	B	1	7/02/12	13:57	0-12	21.79	4911	31.3	2.5	7.03	209	14.9
5B1	5	B	1	7/02/12	8:24	12-34	19.96	2207	13.0	1.1	6.31	166	161.5
5B2	5	B	2	7/02/12	8:50	134-156	20.76	2139	10.4	0.8	6.73	218	42.3
5B3	5	B	3	7/02/12	9:18	234-256	20.66	2129	14.6	1.2	6.59	166	32.6
1A1	1	A	1	6/02/12	8:53	0-3	21.76	6506	19.6	1.5	7.44	110	24.2
1A2	1	A	2	6/02/12	9:16	180-182	21.44	6582	27.0	1.9	7.57	87	366.9
1A3	1	A	3	6/02/12	9:45	290-292	20.86	6664	28.7	2.3	7.59	68	149.8
2A1	2	A	1	6/02/12	11:18	0-10	22.67	2911	26.4	2.0	7.19	16	18.1
2A2	2	A	2	6/02/12	11:31	100-120	20.20	4119	19.0	1.5	7.43	-21	14.8
2A3	2	A	3	6/02/12	12:04	267-289	20.50	4807	17.4	1.4	7.46	10	12.1
3A1	3	A	1	6/02/12	13:16	0-12	27.12	2471	40.0	2.9	5.54	140	21.9
3A2	3	A	2	6/02/12	14:14	78-100	23.09	5171	33.7	2.6	7.12	65	157.4
3A3	3	A	3	7/02/12	11:54	12-34	21.05	5288	18.1	1.4	7.06	173	29.1
4A1	4	A	1	7/02/12	12:49	56-78	19.57	4942	16.5	1.4	7.09	220	17.7
4A2	4	A	2	7/02/12	13:01	134-156	19.33	4959	14.1	1.2	7.12	125	11.0
4A3	4	A	3	7/02/12	13:19	256-278	19.36	4957	14.9	1.2	7.08	100	9.8
5A1	5	A	1	6/02/12	16:25	12-34	19.98	2657	19.4	1.6	7.38	90	38.0
5A2	5	A	2	6/02/12	16:37	112-134	19.64	3419	21.4	1.8	7.10	44	15.3
5A3	5	A	3	6/02/12	16:50	256-278	19.42	3423	22.1	1.8	7.08	34	14.6

Note* There are 5 groups of bores (1 to 5) each with two or three separate bores drilled to different depths. The table shows results ordered with respect to bore depth. (C = shallow alluvial bores, B = deep alluvial bores and A = Underlying Rock bores. See **Figure 8** and **Table 6** in **Section 3.5.1** for location and bore characteristics data.

Table 19 Honeysuckle Property Stygofauna Sampling Water Quality***

Site	Date	Time	Sub-Sample Litreage	Lab Cond µS/cm	Lab pH Units	NH4-N mg/L	PO4-P mg/L	Zinc mg/L	Iron mg/L	Mn mg/L
1A	6/02/12	9:45	290-292	6950	7.5	0.8	<0.01	0.001	0.02	0.13
1B	6/02/12	10:44	256-278	1470	5.8	1.0	0.01	0.006	9.5	1.2
2B	6/02/12	12:40	267-289	2160	4.7	1.7	<0.01	0.016	42	1.5
3A	6/02/12	14:14	78-100	5090	7.3	<0.01	0.34	0.004	1.8	0.14
3B	6/02/12	14:48	234-256	2430	5.6	0.2	0.01	0.018	17	1.2
3C	6/02/12	15:43	134-156	825	6.0	0.1	0.01	0.013	0.46	0.78
4A	7/02/12	13:19	256-278	4980	7.2	0.4	0.02	0.002	0.02	0.39
4B	7/02/12	*	12-24	2980	6.2	<0.1	0.01	0.007	4.9	0.89
5A	6/02/12	16:50	256-278	3300	7.1	0.2	0.01	<0.001	0.21	0.21
5B	7/02/12	8:50	134-156	2120	6.8	<0.1	0.03	0.005	0.02	0.88
5C	7/02/12	**	0-30	345	6.0	0.4	0.45	0.007	0.02	0.1

Notes: *Bore had residual oil film from previous vandalism, ** Sample too silty for metered water quality
*** All other analytes were below detection; NO2, NO3, Cr, As all <0.011mg/L, Cu and Pb <0.001mg/L, Cd <0.0002mg/L and Hg<0.0001mg/L

- Turbidity also decreased with depth from 282 NTU in shallow alluvium to 60 NTU in rock.
- Nitrates, As, Cr, Cu, Pd, Cd and Hg concentrations were all below laboratory detection limits.
- Mean Ammonia (0.58 mg/L), Iron (14.68 mg/L), Zinc (0.0104 mg/L) and manganese (1.134 mg/L) were all at a maximum in the deep alluvials.
- Total Phosphorus was highest in the shallow alluvium (0.23 mg/L).

Table 20 indicates that there were 1452 individuals from 6 taxa identified from the 13 filtered bore samples at Honeysuckle Park on 6 and 7 February 2012. There were also 23 terrestrial fauna or fragments found. Discounting the terrestrial fauna component there were 1402 individuals from 5 taxa in the shallow alluvium bores, 32 individuals from 6 taxa in the deep alluvial bores and 41 individuals from the rock aquifer bores. After further consultations with Dr Hose, the taxa were determined as follows:

- The Collombola springtails are not stygofauna.
- As the majority of the mites were found in the shallow alluvium bore samples the mites were unlikely to be stygofauna and are probably bore colonisers.

Table 20 Results of Stygofauna Sampling and Analysis from Honeysuckle Experimental Bores February 2012*

Bore HPBH	Sub-bore	Depth (mTOC)	Substratum	Mean Bore EC (µS/cm)	Acarina mites	Collembola Springtails	Cyclopoida Copepods	Nematoda Round worm	Rotifera Wheel animals	Tardigrada Water bears	Terrestrial fauna & fragments
3	C	8	Shal alluv	798.8	681			22	1	1	
4	C	6	Shal alluv	289.4							
5	C	6	Shal alluv	830.0	21		17	640	4		15
1	B	16.5	Deep alluv	1693.4	6			1	5		3
2	B	24	Deep alluv	1723.4	1	1		1			
3	B	24	Deep alluv	2079.8	1	1		1		1	
4	B	30	Deep alluv	1944.2	1					1	2
5	B	23	Deep alluv	663.0	3				1	2	
1	A	42	Rock	2955.2	5	1		1			1
2	A	42	Rock	1790.4	1						
3	A	42	Rock	2628.8	7	1		3	5	8	
4	A	42	Rock	4956.6	1						
5	A	42	Rock	2282.0	5						2
				Total	733	4	17	669	16	13	23

Note: * Bore results are grouped in terms of bore depth (mTOC) with the three shallow alluvial (C) bores first, Deep alluvial bores (B) second and rock bores (A) last.

- The Copepods (Cyclopoida) may be stygofauna but as they are also confined to the shallow alluvium samples, they are more likely to be either meiofauna or possibly hyporheic fauna; that is they are most likely confined to the surface saturated soils.
- The remaining three taxa are most likely meiofauna that have either colonised the standing bore waters or form part of the local hyporheic fauna.

The results of this study are in line with Dr Hose's own work on aquifers in the Gosford LGA (Hose et al 2012) where it was concluded that sand-dominated aquifers similar to the Dooralong Valley alluvial aquifer rarely support stygofauna due to the close packing of the sands leaving no room in the interstitial spaces for stygofauna colonisation. Thus, the lack of stygofauna here is consistent with these expectations (see also OES 2009).
It is concluded that the Dooralong Valley alluvium and underlying rock aquifer in the vicinity of the confluence of Jilliby Jilliby and Little Jilliby Jilliby Creeks do not support any stygofauna and that the meiofauna found in the samples are likely to be bore water colonisers, and some organisms could be part of the local hyporheic assemblage that have entered the bores.

4.8 Summary of Study Site Aquatic Ecology

Table 21 provides a summary of the aquatic ecological attributes of the project study area. The macroinvertebrate and SIGNAL ranges are the ranges for site means over all surveys in each sub-catchment.

Table 21 Summary of Project Area Aquatic Ecological Attributes

Sub-Catchment	Number of aquatic plants*	RCE (%)	Water conductivity (µS/cm)	Macro-invertebrate Diversity**	SIGNAL Index	EPT Index	Number of Fish Species***
Wyong River	11 & 1 introduced	72 to 74	Low 233 to 253	25 to 26 (45)	Mod 4.8 to 5.0	8	11 native and 1 pest
Jilliby Jilliby Creek	12	65 to 79	Low to Moderate 286 to 610	19 to 24 (43)	Low 3.3 to 4.2	3	2 native & 1 pest
Wallarah Creek	11	54 to 90	Low (262) to Moderate (1145)	11 to13 (20)	Low 4.0 to 4.3	2.5	1 pest
Porters Creek	8	70 to 78	Low to moderate 233 to 935	15 to 23 (37)	Low 3.3 to 3.7	2.5	1 pest

Notes: *Plants in Wyong River = SKM (2010) and this study combined.
**Numbers in brackets = total number of taxa from the sub-catchment sites.
***Fish in Wyong River = Cummings et al (2008) and this study combined.

The review and field studies undertaken to date in the project aquatic ecology study area have highlighted the following features of the aquatic ecology.

There are no listed aquatic species, endangered ecological communities or critical habitat found or known from the total Wyong River study catchment and none are expected.

A total of seventeen macrophytes were recorded from the combined study area sites over the survey period. The diversity of macrophytes increased over consecutive surveys either as a result of the more favourable conditions for observing macrophytes or owing to recolonisation following scouring by floods immediately prior to the commencement of the first sampling in Autumn 2011. This latter conclusion is in line with the experience of SKM (2008b) who sampled for macrophytes under similar circumstances. In this respect SKM (2008b) recorded 7 additional macrophytes in the Wyong River sub-catchment area, including one introduced species.

For the present study there were no macrophytes recorded in the Wyong River sites, upper Jilliby Jilliby Creek site JCUp, downstream Little Jilliby Jilliby Creek site LJDn and Buttonderry Creek site BC1. With the exception of LJDn, the swampy and lower flow sites such as HHMd, JC2E and SWUp recorded the highest diversities of macrophytes (6 to 7 macrophyte taxa).

There are specific habitat features at Wyong River sites WR1 and WR3, and Jilliby Jilliby catchment sites JCUp and LJDn, that also limit the possibility of macrophyte establishment:

- The site river and creek lengths are highly channelized with flat bottoms, steep and undercut edge banks, and straight sides.
- The site substrates also consist of highly mobile unconsolidated sands that, combined with the other factors, increase the susceptibility of macrophytes to scouring by floods. In contrast the meandering site JC2E, located in one of two main branches of Jilliby Jilliby Creek, was observed to contain isolated backwaters free of flow during the floods, and this site supported six macrophytes and extensive edge and bank vegetation.

Over all sample seasons, the Wyong River sub-catchment sites recorded the highest Diversity, SIGNAL and EPT scores, and Porters Creek sub-catchment sites recorded the lowest SIGNAL scores. Wallarah Creek sites recorded the lowest Diversity scores:

- There were a total of 77 macroinvertebrate taxa identified over the three baseline seasonal surveys with 45 taxa from Wyong River sites, 43 from Jilliby Jilliby Creek sites, 37 from Porters Creek sub-catchment sites and 20 from Wallarah Creek sites.
- Overall mean sub-catchment site aquatic macroinvertebrate diversities ranged from 11 to 26 with the sub-catchment means decreasing in the same manner as overall number of taxa noted above.
- Mean sub-catchment site SIGNAL indices ranged from fair in Wyong River (around 5.0) to poor in Porters Creek sub-catchment sites, with poor to low results for Jilliby Jilliby Creek and Wallarah Creek sub-catchment sites indicating a preponderance of pollution or stress tolerant species.

- The mean sub-catchment EPT scores show the same pattern with a good index (8) for Wyong River sub-catchment sites, and poor index results for all other sub-catchments (2.5 to 3).

The present (2011 to 2012) seasonal results are in line with the original macroinvertebrate sampling in 1999 where the larger stream sites in Wyong River and Jilliby Jilliby Creeks also had higher taxa diversities and higher SIGNAL scores than the smaller proposed infrastructure area creek sites.

Whilst the Wyong River and Jilliby Jilliby Creek assessed habitats are known to support an abundance of native fish species plus aquatic mammals such as Australian water rat and platypus, only two native fish species have been caught or seen over the base-line study period, most likely due to the preponderance of flood or high flow conditions experienced over the study period. Regardless of flood and high flows the streams all supported large populations of the introduced pest fish species plague minnow.

The low aquatic plant and invertebrate ratings, the physical evidence of repeated high flood scouring activity several times during the study period, the lack of native fish and aquatic mammals captures or sightings to date and the pattern of changes in macroinvertebarte assemblage indices over the three sampling periods following the first major flood in June 2011, are all consistent with and reflect the scouring induced habitat destruction impacts arising from the persistent flood activity throughout the study period.

Depending on the vagaries of local climate variations, the continuing baseline surveys are expected to provide more indications of these habitat-destruction impacts or could provide indications of recovery in line with restoration of habitat complexity.

4.8.1 Aquatic GDEs

There are three main aquifers identified in the study area; the alluvial sediments of the coastal valleys and floodplains, the upper shallow weathered zone of the Narrabeen Group and the Wallarah Great Northern coal seam. Of these aquifers the alluvial sediments provide relatively long-term baseflow to Jilliby Jilliby Creek and to Wyong River and the shallow weathered rock aquifer provides limited baseflow to highland gullies or to foothill springs for short periods after rainfall with little expectation of there being any aquatic baseflow GDEs.

The aquatic biota within the main Jilliby Jilliby Creek channels are not considered highly dependent on baseflow as the proportion of base to total flow is relatively low and consequently during prolonged drought periods, the creek rapidly shrinks to a series of isolated pools with little extended duration provided from baseflow. Aquatic biota in isolated water bodies that intercept the water table may be of more importance, as these GDEs may provide better drought refuge than creek pools.

A pilot study for stygofauna diversity and abundance in the alluvial and underlying hard rock aquifers in Jilliby Jilliby Creek was undertaken in February 2012 and it was concluded that the aquifers did not support stygofauna, or at least not to any significant extent. This is in line with other studies of coastal sand aquifers that also found no stygofauna by virtue of the close-grained nature of the alluvial sediments.

4.8.2 Fish passage and stream classification

With regard to fish passage between the estuary and the Wyong River, the Wyong weir and its rock ramp fishway located at the tidal limit of the Wyong River prevented fish passage during drought periods and was estimated to be operational for only 60% of the time (SKM 2008a). Notwithstanding, there were generally sufficient environmental flows and flood events to allow partial fish passage and accordingly there are a variety of native and introduced fish found in the Wyong River, lower Jilliby Jilliby Creek and the lower portion of Little Jilliby Jilliby Creek in the study area, that include species that migrate to and from the estuary to the freshwater streams. The recent upgrade of the weir fishway undertaken as part of the Mardi to Mangrove Pipeline Link project is expected to be operational for 99% of the time and it is anticipated that more fish will be able to colonise the lower reaches of the study area over time as a result.

The Wyong River and Jilliby Jilliby Creek floodplains are also drowned out regularly for some distance upstream during floods, further facilitating fish passage, particularly from the main streams to floodplain wetlands and dams. Natural obstacles plus the ephemeral nature of the majority of the forested ridge gully and foothill slope drainages preclude fish passage and colonisation, and during dry or prolonged low flow periods, water availability and quality of these streams is such that there is little or no useful aquatic habitat available for colonisation by aquatic biota.

Whilst there are a number of natural and constructed obstacles that prevent fish passage from Tuggerah Lake to Wallarah and Spring Creeks during low t flow periods, there would appear to be sufficient fish passage available to the lower portions of these creeks during medium to high flows to allow fish colonisation of the more permanent pools at the lower ends of the freshwater reaches. Creek reaches above the defined key fish habitat sections are generally ephemeral with regard to surface water flow although several wetland areas may hold surface water for longer periods of time. This will need to be investigated further once there are prolonged dry periods in the study area.

