Appendix 11

Aquatic Ecology

South East Open Cut Project

&

Modification to the

Existing ACP Consent

ASHTON COAL
SOUTH-EAST OPEN CUT
ENVIRONMENTAL ASSESSMENT

AQUATIC ECOLOGY IMPACT ASSESSMENT

REPORT PREPARED FOR
ASHTON COAL OPERATIONS PTY LTD

MARINE POLLUTION RESEARCH PTY LTD

JUNE 2009

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Front cover: Dwarf Tree Frog *Litoria fallax* at site P5.

1 INTRODUCTION

Ashton Coal Operations Pty Ltd (ACOL) currently operates a combined open cut and underground (longwall) mine (the Ashton Coal Project ACP) in the middle reaches of the Hunter Valley at Camberwell, some 14 km north of Singleton. The present North East Open Cut (NEOC) is located on the north-eastern side of the New England Highway and the underground mine is located south west of the highway, bounded by Glennies and Bowmans Creeks.

ACOL are seeking approval for the development plus mining of a new open cut mine (designated the South-East Open Cut or SEOC), located immediately to the south of Camberwell Village (i.e., south of the New England Highway) and east of Glennies Creek. The approval is sought under Part 3A of the EP&A Act. Open cut resources in the NEOC are expected to be exhausted by mid 2010, and the SEOC is proposed to provide a continuation of open cut mining operations. The SEOC will therefore integrate with the existing ACP coal handling, preparation and train loading facilities.

Marine Pollution Research Pty Ltd (MPR) has been commissioned to provide an aquatic ecology assessment report to be submitted as part of the approval process. The report has been prepared against the Director-General's requirements (DGRs) provided by the NSW Department of Planning (DoP) on 20 May 2009, which identified "Biodiversity" and “Rehabilitation” as key issues, specifically:

- *“A detailed assessment of the potential impacts of the project on any terrestrial and aquatic threatened species, populations, ecological communities or their habitats; and an offset strategy to ensure that the project will maintain or improve the biodiversity conservation value of the region”.*
- *“A detailed description of the proposed rehabilitation strategy for the project area having particular regard to … the potential for integrating this strategy with any other offset strategies in the region.”*

With regard to aquatic impact assessment, the DGRs also require that the assessment be undertaken using or having regard to the following guidelines:

- Draft Guidelines for Part 3A Threatened Species Assessment (DEC/DPI 2005),
- DPI Fisheries Habitat and Crossing Guidelines (NSW Fisheries 1999a,b),
- NSW State Groundwater Dependent Ecosystems Policy (DLWC 2002) and related documents,
- Management of stream/aquifer systems in coal mining developments guidelines (DWE 2005).

Accordingly, the main objectives of this report are to:

(i) Describe the present aquatic ecology of the study area.
(ii) Assess what possible impacts mining may have on aquatic ecology within the study area,
(iii) Assess possible mitigation measures to achieve a "maintain and improve" outcome for the aquatic ecology of the study area (as per the DEC/DPI, 2005 assessment guidelines).
(iv) Provide details of an aquatic ecology (stream-health) monitoring program to assess possible mining related aquatic ecology impacts.

For the purposes of aquatic ecology assessment, the study area includes the footprint of the proposed SEOC as shown in Figure 1 below, and also extends into the upper catchments of the Glennies Creek sub-catchment drainages which pass through the proposed SEOC plus one other Glennies Creek sub-catchment drainage located immediately south of the SEOC footprint (to be used as a reference sub-catchment). For the consideration of fish passage the study area also includes Glennies Creek upstream to the New England Highway and downstream to the confluence with the Hunter River.

1.1 Project Description

The proposed layout of the SEOC is shown in Figure 1 above. The SEOC is constrained by the New England Highway to the north, cropping coal seams to the east, Glennies Creek and the associated alluvium to the west and mining tenement boundaries to the south.

The SEOC straddles two Exploration Licences, EL4918 and EL 5860A, both held by White Mining Pty Limited (a subsidiary of Felix Resources Limited). Proposed out of pit emplacements, water management facilities and infrastructure are to be located on Authorisation 81, located to the east of EL 5860A and held by Navidale Pty Ltd.

The proposed SEOC will continue open cut mining for seven years beyond the depletion of the existing NEOC, which is expected to finish in 2010. The SEOC will include offices, bathhouse and workshop facilities accessed via a new intersection off the New England Highway. Coal handling facilities will consist of a ROM hopper station and conveyor network with associated water transferral infrastructure through to the existing ACP coal handling, preparation and train loading facilities. Coal will be processed by the existing facilities and loaded onto trains for rail transport to the consumer (export or domestic).

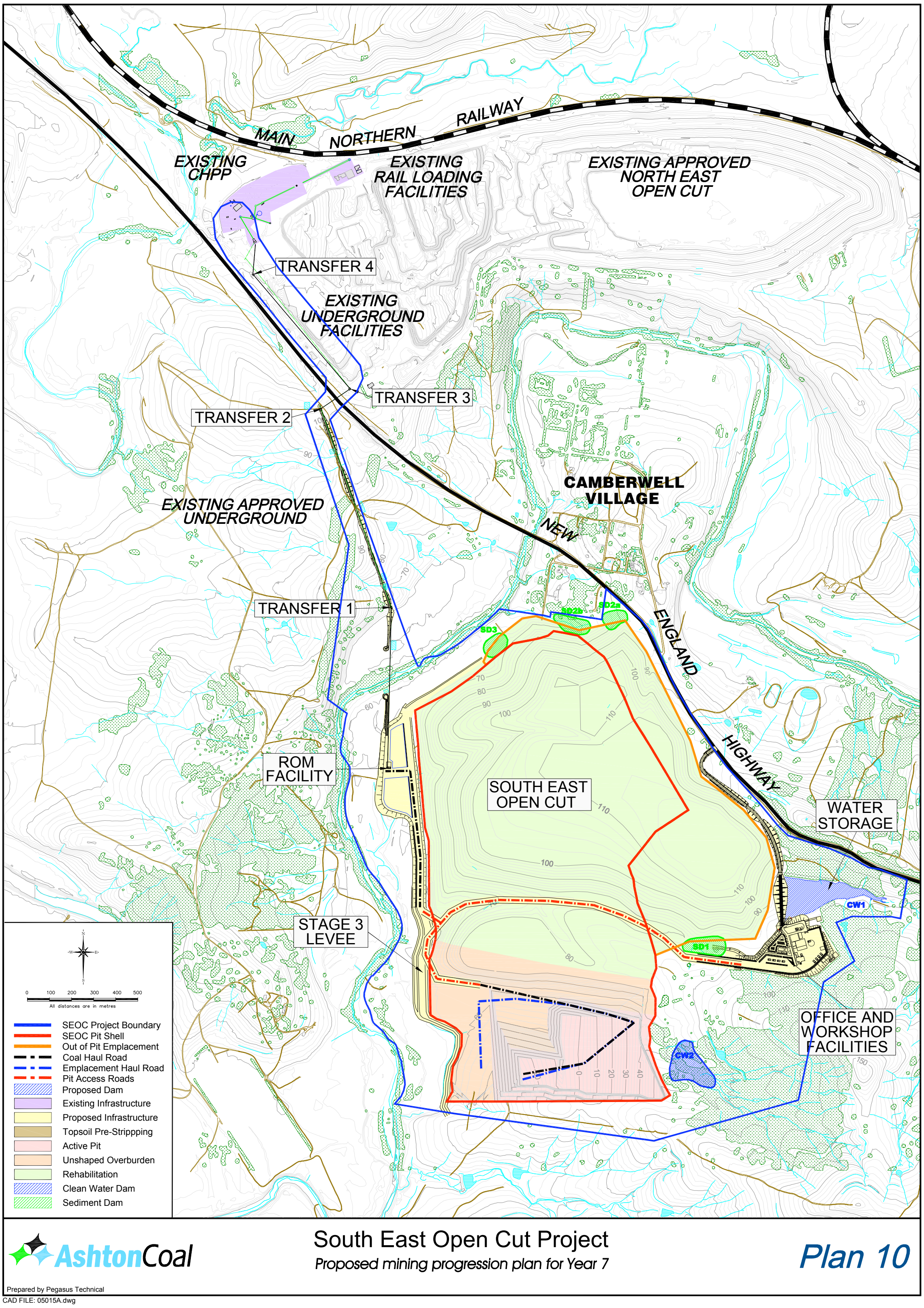

Fig 1
Ashton Coal Project Proposed SEOC

Mining in the SEOC will commence in the north and progress to the south. The final void of the SEOC will be located in the southern corner of the open cut. The location of this void allows potential for continued open cut mining of coal reserves to the south.

1.2 Summary of Site Physical Environmental Attributes

Wells Environmental Services (2009) provides a detailed description of site physical environmental characteristics, some of which are summarised here as they relate to general aquatic ecological aspects. Aspects that have a greater relevance to the assessment of aquatic ecology (e.g., rainfall and Glennies Creek flow characteristics) will be considered in more detail below.

The climate is characterised by typically wet summers and dry winters, seasonal changes are a factor in the distribution of annual rainfall, with a greater proportion of rainfall occurring during the summer months. Over the remaining seasons, the rainfall is spread more evenly with minimum totals generally being recorded in winter. The record for the period 1970 to 1979 indicates a mean monthly evaporation rate of 154 mm with monthly variations between 78 mm in May and 245 mm in January. Much of the year is characterised by a water deficit.

Summers are often characterised by extremely hot conditions, with temperatures in excess of 32ºC being recorded on many occasions over the period of record. On the other hand, minimum temperatures during the winter months tend to be very low with frosts frequently recorded in the general locality. Summer winds are predominantly from the south-southeast. The pattern in autumn and spring are similar and show winds from both the north-northwest and south-southwest, with approximately equal frequency. Winds in winter are generally confined to the north-northwest and northwest.

Soils of the study area are characterised by yellow podsolic soils on mid and upper slopes and drainage lines with patches of yellow soloth soils in some drainage lines. Alluvial soils are present along Glennies Creek.

1.3 General Catchment Attributes

The SEOC is located within the lower reaches of the Glennies Creek (or Fal Brook) catchment (see Figure 2). Hunter Catchment Management Trust (HCMT 2003, 2004) plus Hunter Central Rivers CMA fact sheets provide information on the Glennies Creek catchment, some of which is provided here as it relates to the understanding of the aquatic ecology of the study site.

Land-use in the Glennies Creek catchment below the dam comprises agricultural practices and coal mining. Whilst much of the original vegetation in the catchment has been cleared, remnant vegetation comprises dry sclerophyll forest, shrub, savanna and woodland. There are eucalypt sub-alpine woodlands and some areas of rainforest in the upper catchment. The immediate locality is characterised by areas of predominantly cleared agricultural land utilised for livestock grazing and cultivation and the Ashton open cut and underground coal mining operations.

Glennies Creek is approximately 45km long and flows from its headwaters at Mount Royal (1184m AHD) to the Hunter River (50m AHD). Glennies Creek has a catchment of approximately 49km^2 of which 23km^2 is impounded within Lake St Clair, approximately 20km north-east of the ACP (MPR 2006). Glennies Creek is 39 km long from the dam to the Hunter River. Lake St Clair has a capacity of 284,000 ML and the impoundment is an important supply of regulated water for industry and agriculture on Glennies Creek and the Hunter River. It also supplies drinking water to the town of Singleton.

The SEOC is located on the eastern side of Glennies Creek, and the Glennies Creek confluence with the Hunter River is approximately 1.5km to the south-west of the SEOC. The SEOC sub-catchment has a total area of approximately 600ha (6km^2) and stormwater drains generally in a westerly direction via five unnamed tributaries of Glennies Creek from an elevation of 170m AHD in the east to less than 60m on Glennies Creek (see Figure 3). For the purposes of clarity in this report, these tributaries are referred to as T1 to T5 (north to south, i.e., with T1 Glennies Creek confluence just below the New England Highway and T5 Glennies Creek confluence at the downstream limit of the mining lease area). T4 is the largest of the unnamed tributaries and extends approximately 4km to the east from Glennies Creek. The upper part of the T4 sub-catchment would be dammed to create a clean-water storage for the SEOC (see Figure 1).

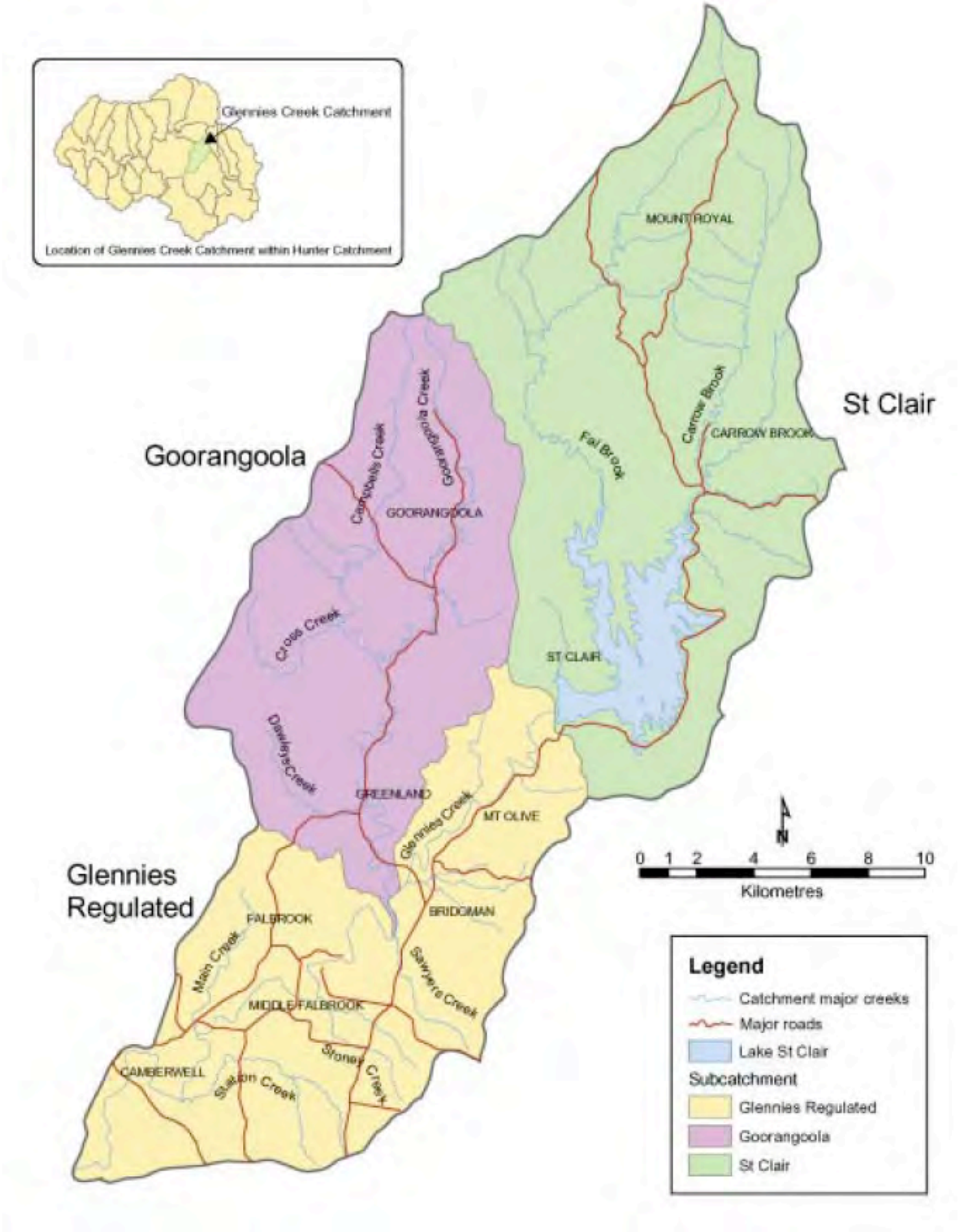

Figure 2
Glennies Creek Catchment. The Proposed
SEOC is in the Glennies Regulated Sub-catchment