Table 22 Applied Stream Classifications (based on DPI Fisheries' Classifications)*

Location**	Water Body	Section	KFH	DPI Class	Comments/Attributes
Inrfastructure Sites					
Tooheys Road					
	Wallarah Ck				
		N Arm above freeway	x	3	Wetland Sections
		N Arm below freeway	x	3	Wetland Sections
		N Arm below highway	√	3(2)	Wetland Sections & Estuary
	Spring Ck				
		S Arm above freeway	x	4	
		S Arm below freeway		3	Wetland sections
		NW Arm above Rail	√ lower part	3(2)	KFH part is Class 2
Hue Hue Road					
	Buttonderry Ck				
		Waste Depot to freeway	x	3(4)	Wetland sections
		Freeway - Porters Ck Wetland	x	4(3)	Intermittent wetland sections
Mining Subsidence Area and reference Sub-catchments					
	Hue Hue Creek				
		Upper to Sandra St	x	4(3)	Intermittent wetland sections
		Sandra St to Porters Ck Wetland	√ lower part	3(2)	KFH and complete wetland
	Jilliby Jilliby Creek		√	2	Through whole study area
	Wyong River		√	1(2)	Through whole study area
	Wyong River & Jilliby Jilliby Ck				
		Vegetated Billabongs & Dams	√(some)	2(3)	Variable (size & permanency)
		Unvegetated dams	x	3(4)	Variable (size & permanency)
	Little Jilliby Jilliby Creek				
		Upper & East	√part	4(3)	Less intermittent downstream
		Mid	√	3	More permanent and wetlands
		Lower	√	3(2)	More permanent downstream
		Splash & Calmans Gullies	√part	4(3)	More permanent downstream
	Jilliby Jilliby Ck Ridge Catchments				
		Lowers Gully south to Baily Rd	√part	4(3)	More permanent downstream
		Durren Road	x	4(3)	Some remnant wetland
		Myrtle Ck	√part	4 to 3	Up to downstream
		Armstrong Ck	√part	4 to 4(3)	Up to downstream
	Wyong River Northern Ridge Catchments				
		Steel Gully to Kidmans Lane	x	4(3)	More permanent downstream
		Bangalow Flat	√part	4 to 3	More permanent downstream

Notes
* KFH = Key Fish Habitat. Water Body Class designations from NSW Fisheries 1999b - see Table A6
** See Figures 2 and 3 for creek sections and sub-catchments and Figures 4 and 5 for KFH locations

As indicated in **Section 1.1** and shown on **Figures 4** and **5**, a number of the streams and water bodies in the study area are designated Key Fish Habitat (KFH) by DPI Fisheries. DPI Fisheries also provide a Fish Habitat Classification Scheme (NSW Fisheries 1999b) that classifies streams and water bodes from major fish habitat (Class 1) to Unlikely fish habitat (Class 4). The full classification scheme is shown in Annexure Table A6.

The study area has been sub-divided into sub-catchments and reaches (as indicated in **Figures 2, 3** and **6** in **Section 1**), and **Table 22** provides a classification of these sub-catchments by KFH and Class designations, based on the results of the aquatic surveys undertaken to date. Classifications are graded, with the main classification given first and any modifier that lowers or increases the score given in brackets. Thus there may be sub-classes between each main class (e.g., 1(2) and 2(1) between Classes 1 and 2). Results are summarised as follows:

Mining subsidence area and reference sub-catchments

- Wyong River in the study area is classified as Class 1(2) as it is a moderate to major fish and aquatic habitat with reasonable to good fish passage to the Tuggerah Lake estuary, and which seldom ceases to flow.
- Jilliby Jilliby Creek is considered Class 2 as it provides good fish habitat and good fish passage but can be reduced to isolated pools, with no flow during prolonged droughts.
- There are numerous isolated wetlands, and billabongs plus farm dams that support wetlands or fringing emergent vegetation on both the Wyong River and Jilliby Jilliby Creek alluvial plains and these are classified as 2(3) by virtue of the valuable additional drought refuge habitat these systems provide for their respective streams. Other water bodies (farm dams and isolated water bodies are classed 3(4) as they provide some aquatic habitat values but dry out more rapidly.
- Upper Little Jilliby Jilliby Creek and the gullies feeding into the middle creek section are considered Class 4(3) by virtue of the ephemeral nature of the drainages and the lack of fish passage.
- The mid section of Little Jillby Jilliby Creek is considered Class 3 - even though it is designated KFH and probably provides some fish passage - by virtue of the presence of semi-permanent ponds and wetlands that are compromised by adverse water quality from erosion of forest tracks due to off-road vehicle use.
- The lower section of Little Jillby Jilliby Creek is classed 3(2) as it is more permanent and has better fish passage, but has overall lower riparian and in-stream habitat diversity values.
- Most of the ridge sub-catchments draining to the above three main streams have designations ranging from 4 to 3 with many being ephemeral and offering no fish passage or even semi-permanent aquatic habitat. Some provide fish passage and more permanent aquatic habitat as they drain to their respective streams.
- Hue Hue Creek classification varies downstream from 4(3) above Sandra St to 3(2) below Sandra Street through to Porters Ck Wetland owing to the continuous and permanent wetland habitat downstream from Sandra Street.

Proposed Infrastructure Areas

- The north arm of Wallarah Creek which runs through the Tooheys Road infrastructure site is considered Class 3 as it provides intermittent permanent to semi-permanent wetland habitat with good aquatic habitat complexity but is unlikely to provide fish passage.
- The lower part of Wallarah Creek, which represents the receiving waters for the infrastructure area runoff, is considered Class 3(2) as the creek becomes more permanent with some fish passage availability, and eventually becomes estuarine, draining to Budgewoi Lake.
- The south arm of Spring Creek flows through the infrastructure area and is considered class 4 above the freeway due to damming for agricultural purposes and becomes class 3 through the infrastructure section owing to the presence of intermittent permanent to semi-permanent wetland habitat with good aquatic habitat complexity but limited fish passage.
- The rail loop crosses the lower part of the north-west arm of Spring Creek just upstream of the tidal limit. It is designated KFH and is considered Class 3(2) owing to the presence of more or less permanent pools with reasonable fish passage. The section of the creek at the proposed crossing is considered Class 2 as it is a permanent creek with good connection to the estuary.

These classifications have various consequences for construction and operation of the project. The classifications proscribe the standards for stream crossings that are required as per the DPI Fisheries guidelines (NSW Fisheries 1999b).

Whilst the classifications also provide a guide to the level of care that is required for potential discharges to the various streams in terms of the quality of the receiving environments, lower classifications may be based on current stream condition and improvements to these stream sections could increase the classification. In effect, the portions of streams designated KFH should all be considered of high value regardless of current classification, as this designation also considers the value of a particular section of stream to the receiving waters below in terms of water supply and quality.

5 IMPACT ASSESSMENT & MITIGATION

The project proposal is summarised in **Section 1.1** above and detailed in the EIS main report (Hansen Bailey 2013). **Figure 34** shows the proposed long wall mining sequence and the relationship of the mining footprint to the surface infrastructure areas, and **Figures 35** to **37** provide layout details of the three proposed surface infrastructure areas. Key features from the point of view of impact assessment for aquatic ecology may be summarised as follows:

- An underground longwall mine to operate for 25 years partially located under Hue Hue Creek, Jilliby Jilliby and Little Jilliby Jilliby Creeks and several small forested catchments draining to the Wyong River.
- Progressive mining in north-south longwalls from east to west.
- An underground drift connecting the mine to surface facilities at the Tooheys Road Site with additional vertical shaft used for personnel transport facilities and mine ventilation at the Buttonderry site.
- Coal stockpiles, conveyors and a rail loop with associated train loading facilities providing for transport to Newcastle, located at Tooheys Road in the Wallarah Creek catchment that drains to Budgewoi Lake.
- Workshops, bathhouses and administration buildings at the Buttonderry site within the Buttonderry Creek catchment draining to Porters Creek Swamp.
- Water supply infrastructure including dams and water treatment plants.
- Air ventilation facilities for the mine including the initial shaft located at the Buttonderry site and a future shaft to be located in Wyong State Forest.

5.1 Assessment of Potential Impacts

There are three general classes of potential impacts arising from longwall coal mining relating to:

- Initial mine setup and surface infrastructure construction.
- The longwall mining process.
- The operation of the surface facilities during mining.

These potential impacts are listed and assessed in regard to the project design in the following sub-sections below.

Figure 34

Proposed Mine Plan showing total project boundary and conceptual longwall mining schedule

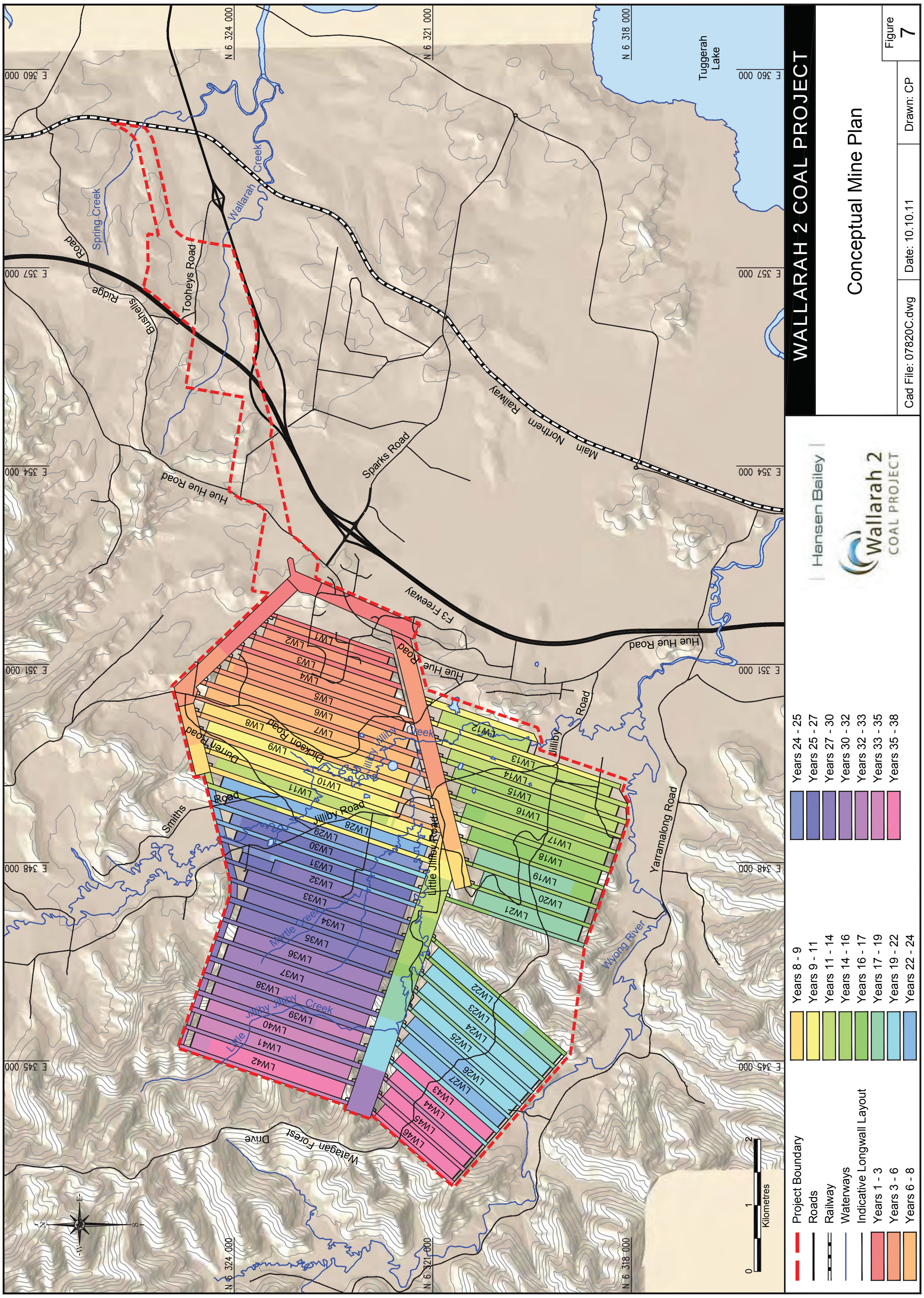


Figure 35 Surface Infrastructure works at Tooheys Roads site in Wallarah Creek catchment, draining to Budgewoi Lake. (Figures 2.3 & 4.2 in WRM 2013)

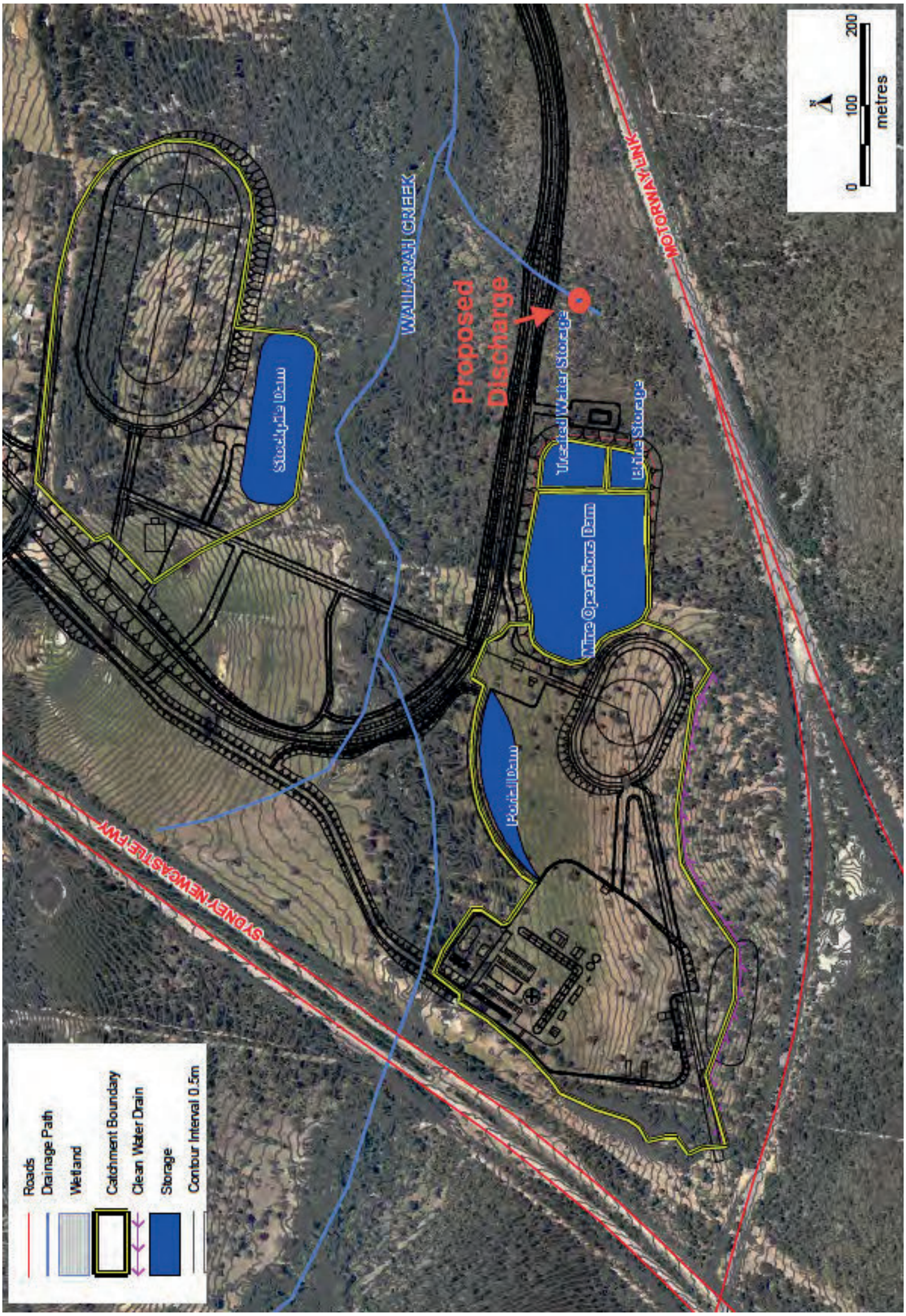


Figure 36

Surface Infrastructure works in Buttonderry Creek draining to Porters Creek Swamp.

(Figure 2.2 in WRM 2013)

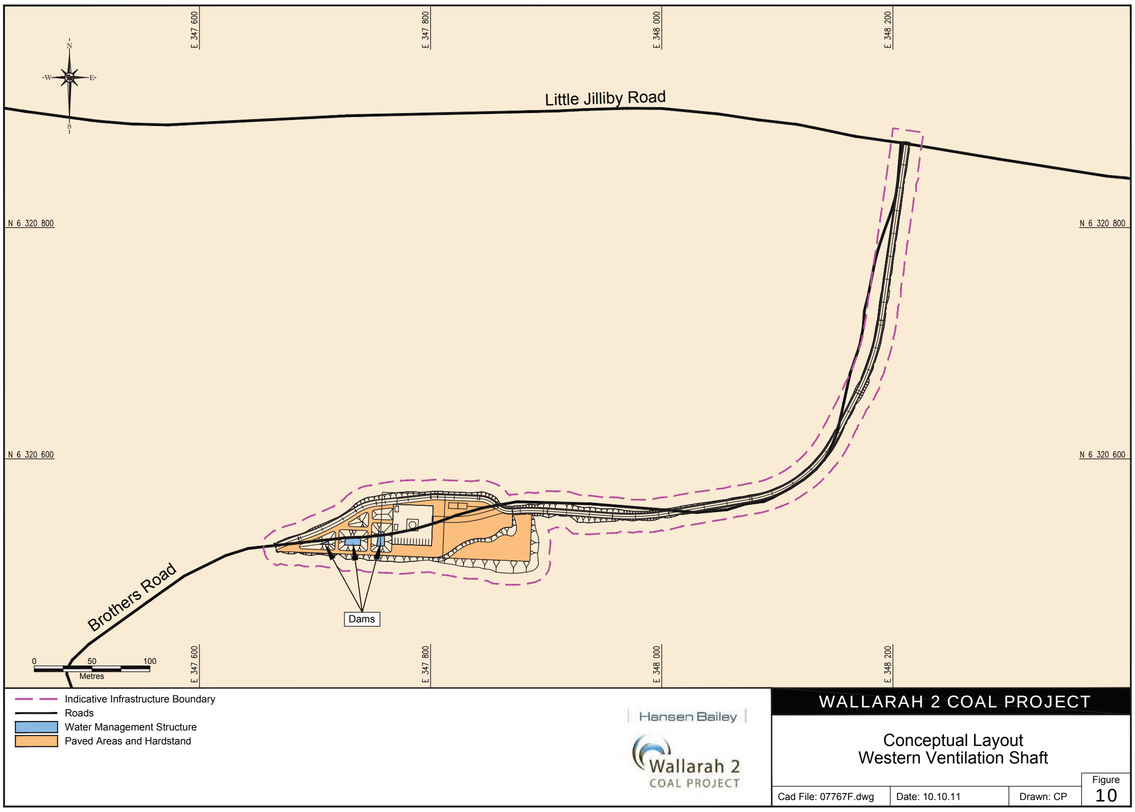


Figure 37 Western Ventilation Shaft Site located on the northern ridge of Armstrong Creek (north arm), draining to Lower Jilliby Jilliby Creek.

5.1.1 impacts associated with surface infrastructure development.

These include bulk surface earthworks for levelling and moulding sites for the various structures and coal handling purposes and temporary road works to access various site works (e.g., the rail loop Spring Creek crossing):

Direct disturbance for placement of the required facilities (buildings, shafts, water pollution and storage dams).

The various components for the two infrastructure areas and for the western shaft site have been sited to avoid where possible, and then to minimise any direct impact on creek lines and associated riparian corridors:

- Whilst the Tooheys Road Site facilities are located between the branches of the northern Wallarah Creek sub-catchment drainages to prevent direct damage to the creek aquatic habitats, there will be a need to clear 1.1 ha of Paperbark swamp and 6 ha of Blackbutt-Turpentine open forest, with portions of this habitat located along the riparian bank of Wallarah Creek. There will also be a need to clear 1.8 ha of Swamp Mahogany forest, which also includes some riparian vegetation along a tributary of Spring Creek (required for the placement of the rail loop). The impact assessment and offsets for the loss of these terrestrial and riparian vegetation communities are addressed in the terrestrial flora and fauna report (Cumberland Ecology 2013), which includes riparian bank rehabilitation measures and establishment of a wetland conservation area to protect the existing wetland within the project boundary. The proposed construction safeguards and the riparian rehabilitation measures will protect and enhance the aquatic ecological attributes of the adjacent stream lines.

- The Buttonderry Site facilities are located on mainly cleared lands some 200 m south-west of Buttonderry Creek, and clearing of vegetation for the site would not directly impact creek or creek riparian habitats. Proposed construction safeguards will protect the aquatic ecological attributes of Buttonderry Creek.
- The Western Ventilation Shaft site is located more than 100 m north of the Armstrong Creek (north arm) on a ridge that is accessible via an existing forest track access (Brothers Road) from Little Jilliby Road, and clearing of vegetation for the site would not directly impact creek or creek riparian habitats.

For all the above works, construction will include suitable safeguards to prevent sediments and dirty construction water entering the creeks. Site designs will also include operational surface water diversion, collection and treatment facilities to prevent sediments plus coal spillages and coal dust entering the creeks from the cleared and developed areas (see WRM 2013 for detailed construction and operational water management measures to achieve these goals).

Additional bulk earthwork spoil disposal will generally be required for initial underground mine construction works including excavation and construction of the drift:

- All construction sites and stockpiles will be suitably bunded to prevent sediment-laden runoff to adjacent creeks.
- Separation of site construction water from clean site runoff water will be achieved by use of capture and diversion channels, storage or treatment dams plus suitable discharge or other water disposal options that minimise impact on the aquatic habitat function of the various creeks (see WRM 2013 for details).

Additional disturbance for roads, rail transport links and other service corridors (power, gas lines, conveyors etc.).

Road, rail and services links at the Tooheys Road site will need to pass over several branches of Wallarah Creek that are not designated Key Fish Habitat (KFH) but are designated Class 3 to 4 fish habitat (see **Section 4.8.2**) and include important wetland plus Wallum froglet habitat (see Cumberland Ecology 2013).

The proposed Tooheys Road site rail loop connects to the main rail north of the Main Northern Rail Spring Creek crossing, and will also require a crossing over Spring Creek, and Spring Creek at this location is designated KFH, and is a Class 2 stream. These crossings will need to be designed to minimise disturbance to riparian and aquatic ecosystems and to ensure minimum disturbance to stream hydrodynamics, water quality and aquatic habitat condition:

- To this end the crossings have been located to avoid wetland components and wallum froglet habitat where possible, and to cross streams at right angles, to minimise disturbance. Protection of Wallarah Creek riparian and aquatic habitat function will require suitably sized culverts plus creek bed treatments to minimise disturbance, as per the DPI Fisheries' Creek Crossing guidelines (NSW Fisheries 1999b).
- Design and construction of the Spring Creek rail loop crossing will need to conform to the Class 2 criteria; namely a large box culvert, or more likely, a bridge crossing (NSW Fisheries 1999b).
- The designs will also need to take into account the flood characteristics of the Wallarah Creek catchment, noting that the existing culvert crossing the F3-Pacific Highway Link Road acts as a hydraulic control for Wallarah Creek, creating a storage area behind the road embankment (WRM 2013 Section 4.7).
- Construction of all crossings will need to include suitable safeguards to prevent sediments and dirty construction water entering the creeks.
- Road and rail line designs will also need to include operational surface water diversion, collection and treatment facilities to prevent sediments plus coal spillages and coal dust entering the creeks.

Whilst the Buttonderry site does not require any creek crossings, the site does slope to Buttonderry Creek, which is designated a Class 3 to 4 aquatic habitat at the runoff locations:

- Construction will require the same precautions for protecting creek riparian and stream habitat attributes as outlined for Wallarah Creek protection above.
- Further, surface water runoff and storage management for the site will need to be designed to take into account the Wyong Shire Council's Porters Creek Wetland Integrated Water Cycle Management Strategy (IWCMS) that aims to control and balance both stormwater and groundwater inflows to Porters Creek, in order to mimic the pre-development water balance within the wetland that is required for proper wetland function (see WRM 2013 for details).

Whilst the Western Ventilation Shaft site does not require any creek crossings, the site is located on a hillside that slopes down to the north arm of Armstrong Creek (a Class 4 creek at this location). The forest track that provides access to the site drains through agricultural land to Little Jilliby Jilliby Creek at its northern end and drains through forest to Armstrong Creek North Arm at its southern end. Little Jilliby Creek is a Class 2 creek down-slope of these works. Construction works will require preparation of a pad for the works plus excavations to make the shaft and these works will require heavy machinery plus haul trucks for spoil disposal:

- The site works plus the access road will need to be designed and constructed to prevent water pollution of the down-slope streams for the duration of the construction program.
- As the road will be used for regular ventilation shaft maintenance, the access road will need to be designed and constructed with suitable long-term stormwater interception and treatment facilities to prevent pollution of down-slope streams.

5.1.2 Longwall mining impacts

Longwall mining includes controlled collapse of each longwall after it is mined out and this causes subsidence. There can be differential or variable slumping (higher subsidence under longwalls and lower subsidence over pillars between longwalls). Depending on the depth and nature (geology) of the overlaying material (overburden), impacts can be expressed in various ways at the surface including:

- Changes to alluvial streambed and floodplain profiles, increasing the potential for erosion in areas where the gradient becomes steeper.
- Sequential ponding and draining can also occur as longwalls progress across a valley, with ponding occurring above subsided longwalls and drainage to the subsided longwall ponds from adjacent longwall areas not yet mined.
- Ponding or draining can also be exacerbated by localised differential variations in groundwater levels (MER 2013).

These processes have the potential for altering flooding regimes, causing localised ponding/damming of catchment runoff waters and causing temporary changes in water depth for water bodies leading to inundation or waterlogging of emergent or marginal/riparian vegetation, and causing aquatic habitat alteration due to draining or additional deepening of existing ponds, wetlands, billabong or dams. The changes can also result in more frequent disconnection of water bodies to the streams or of ponds within a stream during dry periods, which can then impact fish passage and the ability of fish to colonise suitable habitats.

Subsidence can also cause cracking of the surface beneath a stream or other water body leading to a temporary or permanent loss of surface water flows and redirection of surface flows through shallow surface geological features to emerge further downstream with the following consequences:

- In bed-rock constrained streams these changes can lead to drying up of permanent rock pools with loss of aquatic habitat, loss of fish passage plus permanent changes to riparian community structure and composition.
- In bed-rock constrained streams and in steep gullies with mixed bed rock and more fractured rock features, the redirection of surface water through rock fissures can mobilise minerals in the shallow rock leading to water quality changes downstream where the waters re-emerge.

For the forested hills there are steep gullies orientated at various angles to the advancing longwalls, and surface deformation and cracking has the potential to destabilise soils and sediments and mobilise these into creeks and streams increasing sediment loads (erosion) and nutrient loads. In the extreme, surface deformation could also lead to destabilisation and direct loss of valley side vegetation into creeks and streams.

Species and ecological communities that are substantially dependent on aquatic and semi-aquatic habitats sustained by either the direct expression of aquifer water as ponded surface water or by base-flow from aquifers and species that live within aquifers are particularly susceptible to the impacts of subsidence mediated changes to aquifer water table levels and quality:

- Cracking due to subsidence can lead to partial or total drainage of aquifers from immediately above the mine to the mine or in the extreme surface water can be redirected to the mine.
- Cracking due subsidence can also lead to increased drainage between aquifers leading to alterations in water table heights, flow rates and water quality.

The combined potential changes to surface and groundwater hydraulics (quantity, flow rates and quality) have the potential to impact both surface aquatic ecosystems and groundwater dependent ecosystems (GDEs) and adversely impact the connectivity between these aquatic systems including invertebrate drift and fish passage.

As a consequence of these potential impacts from subsidence, *Alteration of habitat following subsidence due to longwall mining* is listed as a Key Threatening Process (KTP) on Schedule 3 of the *Threatened Species Conservation Ac*t. A Key Threatening

Process (KTP) is defined as a process that threatens, or could threaten, the survival or evolutionary development of species, populations or ecological communities. Specifically an action can be a threatening process if it:

- adversely affects two or more threatened species, populations or ecological communities; or
- could cause species, populations or ecological communities that are not currently threatened to become threatened.

Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is also listed as a Key Threatening Process (KTP) on Schedule 3 of the *Threatened Species Conservation Act,* and although the alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is generally related to structural processes such as damming, placing of weirs or road crossings it can also occur as a result of subsidence or other mining related processes.

It is recognised as a major factor contributing to loss of biological diversity and ecological function in aquatic ecosystems, including floodplains. Alteration to natural flow regimes, can occur through reducing or increasing flows, altering seasonality of flows, changing the frequency, duration, magnitude, timing, predictability and variability of flow events, altering surface and subsurface water levels and changing the rate of rise or fall of water levels.

Given the comparatively flat nature of the alluvial plain in the Dooralong Valley and the section of Hue Hue Creek within the mining footprint, the main potential subsidence impacts relate to the creation of additional ponded water bodies, the potential to alter the depths of existing shallow water bodies and the alterations to existing flow regimes with regard to increased isolation of ponds from one another:

- Barriers to fish passage can cause local extinctions or greatly reduce fish abundance and diversity (Thorncraft & Harris 2000), and, if there are longer prolonged periods of no or intermittent surface flow in Jilliby Jilliby Creek over the proposed mining area, the resultant increased barrier to fish migration between the Wyong River and upstream Jilliby Jilliby Creek catchment sites could affect diadromous species that have been previously recorded in the Wyong River catchment (e.g, short and long-finned eel, striped gudgeon, freshwater mullet and Australian Bass).
- Isolation of pools can also favour introduced species like plague minnow, which are capable of rapid reproduction, spawn many times within a year and can tolerate a wide range of environmental conditions. These factors, combined with

a well documented aggression towards native species, can then impact upon native fish and amphibian populations in refuge pool environments. In this latter respect plague minnow are listed as a Key Threatening Process (KTP) for listed amphibians under the TSC Act.

- Isolation of in-stream macrophyte beds from reduced-size pool sites during extended drought period. More generally, aquatic habitats become impacted by exposure of physical structures such as logs, undercut banks, boulders, bank vegetation, and tree roots that would otherwise serve as habitats for fish and macroinvertebrates.
- Aquatic biota can also be impacted by the decline in water quality due to the reduction in pool water volume and lack of pool water replenishment when flow ceases. For example, there can be increases in the amount of filamentous green algae, there can be high turbidity caused by fish disturbing the reduced pool bottom sediments and there can be decreased oxygen concentrations in the water due to the oxygen demand from the concentrated populations of aquatic biota.

MSEC (2013) notes that the mine plan incorporates a number of features to minimise the mining effects, including the orientation of longwall panels in relation to the valley floor, the directions of mining (longwalls mined progressing from east to west, mining each longwall from south to north), and controlled pillar collapse between longwalls to ensure a more even subsidence footprint across the valley.

It is also noted that the modelled surface water and aquifer flow and level changes from subsidence in the Doolalong Valley and Hue Hue Creek would be in the same order as the background dynamic changes in flow and water level of the streams and aquifers in the study area, as it is subjected to natural events that also result in stream, habitat and water quality/quantity changes over time; events such as flooding impacts, changes during prolonged droughts, changes due to altered land-uses or changes in catchment soil stabilisation due to bushfires. That is, the modelling results indicate that post-mining, the overall variation in valley floor topography will be similar to the pre-mining condition.

MSEC (2013 Section 5.3.2.1) notes that whilst potential for ponding remains over LW1S and LW6N, this potential can be alleviated by using variable extraction heights and panel widths. It is also noted that there will be an opportunity to carefully measure the panel to panel subsidence impacts against modelled predictions in the early longwall panel extractions under the Hue Hue Creek valley (Longwalls 1N to 5N) before mining reaches the Dooralong Valley, which would allow for adjustments in the various mining parameters where necessary both in the model and practically, to ensure minimum impact between longwalls (adaptive management).

As described in MSEC (2013), the mine has been designed to reduce subsidence effects and ensure that valley floor aquifers are appropriately protected and continue to remain effectively isolated from any deeper, poor quality aquifers within the bedrock.

Accordingly, it is anticipated that there will be sufficient adaptive opportunities available to ensure that there would not be significant changes to the overall makeup and function of aquatic habitats within the streams on the alluvial plain or within the ponded water bodies over the valley floor as mining progresses. There will also be a range of remedial options that can be incorporated into the mine plan to allow for remediation of smaller or localised impacts on aquatic habitats and aquatic habitat function (such as fish passage) as the mining proceeds.

With regard to subsidence impacts in the forested sub-catchment drainages the results of the aquatic ecological studies presented in this report (**Section 4.4**) and geomorphology surveys (summarised in **Section 2.3** in WRM 2013) have shown that for the most part the smaller low order gully drainages are steep V-shaped gullies with little bed rock constrained structure and mostly boulder cascade constrained drainages. The drainages are ephemeral with short tail flows (i.e., low local base flow and low shallow rock aquifer holding capacity) following rainfall with short lived pools.

Most of the gully drainage lines already show the impacts of rainwater diversion into shallow cracked rock strata, with elevated conductivity and high iron stained base flows (see **Section 4.4.1**). By virtue of the truncated baseflows between wet weather events there are few if any aquatic GDEs in the forested hills.

Accordingly it is concluded that these gully drainages do not currently provide much in the way of aquatic ecology habitat. However, these gullies do provide an important ecological function in being able to provide a good quality, well forested and reasonably stable catchment that is able to deliver clean water to the important aquatic habitats downstream along the valley floors, and this surface water recharge ability is probably the most important function these gullies can provide for the overall aquatic ecology of the region.

With regard to potential subsidence impacts the plasticity of the forested sub-catchment drainages as outlined above means that many of the potential subsidence impacts associated with rock constrained valleys will not occur, are not relevant or will not be exacerbated to any measurable degree. Accordingly, the residual potential combined impacts of subsidence plus tilt and strain that is of concern is the impact on the stability of the vegetation and shallow surface rock along the sides of the gullies and the consequences of increased erosion should the vegetation be destabilised.

MSEC (2013) has considered this aspect of the project (MSEC Report Section 5.9) and concludes that whilst predicted tilts due to subsidence are not likely to result in any significant change in slope such that slope instability could increase, there are some residual risks of slope instability for some steep gullies due to ground curvatures and strain. The report notes that modelling to predict these potential impacts has been undertaken and that as mining is unlikely to reach the western forested hills area of the site for 12-15 years after commencement of the project, there is sufficient time for the Proponent to undertake further assessment of the likely subsidence effects in this area, and to modify the project where necessary. This proposed adaptive management approach would enable subsidence data from the first 12-15 years of mining to be used to inform a more accurate subsidence model for the project as a whole.