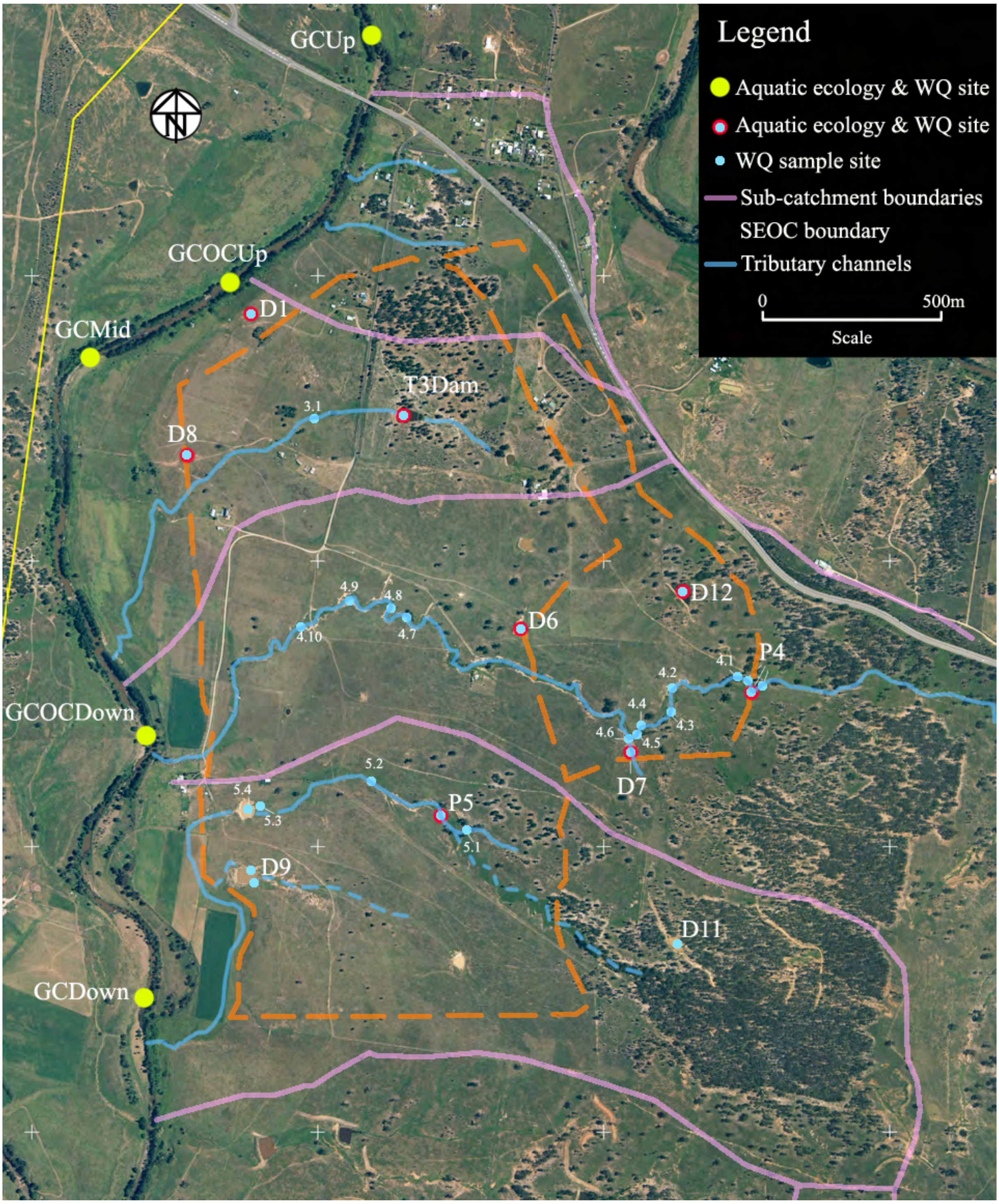

Figure 3
Ashton Coal SEOC Study Area
showing sub-catchments and aquatic ecology study sites

2 STUDY METHODS

With regard to assessing possible impact on aquatic ecology of the project and in order to meet the DGRs requirements, the following study elements were adopted:

- Field studies to assess the aquatic ecology of Glennies Creek and of the project area.
- Additional field walkover inspections of Glennies Creek and tributaries within the study area, to ascertain whether there are any aquatic Groundwater Dependant Ecosystems (GDEs) on the site and to ascertain present aquatic habitat conditions and fish passage attributes.
- A review of the literature regarding potential for open-cut mining related impacts on creek and drainage structure, function and water quality.
- A review of regional aquatic ecology information plus agency data-bases to assess the potential for threatened and protected aquatic species to utilise the creeks and drainages of the study area.

2.1 Glennies Creek and SEOC Field Aquatic Studies

To date there have been four seasonal aquatic ecology surveys undertaken at a number of locations in Glennies Creek (see Figure 3); in autumn and spring 2007 and autumn plus spring 2008 (see MPR 2007, 2008a, 2008b & 2009a for full survey results). The original aquatic ecology sample design (for the autumn 2007 survey) had three sites on Glennies Creek, and for the remaining seasonal studies, two additional sites (GCOCUp and GCOCDown) were included:

- GCUp: An upstream-of-mine reference site located approximately 300m upstream of the New England Highway,
- GCOCUp: a reference site located adjacent the upstream limits of SEOC on Glennies Creek, approximately 600m downstream of the New England Highway,
- GCMid: an intermediate next-to-mining site located approximately 1.2km downstream of New England Highway,
- GCOCDown: a site located towards the downstream limits of the SEOC mine footprint, approximately 2.2km downstream of the New England Highway.

- GCDown: a downstream reference site located approximately 0.9km downstream from GCOCDown, and 2.0km upstream from Hunter River confluence.

In addition to the regular seasonal surveys in Glennies Creek there have been several site walkover inspections plus aquatic ecology sampling surveys undertaken of the SEOC site sub-catchment drainages plus dams. These investigations were undertaken by MPR staff over seven days in 2008; 3 July, 14 to 16 and 28 October plus 9 & 10 December 2008.

A vehicle based survey was also made of Glennies Creek above the New England Highway up to Glennies Dam at this time. Glennies Creek was inspected at road-accessible sites to provide an assessment of the likelihood of native fish colonisation and fish passage attributes of the upper creek. Field notes and photographs were made of the visited sites.

The SEOC tributary study included inspections over the full length of tributaries T1 to T5 (and over the ‘reference’ tributary T6 located to the south of the proposed Open Cut) from their headwaters to confluences with Glennies Creek. Photographic records were made along the study area creek-line and tributaries, to support field notes and observations. Creek and channel riparian areas were inspected for attributes such as bank stability, bank undercutting, closeness of riparian trees to water, recently fallen trees, in-stream logs, pool retention devices, locations of shallow and deeper pool areas, and fish passage potential.

Aquatic ecology and water quality sampling was undertaken at several in-line pond and dam sites on the major tributaries T3 to T5 during the field investigations, to provide an assessment of a representative range of water storage types within the study area (i.e., in-line tributary ponds, and dams, and sampling from turbid and clear water dams).

The aquatic ecology field studies undertaken in Glennies Creek and within the proposed mine area as described above are sufficient to meet the seasonal assessment requirements of the DGRs requirements and that no further field work is required for this impact assessment. Notwithstanding this conclusion, the regular seasonal monitoring of the five sites in Glennies Creek will continue as part of the overall Ashton Coal Project (ACP) whole-of-mine monitoring program with the next scheduled survey in spring 2009. This continuing program will also provide a pre-mining database against which potential mining and post-mining impacts plus recovery can be measured.

2.2 Aquatic Ecology Sampling Methods

The adopted aquatic ecology sampling methods are based on existing methods being utilised for monitoring long-term aquatic ecological change in Illawarra and Hunter coal mining catchments. The study utilises the National River Process and Management Program River Bio-assessment Manual methods (NRPMP 1994) as adapted for the National River Health Program (now referred to as the AusRivAS method (Turak et al 1999, DECC 2004). The AusRivAS protocol provides a number of definitions of sites and habitats within sites for selection of sampling locations and recommends that, wherever possible, two habitats (riffles and edges) be sampled at each site. 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".

Given the location of a number of the study sites in reaches of creeks where there are known to be periods of little or no connecting flow between pools or where there are known to be limited riffle sections available for sampling, it was decided that only pool 'edge' samples would be sampled, as riffle samples could not be guaranteed for all (or possibly even for most) sites at all sample times. The final adopted sampling design includes the following features:

- Sampling of the aquatic macroinvertebrate fauna at five creek pool sites in Glennies Creek twice a year (in spring and autumn) using the AusRivAS sampling, sorting and identification protocols.
- AusRivAS sampling of a representative number of tributary and dam sites in the study area when there has been sufficient rainfall to provide suitable sampling sites.
- Estimation of fish occurrence by a combination of bait-trapping, dip netting and observation, with all captured fish identified in-situ and immediately released.
- Depth profiles of basic water quality parameters: Temperature, Electrical Conductivity (salinity), water acidity (pH), Dissolved Oxygen and Turbidity, at each site during each sampling run.

- Recording of changes in creek riparian condition and of aquatic plant distribution within the study areas at each sampling time.
- Recording of other aquatic fauna utilising the study area aquatic habitats including specific searches for platypus and native water rat, with observations where made of fishing bat, reptiles, birds, turtles and snakes. Platypus and native water rat usage is also assessed by searching for suitable bank conditions for burrow sites or feeding stations and inspection of scats.

2.2.1 Details of field sampling procedure

Aquatic macroinvertebrate assemblages were sampled using a 250 μm mesh dip net over as many aquatic 'edge' habitat types as could be located within each of the pools along the defined stream reach. Net samples were then placed into white sorting trays for in situ live sorting. Live sorting (picking) was 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 were 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 were collected and added to the dip net samples.

In general, representatives of common and/or easily identified rarer taxa were identified 'in the hand' and then released. Also, for rarer specimens for which positive identification could be made in the field (e.g., water scorpions), these were generally released. That is, for protection of the pool macroinvertebrate integrity we adopted a 'sampling with replacement' method. Notwithstanding this procedure, for all taxa which could 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 were not definitive, specimens were retained for later detailed taxonomic analysis in the laboratory.

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

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 for the duration of the combined macroinvertebrate sampling and live picking survey (minimum 1 hour) and then retrieved. Captured fish are identified in situ and released. Any fish caught as part of the macroinvertebrate dip net sampling are also identified, noted and released.

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 were not kept or identified.

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.) and the presence of fresh yabbie holes are also noted.

A submersible Yeo-Kal 911 water quality data logger is used to record water depth, temperature, dissolved oxygen concentration and saturation, pH, conductivity, salinity and turbidity at all aquatic ecology sampling sites.

2.2.2 Laboratory procedures 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).

The organisms from each sample jar (sample site) 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 (spring-tails) 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.

2.3 Data Evaluation

The AusRivAS derived macroinvertebrate data are used to compile site species diversity indices (i.e., number of macroinvertebrate taxa at each site) and site pollution sensitivity indices (using the Stream Invertebrate Grade Number Average Level (SIGNAL) biotic index detailed below). Site condition measurements are used to compile a stream site condition index, based on the River-Creek-Environment (RCE) method developed by Petersen (1992), as reported by Chessman *et al* 1997) for the greater Hunter River catchment. Between season and between site assessments are then made by comparing these site indices and comparing changes in the indices for each site over time (i.e., between surveys).

2.3.1 SIGNAL index

SIGNAL is a pollution tolerance index for stream macroinvertebrates (Chessman, 1995; Chessman *et al*., 1997, Chessman, 2003b). SIGNAL is used to assign average pollution sensitivity grades to each of the sites for site comparisons across each survey and for comparison over time. 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 2003b).

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, Barmuta et al 2002, Chessman 2003a), with each macroinvertebrate family assigned a SIGNAL score ranging from 10 (very pollution intolerant) to 1 (very pollution tolerant). When mean SIGNAL indices are calculated for sites, the sites can be grouped into site condition categories (Chessman *2003b*) as follows:

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

Note that with regard to the assessment of individual site 'health' comparisons provided in Appendix Tables A2, A3 and A7, SIGNAL indices has been used in preference to AusRivAS O/E model calculations, in line with the findings of Walsh (2006), who found that SIGNAL scores provide overall better (more sensitive) indicators for human disturbance than AusRivAS O/E model scores.

Furthermore, Chessman et al (1997) provides catchment-specific SIGNAL scores (HU97) for taxa from the Hunter River based on his studies from 42 reference sites in the region. Accordingly, the taxa identified from this study have been assigned HU97 scores and any taxa that was not assigned a HU97 score in Chessman et al 1997, were assigned the more general SIGNAL-2 score (Chessman 2003). Taxa with no published SIGNAL score are excluded from the site SIGNAL analysis.