As part of the adaptive management approach it would also be appropriate to establish long-term monitoring programs in unmined and to-be-mined gully sub-catchments to allow for predicted and measured mining subsidence impacts to be related to actual catchment impacts. To this end **Figure 2** shows a variety of gully sub-catchments that could be suitable for meeting this need over time. Initial mining for longwalls would proceed west under the low ridge between Hue Hue Creek and Dooralong Valley (LW1N to LW5N), and there may be opportunities to assess potential gully slope destabilisation around the Alison Trig Station.

5.1.3 Impacts associated with surface operations.

There are a number of potential impacts on aquatic ecology associated with the surface operations. These are considered as follows:

Balancing the various water treatment facilities to deal with differential surface and underground 'dirty' water volumes that vary as the mining progresses and also with prevailing climatic conditions (droughts through to floods).

The mine water balance study (WRM 2013) indicates that water within the mine water management system, including groundwater inflows to the underground mine and captured surface runoff, will be treated for use at the site to minimise impacts on the Central Coast water supply system and minimise impacts on creek systems. This will be achieved by replacing any intercepted catchment runoff water at the Tooheys Road Site with treated water of a similar quality on an annual average basis.

The mine will have a water deficit in the early years, then provide surpluses for the life of the mine, as the amount of underground mine water capture is balanced against the ability to return surplus underground make water directly to underground storage. For the intervening years surplus water will be saline and will require treatment prior to reuse or discharge.

Mine water management generally requires collection and treatment of the mine water and surface infrastructure 'dirty' water for re-use which in turn requires extensive surface facilities (storage dams and water treatment facilities) plus combinations of re-uses, storage and/or discharge; either injected back to the mine (generally to worked areas or goaf), for re-use around the surface facilities (e.g., dust control or truck wash), beneficial use off-site or off-site discharge to local waterways.

Mine water management has been detailed in the WRM (2013) Surface Water Impact Assessment and the overall layout of the treatment system is shown in **Figures 35** and **36**. Whilst site dirty water will be collected, settled and stored for re-use, the water balance model concludes that there will be excess water after mine re-use, comprising mainly mine make waters. Treatment of this excess water will include active treatment of the mine make waters in a Reverse Osmosis desalination plant with a capacity of up to 3Ml/day.

A brine water treatment plant will also be utilised to produce a partly dried mixed salt solid waste product for disposal underground. It is likely that use of the brine treatment plant could be implemented during the initial years of the Project and continue until the end of Project year 14 in parallel with the completion of LW11N. The treatment process would then involve treatment of mine water using the RO plant only, with the concentrated brine waste stream pumped direct to underground voids for disposal. It is also anticipated that the project would be able to be a potential provider of treated water for beneficial industrial and non-potable purposes.

Excess treated water will be discharged to Wallarah Creek under terms of an Environmental Protection Licence, with the water quality of the discharge similar to the background water quality in order to protect the existing downstream aquatic ecosystems. The proposed discharge point is shown on Figure 35. As described in WRM (2013 Section 2.3.6) and in this report (**Section 4.2**), Wallarah Creek is a stable, low gradient stream that usually resembles a chain of linear ponds with little or no connecting flow in dry periods. The stream flows with low sinuosity within an alluvial zone generally between 10 metres and 60 metres wide and switches from a well-defined single channel configuration to sections of stable multi-channel flow during higher flow post-rainfall periods. The alluvial zone is well vegetated and stable and features a varying understorey of native vegetation.

Water management options need to be balanced to meet environmental flow and water quality requirements for aquatic ecosystems downstream of the facilities plus ensure connectivity of aquatic ecosystems up and down-stream of the surface facilities.

As noted in **Section 5.1.1**, Buttonderry site water management must take into account the Porters Creek Wetland Integrated Water Cycle Management Strategy (IWCMS) and the Tooheys Road site must ensure the quality and environmental flow attributes of Wallarah Creek are maintained. To this end the Buttonderry and Tooheys Road Mine Water Management Systems have been designed to meet these objectives.

During active mining operations, the mine water management system will capture runoff from areas that would have previously flowed to either Buttonderry Creek or Wallarah Creek at the Buttonderry Site and Tooheys Road Sites respectively. The captured catchment area will remain essentially constant once mining commences:

- The captured catchment area at the Buttonderry Site (7.4 ha) represents approximately 0.1% of the Porters Creek contributing catchment area and as overflows from the Buttonderry Entrance Dam will occur during significant rainfall events, the reduction in runoff volume draining to Porters Creek Wetland will be less than 0.1% and in practical terms will be undetectable.
- At the Tooheys Road Site, the captured catchment represents about 9% of the Wallarah Creek catchment to the downstream limit of the Project Boundary. The loss of this portion of catchment runoff to the creek will be offset by the discharge of treated mine water to the creek.

WRM (2013) have modelled the impacts on flow in Wallarah Creek for the proposed mine licensed discharge and conclude that treated water discharges to Wallarah Creek would be required for the life of the project and increase up to Year 7, remaining fairly consistent thereafter, ranging from 50 to 500 ML/a. Modelling for impacts on downstream flow and water quality show that:

- For the average, wet and dry climate scenarios there are negligible impacts on the frequency of flows greater than 10 ML/d.
- The frequencies of low flows up to 10 ML/d are increased. For example, for the pre-mining case, a flow of 1 ML/d occurred approximately 17 % of the time, whereas during mining it occurs approximately 30 % of the time.
- The expected flow rate of the treated water to be discharged will be less than 3 ML/d (35 L/s).
- The WTP will treat mine waters to a water quality that is consistent with existing

water quality within Wallarah Creek, in order to protect downstream ecosystems.

WRM (2013) conclude that as Wallarah Creek is ephemeral, treated water discharges may occur at times when there is no natural flow in Wallarah Creek. However, based on the proposed quality and relatively low flow rate of treated water discharge, and the good condition of bank vegetation, it is considered that these flows would not result in adverse water quality or hydraulic impacts, such as increased bed and bank erosion. WRM (2013) also notes that whilst the treated water discharge will alter the flow-duration relationship of Wallarah Creek, the creek will remain ephemeral and will still experience a similar frequency of zero to very low flow events.

As the creek will maintain its integrity and water quality plus its responses to flood and low flows but with some additional flows that would lessen the potential impacts of extend droughts it is concluded that the aquatic ecology of Wallarah Creek would not be adversely impacted and there may be a beneficial impact arising from additional drought proofing with the increase in creek flows.

If coal washery or processing facilities are used there will need to be provision for disposal of excess rock material, of coarse coal rejects and of coal fines produced by the processing facilities. Whilst rock material can generally be used beneficially offsite, management of coal waste material would require storage dams, and these in turn would need to be located and managed in such a way as to prevent local surface or groundwater water pollution.

The mine is to be operated as a “zero rejects” mine by not including a coal washery as part of the project.

Many of the surface deformation impacts of subsidence can be mitigated by physical earthworks and these activities themselves carry additional risks of direct loss or disturbance of habitat, possible alterations to soil and shallow surface hydrochemistry leading to water quality changes. Mitigation works may also require roadworks associated with site access, further increasing the risk of habitat disturbance.

It is intended that the mine will undertake these works as part of an Environmental Management Plan (EMP) that will include adaptive management practices with appropriate monitoring and assessment procedures to ensure minimal environmental damage arising from remediation works and to ensure the success of the remediation practices.

5.2 Summary of Impacts on Aquatic Habitats and Biota

Potential construction and operational impacts on the aquatic ecological values at, and downstream of the project infrastructure areas are to be managed by (i) appropriate siting of infrastructure away from aquatic habitats and the associated riparian corridors where possible, (ii) implementation of a Construction Water Management Plan (CWMP) to ensure the protection of aquatic habitats during construction and (iii) an operational Water Management Plan (WMP) to ensure water quality and quantity and preserve and protect downstream aquatic habitats. The WMPs will also specify how site and associated rail, road and services corridor stormwater will be collected, treated and disposed of to ensure the integrity of the local waterways and wetlands.

Potential mining impacts on the aquatic ecology of the longwall mining area are to be minimised by appropriate siting and orientation of the longwalls, coupled with adaptive adjustments to the mining height, longwall lengths and widths, and by pillar collapse, to achieve a post subsidence topography that is no more variable over the Dooralong Valley floor than at present.

Adaptive management of mining parameters plus physical remediation works can also be used to ensure that there are no substantial during-mining changes to undermined aquatic ecology habitats (streamlines, lagoons, wetlands and dams) such that no large scale adjustments in aquatic and wetland habitat characteristics or in fish passage or connectivity would result. Minor remediation works are anticipated and these would be undertaken as part of an Environmental Management Plan (EMP) that will set out the manner in which any minor works are to be undertaken to ensure no additional environmental damage, and to provide appropriate monitoring to measure remediation success.

Assessment of the impacts of subsidence on the shallow alluvial aquifers of the mining areas indicate that the availability and variability of groundwater in the alluvial aquifer will be similar to that of the present alluvial aquifer in the long term with any changes immediately post mining of each long wall panel being within the range of changes observed over normal wet to dry periods for the present aquifer. Accordingly it is not anticipated that there would be any measurable impact on aquatic biota that are dependent on groundwater.

With regard to potential impacts of subsidence on the surface features and shallow surface rock aquifers of the forested hills to the west of Dooralong Valley, the current modelling indicates that there would not be any surface water loss to the mine (by virtue of the depth of overburden over the coal measures) and that cracking and heaving of the surface features of the forested hillside gullies is not likely to have any significant additional impact on aquatic values of the gullies themselves over and above those arising from the present impacts of surface water diversion to the shallow rock aquifers.

Although considered unlikely, the combined effects of subsidence, tilting and strains have the potential to destabilise steep feeder gullies of the forested hills to the west of Dooralong Valley, with possible increased erosion in the gullies leading to changes in surface water hydrology and increased sediment runoff to the detriment of aquatic habitats in the lower valley aquatic habitats. It is concluded that if there were to be stabilisation impacts, these are anticipated to be small and isolated and generally amenable to minor remediation works.

An adaptive management approach is proposed for the management of stream integrity, stability and aquatic ecology function. Proposed monitoring programs will enable impacts to be identified and managed on a case-by-case basis with the aim of minimising engineering works and soil disturbance within the waterway channels and floodplains. Where required, bank stabilisation works and re-vegetation would be undertaken to reduce instability, and the works would be carefully planned to ensure that they are targeted towards actual subsidence impacts, rather than naturally occurring variability in the stream.

The adaptive management approach to subsidence management also allows for monitoring of reference gullies to be undertaken to better anticipate possible gully impacts. Where possible, initial monitoring will target gullies on the ridge between Hue Hue Creek and Dooralong Valley where initial mining is to take place, to allow for confirmation of subsidence modelling, and to ensure that appropriate mining adjustments can be made where required, to prevent aquatic ecology impacts.

With regard to the *Subsidence* and *Alteration to Natural Flow* KTPs and the potential impact on aquatic species, it is concluded that subsidence and mine water discharges from the proposal can be managed such that no threatened aquatic species, populations or ecological communities would be adversely affected and that no aquatic species, populations or ecological communities that are not currently threatened would become threatened.

5.3 Avoidance, Minimisation, Mitigation and Offset Measures

The following measures have been incorporated into the present mine plan to **avoid** and **minimise** impacts on aquatic habitat and biota:

- Positioning infrastructure to avoid aquatic habitats and associated riparian habitats.
- Siting and orientation of longwalls to avoid impact on critical hydrological features such as the confluence of Jilliby Jilliby and Little Jilliby Jilliby Creeks and the upper portions of Little Jilliby Jilliby Creek.
- Make the mine a clean-water discharge and zero rejects mine to avoid water quality impacts from mine discharges and negate potential spillages and discharges that are associated with coal processing operations.
- Provide a mine plan that varies longwall mining height and longwall widths plus incorporates controlled pillar collapse to minimise differential subsidence impact in the Hue Hue and Dooralong Valleys.
- Minimise impacts to creeks in infrastructure areas by locating roads, rail and services corridors away from creeks and ensuring that any necessary crossings are at right angles to the creeks to minimise crossing footprints.
- Implementing Surface Water Management Plans for Construction and Operation to minimise aquatic ecological and water quality impacts.
- Implementing an Environmental Management Plan to enable, monitor and assess the effectiveness of adaptive management strategies to minimise environmental impact on aquatic habitats, biota and function.

Mitigation and **Offset** measures would be implemented to enhance aquatic habitats and thereby benefit aquatic biota. The principal mitigation measure will be the progressive rehabilitation of Wallarah Creek and its riparian banks to compliment the vegetation rehabilitation measures in the upstream properties that are to be undertaken as offset measures for loss of native vegetation. The creek and riparian rehabilitation works should be extended through the infrastructure site to provide a valuable riparian link from the upstream rehabilitation works to intact native forest downstream of the project site.

Other measures include riparian zone remediation and enhancement where possible along Jilliby Jilliby and Little Jilliby Jilliby Creeks, especially around the confluence of the two creeks and along the lower portion of Little Jilliby Jilliby Creek. The suggested priority for riparian corridor revegetation should be to close the gaps between existing vegetated areas to provide more continuous riparian cover that will benefit both aquatic species (by enhancing habitat complexity and providing cover and shade for aquatic habitats) and terrestrial species (that utilise the riparian fringes as corridors).

6 MONITORING & MANAGEMENT OF POSSIBLE IMPACTS

To ensure the environmental outcomes of the project construction, operation and remediation programs a project Environmental Management Plan (EMP) will be developed to incorporate all aspects of environmental control including aquatic ecology.

6.1 Project Environmental Management Plan

The EMP will outline a set of Environmental Management Strategies (EMSs) that detail specific strategies to encourage and enhance the natural ecology within the project lease area. The success of these strategies are to be monitored on a periodic basis and the strategies plus Plan would be 'adaptive' and modified as necessary to address any identified issues so that issues can be resolved and management measures can be implemented in a timely and professional manner. The EMS for aquatic ecology will detail the basis for seasonal or biannual riparian and aquatic flora and fauna monitoring programs to be undertaken pre-, during and post longwall mining and these programs will build on monitoring studies already undertaken for this EIS.

6.2 Aquatic Ecology Monitoring and Management Program

The aquatic ecology (stream health) monitoring program incorporates the existing aquatic ecology study sites and data, and will incorporate data from the on-going biannual (Autumn and Spring) studies to provide baseline data against which changes that may be attributable to construction or operation of the mine can be measured. The baseline data would also set the benchmarks for any mitigation works.

In order to provide successful management measures, aquatic ecology monitoring will be undertaken using a guiding set of criteria and protocols developed to establish the circumstances under which additional mitigation measures would be required, and these would be specified in the Environmental Management Plan and in Trigger Action Response Plans (TARPs). Thus, where perceptible impacts are noted through site monitoring activities, the following general procedure would be applied:

- Undertake additional investigations to ascertain the actual cause (mine-related or other cause) of deteriorating aquatic conditions;
- If mining related, notify relevant government authorities;
- Develop and implement a specific response plan to prevent further impacts, and
- Undertake remediation as required.

As set out in the project TARPs, the response plans would be prepared on a case by case basis, with suggested short-term mitigation measures such as minor physical repair works, which could be implemented until such time that necessary long-term remediation works have been completed.

6.2.1 Specific stream health monitoring

With regard to aquatic ecology (stream health) monitoring, sites are sampled bi-annually. The selection of sites for long-term monitoring for impacts arising from the adopted mine plan is based on the interactions of the longwalls and mine treated water discharges with each of the various sub-catchments indicated on **Figures 2** and **3**. Adaptive management will mean that there will be sequential adjustments of some of the sites and inclusion of other sites over time. Additional sites established in 'Reference' sub-catchments will also be monitored to allow for estimation of non-mining related change. The stream health monitoring plan would also incorporate a number of short-term monitoring sites that would be introduced into the aquatic ecology monitoring program on a staged basis, that is, relative to the progression of construction, mining and rehabilitation activities. The number and location of these sites would also be adjusted to any modified mine plan.

As per the existing monitoring program, sampling of introduced short-term sites would be scheduled into the regular bi-annual sampling program to incorporate before, and at least two after samples from each site according to the scheduled mining program, to enable direct assessment of mining related impacts on individual aquatic habitats, to facilitate the interpretation of long-term monitoring results and to monitor potential impacts of adaptive rehabilitation measures. This schedule would also be applied to fish sampling sites. Decisions to continue monitoring of short term sites beyond the two post-mining studies would be made on a site by site basis, and only if there was evidence of localised construction, mining, discharge or adaptive rehabilitation related impact arising from the before/after comparisons.

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ANNEXURE A

FIELD NOTES

&

SAMPLING DATA

WALLARAH 2 COAL PROJECT

STREAMHEALTH

BASELINE MONITORING PROGRAM

AUTUMN 2011 TO AUTUMN 2012

Table A1.1 Field Comments –Aquatic Ecology Monitoring Sites Autumn 2011		
Date	Site	Comments
28/6/11	WR1	Site sampled on upstream side of Boyds Lane bridge. Water moderately turbid and flowing throughout site length. Maximum width to 14m, average width 8 to 10m, maximum depth to 1.5m, average depth around 0.8m. Site channel banks steep with river incised at a depth of 6 to 8m below surrounding floodplain. Instream banks steep and undercut, with some sections of bank slumping and erosion. High riparian cover along river section with site banks vegetated with trees and shrubs (including eucalypts, river gums, small leaf privet, camphor laurel and coral trees) with wandering dew present along entire site length edge banks. Not much of the edge bank vegetation in contact with the water. Detritus and edge bank vegetation sampled as edge habitat. Layer of silt deposited on plant surfaces and lower banks. Submerged logs present along site length, with most of the channel area scoured free of smaller detritus. Substrate consisting of unconsolidated sand. No macrophytes observed and no filamentous green algae observed in site.
28/6/11	WR3	Site sampled on downstream side of Kidmans Lane bridge crossing. Water moderately turbid with swift flow throughout site length. Maximum width to 20m, average width 14m, maximum depth to 1.5m, average depth around 0.8m. Site channel banks very steep with river incised at a depth of 8-10m below surrounding floodplain. Recent flooding reached depths of 8 to 10m above current water level. Instream banks steep and undercut, with some sections of bank slumping. High riparian cover along river section with site banks well vegetated with trees and shrubs (including eucalypts, river gums and coral trees) with wandering dew present along entire site length edge banks. Not much of the trailing bank vegetation hanging in water. Detritus and edge bank vegetation sampled as edge habitat. Layer of silt deposited on plant surfaces and lower banks. Submerged logs present along site length, with most of the channel area scoured free of smaller detritus. Substrate consisting of unconsolidated sand. No macrophytes observed in site, and no filamentous green algae observed.

1/7/11	JCUp	Site sampled downstream of bridge crossing. Water brown with moderate flow. Maximum depth reaching 1.4m, average depth 0.8m, maximum width 7m and average width 5m. Channel box shaped, with steep and undercut banks incised 3 to 4m below surrounding floodplain. Small tributary coming on from west with very clear water, and no visible flow. High degree of cover (melaleuca, rainforest trees, small leaf privet) in immediate riparian zone though cleared for agriculture beyond this. Upstream of bridge riparian zone similar. Evidence of recent flows 3 to 4m above current water level. Channel banks clayey and blanketed in layer of wandering dew. Trailing bank vegetation (lomandra, tree roots, wandering dew) and detritus sampled as edge habitat. Substrate mostly sand. Logs prevalent. No filamentous green algae observed.
29/6/11	JC2W	Site length similar in form to JCUp. Water brown with moderate flow. Maximum creek width to 8m and average width 5m. Some of the wandering jew covered edge bank areas submerged. Riparian canopy very dense with almost 100% cover in parts, consisting of native rainforest species in addition to coral trees, lantana, small leaf privet and tobacco plant. Channel box shaped narrow and meandering. A number of logs present, with some isolated areas along the edges with accumulated detritus. Substrate sandy and mobile, with some coarser sediments around the road crossing. No macrophytes observed.
30/6/11	JC2E	Upstream of road culvert sampled. Water turbid with sluggish flow throughout site length, and layer of floating particulate matter on water surface. Maximum site pool width to 15m, average width 8m and maximum depth estimated at 1.5 to 2m, average depth between 0.8m and 1m. Evidence of recent flows to at least + 3-4m above current water level. Site channel is divided into two flow paths. Narrow strip of riparian vegetation dense, with mix of natives and weeds including lantana, privet, coral trees, tobacco plant and wandering dew. Channel broad and reaching depths of 2 to 5m below surrounding floodplain. Edge habitats sampled included trailing bank vegetation, detritus and cumbungi (*Typha sp*). Substrate firm clayey with some deposits of fine sediments and organic matter. No filamentous green algae observed.

1/7/11	JC3	Site located around 150m upstream of confluence with Little Jilliby Jilliby Creek. Water turbid with swift flow throughout site length. Maximum creek width 8-10m, average width 5m, with site channel bottom sunken 5-8m below surrounding valley floodplain. Channel banks actively eroding with some large sections of bank recently slumped into creek. Large riparian tree fallen into creek in middle of site. Some of the exposed channel banks consisting of clay. Substrate consisting of unconsolidated mobile sand banks. Mostly native trees in riparian zone, which is consistent along length of site with a high degree of cover. Wandering jew prevalent along site length channel banks. No macrophytes observed.
1/7/11	LJ4	Sampled downstream of bridge crossing. Water brown and flowing through site, with large sections of pool smothered in orange iron precipitate. Maximum pool width to 5m, average width 2m, maximum depth 1.3m, average width 0.8m. Evidence of recent flows to 2 to 4m above current water level. Site channel meandering through length. Upstream channel area densely overgrown with weed. Weeds prevalent along site riparian corridor, including lantana, wandering dew, tobacco plant, willow tree, crofton weed), in addition to native species. Edge banks have been scoured free of vegetation in parts with exposed clayey soil and undercut banks. Trailing bank vegetation (mainly lomandra, ferns and wandering dew, willow roots, grasses), detritus and undercut banks sampled as edge habitat. Only small amounts of detritus around site pool. Very few macrophyte plants observed, only swamp lily (*Ottelia ovalifolia*) and water ribbons (*Triglochin sp*) as single plants. Substrate firm clayey with some areas of soft unconsolidated sandy clay. No filamentous green algae observed.

30/6/11	LJDn	Site sampled around 70m upstream of confluence with Jilliby Creek. Water moderately turbid and flowing. Maximum width to 5m, average width 3m, maximum depth 1.5, average depth 0.4m. Channel meandering, and steeply incised into surrounding floodplain to a depth of 6 to 8m. Evidence that flows breached the floodplain as indicated by debris in fence. High degree of riparian cover along site length, almost 100% in parts. Banks unstable with signs of bank slumping and erosion, and layer of silt deposited on riparian vegetation. The outside banks on the bends have been scoured back to bare clayey soil. Riparian areas covered in wandering dew. Trailing bank vegetation, detritus and undercut banks sampled. Substrate mostly firm clay with sections of unconsolidated sandy sediments. Habitat complexity was low. No filamentous green algae observed.
29/6/11	SWUp	Site located just below F3 freeway culvert on western tributary to Spring Creek. Water moderately turbid and tannin stained and flowing through site length. Most of the site channel is broad (average width 8m) and very shallow (average depth 10-15cm), however at the downstream end the channel deepens (to 0.6m maximum depth) and supports dense cumbungi stands). Channel area densely colonised by a number of macrophytes and weeds including river clubrush (*Schoenoplectus validus*), cumbungi, sedges (C*yperus sp*), common reed (*Phragmites australis*), slender knotweed (*Persicaria decipens*), rush (*Schoenoplectus mucronatus*), crofton weed and purple top. Riparian banks with dense mostly native vegetation on northern bank, and cleared paddocks with limited rural residential dwellings on on southern banks. Edge banks densely vegetated with paperbarks and sedges (*Gahnia sp*). Substrate sandy and consolidated with vegetation.

29/6/11	SW1	Site consists of a heath swamp, and was sampled on upstream side of the property fence. At the downstream end of the site there is a small distinguishable channel (the main area sampled) that terminates at a vehicle crossing that runs along the property fence. Water slightly tannin stained and flowing through site length and downstream. Main flow channel maximum width of 3m, average width of 1m, maximum depth of 1m, average depth 0.6m. Upstream of this point the flow was broad (ranging between 50 to 80m width) and shallow (mostly less than 10-15cm depth) soak with no main flow channel identified, and would most likely be moist but not retain surface water during periods of lower flow. Channel with abundant overhanging and trailing bank vegetation, and water ribbons and charophytes in site pools. Detritus, edge banks, trailing bank vegetation and water ribbons sampled as edge habitat. Substrate firm clay with layer of detritus over top. No filamentous green algae observed.
29/6/11	SWDn	Site located on Spring Creek just above confluence with western tributary. Water moderately turbid with flow throughout channel length. Maximum depth to 1.0m, though average depth 0.4m. Creek width ranges between 3 and 7m. Banks steep and undercut, channel flat bottomed and box shaped. Edge bank vegetation continuous along site edge banks (mostly lomandra and sedges (*Gahnia sp*). Riparian vegetation mostly native eucalypt and swamp paperbark, continuous along site length. Substrate mostly unconsolidated sand. Submerged logs present along site. No macrophytes observed. Downstream channel area feeds into large round pool.
29/6/11	WCUp	Site located below creek crossing around 100m downstream from F3 freeway culvert. Water turbid and flowing through site. Channel narrow, box shaped and meandering. Maximum width to 5m, average width 1-1.5m. Maximum depth around 1.0m. Recent high flows to +3-5m above current water level. Riparian vegetation constant and providing a high degree of cover over creek, and prolific along site channel banks and trailing into stream. Banks undercut and covered in lomandra and sedges (*Gahnia* sp). Swamp lily present.

30/6/11	WC1	Water turbid and flowing through site length. Maximum width 6 to 7m, average width 1.5 to 2m, maximum depth to 1.3m, average depth 0.7m. Site channel meandering throughout site length, with steep and undercut banks covered in Lomandra and Gahnia. Channel incised steeply into surrounding floodplain to a depth of between 2m and 5m. Riparian vegetation dense with high degree of riparian cover. Moss prevalent along site length. Moderate amounts of detritus on channel bottom, evidence of prolonged accumulation of organic matter by release of sulphur odour when disturbed. Trailing bank vegetation, spike rushes (*Eleocharis ?gracilis*) and water ribbons, detritus and undercut banks sampled as edge habitat. Instream banks and substrate firm clayey, with some isolated areas of sand accumulation. No filamentous green algae observed. Dam situated on northern bank adjacent site, at which a red groined froglet *Paracrinia haswelii* was recorded.
29/6/11	WCDn	Site length channel similar to WC1, though broader and deeper. Water turbid and flowing through site. Site creek width estimated at 8-10m, average width 5m. Maximum depth estimated at 1.5m. Riparian vegetation dense with high degree of riparian cover. The land to the north-eastern side of the creek has been cleared for agriculture. Site channel meandering throughout site length with steep and undercut banks covered in Lomandra and Gahnia and bracken ferns. No macrophytes observed, though limited access to site length.
27/6/11	BC1	Site sampled on upstream side of Hue Hue Rd culvert. Water turbid and flowing throughout site length. Maximum stream width to 6m, average width 4m, maximum depth 1.2m, average depth 0.7m. Site channel meandering through forest with high degree of riparian cover along site length, consisting mostly of eucalypts, ferns, Melaleuca. Channel incised to a depth of 2 to 5m into surrounding floodplain valley floor. Forest floor densely occupied by Lomandra and sword grass (*Gahnia sp*), especially along the stream edges. Detritus and trailing bank vegetation sampled as edge habitat. Stream channel banks firm, though bare and undercut along immediate edges above water. Banks clayey and exposed. Evidence of recent high flows to 1.5 to 2m above current water level. Substrate firm clayey with limited loose sediment deposits, and some isolated areas of detritus build up. No macrophytes observed in site, with cumbungi present on downstream side of road crossing. No filamentous green algae observed.

30/6/11	HHMd	Site sampled on downstream side of road culvert. Water turbid and flowing through site. Width of main flow channel between 5m and 10m and relatively shallow. Width of broader waterbody ranging between 20m and 50m with no visible signs of flow. Maximum depth to 0.9m, average depth 0.4m. Downstream of road culvert exists a melaleuca swamp with some invasive weeds (crofton weed) present. The land upstream of the road culvert is cleared paddocks (though pastures are long) with some isolated pockets of melaleuca and tea tree, and cumbungi on the upstream side of the road crossing. Edge habitats sampled consist of submerged vegetation (terrestrial grasses and weeds), slender knotweed and detritus. Substrate mostly firm sandy with some deposits of unconsolidated finer material, and detritus layer throughout most of channel area. No filamentous green algae observed.

Table A1.2 Field Comments –Aquatic Ecology Monitoring Sites Spring 2011

Date	Site	Comments
12/10/11	WR1	General site conditions and available aquatic habitats similar to previous sample occasion, water level around 10cm higher. Site channel mostly unchanged since previous sample. Water moderately turbid and flowing throughout site length. Maximum pool depth around 1.5m. Detritus and edge bank vegetation sampled as edge habitat. Large logs and branched prevalent throughout site length. Layer of silt deposited in areas of lower flow. Substrate mostly unconsolidated sandbanks. Evidence of Australian water rat feeding station with recent tracks and scattered freshwater mussel shells. No macrophytes observed and no filamentous green algae observed in site.
12/10/11	WR3	General site conditions and available aquatic habitats similar to previous sample occasion, water level around 10cm higher. Lower channel banks (just above waterline) very soft and muddy. Maximum depth estimated at 1.5m to 2m. Water moderately turbid and flowing throughout site length. Detritus and edge bank vegetation, and undercut banks sampled as edge habitat. Many submerged logs present along site length, with few areas with deposits of fine detritus. Substrate consisting of unconsolidated sandbanks. No macrophytes observed in site, and no filamentous green algae observed. Australian water rat tracks present along channel banks.

13/10/11	JCUp	General site pool dimensions, habitats and sample condition similar to previous sample. Water slightly turbid, and flowing throughout site length. Maximum depth to 1.4m. Evidence of recent high flow water levels to at least 3m above current water levels. Edge trailing bank vegetation, undercut banks and detritus sampled as edge habitat. Substrate consists of mobile and unconsolidated sandbanks along site length. Submerged and emergent logs prevalent throughout site. Filamentous green algae present along site length.
13/10/11	JC2E	General site pool dimensions similar to Autumn 2011 sample. No observable flow within site. Water moderately turbid with abundant floating debris on pool water surface. Maximum pool depth estimated around 1.5m. Edge habitats sampled included trailing bank vegetation, detritus and cumbungi. Substrate firm clayey sand smothered with layer of detritus (both fine and coarse) which releases strong sulphur odour when disturbed. Filamentous green algae present in small to moderate amounts.
13/10/11	LJ4	Similar flow and water levels to previous sample occasion. Water of moderate turbidity, and flowing throughout site length. Maximum depth around 1.5m. Evidence of recent high flows indicated by debris lines on banks (to +3-4m). Trailing bank vegetation, detritus, submerged slender knotweed and undercut banks sampled as edge habitat. Globular algae present on substrate, and isolated areas of orange precipitate. Substrate firm clayey with some areas of soft unconsolidated sandy clay. Filamentous green algae present in small to moderate amounts.
12/10/11	LJDn	General pool dimensions and water levels similar to Autumn 2011 sample. Water moderately turbid and flowing throughout site length. Maximum depth estimated at 1.7m. Trailing bank vegetation, detritus and undercut banks sampled. Debris lines on banks indicate possible recent high flows. Substrate mostly firm clay with main pool basin filled with soft unconsolidated sandy sediments. Few submerged areas in main channel with accumulations of detritus. Habitat complexity was low (similar to previous sample). Possible platypus burrow observed in southern bank. No filamentous green algae observed.

13/10/11	SW1	Water level around 10cm than previous survey and surface flow confined to main channel area (as opposed to Autumn 2011 survey which supported broad sheet flow). Flow trickling throughout site length, water dark tannin stained. Maximum pool width to 3m, average width to 1m, maximum pool depth to 1.0m. Site channel with abundant overhanging and edge bank vegetation, and water ribbons in site pools. Site aquatic habitats unchanged since Autumn 2011, and consisted of detritus, undercut banks, trailing bank vegetation and water ribbons. Substrate firm clay with layer of detritus over top. No filamentous green algae observed. Charophytes present.
14/10/11	WC1	General pool dimensions and water level similar to Autumn 2011 sample. Water tannin stained with low flow throughout site length. Recent flow levels to +3m to 4m above current (normal background) water levels as indicated by prominent debris line on levee banks. Maximum observed depth to 1.2m. Moderate amounts of detritus on channel bottom, evidence of prolonged accumulation of organic matter by release of sulphur odour when disturbed. Trailing bank vegetation, spike rushes and water ribbons and river clubrush (, detritus and undercut banks sampled as edge habitat. Instream banks and substrate firm clayey, with some isolated areas of sand accumulation. No filamentous green algae observed. Red groined froglet and dwarf tree frog *Litoria fallax* heard from dam adjacent the site.
13/10/11	BC1	General pool dimensions and water level similar to Autumn 2011 sample. Water turbid with low flow throughout site length. Maximum depth to 1.2m. Recent flows to 1.8m above current water levels as indicated by debris lines on bank. Detritus and trailing bank vegetation sampled as edge habitat (mostly Lomandra and sword grass). Banks clayey and exposed. Substrate firm clayey with limited loose sediment deposits. Moderate amounts of detritus on channel bottom, evidence of prolonged accumulation of organic matter by release of sulphur odour when disturbed. No macrophytes observed in site, with cumbungi present on downstream side of road crossing. No filamentous green algae observed.