3 STUDY RESULTS

3.1 General Literature Review

The aquatic ecology assessment report (MPR 2001) for the Ashton Coal Project Environmental Impact Statement (EIS) prepared by HLA-Envirosciences Pty Ltd (HLA 2001) included some preliminary sampling of macroinvertebrate fauna from both Glennies and Bowmans Creeks (in October 2001 during a prolonged drought period), plus a review of the regional aquatic ecology literature. The study concluded that previous EIS flora and fauna studies for mines adjacent to the study site (particularly those upstream on Glennies and Bowmans Creeks) did not include specific assessments of the aquatic environment, fish habitat or fish species and that at that time there were no published studies of the fish fauna, fish habitats or the aquatic ecology of the lower sections of Bowmans and Glennies Creek flowing through the Ashton project area. There were fish and aquatic macroinvertebrate studies undertaken for Glennies Creek at and above Camberwell Village (Cooke 2001 and Chessman et al 1997).

With regard to the application of the SIGNAL HU-97 index for the present study (see Section 2.3.1 above), Chessmen et al (1997) studied two sites in the upper Glennies Creek catchment (HU06 in Carrow Brook, an upper tributary of Lake St Clair above Glennies Creek Dam, and HU08 at “The Rocks”, downstream of the dam. The closest sites on the Hunter River to the Glennies Creek confluence are HU19 upstream at Jerrys Plains and HU15 downstream at Long Point. Chessman (1997) reported the following mean site scores for these sites:

- HU06, Carrow Brook 5.5
- HU08 The Rocks 5.2
- HU19 Jerrys Plains 4.7
- HU15 Long Point 4.6

MPR (2001) provided a compilation table of known and expected fish species from both Bowmans and Glennies Creeks. This table was used as a base to compile an updated table of known and expected fish for the present study (see Table 8 below).

Hunter Catchment Management Trust (2003) provided an overview of the total Glennies Creek catchment ecology with an emphasis on landuse and catchment management. With regard to aquatic ecosystems the report does not provide any additional macroinvertebrate data but it does provide a compilation table of known and expected fish species for Glennies Creek based on unpublished DPI data. The data from this table was also used to provide the compilation table for this present report (see Section 3.4.3 below). The report also provides an overview assessment of catchment water quality plus comprehensive flora and fauna lists for the total catchment.

With respect to aquatic ecological assessments within the study area and locality, a number of studies have been conducted since the MPR 2001 study. These studies are summarised below:

- ACOL has been undertaking monthly 'whole of mine' water quality monitoring of sites in Bowmans Creek, Bettys Creek, Glennies Creek and the Hunter River since September 2004. Water quality parameters include pH, electrical conductivity (EC), alkalinity (total hardness as mg/L CaCO3), total dissolved solids (TDS), total suspended solids (TSS) and oil & grease.
- ERM (2006) summarised initial aquatic ecology monitoring results for Ashton Mine for the spring 2005 to autumn 2006 period. The monitoring was undertaken in Bowmans Creek and full aquatic monitoring reports are contained as appendices to the ERM (2006) report (TEL 2006a, 2006b). Monitoring included macroinvertebrate, fish (using electro-fishing) and water quality sampling. The TEL reports also provided an updated literature review for aquatic ecosystems in Bowmans Creek.
- MPR undertook aquatic ecology monitoring as part of the EMP for Liddell Open Cut mine over the same survey period as the TEL studies (MPR 2005, 2007). Monitoring studies included macroinvertebrate, fish and water quality sampling from three sites located upstream of the Ashton Coal Mine on Bowmans Creek.
- MPR have been undertaking bi-annual aquatic ecology monitoring studies within Glennies and Bowmans Creeks on behalf of ACOL, from 2007 onwards. To date there have been four aquatic ecology monitoring surveys conducted; in autumn and spring 2007 and autumn plus spring 2008 (MPR 2007, 2008a, 2008b, in press).
- Recent environmental assessments for expanded long-wall plus open-cut mining for the Integra Coal Glennies Creek Mine Operation (located in the Bowmans and Glennies creek catchments) do not provide any additional aquatic environmental information relevant to this study.

3.2 Glennies Creek Aquatic Ecology

The ecological value of the Glennies Creek aquatic habitats is linked to both habitat availability and condition (reviewed in Section 3.2.1 below) and to the water quality attributes of the ponded waters (see Section 3.2.2). Results of aquatic biota field studies are then presented in Sections 3.2.3 to 3.2.5.

3.2.1 Creek geomorphology

Glennies Creek is a major perennial sub-catchment of the Hunter River and differs from other sub-catchment creeks by virtue of its function in supplying make-up water to the Hunter River via regular controlled releases from the Lake St. Clair impoundment above Glennies Creek Dam.

For the purposes of assessing proposed mining impact, the description of the Glennies Creek study area is confined to the lower section of Glennies Creek from the New England Highway Bridge to the confluence with the Hunter River (see Sections 1.2 and 1.3 above plus HCMT (2003) for more detail of the overall Glennies Creek catchment). Within the defined study area, Glennies Creek comprises a more or less single continuous pool from the New England Highway to the Hunter River with a series of shallow constrictions and riffle/shoals spaced more or less evenly along the length of the creek:

- Figure 4 shows a rock confined pool on Glennies Creek upstream of (and under) the New England Highway.
- Figure 5 shows the cobble riffle at the lower end of this pool. Figure 5 also shows upended River She-Oaks (*Casuarina cumminghamia*) that were established on the cobble riffle banks prior to the major flood event in June 2007.

The creekbed meanders through the site bordered by floodplains of varying heights. Instream banks are commonly near vertical at the pool edges and undercut in parts. Most of the study area supports relatively steep (45°) riparian banks angled up to the perched floodplain reaching heights of 10m above the creekbed in parts.

Channel substrates consist of gravel and cobble beds with some sandbanks in areas of lower flow, and very few accumulations of finer material have been observed during field inspections or aquatic ecology sampling. Bank instability has been noted in the creek channel areas where exposed cobble banks have been opportunistically colonised by River She-Oak and Willow (*Salix babylonica*), shrubs and introduced weeds.

Figure 4
Glennies Creek Upstream of New England Highway

Figure 5
Glennies Creek Immediately Downstream of New England Highway

The western bank sub-catchments discharging to Glennies Creek are very small due to a ridgeline running north to south within close proximity to the creek, and there are no defined drainage channels within the western bank sub-catchments. The Glennies Creek eastern bank confluences and tributary drainages are discussed below in Section 3.3.1.

3.2.2 Glennies Creek flow and water quality

Glennies Creek flow and water quality data are available from three sources; NSW Department of Waters and Energy (DWE) flow and water quality gauges, ACOL monthly water quality monitoring data and MPR water quality sampling results obtained during aquatic ecology field surveys.

There are three DWE continuous flow and water quality gauges established on Glennies Creek and the data are available as daily means via the DWE)web-site. Data have been obtained and graphed for the period 1 January 2006 to 13 October 2008 from the Middle Falbrook Site (Gauge 210044, located about 9km upstream of the study site - see Figure 2). The graphed results are shown in Figures 6 and 7 below.

ACOL have been monitoring a network of water quality monitoring stations on Glennies and Bowmans Creeks plus on the Hunter River upstream and downstream of the two creek confluences since 2004. In terms of Glennies Creek inputs and outputs, the following monitoring sites are relevant:

- A water quality monitoring site above New England Highway (SM7 above all potential Ashton mining activities.
- Two sites in Glennies Creek below the New England Highway (SM8 and SM9).
- Two sites in the Hunter River, SM14 upstream and SM12 downstream of the Glennies Creek confluence.

Full results of the ACOL water quality monitoring are provided in ACOL Annual Environmental Monitoring Reports (AEMR) and WorleyParsons (2009) provides detailed analysis of the ACOL monthly water quality results over all Glennies Creek and Hunter River monitoring sites in the Surface Water Management Report (SWMR). WorleyParsons (2009) also noted that the dam has a significant impact on the natural flow regime of Glennies Creek through moderating flood events and releasing stored water during dry periods to maintain base flows.

MPR has undertaken field water quality surveys during the seasonal aquatic ecology surveys on Glennies Creek; in autumn and spring 2007 plus autumn and spring 2008. Results of these surveys are shown in Appendix Table A1, which also provides summary statistics for the data. Field sampling sites are shown in Figure 3 above.

The combined flow and water quality results, as they relate to the understanding of the aquatic ecology of Glennies Creek may be summarised as follows:

- There were drought conditions from the beginning of the monitoring period in January 2006 up to the major storm and flood event in early June 2007 with a peak mean flow of some 17500 ML/day. Over that period the combined baseflow and environmental flow provided from Glennies Creek Dam varied between 2 to 260 ML/day mean flow.
- Following the June 2007 flood and through to October 2008 there were 9 large flow events spread more of less evenly over the period, with peak mean flows between 1500 and 13,000 ML/day. The September 2008 event was the largest since the June 2007 flood.
- Over the drought period preceding the June 2007 flood, water conductivity varied between 300 and 400 μS/cm with some short-term spikes up to 680 μS/cm. ACOL monthly water quality monitoring recorded similar mean values for Glennies Creek sites, which ranged between 393 μS/cm and 396 μS/cm since 2004.
- Over the post 2007 flood period conductivity has been elevated and highly variable ranging between 400 and 900 μS/cm with spikes of low conductivity coinciding with the major storm events.
- Mean conductivity results for the ACOL monitoring sites in the Hunter River upstream from the Glennies Creek confluence have been higher than that encountered in Glennies Creek, ranging from 753 μS/cm at SM9 (upstream from Bowmans Creek confluence) to 853 μS/cm at SM14.
- Daily water temperature, recorded at the Middle Falbrook gauge varied seasonally with minimum winter temperature around 8°C and maximum summer temperatures around 26°C during the two drought summers and up to 29°C in February 2008.
- Dissolved oxygen, measured during the aquatic ecology surveys has been generally good and ranged between 55.2% saturation recorded in autumn 2007 to 91.0% sat in autumn 2008, with an overall mean value (± standard error) of 74.1 ± 2.8% sat.
- Water pH values in Glennies Creek are slightly alkaline. Mean values for the ACOL monitoring sites range between 7.8 and 7.9 pH units over the period since 2004. Over the four aquatic ecology surveys since 2006 MPR has recorded pH values ranging between 7.52 pH units in June 2007 and 9.32 pH units in May 2008.
- Water clarity during the seasonal monitoring surveys has generally been good, with mean values ranging between 10.7 ± 1.4 NTU in autumn 2008 and 25.3 ± 3.8 NTU in spring 2008. During the spring 2007 survey water turbidity was higher, reaching 255.4 NTU, with a survey mean of 150 ± 27.8 NTU.

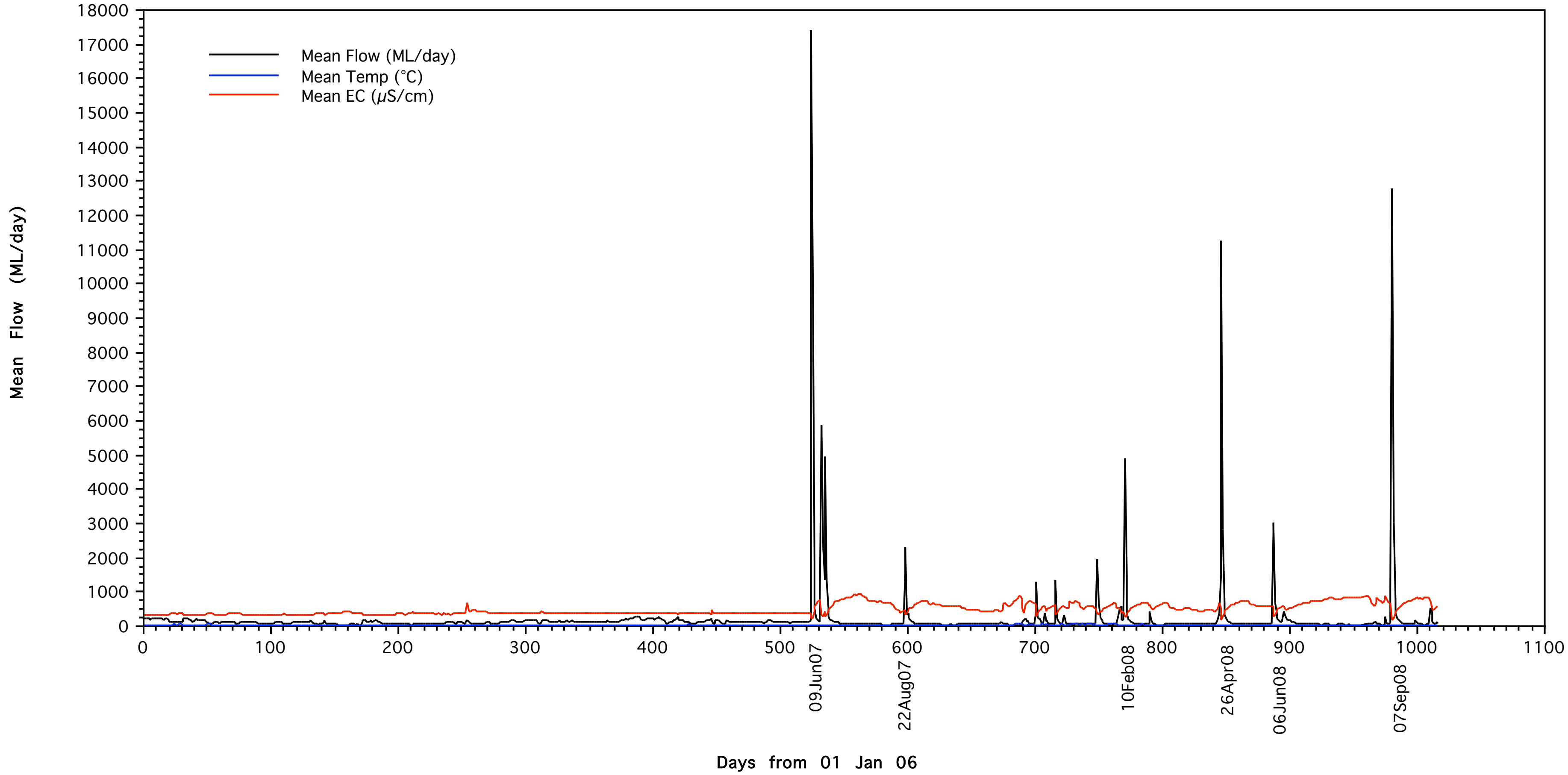

Figure 6
Mean Daily Flow, Water Temperature and Conductivity from 1 January 2006 to Mid October 2008
(with expanded scale to indicate occurrences and magnitude of major flood events)