13/10/11	HHMd	Water level receded around 0.2m since previous sample, reducing the overall width of waterbody compared to Autumn 2011 survey. Water moderately turbid and no observable surface flow anywhere within site channel. Water confined to main channel area, maximum width to 12m, average width 3m and maximum depth to 0.8m. The edge habitats sampled were similar to Autumn 2011 and consisted of submerged vegetation (terrestrial grasses and weeds), slender knotweed and detritus. Substrate mostly firm sandy with some deposits of unconsolidated finer material, and detritus layer throughout most of channel area. No filamentous green algae observed.

Table A1.3 Field Comments –Aquatic Ecology Monitoring Sites Autumn 2012

Date	Site	Comments
15/5/12	WR1	Water level around 30-40cm lower than both former surveys, though most of the site pool dimensions similar to former surveys. Water relatively clear and flowing throughout site length. Maximum depth ~1.3m to 1.5m, average depth around 0.5m to 0.6m. Detritus, undercut banks and trailing edge bank vegetation sampled as edge habitat. Large logs and branched prevalent throughout site length. Build up of silt in areas of lower flow. Substrate mostly unconsolidated sandbanks. No filamentous green algae observed. A number of Australian water rat tracks and feeding station (at the same location as for Spring 2011) observed on northern bank.
16/5/12	WR3	Water level around 30-40cm lower than both former surveys. Water relatively clear and flowing through site length. Maximum stream width 12m to15m, average width 9m, maximum depth around 1.2m. The available edge habitats included detritus and edge bank vegetation, logs and undercut banks. Substrate consisting of sandbanks. Orange precipitate present along sections of edge bank. No macrophytes observed in site, and filamentous green algae present in small amounts. Australian water rat tracks present along channel banks on northern bank.

16/5/12	JCUp	Water level around 10cm to 20cm lower than previous surveys, though general pool dimensions similar to previous samples. Water slightly turbid, and flowing throughout site length. Maximum depth to 1.0m. The aquatic edge habitats sampled included edge trailing bank vegetation, undercut banks and detritus. Substrate consists of mobile and unconsolidated sandbanks along site length. Submerged and emergent logs prevalent throughout site. Filamentous green algae present in small amounts along site length.
16/5/12	JC2E	General water levels and site pool dimensions similar to former sample occasions. Water moderately turbid with no observable flow in site length. Maximum depth estimated at 1.2m to 1.5m. Abundant floating algae and particulate matter smothering water surface, with a strong odour coming from waterbody (like blood and bone). Edge habitats sampled included trailing bank vegetation, detritus and cumbungi. Substrate firm clayey sand and smothered with detritus which releases strong sulphur odour when disturbed. Filamentous green algae present in small to moderate amounts.
15/5/12	LJ4	Water level around 30cm lower than previous sample occasion. Water of slight to moderate turbidity and flowing throughout site length. General pool and stream dimensions similar to previous sample occasions (width and pool lengths), maximum depth to 1.5m. Evidence of recent high flows indicated by debris lines on banks (to +3m), and riparian weeds have proliferated since previous sample (fleabane, lantana, cobblers pegs, wild tobacco). Trailing bank vegetation, detritus, submerged slender knotweed and undercut banks sampled as edge habitat. Leaf litter abundant. Orange precipitate present along areas of edge bank isolated from flows. Substrate firm clayey with some areas of soft unconsolidated sandy sediments. Filamentous green algae abundant in some parts of the site, absent in others.
16/5/12	LJDn	Water level around 10cm to 20cm lower than former surveys. Water moderately clear and flowing throughout site length. Maximum width to 5m, average width 2m, maximum depth around 1.2m, average depth 0.3m. Trailing bank vegetation, detritus and undercut banks sampled as edge habitats. Debris lines on banks indicate possible recent high flows (+2-3m above current water levels). Substrate mostly firm clay with main pool basin filled with soft unconsolidated sandy sediments. Orange precipitate present along some of the areas of lower flow. No filamentous green algae observed.

17/5/12	SW1	Water level around 5-10cm lower than Spring 2011 survey, and as for the Spring survey, surface water confined to main channel area (from downstream end fence-line upstream for distance of ~30m. Water moderately clear and tannin stained, with no flow. Maximum pool width to 3m, average width to 1m, maximum pool depth to 0.7m. Aquatic habitats unchanged since Spring 2011 survey, and consisted of detritus, undercut banks, trailing bank vegetation and water ribbons. Charophytes present. Substrate firm clay with layer of detritus over top. No filamentous green algae observed.
17/5/12	WC1	Water level around 10cm to 15cm lower than former samples, though channel dimensions relatively unchanged. Water slightly turbid with some tannin staining, and no observable flow throughout site length. Maximum depth to 1.4m. Floating algae smothering water surface throughout site length. Trailing bank vegetation, spike rushes and water ribbons and river clubrush, detritus and undercut banks sampled as edge habitat. Instream banks and substrate firm clayey, with some isolated areas of sand accumulation. Strong odour of sulphur gas when the detritus is disturbed. Filamentous green algae present in small amounts. Juvenile kangaroo stuck in pool at upper end of pool.
17/5/12	BC1	General pool dimensions and water level similar to both former sample occasions. Evidence of recent flows to 1.0m above current water levels. Water clear, slightly tannin stained with low flow throughout site length. Maximum depth ~1.4m. Detritus, undercut banks and trailing bank vegetation sampled as edge habitat. Edge banks clayey and exposed. Substrate firm clayey with some areas with accumulated loose sediment deposits. Abundant eucalypt detritus on channel basins and release of sulphur odour when disturbed. Juvenile growths of water ribbons and slender knotweed in site. Filamentous green algae present in small amounts.

17/5/12	HHMd	Water level around 20cm lower than Spring 2011 survey. Water turbid with no flow within site length. Surface water limited to culvert and main channel area downstream for a distance of 50m. Average width 2m and maximum width around 12m, maximum depth 0.5m, average depth around 0.3m. Evidence of recent high flows to 0.6m to 0.8m above current water levels. Edge habitats similar to former surveys, consisting trailing bank vegetation (grasses and weeds), slender knotweed and detritus. Substrate mostly firm sandy with some deposits of unconsolidated finer material, and detritus layer throughout most of channel area. Filamentous green algae present in small amounts.

Table A - 2 Site Macrophyte Occurrence

Common name	Genus/spp	Au11	Au11	Au11	Au11	Au11	Au11	Au11	Au11	Au11	Au11	Sp11	Sp11	Sp11	Sp11	Sp11	Sp11	Sp11	Sp11	Sp11	Sp11	Au12	Au12	Au12	Au12	Au12	Au12	Au12	Au12	Au12	Au12
		WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHmd	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd
Azolla	*Azolla sp*				1																										
Marsh Culbrush	*Bolboschoenus fluviatilis*																				1										1
Starwort	*Callitriche sp*																									1					
Tall Spikerush	*Eleocharis sphacelata*								1										1							1			1		
Spikerush	*Eleocharis ?gracilis*								1										1										1		1
Swamp Lily	*Ottelia ovalifolia*					1										1			1							1			1		1
Slender Knotweed	*Persicaria decipens*				1						1				1	1					1				1	1				1	1
Frogsmouth	*Philydrum lanuginosum*																														1
River Buttercup	*Ranunculus inundatus*										1										1										1
Sagittaria	*Sagittaria platyphylla*																									1					
River Clubrush	*Schoenoplectus validus*														1	1									1						
Duck Weed	*Spirodela sp*				1										1										1						
Water Ribbons	*Triglochin sp*					1		1	1						1	1		1	1		1				1	1		1	1	1	
Cumbungi	*Typha spp*				1					1	1				1										1						1
Charophytes								1										1								1		1			

Appendix Table A-3.1 Modified Riparian, Channel and Environment (RCE) Inventory (after Chessman et al 1997) - Autumn 2011.

Descriptor	Category	Value	WR1	WR3	JCUp	JC2W	JC2E	JC3	LJ4	LJDn	SWUp	SW1	SWDn	WCUp	WC1	WCDn	BC1	HHMd
1	Land-use pattern beyond immediate riparian zone																	
	Undisturbed native vegetation	4										4	4	4	4	4		
	Mixed native vegetation and pasture/exotics	3	3	3				3	3	3	3						3.5	3
	Mainly pasture, crops or pine plantation	2			2.5	2	2											
	Urban, some vegetation	1																
	Industrial, little vegetation	0																
2	Width of riparian strip-of woody vegetation																	
	More than 30 m	4	4			4						4	4	4	4	4	4	4
	Between 5 and 30 m	3		3.5	3.5		3.5	3.5	3.5	3.5	3							
	Less than 5 m	2																
	No woody vegetation	1																
	No Vegetation	0																
3	Completeness of riparian strip of woody vegetation																	
	Riparian strip without breaks in vegetation	4	4	4	4		4	4	4	4		4	4	4	4	4	4	4
	Breaks at intervals of more than 50 m	3				3.5												
	Breaks at intervals of 10-50 m	2									2							
	Breaks at intervals of less than 10 m	1																
	No riparian strip at all	0																
4	Vegetation of riparian zone within 10 m of channel																	
	Native tree and shrub species	4										4	4	4	4	4		
	Mixed native and exotic trees and shrubs	3	3	3.5	3		3	3.5	3	3.5	3						3.5	3
	Exotic trees and shrubs	2				2.5												
	Exotic grasses/weeds	1																
	No vegetation at all	0																
5	Stream bank structure																	
	Banks fully stabilized by trees, shrubs, concrete	4	4	4		4						4	4		4	4	4	4
	Banks firm but held mainly by grass and herbs	3			3.5		3.5	3.5	3.5	3.5	3			3.5				
	Banks loose, partly held by sparse grass, rubble	2																
	Banks unstable, mainly loose sand or soil	1																
	Banks actively eroding	0																
6	Bank undercutting																	
	None, or restricted by tree roots or man-made	4										4						4
	Only on curves and at constrictions	3					3				3							
	Frequent along all parts of stream	2	2	2	2.5	2.5		2	2.5	2			2	2	2	2	2	
	Severe; bank collapses common	1																
	Total bank collapse	0																
7	Channel form																	
	Deep; width:depth ratio less than 8:1	4	4		4			4	4	4			4	4	4	4	4	
	Medium; width:depth ratio 8:1 to 15:1	3		3.5		3.5	3				3							
	Shallow; width:depth ratio greater than 15:1	2										2						2
	Artificial; concrete or excavated channel< 8:1	1																
	Artificial; concrete or excavated channel > 8:1	0																
8	Riffle/pool sequence																	
	Frequent alternation of riffles and pools	4																
	Long pools with infrequent short riffles	3	3					3		3			3	3.5	3.5	3.5	3	
	Natural channel without riffle/pool sequence	2		2.5	2.5	2	2		2			2						2
	Artificial channel; some riffle/pool sequence	1									1.5							
	Artificial channel; no riffle/pool sequence	0																
9	Retention devices in stream																	
	Many large boulders and/or debris dams	4																
	Rocks/logs present; limited damming effect	3	3	3		3						3		3	3.5	3.5		
	Rocks/logs present but unstable; no damming	2			2		2	3	2.5	2			2					2
	Stream or channel with few or no rocks/logs	1									1						1	
	Artificial channel; no retention devices	0																
10	Channel sediment accumulations																	
	Little or no accumulation of loose sediments	4										4						
	Some gravel bars but little sand or silt	3													3.5	3.5	3.5	
	Bars of sand and silt common	2			2	2.5	2	2	2.5	2			2	2.5				
	Braiding by loose sediment	1	1.5	1.5							1							1
	Complete in-filled muddy channel	0																
11	Stream bottom																	
	Mainly clean stones with obvious interstices	4																
	Mainly stones with some cover of algae/silt	3				3									3	3		
	Bottom heavily silted but stable	2					2	2	2					2			2	2
	Bottom mainly loose and mobile sandy sediment	1	1	1	1.5					1		1	1.5					
	Bottom mainly loose and mobile muddy sediment	0									0.5							
12	Stream detritus																	
	Mainly unsilted wood, bark, leaves	4										4			4	4		
	Some wood, leaves, etc. with much fine detritus	3			3	3	3	3	3				3	3				
	Mainly fine detritus mixed with sediment	2	2	2							2						2	2
	Little or no organic detritus, mainly sandy	1								1								
	No organic detritus, mainly mud	0																
13	Aquatic vegetation																	
	Little or no macrophyte or algal growth	4	4	4	4			4	4	4		4	4	4			4	
	Substantial algal growth; few macrophytes	3				3.5									3.5	3.5		3.5
	Substantial macrophyte growth; little algal growth	2					2				2							
	Substantial macrophyte and algal growth	1																
	Total cover of macrophytes plus algae	0																
	RCE Score		38.5	37.5	38.0	39.0	35.0	40.5	39.5	36.5	28.0	44.0	41.5	43.5	47.0	47.0	40.5	36.5
	RCE %age		74.0	72.1	73.1	75.0	67.3	77.9	76.0	70.2	53.8	84.6	79.8	83.7	90.4	90.4	77.9	70.2

Appendix Table A-3.2 Modified Riparian, Channel and Environment (RCE) Inventory (after Chessman et al 1997) - Spring 2011.

Descriptor	Category	Value	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd
1	Land-use pattern beyond immediate riparian zone											
	Undisturbed native vegetation	4							4	4		
	Mixed native vegetation and pasture/exotics	3	3	3			3	3			3.5	3
	Mainly pasture, crops or pine plantation	2			2.5	2						
	Urban, some vegetation	1										
	Industrial, little vegetation	0										
2	Width of riparian strip-of woody vegetation											
	More than 30 m	4	4						4	4	4	4
	Between 5 and 30 m	3		3.5	3.5	3.5	3.5	3.5				
	Less than 5 m	2										
	No woody vegetation	1										
	No Vegetation	0										
3	Completeness of riparian strip of woody vegetation											
	Riparian strip without breaks in vegetation	4	4	4	4	4	4	4	4	4	4	4
	Breaks at intervals of more than 50 m	3										
	Breaks at intervals of 10-50 m	2										
	Breaks at intervals of less than 10 m	1										
	No riparian strip at all	0										
4	Vegetation of riparian zone within 10 m of channel											
	Native tree and shrub species	4							4	4		
	Mixed native and exotic trees and shrubs	3	3	3.5	3	3	3	3.5			3.5	3
	Exotic trees and shrubs	2										
	Exotic grasses/weeds	1										
	No vegetation at all	0										
5	Stream bank structure											
	Banks fully stabilized by trees, shrubs, concrete	4	4	4					4	4	4	4
	Banks firm but held mainly by grass and herbs	3			3.5	3.5	3.5	3.5				
	Banks loose, partly held by sparse grass, rubble	2										
	Banks unstable, mainly loose sand or soil	1										
	Banks actively eroding	0										
6	Bank undercutting											
	None, or restricted by tree roots or man-made	4							4			4
	Only on curves and at constrictions	3				3						
	Frequent along all parts of stream	2	2	2	2.5		2.5	2		2	2	
	Severe; bank collapses common	1										
	Total bank collapse	0										
7	Channel form											
	Deep; width:depth ratio less than 8:1	4	4		4		4	4		4	4	
	Medium; width:depth ratio 8:1 to 15:1	3		3.5		3						
	Shallow; width:depth ratio greater than 15:1	2							2			2
	Artificial; concrete or excavated channel< 8:1	1										
	Artificial; concrete or excavated channel > 8:1	0										
8	Riffle/pool sequence											
	Frequent alternation of riffles and pools	4										
	Long pools with infrequent short riffles	3	3					3		3.5	3	
	Natural channel without riffle/pool sequence	2		2.5	2.5	2	2		2			2
	Artificial channel; some riffle/pool sequence	1										
	Artificial channel; no riffle/pool sequence	0										
9	Retention devices in stream											
	Many large boulders and/or debris dams	4										
	Rocks/logs present; limited damming effect	3	3	3					3	3.5		
	Rocks/logs present but unstable; no damming	2			2	2	2.5	2				2
	Stream or channel with few or no rocks/logs	1									1	
	Artificial channel; no retention devices	0										
10	Channel sediment accumulations											
	Little or no accumulation of loose sediments	4							4			
	Some gravel bars but little sand or silt	3								3.5	3.5	
	Bars of sand and silt common	2			2	2	2.5	2				
	Braiding by loose sediment	1	1.5	1.5								1
	Complete in-filled muddy channel	0										
11	Stream bottom											
	Mainly clean stones with obvious interstices	4										
	Mainly stones with some cover of algae/silt	3								3		
	Bottom heavily silted but stable	2				2	2				2	2
	Bottom mainly loose and mobile sandy sediment	1	1	1	1.5			1	1			
	Bottom mainly loose and mobile muddy sediment	0										
12	Stream detritus											
	Mainly unsilted wood, bark, leaves	4							4	4		
	Some wood, leaves, etc. with much fine detritus	3			3	3	3					
	Mainly fine detritus mixed with sediment	2	2	2							2	2
	Little or no organic detritus, mainly sandy	1						1				
	No organic detritus, mainly mud	0										
13	Aquatic vegetation											
	Little or no macrophyte or algal growth	4	4	4	4			4	4		4	
	Substantial algal growth; few macrophytes	3					3.5			3.5		3.5
	Substantial macrophyte growth; little algal growth	2				2						
	Substantial macrophyte and algal growth	1										
	Total cover of macrophytes plus algae	0										
	RCE Score		38.5	37.5	38.0	35.0	39.0	36.5	44.0	47.0	40.5	36.5
	RCE %age		74.0	72.1	73.1	67.3	75.0	70.2	84.6	90.4	77.9	70.2

Appendix Table A-3.3 Modified Riparian, Channel and Environment (RCE) Inventory (after Chessman et al 1997) - Autumn 2012.

Descriptor	Category	Value	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd
1	Land-use pattern beyond immediate riparian zone											
	Undisturbed native vegetation	4							4	4		
	Mixed native vegetation and pasture/exotics	3	3	3			3	3			3.5	3
	Mainly pasture, crops or pine plantation	2			2.5	2						
	Urban, some vegetation	1										
	Industrial, little vegetation	0										
2	Width of riparian strip-of woody vegetation											
	More than 30 m	4	4						4	4	4	4
	Between 5 and 30 m	3		3.5	3.5	3.5	3.5	3.5				
	Less than 5 m	2										
	No woody vegetation	1										
	No Vegetation	0										
3	Completeness of riparian strip of woody vegetation											
	Riparian strip without breaks in vegetation	4	4	4	4	4	4	4	4	4	4	4
	Breaks at intervals of more than 50 m	3										
	Breaks at intervals of 10-50 m	2										
	Breaks at intervals of less than 10 m	1										
	No riparian strip at all	0										
4	Vegetation of riparian zone within 10 m of channel											
	Native tree and shrub species	4							4	4		
	Mixed native and exotic trees and shrubs	3	3	3.5	3	3	3	3.5			3.5	3
	Exotic trees and shrubs	2										
	Exotic grasses/weeds	1										
	No vegetation at all	0										
5	Stream bank structure											
	Banks fully stabilized by trees, shrubs, concrete	4	4	4					4	4	4	4
	Banks firm but held mainly by grass and herbs	3			3.5	3.5	3.5	3.5				
	Banks loose, partly held by sparse grass, rubble	2										
	Banks unstable, mainly loose sand or soil	1										
	Banks actively eroding	0										
6	Bank undercutting											
	None, or restricted by tree roots or man-made	4							4			4
	Only on curves and at constrictions	3				3						
	Frequent along all parts of stream	2	2	2	2.5		2.5	2		2	2	
	Severe; bank collapses common	1										
	Total bank collapse	0										
7	Channel form											
	Deep; width:depth ratio less than 8:1	4	4		4		4	4		4	4	
	Medium; width:depth ratio 8:1 to 15:1	3		3.5		3						
	Shallow; width:depth ratio greater than 15:1	2							2			2
	Artificial; concrete or excavated channel< 8:1	1										
	Artificial; concrete or excavated channel > 8:1	0										
8	Riffle/pool sequence											
	Frequent alternation of riffles and pools	4										
	Long pools with infrequent short riffles	3	3					3		3.5	3	
	Natural channel without riffle/pool sequence	2		2.5	2.5	2	2		2			2
	Artificial channel; some riffle/pool sequence	1										
	Artificial channel; no riffle/pool sequence	0										
9	Retention devices in stream											
	Many large boulders and/or debris dams	4										
	Rocks/logs present; limited damming effect	3	3	3					3	3.5		
	Rocks/logs present but unstable; no damming	2			2	2	2.5	2				2
	Stream or channel with few or no rocks/logs	1									1	
	Artificial channel; no retention devices	0										
10	Channel sediment accumulations											
	Little or no accumulation of loose sediments	4							4			
	Some gravel bars but little sand or silt	3								3.5	3.5	
	Bars of sand and silt common	2			2	2	2.5	2				
	Braiding by loose sediment	1	1.5	1.5								1
	Complete in-filled muddy channel	0										
11	Stream bottom											
	Mainly clean stones with obvious interstices	4										
	Mainly stones with some cover of algae/silt	3								3		
	Bottom heavily silted but stable	2				2	2				2	2
	Bottom mainly loose and mobile sandy sediment	1	1	1	1.5			1	1			
	Bottom mainly loose and mobile muddy sediment	0										
12	Stream detritus											
	Mainly unsilted wood, bark, leaves	4							4	4		
	Some wood, leaves, etc. with much fine detritus	3			3	3	3					
	Mainly fine detritus mixed with sediment	2	2	2							2	2
	Little or no organic detritus, mainly sandy	1						1				
	No organic detritus, mainly mud	0										
13	Aquatic vegetation											
	Little or no macrophyte or algal growth	4	4	4	4			4	4		4	
	Substantial algal growth; few macrophytes	3					3.5			3		3.5
	Substantial macrophyte growth; little algal growth	2										
	Substantial macrophyte and algal growth	1				1						
	Total cover of macrophytes plus algae	0										
	RCE Score		38.5	37.5	38.0	34.0	39.0	36.5	44.0	46.5	40.5	36.5
	RCE %age		74.0	72.1	73.1	65.4	75.0	70.2	84.6	89.4	77.9	70.2

Annexure Table A4 W2CP Baseline Survey Field Water Quality Readings Au 11, Sp 11 and Au 12

Site	Date	Time	Depth	Temp	Cond	Sal	DO	DO	pH	Turb
			m	°C	µS/cm	ppt	%sat	mg/l	Units	NTU
WR1	28/06/11	14:25	0.2	10.95	236	0.10	77.9	7.8	6.25	18.6
WR3	28/06/11	10:51	0.2	10.95	234	0.10	85.1	8.5	6.21	15.2
JCUp	1/07/11	12:07	0.1	12.19	349	0.16	83.9	8.2	6.25	45.2
JC2E	30/06/11	15:35	0.1	13.23	286	0.13	69.0	6.6	6.35	38.1
JC2W	29/06/11	15:42	0.2	11.69	422	0.19	88.1	8.7	6.56	30.4
JC3	1/07/11	13:39	0.2	12.21	327	0.15	72.2	7.0	6.30	36.3
LJ4	1/07/11	10:32	0.2	12.22	394	0.18	76.8	7.5	6.31	22.1
LJDn	30/06/11	14:16	0.2	12.65	399	0.19	83.3	8.0	6.55	44.6
SW1	29/06/11	12:55	0.1	12.85	282	0.13	99.4	9.5	5.24	48.8
WC1	30/06/11	11:03	0.2	12.88	256	0.11	63.8	6.1	5.52	37.9
BC1	27/06/11	14:41	0.1	10.59	291	0.13	59.6	6.0	6.73	139.6
HHMd	30/06/11	12:21	0.2	14.53	233	0.10	65.0	6.0	5.63	54.7
WR1	12/10/11	13:28	0.1	14.52	233	0.11	117.1	10.8	6.38	19.8
WR3	12/10/11	12:08	0.1	14.58	251	0.11	188.2	17.4	6.04	26.6
JCUp	13/10/11	11:04	0.1	14.48	412	0.20	139.1	12.9	6.35	23.8
JC2E	13/10/11	9:47	0.1	17.18	253	0.11	98.0	8.6	6.25	33.2
JC2E	13/10/11	9:48	0.3	17.01	265	0.12	98.6	8.6	6.20	32.6
JC2E	13/10/11	9:48	0.7	16.75	296	0.14	101.3	8.9	6.17	32.9
LJ4	13/10/11	8:29	0.1	14.18	397	0.19	168.6	15.7	6.25	15.2
SW1	13/10/11	15:20	0.1	15.36	413	0.19	98.4	8.9	5.21	15.2
WC1	14/10/11	8:23	0.1	15.10	640	0.33	50.6	4.6	5.53	22.4
BC1	13/10/11	14:03	0.1	15.73	287	0.13	116.2	10.5	6.88	76.4
HHMd	13/10/11	12:56	0.1	17.88	387	0.19	94.0	8.1	5.69	27.3
WR1	15/05/12	13:32	0.1	10.86	353	0.19	103.9	10.1	6.19	17.0
WR1	15/05/12	13:32	0.6	10.86	333	0.19	103.4	10.1	6.21	16.8
WR3	16/05/12	9:43	0.1	10.80	290	0.16	101.9	9.9	6.12	12.5
WR3	16/05/12	9:43	0.7	10.81	295	0.17	101.8	9.9	6.22	13.8
JCUp	16/05/12	15:02	0.1	11.39	521	0.28	90.8	8.7	6.34	18.4
JC2E	16/05/12	13:29	0.1	13.05	441	0.24	43.3	4.0	6.22	23.5
JC2E	16/05/12	13:29	0.7	12.48	443	0.24	44.4	4.2	6.25	20.3
JC2W	16/05/12	13:20	0.1	12.09	505	0.27	93.4	8.8	6.50	22.5
JC2W	16/05/12	13:20	0.4	12.08	503	0.26	93.4	8.8	6.48	22.4
LJ4	15/05/12	10:42	0.1	11.67	601	0.31	74.4	7.1	6.31	36.5
LJ4	15/05/12	10:42	0.4	11.67	559	0.29	72.8	7.0	6.24	37.1
LJDn	16/05/12	11:32	0.1	12.29	610	0.31	97.6	9.2	6.47	34.7
LJDn	16/05/12	11:33	0.6	12.29	605	0.31	97.5	9.2	6.46	34.5
SW1	17/05/12	14:36	0.1	11.28	534	0.29	63.7	6.1	4.92	12.8
SW1	17/05/12	14:36	0.5	10.95	530	0.28	63.4	6.2	4.88	12.7
WC1	17/05/12	13:12	0.1	12.62	1145	0.59	25.3	2.4	5.54	56.5
WC1	17/05/12	13:12	0.4	12.42	1150	0.59	26.1	2.4	5.49	56.3
BC1	17/05/12	11:26	0.1	11.83	935	0.49	24.0	2.3	6.64	16.3
BC1	17/05/12	11:26	0.4	11.73	993	0.52	23.8	2.3	6.59	16.1
BC1	17/05/12	11:26	1.1	11.71	1038	0.54	23.9	2.3	6.57	27.3
HHMd	17/05/12	10:09	0.1	11.47	514	0.27	89.0	8.5	5.85	114.8
HHMd	17/05/12	10:09	0.3	10.70	515	0.27	92.2	9.0	5.82	109.6

Annexure Table A5 Wallarah Project Macroinvertebrate & Fish Sampling Results

										Life Stage			28/06/11	28/06/11	1/07/11	30/06/11	1/07/11	30/06/11	29/06/11	30/06/11	27/06/11	30/06/11	12/10/11	12/10/11	13/10/11	13/10/11	13/10/11	12/10/11	13/10/11	14/10/11	13/10/11	13/10/11	15/05/12	16/05/12	16/05/12	16/05/12	15/05/12	16/05/12	17/05/12	17/05/12	17/05/12	17/05/12	1999					
Phylum	Class	Sub-Cl	Order	Sub-Order	Family	Sub-Family	Genus/spp	Common name	Description	L	N	A	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHmd	WR1	WR3	JCUp	JC2E	LJ4	LJDn	SW1	WC1	BC1	HHMd	ERM	Occurrence	SIG-2	Au11	Sp11	Au12
Arthropoda	Insecta		Coleoptera		Curculionidae			Weevils																																			1	1	2			
Arthropoda	Insecta		Coleoptera		Dytiscidae			Diving Beetles		x		x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	29	2	10	10	8
Arthropoda	Insecta		Coleoptera		Elmidae			Riffle Beetles		x		x	1	1	1								1	1	1								1	1	1								1	10	7	3	3	3
Arthropoda	Insecta		Coleoptera		Gyrinidae			Whirligig Beetles		x		x	1	1	1		1	1						1	1			1							1		1	1					1	12	4	5	3	3
Arthropoda	Insecta		Coleoptera		Haliplidae			Crawling Water Beetles				x											1	1																				2	2		2	
Arthropoda	Insecta		Coleoptera		Hydraenidae			Scavenger Water Beetles				x		1																					1									2	3	1		1
Arthropoda	Insecta		Coleoptera		Hydrophilidae			Scavenger Water Beetles				x			1	1		1			1	1			1						1	1								1		1	1	11	2	5	3	2
Arthropoda	Insecta		Coleoptera		Hygrobiidae			Screech Beetles																																			1	1	1			
Arthropoda	Insecta		Coleoptera		Psephenidae			Water Pennies		x				1																														1	6	1		
Arthropoda	Insecta		Coleoptera		Scirtidae			Marsh Beetles		x					1	1	1	1				1			1						1					1	1	1					1	11	6	5	2	3
Arthropoda	Insecta		Diptera		Ceratopogonidae			Biting Midges		x			1		1	1	1	1				1		1	1	1	1	1					1	1			1							14	4	6	5	3
Arthropoda	Insecta		Diptera		Chaoboridae			Phantom Midges		x																													1		1	1		3	2			3
Arthropoda	Insecta		Diptera		Chironomidae	Chironominae		Bloodworms		x			1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30	3	9	10	10
Arthropoda	Insecta		Diptera		Chironomidae	Tanypodinae		Bloodworms		x			1	1	1	1	1	1				1	1	1	1	1	1	1					1	1	1	1	1	1		1				20	4	7	6	7
Arthropoda	Insecta		Diptera		Culicidae			Mosquitoes		x																										1							1	2	1			1
Arthropoda	Insecta		Diptera		Psychodidae			Moth Flies		x								1																										1	3	1		
Arthropoda	Insecta		Diptera		Sciomyzidae			Marsh Flies		x																						1												1	2		1	
Arthropoda	Insecta		Diptera		Simuliidae			Black Flies		x			1	1	1		1	1					1	1	1		1	1							1		1	1					1	14	5	5	5	3
Arthropoda	Insecta		Diptera		Tipulidae			Crane Flies		x			1		1	1							1	1										1	1			1						8	5	3	2	3
Arthropoda	Insecta		Ephemoptera		Baetidae			Mayflies			x		1	1								1	1	1		1			1			1	1	1	1	1	1	1	1			1	1	17	5	3	5	8
Arthropoda	Insecta		Ephemoptera		Caenidae			Mayflies			x		1	1									1	1									1	1									1	7	4	2	2	2
Arthropoda	Insecta		Ephemoptera		Leptophlebiidae			Mayflies			x		1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1	28	8	9	10	8
Arthropoda	Insecta		Hemiptera		Corixidae			Lesser Water Boatmen					1	1	1	1		1				1	1	1	1	1		1				1			1		1					1	1	16	2	6	6	3
Arthropoda	Insecta		Hemiptera		Gelastocoridae			Toad Bugs																			1																1	2	5		1	
Arthropoda	Insecta		Hemiptera		Gerridae			Water Striders					1	1							1		1	1			1				1		1	1			1	1			1	1	1	14	4	3	4	6
Arthropoda	Insecta		Hemiptera		Hydrometridae			Water Measurers							1						1			1				1		1													1	6	3	2	3	
Arthropoda	Insecta		Hemiptera		Mesoveliidae			Water Treaders																								1												1	2		1	
Arthropoda	Insecta		Hemiptera		Nepidae			Needle Bugs																																			1	1	3			
Arthropoda	Insecta		Hemiptera		Notonectidae			Backswimmers								1	1	1			1	1				1		1			1	1					1				1		1	12	1	5	4	2
Arthropoda	Insecta		Hemiptera		Pleidae			Pygmy Backswimmers					1		1	1						1			1	1										1								7	2	4	2	1
Arthropoda	Insecta		Hemiptera		Veliidae			Small Water Striders						1													1	1					1				1					1	1	7	3	1	2	3
Arthropoda	Insecta		Lepidoptera		Pyralidae			Moths		x										1																						1		2	3	1		1
Arthropoda	Insecta		Megaloptera		Cordyalidae			Dobsonflies		x					1																				1									2	7	1		1
Arthropoda	Insecta		Megaloptera		Sialidae			Alderflies		x			1																	1														2	5	1	1	
Arthropoda	Insecta		Odonata	Epiproctophora	Aeshnidae			Dragonflies		x												1					1		1			1								1		1	1	7	4	1	3	2
Arthropoda	Insecta		Odonata	Epiproctophora	Austropetaliidae			Dragonflies																																			1	1	10			
Arthropoda	Insecta		Odonata	Epiproctophora	Cordulephyidae			Dragonflies		x									1										1								1		1					4	5	1	1	2
Arthropoda	Insecta		Odonata	Epiproctophora	Gomphidae			Dragonflies		x			1																1					1									1	4	5	1	1	1
Arthropoda	Insecta		Odonata	Epiproctophora	Hemicorduliidae			Dragonflies		x			1	1	1	1							1				1		1			1			1							1	1	11	5	4	4	2
Arthropoda	Insecta		Odonata	Epiproctophora	Libellulidae			Dragonflies		x												1					1								1							1		4	4	1	1	2
Arthropoda	Insecta		Odonata	Epiproctophora	Telephlebiidae			Dragonflies		x				1									1	1	1								1											5	9	1	3	1
Arthropoda	Insecta		Odonata	Zygoptera	Coenagrionidae			Damselflies		x			1		1	1	1	1	1		1	1	1		1	1	1		1	1		1			1	1			1	1		1	1	21	2	8	7	5
Arthropoda	Insecta		Odonata	Zygoptera	Isostictidae			Damselflies		x																			1				1	1		1	1			1	1		1	8	3		1	6
Arthropoda	Insecta		Odonata	Zygoptera	Lestidae			Damselflies		x			1		1		1					1					1					1												6	1	4	2	
Arthropoda	Insecta		Odonata	Zygoptera	Megapodagrionidae			Damselflies		x					1		1		1	1	1				1						1		1	1	1		1		1	1	1		1	15	5	5	2	7
Arthropoda	Insecta		Odonata	Zygoptera	Synlestidae			Damselflies		x													1	1			1																	3	7		3	
Arthropoda	Insecta		Trichoptera		Atriplectididae			Caddis Flies		x														1										1										2	7		1	1
Arthropoda	Insecta		Trichoptera		Calamoceratidae			Caddis Flies		x			1	1	1								1	1									1	1	1	1	1	1						11	7	3	2	6
Arthropoda	Insecta		Trichoptera		Calocidae			Caddis Flies		x																																	1	1	9			
Arthropoda	Insecta		Trichoptera		Ecnomidae			Caddis Flies		x																							1						1					2	4			2
Arthropoda	Insecta		Trichoptera		Helicopsychidae			Caddis Flies		x																																	1	1	8			
Arthropoda	Insecta		Trichoptera		Hydrobiosidae			Caddis Flies		x													1					1						1				1						4	8		2	2
Arthropoda	Insecta		Trichoptera		Hydroptilidae			Caddis Flies		x																1						1					1							3	4		2	1
Arthropoda	Insecta		Trichoptera		Leptoceridae			Caddis Flies		x			1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30	6	9	10	10
Arthropoda	Insecta		Trichoptera		Odontoceridae			Caddis Flies		x			1	1				1					1	1									1	1									1	8	7	3	2	2
Arthropoda	Insecta		Trichoptera		Philorheithridae			Caddis Flies		x			1	1																			1	1				1						5	8	2		3
Arthropoda	Insecta		Trichoptera		Polycentropodidae			Caddis Flies		x			1																															1	7	1		
Arthropoda	Arachnida		Acarina	Hydracarina				Freshwater Mites					1	1	1	1	1	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1		1	26	6	8	9	8
Arthropoda	Collembola							Springtails														1																						1	1	1		
Arthropoda	Crustacea	Branch	Diplostra	Cladocera				Water Fleas					1	1		1		1	1		1	1	1			1	1	1			1	1				1	1				1	1	1	18	*	7	6	4
Arthropoda	Crustacea	Copep	Calanoida		Centropagidae			Copepods																												1						1		2	*			2
Arthropoda	Crustacea	Copep	Cyclopoida		Cyclopidae			Copepods						1		1	1	1		1	1	1	1		1	1	1	1			1	1				1	1			1	1	1		19	*	7	7	5
Arthropoda	Crustacea		Amphipoda		Eusiridae			Side Swimmers																																			1	1	7			
Arthropoda	Crustacea		Amphipoda		Talitridae			Side Swimmers																										1				1					1	3	3			2
Arthropoda	Crustacea		Amphipoda					Side Swimmers																																			1	1	3			
Arthropoda	Crustacea		Decapoda		Atyidae			Freshwater Shrimp					1	1	1		1	1	1				1	1	1		1	1	1				1	1	1	1	1	1	1	1		1	1	22	3	6	6	9
Arthropoda	Crustacea		Decapoda		Parastacidae			Crayfish/ Yabbie											1			1							1		1	1			1				1			1	1	9	4	2	3	3
Arthropoda	Ostracoda							Seed Shrimps								1							1			1	1					1											1	6	*	1	4	
Annelida	Hirudinea				Glossiphoniidae			Leeches								1	1									1														1				4	1	2	1	1
Annelida	Oligochaeta							Freshwater Worms					1	1	1	1	1	1				1	1		1		1	1			1		1	1	1	1	1		1		1		1	20	2	7	5	7
Mollusca	Bivalvia				Sphaeriidae			Pea Shells					1	1	1		1							1	1		1	1		1	1		1	1			1	1			1			15	5	4	6	5
Mollusca	Gastropoda				Ancylidae			Freshwater Limpets											1		1	1							1			1								1		1	1	8	4	3	2	2
Mollusca	Gastropoda				Physidae		*Physa acuta*	Freshwater Snails							1	1	1	1			1	1			1	1	1					1				1	1							12	1	6	4	2
Mollusca	Gastropoda				Planorbidae			Freshwater Snails								1			1			1							1			1							1			1	1	8	2	3	2	2
Platyhelmint	Temnocephalidea				Temnocephalidae			Temnocephalans																				1																1	5		1	
Platyhelmint	Turbellaria		Tricladida		Dugesiidae			Flatworms					1		1	1	1	1								1	1										1	1				1		10	2	5	2	3
Porifera					Spongillidae			Sponges																											1						1			2	3			2
Chordata	Amphibia							Tadpoles									1					1																	1			1		4	*	2		2
Chordata	Amphibia				Myobatrachidae		*Crinia signifera*	Common Froglet														1																						1	*	1		
Chordata	Osteichthyes				Eleotridae		*Gobiomorphus/ Philypnodon sp*	Gudgeon					1	1		1		1					1			1								1										7	*	4	2	1
Chordata	Osteichthyes				Eleotridae		*Hypseleotris galii*	Firetail Gudgeon																1																				1	*		1	
Chordata	Osteichthyes				Eleotridae		*Philypnodon grandiceps*	Flathead Gudgeon							1		1								1			1																4	*	2	2	
Chordata	Osteichthyes				Eleotridae		*Philypnodon sp*	Flathead Gudgeon																									1		1		1	1						4	*			4
Chordata	Osteichthyes				Poeciliidae		*Gambusia holbrooki*	Eastern Gambusia					1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1			1	1			1	1	1	1		23	*	9	8	6
								Total number of invertebrate taxa per site:					30	26	26	22	21	21	12	8	14	25	26	24	22	19	25	20	15	9	15	23	22	24	23	17	27	19	13	15	15	22	41	76				
Notes:	* Represents those taxa for which SIGNAL-2 scores are not available									Site SIGNAL2 Scores:			4.48	4.92	3.81	3.05	3.55	3.53	4.00	4.71	3.15	3.30	4.91	4.96	4.19	3.31	3.91	4.11	4.07	4.44	4.15	3.30	4.95	5.04	4.13	3.64	4.00	4.95	3.92	3.79	3.85	3.26	4.23					
												EPT:	8	7	3	1	2	2	2	2	2	3	7	7	2	4	2	3	3	2	2	4	8	9	4	3	5	6	4	2	2	2	7					