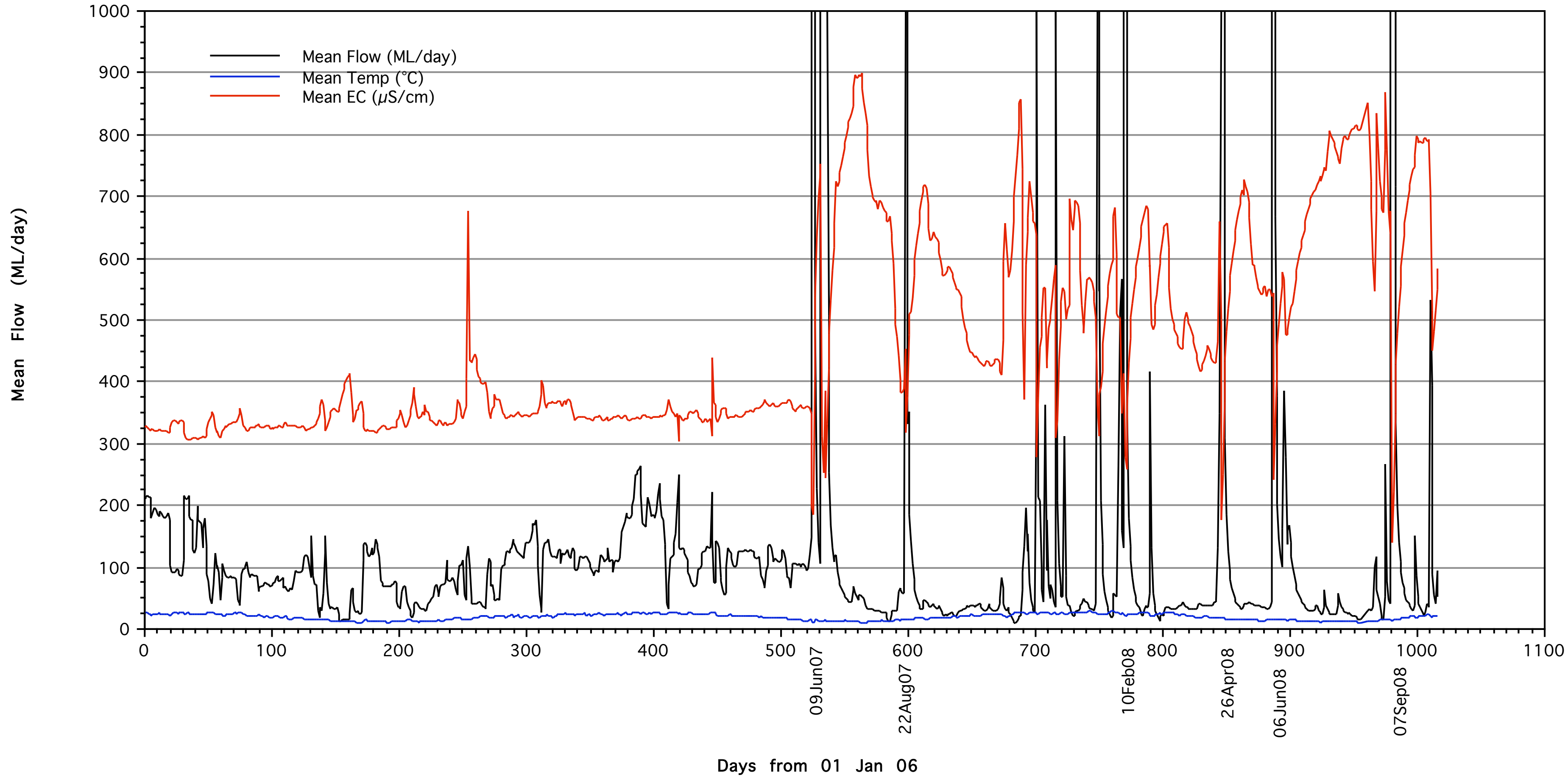

Figure 7
Mean Daily Flow, Water Temperature and Conductivity(EC) from 1 January 2006 to Mid October 2008
(with reduced scale to show low flows and changes in temperature and conductivity)

3.2.3 Glennies Creek study site aquatic habitats

Glennies Creek comprises sections of deep, broad flat-bottomed pools separated by narrower meandering channels that support riffle zones during low flow conditions. Creek flows have been continuous throughout the study area on all survey occasions, enabling fish passage from the Hunter River to upstream locations in Glennies Creek. Seasonal average site pool depths range between 1 to 1.5m, with maximum pool depths ranging between 1.5 and 2m. Maximum creek widths in site reaches vary between 15m and 25m, with the shallower riffle sections commonly spanning 5m or less.

Edge habitats sampled for the seasonal surveys include macrophyte beds, stream detritus, logs, trailing bank roots and vegetation. The main aquatic plant communities present in the study area include the emergent cumbungi (*Typha spp*), common reed (*Phragmites australis*) plus submerged beds of clasped pondweed (*Potamogeton perfoliatus*), *Myriophyllum sp*, and the introduced *Elodea*.

The creekline riparian native vegetation is dominated by narrow (and sometimes fragmented) corridors of River She-Oak woodland mixed with the introduced Willow, with a suite of introduced shrubs and grasses. Both tree species provide cover over the creek waterbody, stability to the banks and contribute to the woody debris and detritus input to the creek. Larger logs and tree trunks are also used for shelter and foraging by fish species.

Sections of Glennies Creek riparian were destroyed following the June 2007 floods especially within the areas of unconsolidated gravel beds in the creek channels that are colonised by both tree species. Channel substrates consist mainly of cobble and gravel beds interspersed by sandy shoals in sections of lower flow. Large boulder outcrops from the channel banks were mainly confined to the upper half of the study area (GCUp to GCMid), and were relatively infrequent.

Full results of Glennies Creek site RCE analysis for December 2008 are contained in Appendix Table A2 and are summarised in Table 1 below. Overall site scores were similar and the channel environments were in relatively good condition. Five categories scored lower over all sites; completeness of riparian vegetation, land use beyond riparian zone, stream bank structure, bank undercutting and retention devices instream.

The upper sites GCUp to GCMid scored slightly higher than the bottom two sites, owing mainly to higher scores in the category ‘completeness of riparian strip of woody vegetation’. Riparian woody vegetation is continuous throughout the site reaches, whereas in the lower sites (GCOCDown and GCDown) the riparian corridors are sparse and disconnected on the eastern banks.

Table 1 Glennies Creek Site RCE Scores		
Site	Score	%
GCUp	35	67
GCOCUp	34	65
GCMid	35	67
GCOCDown	33	63
GCDown	33	63

3.2.4 Macroinvertebrates and fish

The combined sampling data from the seasonal monitoring surveys for Glennies Creek are contained in Appendix Tables A3 and A4 and statistical summary results are presented in Tables 2 & 3 below:

- Appendix Table A3 provides a master list of all taxa found during all surveys undertaken for this project (i.e., for both Glennies Creek and for project sub-catchment sample sites.
- Appendix Table A4 provides the full macroinvertebrate taxa occurrence data for the seasonal Glennies Creek sites and provides the calculated site SIGNAL indices plus mean site occurrence data for each sample occasion.

A total of 18 edge-habitat sites have been sampled over 4 surveys between autumn 2007 and spring 2008. There have been 60 macroinvertebrate taxa (taken to AusRivAS/SIGNAL required family level) identified from Glennies Creek sites over the four seasonal monitoring surveys. The majority of the fauna were insects (44 taxa) and comprised the following groupings (at order level):

- 8 Coleoptera families (beetles),
- 10 Diptera families (midges, mosquitoes and flies),
- 3 Ephemeroptera families (mayflies),
- 7 Hemiptera families (true water bugs, water boatmen, backswimmers etc),
- 7 Odonata families (dragonflies and damselflies),
- 8 Trichoptera families (caddis flies),
- 1 Lepidoptera family (moths).

The remaining invertebrate taxa comprised crustaceans (5 taxa) and molluscs (5 taxa), with aquatic mites, flatworms, seed shrimps, freshwater worms, leeches and sponges all present as single taxa.

There were 6 taxa occurring at every site over all surveys; they were midge flies (sub-family Chironominae), mayflies (family Baetidae), water boatmen (family Corixidae), damselflies (family Coenagrionidae), caddis-flies (family Leptoceridae) and freshwater shrimp (family Atyidae). Three other taxa occurred frequently (>75% of sites); mayflies (family Caenidae), micro-caddis (family Hydroptilidae) and the introduced snail *Physa acuta* (family Physidae).

Table 2 Glennies Creek Seasonal Site Diversity							
Site Season	GC Up	GCOC Up	GC Mid	GCOC Down	GC Down	Mean	SE
Au07	26		17		14	19.0	3.61
Sp07	22	26	22	23	20	22.6	0.98
Au08	26	24	24	24	23	24.2	0.49
Sp08	21	20	21	22	20	20.8	0.37
Mean	23.8	23.3	21.0	23.0	19.3	-	-
SE	1.31	1.76	1.47	0.58	1.89	-	-

Individual site diversity ranged between 14 taxa at GCDown and 26 taxa at GCUp and GCOCUp. The mean number of taxa per site values (± standard error) show that the initial ‘post flood’ survey in autumn 2007 recorded the lowest diversity of taxa over all surveys (19.0 ± 3.6 taxa). Mean values increased over the next two surveys (spring 2007 and autumn 2008) before falling again during the spring 2008 survey (20.8 ± 0.37 taxa).

Despite the spring 2008 decrease in site diversity, it would appear that the variation in habitat availability between sites in Glennies Creek has reduced, as indicated by the reduction in standard error values over time. In addition to this the overall creek SIGNAL values (shown below in Table 3) indicate that the general creek condition has improved from ‘moderately impaired’ in both 2007 plus autumn 2008 surveys to ‘mildly impaired’ for spring 2008.

Table 3 Seasonal Site SIGNAL Values						
SIGNAL Season	GC Up	GCOC Up	GC Mid	GCOC Down	GC Down	Creek SIGNAL
Au07	4.71		4.63		4.50	4.63
Sp07	5.48	5.08	4.71	4.67	4.55	4.91
Au08	4.96	4.95	5.00	4.71	4.62	4.85
Sp08	5.30	4.95	5.20	4.95	4.65	5.01
Mean	5.11	4.99	4.88	4.78	4.58	-
SE	0.17	0.04	0.13	0.09	0.03	-

- The individual site SIGNAL values over all surveys ranged between 4.50 at GCDown in autumn 2007 and 5.48 at GCUp in spring 2007.

- In terms of individual taxa, there was a full spectrum of pollution sensitivity ratings ranging from 1 (very tolerant) to 10 (very sensitive).
- SIGNAL values indicate the majority of sites to be ‘moderately impaired’ with a few ‘mildly impaired’ sites. To place these results in perspective, Chessman (1997) had two reference sites in Glennies Creek located above the study area, which also returned ‘mild impairment’ SIGNAL values of 5.2 and 5.5 respectively from locations just below Glennies Creek dam and just above the dam on Carrow Brook.
- The autumn 2007 survey provided the lowest SIGNAL values for each site and for the combined creek SIGNAL score (4.63) to date.
- For each survey there was a general decrease in SIGNAL values from the upstream end of the study area to the downstream end, with GCDown recording the lowest value in each survey.

There have been at least four species of native fish and two introduced species recorded from Glennies Creek sites over the three surveys (Table 4):

Table 4 Seasonal Fish Occurrence

	No of surveys	N=18	N=3	N=5	N=5	N=5
Genus/spp	Common name	Total survey	Au07	Sp07	Au08	Sp08
Anguilla reinhardtii	Long-Finned Eel	2			1	1
Cyprinus carpio	Carp	4				4
Eleotridae	Gudgeon	9	1	5		3
Mugil cephalus	Mullet	3			2	1
Gambusia holbrooki	Eastern Gambusia	17	2	5	5	5
Retropinna semoni	Australian Smelt	10		5	1	4

- The introduced plague minnow *Gambusia holbrooki* has been the most commonly encountered species, occurring at every site except one (GCMid in post flood survey autumn 2007).
- The observed native fish include Australian smelt (*Retropinna semoni*), gudgeons (*Philypnodon sp*), bully mullet (*Mugil cephalus*) and the long-finned eel (*Anguilla reinhardtii*).

- An unconfirmed fish sighting was made at GCOCDown in autumn 2008. The species was most likely a long-finned eel or a native freshwater catfish, both expected species.
- The introduced pest species carp *Cyprinus carpio* was not observed during the initial three seasonal surveys but was observed in Glennies Creek during the October 2008 field investigations and at four sites in the spring 2008 survey.

The presence of carp within Glennies Creek is known to be more widespread than indicated by these results, and the lack of observations during the three seasonal surveys could be attributed to the fact that the surveys were conducted during, or following relatively high flow events where observations were limited due to depth, low water clarity and high flows.

3.2.5 Glennies Creek aquatic mammals and reptiles

During the October 2008 field investigations both native water rat *Hydromys chrysogaster*, and platypus *Ornithorhynchus anatinus*, were observed in the long pool section adjoining the Glennies Creek GCOCUp site. There were also multiple observations of long necked turtles *Chelodina longicollis* and eastern water dragon (*Physignathus lesueurii*). Water birds observed included water hens, black duck, wood duck and white-faced herons.

3.3 Study Site Tributary Aquatic Ecology

As described above and shown in Figure 3, there are five sub-catchments draining to Glennies Creek within the project area. Drainage morphology ranges from simple grassy swale drainage ditches to full chain-of-pond creek systems.

3.3.1 Geomorphology

The area within the SEOC proposal area has been extensively cleared for agriculture with the exception of the commons in T2, which consists of Central Hunter Ironbark-Spotted Gum-Grey Box Forest (ERM 2009). A larger area of regenerating Iron Bark dominated woodlands occupies the upper catchment slopes of T4 and T5 to the east of the SEOC project area (ERM 2009). Agricultural practises currently operating within the SEOC area include cattle grazing and crop cultivation, both of which utilise Glennies Creek and the numerous dams for irrigation and water supply.

The sub-catchment tributary drainages range from shallow grassed swales with no real channel structure to chain of ponds with semi-permanent to permanent aquatic habitat. The smallest tributary, T1 is the most northerly drainage and is around 250m in length. There is clearly no defined channel and, during field inspections, there was no surface water present within T1, nor any indication of aquatic habitat except immediately after rainfall. T1 watershed is located outside the northern boundary of the proposed SEOC footprint.

T2 sub-catchment drainage is approximately 800m in length and originates at the New England Highway, and flows in a westerly direction abutting the northern edge of the commons' woodland toward Glennies Creek. As with T1, there is no defined channel basin and the majority of the drainage length consists of a shallow, broad grassed swale. There are small sections of gully erosion on the upstream side of Glennies Rd consistent with that found in T3, T4 and T5, however no water was observed.