ANNEXURE B

WALLARAH 2 COAL PROJECT

STREAMHEALTH

BASELINE MONITORING PROGRAM

SEASONAL SITE PHOTOGRAPHS

AUTUMN 2011

Plate 1: Looking upstream at WR1.

Plate 2: Looking upstream at WR1.

Plate 3: Looking downstream in WR1 toward Boyds Lane bridge.

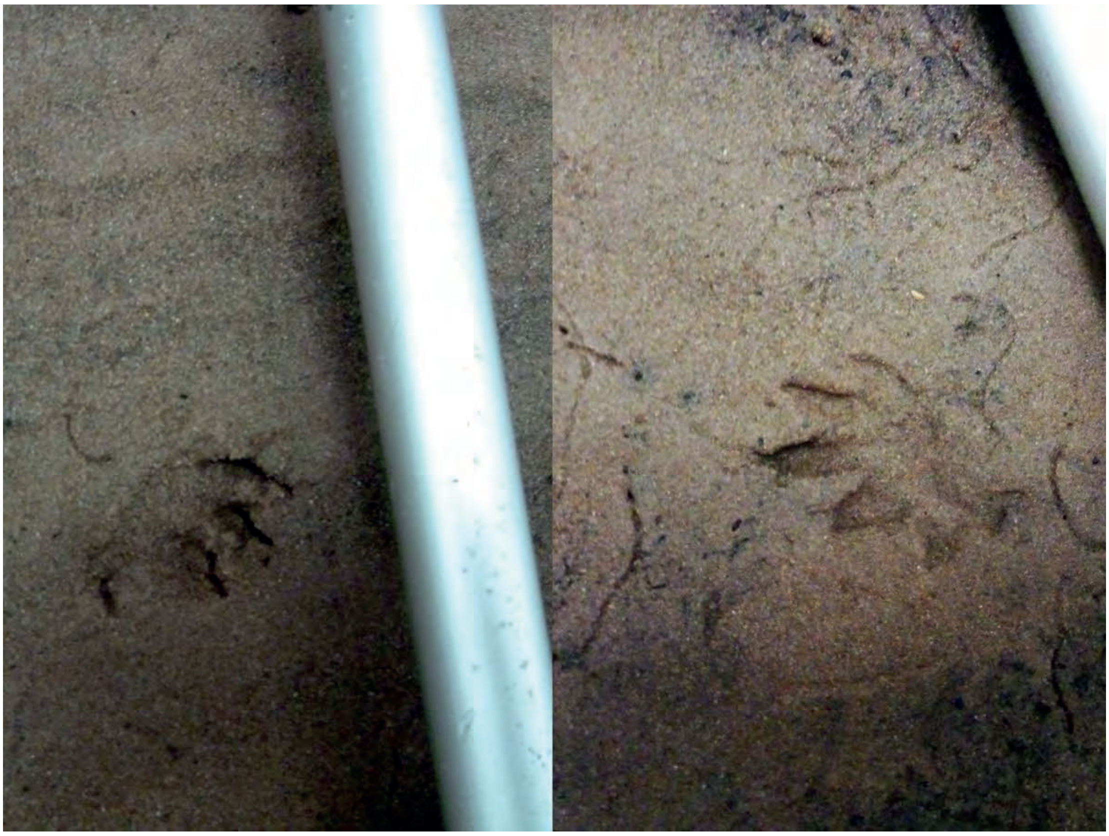

Plate 4: Two different views of tracks that were observed on a sandbank at WR1.

Plate 5: Riparian corridor canopy cover at WR1.

Plate 6: Looking upstream from WR3 from Kidmans Lane bridge. Note the number of submerged logs (snags).

Plate 7: Looking downstream into WR3 from Kidmans Lane bridge.

Plate 8: Looking upstream along edge banks in WR3. Note the undercut banks.

Plate 9: Looking upstream from bridge at JCUp.

Plate 10: Looking downstream from bridge at JCUp.

Plate 11: JCUp site channel looking downstream. Wandering dew (left bank) was prevalent throughout much of the Jilliby Jilliby Creek, Little Jilliby Jilliby Creek and Wyong River riparian areas.

Plate 12: Looking upstream in JC2E.

Plate 13: Looking upstream from bridge crossing at JC2E.

Plate 14: Looking downstream from JC2E bridge crossing.

Plate 15: Looking upstream from bridge at JC2W.

Plate 16: Looking downstream from bridge at JC2W.

Plate 17: Looking upstream at JC3.

Plate 18: Fallen tree at JC3.

Plate 19: Looking downstream at JC3.

Plate 20: Edge bank erosion at JC3.

Plate 21: Looking upstream under bridge crossing at LJ4.

Plate 22: Downstream end of LJ4 looking upstream.

Plate 23: Iron precipitate at LJ4.

Plate 24: Flathead gudgeon at LJ4.

Plate 25: Looking upstream at LJDn. Note the steep uncovered banks and sandy substrate.

Plate 26: Looking downstream at LJDn.

Plate 27: SWUp looking upstream towrd the freeway.

Plate 28: SWUp looking downstream.

Plate 29: Looking across the broader flow channel at SW1.

Plate 30: Looking upstream at SW1.

Plate 31: SW1 Channel looking usptream.

Plate 32: Looking downtream from the fenceline at the downstream limits of SW1.

Plate 33: Looking upstream at SWDn.

Plate 34: Looking upstream at SWDn.

Plate 35: Looking upstream toward freeway in Wallarah Creek.

Plate 36: Looking downstream at WCUp.

Plate 37: Looking upstream at WC1. Note the abundance of trailing bank vegetation (mostly lomandra and sedges).

Plate 38: Looking downstream at WC1.

Plate 39: Looking downstream at WC1.

Plate 40: Looking upstream at lower end of WCDn from Motorway Link Rd 111.

Plate 41: Looking downstream at Wallarah Creek from the downstream side of Motorway Link Rd 111 culvert.

Plate 42: Looking upstream at BC1.

Plate 43: Undercut earth banks at BC1. Most of the edge bank vegetation at this site was above the waterline.

Plate 44: Looking downstream in Buttonderry Creek from the Hue Hue Rd crossing culvert.

Plate 45: Looking usptream from Sandra Rd crossing in Hue Hue Creek.

Plate 46: Upstream end of HHMd.

Plate 47: Shallow submerged edge habitat at HHMd.

ANNEXURE C

WALLARAH 2 COAL PROJECT

STREAMHEALTH

BASELINE MONITORING PROGRAM

SEASONAL SITE PHOTOGRAPHS

SPRING 2011

Plate 1: Looking upstream from bridge at JCUp Spring 2011.

Plate 2: Looking downstream from bridge at JCUp.

Plate 3: Looking downstream at JCUp.

Plate 4: Looking upstream at JC2E site channel.

Plate 5: Looking upstream at JC2E from road crossing.

Plate 6: Looking downstream from JC2E road crossing.

Plate 7: Looking upstream from JC2W road crossing.

Plate 8: Looking downstream from JC2W road crossing.

Plate 9: Looking upstream from bridge at LJ4.

Plate 10: Looking upstream at LJ4.

Plate 11: Looking downstream at LJ4.

Plate 12: Looking across the SW1 channel. Note the water level difference compared to Autumn 2011.

Plate 13: Looking upstream at SW1.

Plate 14: Surface water in channel at lower end of SW1.

Plate 15: Looking upstream through main channel at SW1.

Plate 16: Looking upstream at upstream end of WC1.

Plate 17: Looking downstream at WC1.

Plate 18: Lower end of WC1 looking downstream.

Plate 19: Pool at lower end of WC1.

Plate 20: Looking downstream at upstream end if BC1.

Plate 21: Looking upstream from lower end of BC1.

Plate 22: Looking upstream from HHMd road crossing.

Plate 23: Upper end of HHMd below road culvert.

Plate 24: Looking downstream along main channel at HHMd.

ANNEXURE D

WALLARAH 2 COAL PROJECT

STREAMHEALTH

BASELINE MONITORING PROGRAM

SEASONAL SITE PHOTOGRAPHS

AUTUMN 2012

Plate 1: Looking upstream at WR1 in Autumn 2012.

Plate 2: Looking upstream at WR1.

Plate 3: Looking downstream toward bridge at WR1.

Plate 4: Water rat tracks at WR1.

Plate 5: Multiple freshwater mussel shells at feeding station at WR1.

Plate 6: Looking upstream from bridge at WR3.

Plate 7: Looking upstream at WR3.

Plate 8: Looking downstream at WR3.

Plate 9: Edge bank iron precipitation at WR3.

Plate 10: Water rat tracks at WR3.

Plate 11: Native gudgeon at WR3.

Plate 12: Looking downstream at JCUp.

Plate 13: Looking downstream at JCUp.

Plate 14: Freshwater sponges at JCUp.

Plate 15: Looking upstream at JC2E. Note the layer of particulate matter smothering the water surface.

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Plate 16: Edge habitat at JC2E.

Plate 17: Looking upstream from road crossing at JC2W. Note the water level difference between this survey, and former surveys.

Plate 18: Looking downstream from road crossing at JC2W.

Plate 19: Looking upstream under bridge at LJ4.

Plate 20: Looking upstream at LJ4.

Plate 21: Lower end of LJ4.

Plate 22: Native gudgeon at LJ4.

Plate 23: Upper end of LJDn looking upstream. Note the variation in wateer levels compared to Autumn 2011 (below).

Plate 24: Looking upstream at LJDn in Autumn 2011.

Plate 25: Looking usptream through channel at LJDn.

Plate 26: Lower end of LJDn looking downstream.

Plate 27: Looking across SW1 drainage channel. Note the variation in water levels between Autumn and Spring 2011 surveys (below).

Plate 28: SW1 channel flowing left to right in Autumn 2011.

Plate 29: Site SW1 channel in Spring 2011.

Plate 30: Pool at SW1 (Autumn 2012).

Plate 31: Looking upstream through channel area at SW1.

Plate 32: Pool at lower end of SW1.

Plate 33: Looking upstream at WC1.

Plate 34: Looking downstream through channel area at WC1.

Plate 35: Looking downstream at WC1.

Plate 36: Pool at lower end of WC1. Note the floating particulate matter on the pool surface.

Plate 37: Looking downstream at upstream end of BC1.

Plate 38: Looking upstream from lower end of site at BC1.

Plate 39: Edge habitats at BC1.

Plate 40: Looking usptream from HHMd road crossing.

Plate 41: Downstream side of road culvert at HHMd.

Plate 42: Looking downstream through HHMd main channel area.