T3 sub-catchment tributary extends for approximately 1.8km from the New England Highway west to the alluvial floodplain of Glennies Creek before heading to in a south-westerly direction toward the confluence with Glennies Creek. The majority of the tributary channel consists of non-defined grassy swales intersected by stock watering dams, however a number of smaller depressions and erosion holes exist downstream from Glennies Rd to the alluvial floodplain which would offer some degree of refuge habitat for aquatic fauna for a period after rainfall (see Figure 8 below). The final 500m of T3 overlying Glennies Creek alluvial terraces consists of broad, deeply grassed channels with no indication of providing any form of sustained aquatic habitat. The channel area leading up to the confluence of T3 and Glennies Creek is non-distinct, and rises up to a bench at the Glennies Creek channel edge.

Sub-catchment tributary T4 is the longest drainage within the study area reaching 4km from the headwaters adjacent the New England Highway to Glennies Creek confluence, of which the upper 1.8km is located above the SEOC mine footprint boundary. The channel structure for much of the tributary is characterised by sections of stepped in-line ponds separated by grassed swales with no real stream structure at all (as seen in Figure 9 below). Gully erosion is prevalent throughout the cleared sections of T4, although there were some sections in the upper study area (around sample site P4) with rocky pools and riparian vegetation, which stabilise the banks and minimise the impacts of stock. The condition of the banks varied between being vegetated by grasses to bare clayey banks, and the substrates within sample sites were consistently soft and muddy.

Figure 8 T3 inline aquatic habitat

Figure 9 Channel structure in T4

The southern-most drainage system within the SEOC boundary is T5. From the headwaters T5 drains in a north-westerly direction for 1.9km before turning south and running almost parallel to Glennies Creek for 1km to the confluence. The channel structure within the SEOC area is similar to that found in the larger tributary T4 although there is a higher proportion of grassed swales to chain of ponds sections compared to T4. The upper 1km of T5 is situated above the limit of the SEOC boundary, and despite containing more widespread catchment and riparian vegetation, offers little in the way of aquatic habitat except for dams.

There are numerous in-line dams throughout the study area, on T3 and T5 within the mining lease area, and on T4 above the lease area, adjacent the New England Highway.

3.3.2 Sub-catchment site flow and water quality

As noted in Section 3.2.2 there have been nine major Glennies Creek flow events coinciding with major storm and rainfall activity in the region over the period July 2007 to September 2008, with the largest runoff event being the September 2008 event (see Figure 6):

- From photographic records (Wendy Bowman pers. comm., October 2008), it would appear that most of the Glennies Creek flood-plain was inundated during the July 2007 flood, with the riparian confluences of the major sub-catchment creeks drowned out, providing a fish passage link between Glennies Creek and the sub-catchment creeks.
- For both the July and October 2008 field inspections there was abundant water for the support of aquatic biota throughout the SEOC sub-catchments T1 to T5. Although there was no obvious surface flow at any of the sites sampled, water levels in dams, in-line ponds and shallow soaks were generally close to brim-full.

Appendix Tables A5.1 and A5.2 show the field water quality data collected during the three sampling periods (July, October and December 2008), and Figure 3 shows the locations of water quality sites:

- Appendix Table A5.1 shows the complete field water quality results for all sites including depth profile readings.
- Appendix Table A5.2 provides a comparison the results for the site surface water quality readings.

For the July sampling the pH probe was defective and accordingly there are no pH data. Results for the surface water quality recorded from the sub-catchment tributary creeks, including in-line dams may be summarised as follows:

- Temperature of surface waters ranged between 11.0°C and 14.8°C in July 2008 and 16.9°C and 29.2°C in October 2008.
- Conductivity was generally low for sub-catchment tributary drainages, ranging between 70μS/cm and 250μS/cm for the majority of sites. At sample site P5 conductivity was higher reaching 589μS/cm, and although conductivity of surface water at T4.6 was within the range of other T4 sub-catchment pools at 172μS/cm, the conductivity of the pools' deeper water was higher at 334μS/cm.
- Dissolved oxygen (DO) values were generally moderate to high for all T3 and T4 samples recorded in July 2008, and ranged between 52.5% saturation and 89.1% sat. Similarly, DO values for T3 and T5.1 dam sites in October were also high, ranging between 84.5% sat and 91.5% sat. All October dissolved oxygen readings from in-line ponds in T4 and T5 (with the exception of site T5.3, located immediately above Dam10) were very low to low, ranging from 5.6% sat to 36.5% sat.
- Water pH values within all sub-catchment tributary pools were slightly acidic ranging between 6.54 pH units to 6.98 pH units. Values within the sub-catchment tributary in-line dams were slightly higher, ranging from 7.30 pH units to 7.71 pH units.
- Water turbidity was slight to moderate at most sites in all three tributaries, ranging from 17.8 NTU to 98.9 NTU, and high at five sites in T4 and T5, ranging from 187.5 NTU to 600.0 NTU.

Results for the surface water quality comparisons from the sub-catchment off-line dams may be summarised as follows:

- Temperatures were lower for the mid October survey ranging between 18.6°C and 22.9°C when compared to the late October and December surveys (29.7°C to 32.4°C).
- Conductivity was generally low ranging between 92μS/cm and 175μS/cm, except for Dam1, which was slightly higher at 300μS/cm.
- Dissolved oxygen values varied between 35.4% sat and 132.8% sat, with an overall mean of 71.0 ± 14.9% sat.
- With the exception of Dam9 and Dam12, pH values at all off-line dam sites were around neutral, ranging between 6.86 pH units and

7.44 pH units. Dam9 and Dam12 waters were alkaline (9.09 pH units and 9.19 pH units respectively).

- Water turbidity at off-line dam sites varied from clear water (3.7 NTU at Dam12) to turbid (386.6 NTU at Dam11).

3.3.3 Sub-catchment sites aquatic habitats

Two sub-catchment pool sites (on P4 and P5) plus six dam sites (from T3, T4 and T5 catchments) were sampled for aquatic biota during the sub-catchment assessment, undertaken between October and December 2008 (see site locations on Figure 3). Appendix Table A2 provides site RCE results and Appendix Table A6 provides site field notes.

For the tributary sites (P4 and P5) pool dimensions were similar, ranging between 15 and 25m length, 4-5m maximum width and around 1.5m maximum depth. Table 5 shows that relative dam sizes varied from small (15 to 20m long and wide, with depths of 1.2 to 2m) to large (50 to 60m long and 45 to 75m wide, from 2.5 to 5m depth) sizes.

Table 5 SEOC Sub-catchment Dam Dimensions

	Dam1	Dam6	Dam7	Dam8	T3Dam	Dam12
Length (m)	15	20	20	20	60	50
Width (m)	15	15	20	15	45	75
Depth (m)	1.2	1.5	2	1.2	2.5	~3-5

Tributary pool and dam site edge habitats sampled were similar, with macrophyte beds, stream detritus, logs and trailing bank vegetation. Aquatic plants were present at most sample sites. The most commonly encountered submerged and emergent macrophytes were floating and blunt pondweed, with swamp lily, cumbungi, and emergent sedges (*Eleocharis spp*). Other water plants also present but in smaller amounts were water primrose, rushes (*Schoenoplectus mucronatus*) and water nymph (*Najas tenuifolia*). Around the perimeter of some dams there were submerged areas of the emergent grass (*Paspalum sp*.).

Tributary channel and dam substrates were similar, mostly clayey sediments with some sand deposits. At all sites, and most sections of tributary that had incised channels, gully erosion was prevalent. Cattle stock has access to tributary pools over the majority of the SEOC drainage area. Tributary site P4 was the only site that contained natural rock-bars, and rocky outcrops within the channel or aquatic habitats. Within the SEOC area the tributary riparian vegetation is very poor. For the majority of the channel lengths of the major tributaries (T3, T4 and T5) there is no riparian woody vegetation, with banks being held together by sparse pasture species. Sites P4 and T3Dam do have limited amounts of riparian woodlands although the corridors are fragmented.

RCE scores (Table 6) were generally low due to low scores in the following categories; width and completeness of riparian vegetation, vegetation within the riparian zone, riffle/ pool sequence, stream detritus and aquatic vegetation. Site P4 recorded the highest RCE score due to the presence of riparian vegetation and more complex channel structure.

Table 6 Tributary Site RCE Scores		
P4	32	62
P5	24	46
T3dam	25	48
Dam1	24	46
Dam7	22	42
Dam8	23	44
Dam6	23	44
Dam12	21	40

3.3.4 Macroinvertebrates, fish and other aquatic biota

A total of 8 sub-catchment sites were sampled during the spring 2008 AusRivAS sample season (see Figure 3 for site locations). The sampling data from the survey of the sub-catchment tributary sites are contained in Appendix Tables A3 and A7 and statistical summary results are presented in Table 7 below:

- Appendix Table A3 provides a master list of all taxa found during all surveys undertaken for this project (i.e., for both Glennies Creek and for project sub-catchment sample sites.
- Appendix Table A7 provides the full macroinvertebrate taxa and fish occurrence data for the sub-catchment tributary sites and provides the calculated site SIGNAL indices plus mean site occurrence data.

A total of 45 macroinvertebrate taxa were identified from the eight sites sampled. The macroinvertebrate fauna was made up primarily of insect taxa (29 taxa), followed by molluscs (7 taxa) and crustaceans (5 taxa), with water mites, seed shrimps, leeches and freshwater worms making up the remainder (one taxa).

The most commonly occurring organisms were; water mites (sub-order Acarina), diving beetles (family Dytiscidae), midge flies (sub-family Chironominae), water boatmen (family Corixidae), backswimmers (family Notonectidae), damselflies (family Coenagrionidae) and caddis-flies (family Leptoceridae).

Seven other taxa occurred frequently (>75% of sites); mayflies (family Baetidae), dragonflies (families Aeshnidae and Libellulidae), damselflies (family Lestidae), water fleas (sub-order Cladocera), seed shrimps (class Ostracoda) and copepods (family Cyclopidae). The cultivated native yabby (*Cherax destructor*) was present in the Dam 1 site.

Table 7 Sub-catchment Sample Site Macroinvertebrate Diversity & SIGNAL Scores

Site	P4	P5	T3 dam	Dam 1	Dam 6	Dam 7	Dam 8	Dam 12	Mean	SE
Taxa diversity	23	20	18	19	19	22	21	21	20.4	0.6
SIGNAL	4.63	4.71	4.13	4.06	4.19	4.47	4.11	3.81	4.26	0.11

Individual site diversity ranged between 18 and 23 taxa, and the mean number of taxa per site was 20.4 ± 0.6 taxa. Site SIGNAL values ranged between 3.81 at Dam12 and 4.71 at P5 with a mean SIGNAL score of 4.26 ± 0.1. These ratings indicate Dam12 to be ‘severely impaired’ with the remaining sites ‘moderately impaired’.

Fish were caught from one site only during the sub-catchment tributary field investigations. The introduced pest species plague minnow was present at T3Dam. Whilst the landowner of Dam 12 stated that the dam contained golden perch (*Macquaria ambigua*) from stocking with around 200 fish five years ago, no golden perch were observed during sampling. Long necked turtles were present at four locations within the study area and one location upstream of the EL boundary on T4. The eastern water dragon was also observed at an in-line dam located 50m upstream of P5 sample site. Numerous green reed frogs *Litoria fallax* (see front cover) were observed on cumbungi leaves in P5. White faced herons, spur-whinged plovers, wood ducks and black ducks, and swamp hens were also observed on or around dams.

3.4 Summary of SEOC Site Aquatic Ecology

3.4.1 Aquatic habitats

By virtue of the present function of Glennies Creek, namely to provide environmental and compensatory base-flow to the Hunter River from the Glennies Creek dam storage at Lake St Claire, Glennies Creek can be classed as a perennial creek with a mixed seasonal plus a downstream demand component for determining daily flows at any one time. Based on the analysis of the 2006 to 2008 gauge data for Middle Falbrook gauging site, which straddled the end of a prolonged drought period (in June 2007) followed by a relatively wet period (to

September 2008), the drought baseflow component is generally higher than the non-flood base-flow during the wet period.

Glennies Creek is deeply incised into its channel throughout the study area and consequently the banks are generally steep and in some cases unstable. Other than at the New England Highway road bridge there are minimal rocky outcrops instream, with the channel comprising several long pools more or less permanently connected with their downstream ends defined by shallow but mostly submerged drift sediment and cobble banks which partially obstruct the channel and comprises areas of cobbles with some drift sediment banks. Large woody debris occurs in the creek and is generally swept against the banks. There were no rock-bar limited pools found in the creek over the 1.5 year study period.

There are five sub-catchment drainages to Glennies Creek from the project area. The two upper sub-catchments T1 and T2 are very small and drain from the New England Highway through the town common and through the rural sub-division portion of the study site generally via grassy swales. The connections to Glennies Creek are deeply incised and eroded into the Glennies Creek bank and are partially filled with waste metal and rock rubble. These sub-catchment drainages do not provide any significant aquatic habitat.

Sub-catchment T3 is longer with a slightly larger catchment. It also drains via the Town Common then through cleared agricultural lands, before meandering across the Glennies creek flood plain. Its confluence is also deeply incised and eroded into the Glennies Creek bank. There are a number of in-line plus feeder dams on this tributary, including the large dam in the town common. Between dams, the creek is generally confined to grassy swales and the swales in the flood plain are often boggy after rainfall. There are no significant aquatic habitats within the creek line other than the inline and feeder dams.

Sub-catchment T4 is the largest sub-catchment and has the longest creek line. The creek has its origins well to the east of the Ashton SEOC project area and flows through alternate lightly wooded areas plus cleared farmlands. The creek has a more or less well defined structure with narrow V shaped channels in the upper wooded section plus a broad and highly meandering chain of ponds flood plain for much of its length. There are both in-line and feeder drainage dams all along the length of the creek. The creek itself has many sections of shallow clay-incised ponds alternating with grassy/boggy riffle sections plus narrow and deep rock or tree root confined pools. The creek flows through agricultural lands under cultivation in the Glennies Creek floodplain before plunging to Glennies creek via a deeply incised and eroded channel in the Glennies Creek riparian bank.

Sub-catchment T5 is the second largest sub-catchment within the Ashton SEOC project area. It has similar characteristics to T4 sub-catchment drainage but with overall less frequent pool/pond structure and more grassy swale connection between ponds. There are two large dams where the tributary drains to the Glennies creek floodplain, one in-line and the other on a major feeder line to the tributary. The feeder dam was brimful at the time of sampling but the in-line dam held considerably less water due to an old breach in the dam wall.

3.4.2 Macroinvertebrate Fauna

For the study period from autumn 2007 to summer 2008, a total of 70 macroinvertebrate taxa were identified, 60 from Glennies Creek and 45 from sub-catchment tributary aquatic ecology sample sites. Whilst the macroinvertebrate diversity was higher for Glennies Creek sites (mean 21.9 ± 0.7 taxa per site), the sub-catchment sites (sampled once in October 2008) compared favourably, with a mean of 20.4 ± 0.6 taxa per site.

There were 22 taxa found in Glennies Creek sites that were not recorded in the sub-catchment sites, 18 of which were insect taxa. There were 10 taxa specific to sub-catchment sites. That is, 36 taxa were found in both creek and sub-catchment sites. A number of the more sensitive macroinvertebrate groups such as caddis-flies were better represented in Glennies Creek sites (8 taxa) with only 3 taxa found in the sub-catchment sites. However, some taxa that are key indicators of longer-lasting (i.e., drought resistant) sites were found in sub-catchment sites (e.g., freshwater shrimp at P5 and Dam7, freshwater limpets at P4, P5 and Dam7).

Comparison of site SIGNAL indices indicated that Glennies Creek macroinvertebrate assemblages included slightly more pollution-sensitive animals, with more tolerant taxa occurring in the sub-catchment sites. Despite this difference, both creek and sub-catchment sites supported a range of pollution tolerant taxa, ranging from most-sensitive rating 10 (mayfly family Leptophlebiidae at sites P4, P5) to least-sensitive rating (snail family Physidae, T3Dam).

3.4.3 Fish, threatened species and other fauna

Based on the combined sampling from Glennies Creek plus the more intensive sampling on the adjacent Bowmans Creek, particularly during the drought prior to the June 2007 floods, there have been 16 fish species recorded from the combined Glennies and Bowmans Creek lower catchments, three of which are introduced species (see Table 8 below).

HCMT (2003) listed three other expected fish species for Glennies Creek below the dam, none of which have been recorded from either Glennies or Bowmans Creek to date; freshwater herring, common jollytail and freshwater mullet. HCMT (2003) also summarise recent fingerling releases into Lake St Claire from 1997 to 2002. Over that period Australian bass, golden perch and silver perch fingerlings have been released with 24,500 Australian bass and 80,000 silver perch released during the period 2001-2002.

Table 8 Fish Species Recorded from Glennies and Bowmans Creeks

Family	Species	Common name/s	Life cycle*	Recorded **	Native/ Introduced
Anguillidae	*Anguilla australis*	Short-finned Eel	C	B,G2	N
Anguillidae	*Anguilla reinhardtii*	Long-finned Eel	C	B,G2	N
Atherinidae	*Craterocephalus amniculus*	Darling Hardyhead	U	B	N (species of concern)
Cyprinidae	*Cyprinus carpio*	Common Carp	L	B,G	I
Cyprinidae	*Carassius auratus*	Goldfish	L	G2	I
Eleotridae	*Gobiomorphus australis*	Striped Gudgeon	A	B,G2	N
Eleotridae	*Gobiomorphus coxii*	Cox's Gudgeon	P	B,G2	N
Eleotridae	*Hypseleotris compressa*	Empire Gudgeon	U	B	N
Eleotridae	*Philypnodon grandiceps*	Flathead Gudgeon	U	B,G2	N
Eleotridae	*Philypnodon macrostomus*	Dwarf Flathead Gudgeon	U	B	N
Mugilidae	*Mugil cephalus*	Sea Mullet	A	B,G	N
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	C	B,G1,G2	N stocked
Plotosidae	*Tandanus tandanus*	Freshwater Catfish	L	B,G2	N (species of concern)
Poeciliidae	*Gambusia holbrooki*	Plague Minnow	L	B,G	I
Retropinnidae	*Retropinna semoni*	Australian Smelt	P	B,G1.G2	N
Scorpaenidae	*Notesthes robusta*	Bullrout	U	G2	N

Key:

Amphidromous (fish that migrate between the estuary and the sea, but not for breeding purposes).

Catadromous (fish that spend most of their lives in freshwater but migrate to the sea to breed).

Potadromous (fish that migrate wholly within freshwater).

Local (species that require fish passage only in their immediate environment).

U- Unknown

Note *: Life cycle characteristics referenced from Thorncraft & Harris 2000.

** Based on present studies and HTMC(2003) DPI results Table 7

** B=Bowmans, G1 = Glennies (from this study), G2 = known from DPI, E= Expected (DPI)

Although Australian smelt are listed as potadromous, recent studies of populations in coastal drainages of south-eastern Australia showed that a majority of the fish analysed inhabited the sea or estuaries during early life stages (Crook *et al* 2008).

No species of fish or aquatic invertebrates, as currently listed under the NSW Fisheries Management Act 1994 (FMA), or under the Commonwealth Environment Protection & Biodiversity Conservation Act 1999 (EPBC Act), were recorded or are expected in any of the monitoring conducted to date, and no protected fish, as listed under the FMA, have been found or observed in either Bowmans or Glennies Creeks. Two species are listed as species of concern in Morris *et al* 2001; The Darling hardyhead and the Freshwater catfish.

- The Darling hardyhead (*Craterocephalus amniculus*) is listed due to its taxonomic uncertainty. The Darling hardyhead is endemic to streams in the upper Darling River system. Specimens tentatively identified as *Craterocephalus amniculus* were collected from upper Bowmans Creek in 1976 and 1980, though no further individuals have since been collected (cited in Morris *et al* 2001). This species has not been observed or caught in any of the surveys conducted on behalf of ACOL (from 2005 onwards) and was not caught during the TEL electro-fishing survey of Bowmans Creek in (2005-2006). It is not known from Glennies Creek.
- Morris *et al* 2001 note that whilst the freshwater catfish (*Tandanus tandanus*) is not currently listed as threatened in coastal NSW rivers, its distribution and abundance has been significantly reduced throughout the southern parts of its known range. Freshwater catfish are generally found close to sand or gravel bottoms in slow moving streams, lakes and ponds with fringing vegetation (Allen *et al* 2002), habitat features consistent with that encountered in Glennies Creek.

The Adams Emerald Dragonfly *Archaeophya adamsi* Fraser, 1959 (family Gomphomacromiidae) is listed as vulnerable under the FMA. It is the only NSW species of this genus and family, and the majority of its life-cycle is aquatic. The larvae of *A. adamsi* have an estimated aquatic life span of more than 7 years, which is the vast majority of its total life span. Low population sizes and a long larval period indicate an extremely low rate of natural recruitment and therefore slow recovery from population declines. Specimens of *A. adamsi* are extremely rare, having only been found in small streams, with occasional finds of single aquatic larvae or exuviae. Prior to 1998, only 5 adult specimens were known, indicating that this species has extremely low local population sizes.

A. adamsi has been collected from 4 localities in NSW: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford; Tunks Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains and Hungry Way Creek in Wollemi National Park. The species has not been found elsewhere in the Hawkesbury watershed or in the Sydney region, despite active collecting over the last 30 years. The most frequent habitat type identified for this species is small lowland feeder stream with clear and non-polluted running stream water and high riparian vegetation cover.

Chessman et al (1997) sampled macroinvertebrate fauna from 42 sites in the Hunter River catchment (with two sites in Glennies Creek) and recorded no Gomphomacromiidae. Surveys of Glennies Creek over four seasonal sampling events (MPR unpublished data) also found no Gomphomacromiidae, even though all surveys included specific searches for Gomphomacromiidae. Accordingly, the potential for finding *A. adamsi* in the northern streams feeding into the Hunter River is therefore considered remote. Nevertheless, owing to the poor level of knowledge of this species throughout the state plus the presence of numerous 'small feeder streams with clear running stream water and high riparian vegetation cover' the presence of this species in the region cannot be entirely discounted.

Whilst the presence of *A. adamsi* in sections of upper Glennies Creek feeder streams cannot be entirely discounted, its presence can be discounted from the discharges draining from the project area to Glennies Creek. These ephemeral drainages do not fit the description of 'small feeder streams', do not have 'dense riparian vegetation cover and do not have permanent pools (other than in-line farm dams). That is, it is considered that Adams Emerald Dragonfly would not occur in the project area stream sections or in Glennies Creek adjacent to the project area.

The introduced pest species, plague minnow (*Gambusia holbrooki*), has been the most commonly encountered fish during all aquatic ecology monitoring surveys. They have been recorded at all sampling events including the recent site walkovers in October 2008 and have been caught or observed at 17 of the 18 monitoring events in Glennies Creek between autumn 2007 and autumn 2008. Carp have also been observed in Glennies Creek with the exception of high flow periods encountered during autumn and spring 2007. Goldfish have not been captured or sighted during the studies for this project but are listed as present in the DPI Fisheries’ records (HMCT 2003).

With regard to other possible fauna associated with the Glennies Creek aquatic habitats, this study has recorded platypus, and native water rat from Glennies Creek within the study area, plus amphibians, reptiles (lizards, snakes and turtles) from both Glennies Creek and the sub-catchment aquatic habitats.

3.4.4 Fish passage considerations

With regard to fish passage, Glennies Creek in the study area provides a continuous passage for fish to move upstream from the Hunter River into the upper catchments of Glennies Creek. Furthermore, even though Glennies Creek has been impounded behind Glennies Creek Dam and there is no possibility of fish passage upstream past the dam, there are no artificial impediments to fish passage up the Goorangoola Creek sub-catchment of Glennies Creek (see Figure 2).

Regarding fish passage into the study area sub-catchment creeks, there are suitable long-term drought refuge ponds and dams in the T3, T4 and T5 sub-catchments. Even though the sub-catchment confluences with Glennies Creek are mostly steep and deeply incised into the Glennies Creek riparian slope, the observations and measurements of flood levels for the June 2007 floods (see WorleyParsons 2009) indicate that Glennies Creek does overbank and fill out its flood plain to the extent that fish passage can become possible, at least to sub-catchments T4, T5 and possibly to T3. That is, high flow events can facilitate the movement of fish from Glennies Creek upstream into the tributary sub-catchments once the Glennies Creek floodplain banks are drowned out.

The only available permanent aquatic habitat in sub-catchment tributary T5 above the mining area is in the form of a dam (Dam11). Fish passage between Dam11 and the next available permanent water downstream (T5.1 dam) is very poor, owing to the lack of incised channel area, sandy substrate and steepness of terrain in the vicinity of Dam11. With the exception of Dam11, field inspections in the upper parts of T5 (at the top of the mining area and upstream) revealed no aquatic refuge habitat, nor any indication that the drainage could retain water for any useful amount of time. Thus, it is considered that sub-catchment T5 does not provide suitable fish passage or any long-term fish habitat function.

In terms of fish passage potential in sub-catchment tributary T4, aquatic refuge is more widespread than in T5, both within, as well as upstream of, the mine area. Permanent and semi-permanent aquatic refuges exist in the form of dams and stepped in-line ponds, and the potential for fish to access these habitats during and for a period after significant rainfall cannot be discounted. That is, even though the only opportunities for fish to access the upper T4 sub-catchment is during high flow events, there is potential for the habitats to support fish. Thus, it is considered that sub-catchment T4 does provide suitable fish passage and long-term fish habitat function (except under prolonged drought conditions).

Although the only fish species that was recorded from sub-catchment drainages was the introduced pest species plague minnow (from one dam only on T3), there may well be native fish in the permanent tributary ponds, despite not being observed or caught during field sampling. Thus, for example, it is most likely that the native freshwater eel (*Anguilla reinhardtii*) occurs throughout the sub-catchment tributaries.

With regard to deliberate stocking, golden perch (*Macquaria ambigua*) have reputedly been stocked into dam 12 although no individuals were caught or observed during the process of sampling.

3.4.5 Groundwater dependent ecosystems (GDEs)

Both the Groundwater Report (Aquaterra 2009) and this aquatic report considered the occurrence of GDEs in the study area. Potential GDEs were identified using the eight-step rapid assessment (DLWC 2002), and it was concluded that there are no known or likely wetland, terrestrial or aquifer/cave ecosystem GDEs in the study area. Whilst there were several flushes of green observed in drainage channels leading to dams, inspection of these indicated that the flush of new grass growth could be attributed to shallow sub-surface water flow associated with recent rainfall. Assessment of Glennies Creek plus tributary creek riparian vegetation did not indicate any specific riparian plant communities, which could be considered groundwater dependent.

With regard to the degree of dependency of possible aquatic or hyporheic GDEs to baseflow in the Glennies Creek study area the following factors are relevant:

- Glennies Creek is perennial with sub-surface creek sediment saturation controlled for the majority of the time by surface water rather than upwelling groundwater.
- Due to there being surface flow most of the time, riparian and edge emergent vegetation plus riffle zone fauna are more dependent on fluctuating surface water levels than on groundwater upwelling, and there is insufficient groundwater upwelling to make any significant impact on surface water levels except under prolonged drought periods.
- Owing to the controlled release nature of the water passing through Glennies Creek at the study site, there is generally sufficient surface water during prolonged drought conditions such that the baseflow cannot become significant.

It is concluded that possible aquatic and hyporheic GDEs in Glennies Creek within the study area would not be considered significantly dependent on baseflow groundwater.

3.4.6 Creek and tributary stream classifications

The results of the combined aquatic ecology literature review, field studies and surface water plus groundwater study results were used to classify the SEOC sub-catchment drainages and the receiving waters (Glennies Creek) against the NSW DPI Fisheries' stream classification scheme (NSW Fisheries 1999b, as summarised in Table 9 below). Findings are summarised as follows;

- Glennies Creek within the study area provides valuable fish habitat and supports permanent flow throughout its length. A number of native fish species are known to inhabit the area, and platypus reside within the study area. Aquatic vegetation is present throughout the creek length. There are no site significant impediments to fish or platypus migration through the study area. Therefore, Glennies Creek within the study area must be considered a Class 2 stream under the NSW Fisheries' classification scheme.
- The SEOC sub-catchment tributaries T1 and T2 are classified as Class 4 drainages. They are generally dry gullies, grassy pasture depressions or shallow floodplain depressions with no permanent wetland aquatic flora present. They have intermittent flow during rain events only and most have little or no defined drainage channels. There is little or no free-standing water or pools after rain events (other than in the in-line farm dams).
- Sub-catchment tributary T3 is considered a Class 3 drainage as it contains permanent aquatic habitats, aquatic vegetation, supports fish populations (albeit exotic species) and turtles. Whilst T3 has minimal defined channel areas, there is a series of ponds and dam habitats downstream of Glennies Rd that would become connected following rainfall.
- Both the sub-catchment tributaries T4 and T5 are considered to be Class 2/3 habitats as they do provide more or less permanent aquatic habitats and moderate drought refuge, are known to support frog and turtle populations and have the potential to support native fish. Both drainages contain alternating sections of clearly defined channels followed by sections with no defined channel areas at all. Aquatic vegetation is present in both of the tributaries.

Table 9: Fish Habitat Classification Scheme

Class 1 - Major fish habitat Large named permanently flowing stream, creek or river. Threatened species habitat or area of declared "critical habitat' under the threatened species provisions of the Act. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
Class 2 - Moderate fish habitat Smaller named permanent or intermittent stream, creek or watercourse. Clearly defined drainage channels with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
Class 3 - Minimal fish habitat Named or unnamed watercourse with intermittent flow, but has potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). None to minimal defined drainage channel. Semi- permanent pools, ponds, farm dams or wetlands nearby, or form in the watercourse after a rain event. Watercourse interconnects wetlands or stream habitat.
Class 4 - Unlikely fish habitat Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event finishes (e.g. dry gully, shallow floodplain depression with no permanent wetland aquatic flora present). No aquatic or wetland vegetation present.

Source: NSW Fisheries (1999b)

4 IMPACT ASSESSMENT

The proposed SEOC (see Figure 1) includes the construction, operation and rehabilitation of an open cut mine over a period of seven years. Potential impacts arising from the construction and operation of the SEOC that relate to aquatic ecology include;

- Loss of sub-catchment aquatic habitats,
- Changes to water quality and quantity relationships during and post mining within and between the sub-catchment aquatic habitats and to Glennies Creek,
- Lowering of the water table within Glennies Creek and its associated alluvium,
- Leakage of Glennies Creek water to the mine pit.

4.1 Relationship of SEOC to Sub-catchments

Detailed site plans for the SEOC stages over the seven-year mining period are presented in WorleyParsons (2009). The relationship between the sub-catchment tributary drainages and the mine progression are as follows;

- Sub-catchment tributary T1 is not directly affected by the proposal.
- The southern half of T2 will be lost to proposed open cut mining. The sub-catchment will also accommodate part of the environmental bund/ overburden emplacement, plus sediment water basins for runoff from rehabilitated land. This area will be the first to be rehabilitated as mining proceeds southwards.
- The majority of mining undertaken within T3 sub-catchment will be completed within a period of 1 to 3 years. The upper catchment adjacent the New England Highway will be lost to the environmental bund/ overburden emplacement, with a temporary mine water basin and site infrastructure located in the lower catchment. The rest of the drainage above Glennies Creek flood plain will be directly lost to the proposed open cut mine.
- The main site infrastructure works, site access road, overburden dump, clean water dam storage and sediment water basin will be located in the upper catchment of T4. The majority of the lower half of T4 drainage will be directly lost to mining. A temporary mine water holding dam will be located in the lower catchment near the western pit boundary adjacent Glennies Creek in year 3.

- The sub-catchment area of T5 will accommodate part of the site infrastructure, plus secondary clean water dam (to come online between year 3 and 5), and a temporary mine water holding dam around year 5. Most of the lower section of T5 drainage will be lost to mining in the second half of the mining period.

4.1.1 Direct impacts to tributary and Glennies Creek aquatic ecology

With respect to aquatic habitat in the defined project area, the main direct impact is the loss of drainage lines and farm dams to the various mining elements. Whilst much of the combined sub-catchment tributaries to be lost comprises creek sections with poor water retention capabilities and no or little aquatic habitats, sections of the larger tributaries T3 to T5 provide permanent refuges and habitat for aquatic macroinvertebrates, frogs and reptiles, birds, plant communities and possibly for native fish (see Section 3.4.4 above). These sections also support riparian and fringing terrestrial habitats that border the aquatic refuges, along with the associated animals such as insectivorous birds and bats.

On the downstream (western) side of the proposed pit/ infrastructure boundary overlying the flood plain alluvial terraces, none of the tributary drainage channels supported aquatic habitats, nor was there any indication that semi-permanent surface water would prevail for any extended periods after rainfall. Thus the impacts of losing the upstream feeder channels on the potential surface water aquatic habitat resources of this area are considered minor.

Although the contribution of tributary drainages to the alluvial terrace surface water storage is insignificant, the contribution to groundwater recharge within Glennies Creek alluvials is an important issue. As detailed in Aquaterra (2009), the maximum predicted drawdown of the groundwater within Glennies Creek alluvium during mining, is in the order of 1.5m, localised at the western margin of the SEOC. The majority of the alluvium is expected to experience draw-downs of 0.5m or less (Aquaterra 2009). From the aquatic ecological perspective, it is concluded that there are no significant surface water aquatic habitats or any aquatic GDEs supported by the alluvial groundwater, thus this impact is not considered to be of major concern.

The lowering of groundwater levels will result in a consequent reduction in baseflow contributing to Glennies Creek, however the proportionate amount of contributions is minor (0.03% of average base flow, or 0.33% of 5% percentile flow in this section of creek) which will cause the reach of Glennies Creek within the assessment area to change from a slightly gaining stream to a slightly loosing stream during mining operations (Aquaterra 2009).

Inflows of Glennies Creek alluvial flow to the mine pit is expected to commence in year 3 and reach a maximum of $24m^3/d$ by year 7 of the mine operation. Post mining, water levels within the alluvium are expected to return to pre-mining levels within 100 years. Some minor residual impacts (<1m drawdown) may remain within the Permian coal seams, but this is expected to have a negligible impact on surface water tables or river baseflows (Aquaterra 2009).

As shown in section 3.2.2, Glennies Creek within the study area is already subjected to variable flow rates due to a combination of natural factors such as catchment rainfall and evaporation, plus dam releases, irrigation and water consumption from agricultural and mining operations upstream areas. Accordingly the predicted losses from the alluvial aquifer and the effect of this on Glennies Creek stream flows, based on the findings presented in the Groundwater report (Aquaterra 2009), are considered to have minimal potential for impact on the aquatic ecology of Glennies Creek or downstream.

4.1.2 Indirect impacts to aquatic ecology

The main indirect impact on aquatic ecology arising from the proposal relates to the issue of surface water and groundwater quality and quantity for study area and downstream aquatic habitats during and post mining.

The Surface Water Management Report (WorleyParsons 2009) contains specific details about the collection, diversion, treatment and reuse of stormwater runoff from the project site and the sub-catchments above the project site in T4 and T5, plus the disposal of runoff to Glennies Creek. The initial phase of mine construction and operation includes the establishment of a clean water dam in above the mining boundary on T4, followed by the establishment of a second clean water dam located in the upper catchment of T5 between years 3 to 5. These dams provide two functions; intersecting the upper catchment runoff to prevent inflows to the SEOC mine, and providing a clean water contribution to Glennies Creek to compensate for loss of mining related sub-catchment input of surface water runoff and seepage.

With regard to potentially contaminated surface runoff or infiltrated water:

- Dirty water captured within the open cut will be contained and used within the mine for dust suppression within the SEOC or piped to other areas within the Ashton Coal Project (ACP) for use elsewhere.
- Sediment water basins will be created over the life of the mine to capture surface runoff from the rehabilitated overburden. These

storages will also serve as alternative sources of water for use within the ACP if the primary water source becomes depleted.

With regard to groundwater quantity and quality impacts during mining, Aquaterra (2009) notes that as groundwater flows will be towards the pit, no groundwater quality impacts are expected on aquifers outside of the pit shell during mining operations. Post-mining there is potential for some flow of water from the pit to Glennies Creek as the pit void and overburden become saturated. Aquaterra (2009) predicts that the water quality impacts arising from the mine to Glennies Creek alluvial aquifer and Glennies Creek post-mining would be negligible and that long-term recovery should take place within 100 years.

5 MITIGATION MEASURES

With regard to mitigation measures DEC/ DPI (2005) outlines a stepped process for achieving mitigation of impacts; firstly, avoiding the impact; this may mean making some changes to the proposed development. If avoidance is not possible, then some form of mitigation may be required. Finally, if neither avoidance nor mitigation is possible, then some form of offset or compensation will be required. This could entail the construction or rehabilitation of similar habitat nearby.

The main avoidance measure undertaken for the SEOC project was moving the western pit and infrastructure boundary back from Glennies Creek to avoid significant impacts on Glennies Creek alluvials and avoid potential impacts to the groundwater exchange (including potential loss of water from Glennies Creek to the mine).

Proposed mitigation for the loss of valuable sub-catchment aquatic habitat includes the construction of new sub-catchment drainages with aquatic habitat function within the overburden profile (see WorleyParsons 2009 for details) and the reconnection of the upstream T4 sub-catchment through to Glennies Creek via a constructed channel connection. The creation of drainage lines and of new dams would be integrated with site overburden rehabilitation plans and would incorporate appropriate design of bed control structures and of aquatic habitat attributes using rehabilitation guidelines as per (for example) Rutherford et al (2000).

Impact of cattle on the present tributary channels and aquatic habitats is evident in T3, T4 and T5, in the form of channel erosion from stock access routes, nutrient inputs from manure, water quality issues and trampling of edge macrophyte communities. Therefore, excluding cattle access to rehabilitated aquatic ecosystems is imperative for achieving desired aquatic and riparian ecological function. Accordingly, newly built in-line ponds desired aquatic and riparian ecological function. Accordingly, newly built in-line ponds and selected dams would be progressively 'value added' with aquatic habitat (fringing emergent and submerged macrophytes) established in the water-bodies plus riparian shade trees and shrubs planted around the perimeters to lower evaporation losses and provide valuable roosting plus foraging habitat for woodland and wading birds, and bats. Dams plus riparian wooded habitats would be fenced off from direct stock access, further enhancing aquatic and riparian habitat values. Stock watering could be achieved by gravity fed 'on demand' watering stations.

These areas of habitat diversity could provide key habitat for a diversity of species and would compliment long-term rehabilitation works proposed within the Glennies Creek riparian corridors, as described in ERM (2009) plus proposed rehabilitation works on the remaining property drainages. The drainage line and dam rehabilitation plans would need to be integrated with site overburden rehabilitation plans and the Glennies Creek riparian habitat rehabilitation plan (ERM 2009), to extend connective corridors between Glennies Creek and sub-catchment tributary riparian works.

With respect to dewatering areas of aquatic habitat it is recommended that, prior to de-watering of dams and in-stream ponds to be lost to mining, native fish species and turtles should be collected and translocated to Glennies Creek, or in the case of any golden perch that have been stocked in Dam12, to another suitable farm dam. Note that translocation operations would also need to be approved by DPI Fisheries, as under Part 7(7) of the FMA, live fish cannot be released into any waterway, including ponds, dams or drains, without authorisation from DPI (Fisheries).

6 SUMMARY

Whilst the construction, operation and rehabilitation activities for the proposed Ashton SEOC mine will not result in any significant impact on the aquatic ecological attributes in Glennies Creek or downstream of Glennies Creek and will not affect the valuable fish refuge and passage attributes of the creek, the mining works will result in the loss of some valuable sub-catchment in-stream aquatic habitat plus the disconnection of upstream drainage lines from the lower connections to Glennies Creek. This loss will be partially offset by the restoration of some sub-catchment aquatic stream habitat as part of the overburden rehabilitation program, which will also restore the main connections between upstream sub-catchments and Glennies Creek. Further mitigation measures include riparian and stream aquatic habitat restoration and rehabilitation works along Glennies Creek and within the Glennies Creek floodplain. Additional aquatic and riparian habitat enhancements will be achieved by excluding live-stock access from new or rehabilitated riparian corridors and dams and providing on-demand stock watering.

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APPENDIX A

FIELD AQUATIC ECOLOGY
AND
WATER QUALITY DATA

GLENNIES CREEK AND
SEOC SUB-CTATCHMENTS
2007 to 2009

Drought Refuge Pool P4 in Sub-catchment T4

Appendix Table A1

Field Water Quality Results and Statistics from Glennies Creek Seasonal Sampling

Site	Date	Time	Depth	Temp	Cond	Sal	DO	DO	pH	ORP	Turb
			M	C	μS/cm	ppt	%sat	mg/l	Units	mv	ntu
GCUp	26/06/07	15:32	0.2	13.31	715	0.39	59.1	6.2	7.56	295	22.9
GCMid	28/06/07	13:43	0.2	11.33	675	0.37	57.4	6.3	7.62	406	18.6
GCDown	27/06/07	14:54	0.2	12.28	686	0.38	55.2	5.9	7.52	295	20.5
GCUp	19/12/07	17:29	0.2	24.66	353	0.17	77.9	6.5	8.07		109.4
GCOCUp	20/12/07	09:17	0.2	23.14	359	0.17	66.0	5.6	9.25		101.6
GCMid	19/12/07	16:01	0.2	24.15	352	0.17	84.4	7.1	8.64		130.8
GCOCDown	19/12/07	10:44	0.2	22.34	279	0.13	80.6	7.0	8.04		255.4
GCDown	19/12/07	12:08	0.2	23.00	367	0.18	87.6	7.5	8.13		153.0
GCUp	13/05/08	11:06	0.2	15.14	681	0.32	83.8	8.4	9.32	298	8.3
GCOCUp	14/05/08	10:24	0.2	14.96	660	0.33	64.3	6.5	9.23	615	7.6
GCMid	14/05/08	12:05	0.2	15.20	666	0.32	90.3	9.1	9.28	297	9.7
GCOCDown	13/05/08	14:52	0.2	16.54	704	0.36	91.0	8.9	8.81	296	14.6
GCDown	13/05/08	13:01	0.2	15.40	651	0.32	85.4	8.5	9.22	297	13.2
GCUp	10/12/08	16:39	0.3	26.84	663	0.35	76.5	6.1	7.86	569	16.4
GCOCUp	10/12/08	13:46	0.5	26.39	535	0.28	76.3	6.1	7.87	466	18.6
GCMid	10/12/08	15:15	0.4	27.19	579	0.31	72.4	5.7	7.76	537	37.9
GCOCDown	10/12/08	10:33	0.5	25.25	585	0.31	67.3	5.5	7.75	589	25.3
GCDown	10/12/08	09:07	0.4	24.49	590	0.32	59.0	4.9	7.64	635	28.3
		AU07	Min	11.33	675	0.37	55.2	5.9	7.52	295	18.6
		AU07	Max	13.31	715	0.39	59.1	6.3	7.62	406	22.9
		AU07	Mean	12.31	692.0	0.38	57.2	6.1	7.57	332.0	20.7
		AU07	SE	0.57	11.9	0.01	1.1	0.1	0.03	37.0	1.2
		SP07	Min	22.34	279	0.13	66.0	5.6	8.04		101.6
		SP07	Max	24.66	367	0.18	87.6	7.5	9.25		255.4
		SP07	Mean	23.46	342.0	0.16	79.3	6.7	8.43		150.0
		SP07	SE	0.42	16.0	0.01	3.7	0.3	0.23		27.8
		AU08	Min	14.96	651	0.32	64.3	6.5	8.81	296	7.6
		AU08	Max	16.54	704	0.36	91.0	9.1	9.32	615	14.6
		AU08	Mean	15.45	672.4	0.33	83.0	8.3	9.17	360.6	10.7
		AU08	SE	0.28	9.3	0.01	4.9	0.5	0.09	63.6	1.4
		SP08	Min	24.49	535	0.28	59.0	4.9	7.64	466.00	16.4
		SP08	Max	27.19	663	0.35	76.5	6.1	7.87	635.00	37.9
		SP08	Mean	26.03	590.4	0.31	70.3	5.7	7.78	559.20	25.3
		SP08	SE	0.51	20.6	0.01	3.3	0.2	0.04	28.20	3.8
		All	Min	11.33	279	0.13	55.2	4.9	7.52	295	7.6
		All	Max	27.19	715	0.39	91.0	9.1	9.32	635	255.4
		All	Mean	20.09	561.1	0.29	74.1	6.8	8.31	430.38	55.1
		All	SE	1.32	35.0	0.02	2.8	0.3	0.16	39.34	16.0

Appendix Table A2 RCE Results for Glennies Creek and Project Area Sub-catchment Sampling Sites
Modified Riparian, Channel and Environment (RCE) Inventory (After Chessman et al 1997).

Descriptor			**Value**	**Site Number and Designation**												
		Category		1	2	3	4	5	6	7	8	9	10	11	12	13
				GC Up	GCOC Up	GC Mid	GCOC Down	GC Down	P4	P5	T3 dam	Dam 1	Dam 7	Dam 8	Dam 6	Dam 12
1	Land-use pattern beyond immediate riparian zone															
		Undisturbed native vegetation	4													
		Mixed native vegetation and pasture/ exotics	3			3			3							
		Mainly pasture, crops or pine plantation	2	2	2		2	2		2	2	2	2	2	2	2
		Urban, some vegetation	1													
		Industrial, little vegetation	0													
2	Width of riparian strip of woody vegetation															
		More than 30m	4													
		Between 5 and 30m	3	3	3	3	3	3	3		3					
		Less than 5m	2							2						
		No woody vegetation	1									1	1	1	1	1
		No vegetation	0													
3	Completeness of riparian strip of woody vegetation															
		Riparian strip without breaks in vegetation	4													
		Breaks at intervals of more than 50m	3													
		Breaks at intervals of 10-50m	2	2	2	2			2							
		Breaks at intervals of less than 10m	1				1	1		1	1					1
		No riparian strip at all	0									0	0	0	0	
4	Vegetation of riparian zone within 10m of channel															
		Native tree and shrub species	4													
		Mixed native and exotic trees and shrubs	3	3	3	3	3	3	3							
		Exotic trees and shrubs	2													
		Exotic grasses/ weeds	1							1	1	1	1	1	1	1
		No vegetation at all	0													
5	Stream bank structure															
		Banks fully stabilized by trees, shrubs, concrete	4													
		Banks firm but held mainly by grass and herbs	3								3	3		3	3	3
		Banks loose, partly held by sparse grass, rubble	2	2	2	2	2	2	2	2			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
		Only on curves or at restrictions	3								3	3		3	3	
		Frequent along all parts of stream	2	2	2	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						
		Medium; width:depth ratio 8:1 to 15:1	3	3	3	3	3	3			3	3	3	3	3	3
		Shallow; width:depth ratio greater than 15:1	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	4												
		Long pools with infrequent short riffles	3		3	3	3	3								
		Natural channel without riffle/ pool sequence	2						2	2						
		Artificial channel; some riffle/ pool sequence	1													
		Artificial channel; no riffle/ pool sequence	0								0	0	0	0	0	0
9	Retention devices in stream*															
		Many large boulders and/ or debris dams	4								4	4	4	4	4	4
		Rocks/ logs present; limited damming effect	3						3							
		Rocks/ logs present but unstable; no damming	2	2	2	2	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													
		Some gravel bars but little sand or silt	3	3	3	3	3	3								
		Bars of sand and silt common	2						2		2	2	2	2	2	
		Brainding by loose sediment	1							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	3	3								
		Bottom heavily silted but stable	2						2	2	2	2	2	2	2	
		Bottom mainly loose and mobile sandy sediment	1													
		Bottom mainly loose and mobile muddy sediment	0													0
12	Stream detritus															
		Mainly unsilted wood, bark, leaves	4													
		Some wood, leaves etc. with much fine detritus	3	3	3	3	3	3								
		Mainly fine detritus mixed with sediment	2							2		2	2			
		Little or no organic detritus, mainly sandy	1												1	
		No organic detritus, mainly mud	0						0		0			0		0
13	Aquatic vegetation															
		Little or no macrophyte or algal growth	4						4							
		Substantial algal growth; few macrophytes	3	3	3	3	3	3								
		Substantial macrophyte growth; little algal growth	2							2				2		
		Substantial macrophyte and algal growth	1								1	1	1		1	1
		Total cover of macrophytes plus algae	0													
		RCE Score		35	34	35	33	33	32	24	25	24	22	23	23	21
		RCE %age		67	65	67	63	63	62	46	48	46	42	44	44	40

Appendix Table A3

Master Table of Macroinvertebrate Fauna collected from Project Area

Phylum	Class	Order	Sub-Order	Family	Sub-Family	Genus/spp	Common Name / Description	Life Stage L	N	A	Glennies Creek	Tribs	SIGNAL Indices HU-97	SIG-2	Taxa No
Arthropoda	Insecta	Coleoptera		Dytiscidae			Diving Beetles	x		x	1	1	2	2	1
Arthropoda	Insecta	Coleoptera		Elmidae			Riffle Beetles	x		x	1		8	7	2
Arthropoda	Insecta	Coleoptera		Gyrinidae			Whirligig Beetles	x		x	1	1	5	4	3
Arthropoda	Insecta	Coleoptera		Haliplidae			Crawling Water Beetles	x		x	1		*	2	4
Arthropoda	Insecta	Coleoptera		Hydraenidae			Scavenger Water Beetles			x		1	5	3	5
Arthropoda	Insecta	Coleoptera		Hydrochidae						x	1		4	4	6
Arthropoda	Insecta	Coleoptera		Hydrophilidae				x		x	1	1	4	2	7
Arthropoda	Insecta	Coleoptera		Psephenidae			Water Pennies	x			1		7	6	8
Arthropoda	Insecta	Coleoptera		Scirtidae			Marsh Beetles	x			1	1	6	6	9
Arthropoda	Insecta	Diptera		Ceratopogonidae			Biting Midges	x			1	1	5	4	10
Arthropoda	Insecta	Diptera		Chaoboridae			Phantom Midges	x				1	*	2	11
Arthropoda	Insecta	Diptera		Chironomida	Chironominae		Bloodworms	x			1	1	3	3	12
Arthropoda	Insecta	Diptera		Chironomida	Orthocladiinae			x			1	1	3	4	13
Arthropoda	Insecta	Diptera		Chironomida	Tanypodinae			x			1	1	3	4	14
Arthropoda	Insecta	Diptera		Culicidae			Mosquitoes	x			1		6	1	15
Arthropoda	Insecta	Diptera		Empididae			Dance Flies	x			1		*	5	16
Arthropoda	Insecta	Diptera		Muscidae?				x			1	1	*	1	17
Arthropoda	Insecta	Diptera		Simuliidae			Black Flies	x			1		5	5	18
Arthropoda	Insecta	Diptera		Stratiomyidae			Soldier Flies	x			1		3	2	19
Arthropoda	Insecta	Diptera		Tabanidae			March Flies	x			1		*	3	20
Arthropoda	Insecta	Ephemeroptera		Baetidae			Mayflies		x		1	1	7	5	21
Arthropoda	Insecta	Ephemeroptera		Caenidae					x		1	1	5	4	22
Arthropoda	Insecta	Ephemeroptera		Leptophlebiidae					x		1	1	10	8	23
Arthropoda	Insecta	Hemiptera		Belastomatidae			Giant Water Bugs				1		*	1	24
Arthropoda	Insecta	Hemiptera		Corixidae			Lesser Water Boatmen				1	1	3	2	25
Arthropoda	Insecta	Hemiptera		Gerridae			Water Striders				1	1	7	4	26
Arthropoda	Insecta	Hemiptera		Hydrometridae			Water Measurers				1	1	*	3	27
Arthropoda	Insecta	Hemiptera		Nepidae			Needle Bugs					1	*	3	28
Arthropoda	Insecta	Hemiptera		Notonectidae			Backswimmers				1	1	6	1	29
Arthropoda	Insecta	Hemiptera		Pleidae			Pygmy Backswimmers				1	1	*	2	30
Arthropoda	Insecta	Hemiptera		Veliidae			Small Water Striders				1	1	6	3	31
Arthropoda	Insecta	Lepidoptera		Pyralidae			Moths	x			1		6	3	32
Arthropoda	Insecta	Odonata	Epiproctophora	Aeshnidae			Dragonflies	x			1	1	7	4	33
Arthropoda	Insecta	Odonata	Epiproctophora	Gomphidae				x			1		6	5	34
Arthropoda	Insecta	Odonata	Epiproctophora	Hemicorduliidae				x			1	1	4	5	35
Arthropoda	Insecta	Odonata	Epiproctophora	Libellulidae				x				1	4	4	36
Arthropoda	Insecta	Odonata	Epiproctophora	Lindeniidae			Exuviae	x				1	*	3	37
Arthropoda	Insecta	Odonata	Zygoptera	Coenagrionidae			Damselflies	x			1	1	2	2	38
Arthropoda	Insecta	Odonata	Zygoptera	Isostictidae				x			1		6	3	39
Arthropoda	Insecta	Odonata	Zygoptera	Lestidae				x				1	*	1	40
Arthropoda	Insecta	Odonata	Zygoptera	Megapodagrionidae				x			1		6	5	41
Arthropoda	Insecta	Odonata	Zygoptera	Protoneuridae				x			1		4	4	42
Arthropoda	Insecta	Trichoptera		Atriplectididae			Caddis Flies	x			1		*	7	43
Arthropoda	Insecta	Trichoptera		Calamoceratidae				x			1		9	7	44
Arthropoda	Insecta	Trichoptera		Conoesucidae				x			1		8	7	45
Arthropoda	Insecta	Trichoptera		Ecnomidae				x			1	1	5	4	46
Arthropoda	Insecta	Trichoptera		Hydrobiosidae				x			1		8	8	47
Arthropoda	Insecta	Trichoptera		Hydropsychidae				x			1		6	6	48
Arthropoda	Insecta	Trichoptera		Hydroptilidae				x			1	1	4	4	49
Arthropoda	Insecta	Trichoptera		Leptoceridae				x			1	1	7	6	50
Arthropoda	Arachnida	Acarina	Hydracarina				Freshwater Mites				1	1	*	6	51
Arthropoda	Crustacea	Diplostraca	Cladocera				Water Fleas				1	1	*	*	52
Arthropoda	Crustacea	Calanoida		Centropagidae			Copepods				1	1	*	*	53
Arthropoda	Crustacea	Cyclopoida		Cyclopidae							1	1	*	*	54
Arthropoda	Crustacea	Decapoda		Atyidae			Freshwater Shrimp				1	1	6	3	55
Arthropoda	Crustacea	Decapoda		Palaemonidae			Freshwater Prawns				1		*	4	56
Arthropoda	Crustacea	Decapoda		Parastacidae		*Cherax destructor*	Yabbies					1	*	4	57
Arthropoda	Ostracoda						Seed Shrimps				1	1	*	*	58
Annelida	Hirudinea			Glossiphoniidae			Leeches				1	1	3	1	59
Annelida	Oligochaeta						Freshwater Worms				1	1	*	2	60
Mollusca	Bivalvia			Corbiculidae			Basket Shells				1		4	4	61
Mollusca	Bivalvia			Sphaeriidae			Pea Shells				1	1	5	5	62
Mollusca	Gastropoda			Ancylidae			Freshwater Limpets				1	1	7	4	63
Mollusca	Gastropoda			Bithyniidae			Freshwater Snails					1	*	3	64
Mollusca	Gastropoda			Lymnaeidae							1	1	4	1	65
Mollusca	Gastropoda			Physidae							1	1	1	1	66
Mollusca	Gastropoda			Planorbidae								1	5	2	67
Mollusca	Gastropoda			Thiaridae								1	2	4	68
Platyhelminth	Turbellaria	Tricladida		Dugesiidae			Flatworms				1		3	2	69
Porifera				Spongillidae			Sponges				1		*	3	70
Chordata	Amphibia			?			Tadpoles					1	*	*	
Chordata	Amphibia			Hylidae		*Litoria fallax*	Dwarf Tree Frog					1	*	*	
Chordata	Osteichthyes			Anguillidae		*Anguilla reinhardtii*	Long-Finned Eel				1		*	*	
Chordata	Osteichthyes			Cyprinidae			Carp				1		*	*	
Chordata	Osteichthyes			Eleotridae			Gudgeons				1		*	*	
Chordata	Osteichthyes			Eleotridae		*Philypnodon sp*	Dorsal rays VII to VIII-I, 10				1		*	*	
Chordata	Osteichthyes			Mugilidae		*Mugil cephalus*	Mullet				1		*	*	
Chordata	Osteichthyes			Poeciliidae		*Gambusia holbrooki*	Eastern Gambusia				1	1	*	*	
Chordata	Osteichthyes			Retropinnidae		*Retropinna semoni*	Australian Smelt				1		*	*	
Chordata	Osteichthyes			Either Eel Tailed Catfish or Long-Finned Eel (observed briefly)							1		*	*	
Chordata	Reptilia	Testudines		Chelidae		*Chelodina longicollis*	Long Necked Turtle					1	*	*	
Notes:	* represents those taxa for which SIGNAL-2 scores are not available, or do not apply						Total number of invertebrate taxa per site				60	45			
	(including taxa recorded as shell only)						SIGNAL Scores				4.75	4.19			
	Taxa present as exuviae were not included in totals														

Appenidx Table A4

Seasonal Macroinvertebrate and Fish Data for Glennies Creek Monitoring Sites

													Autumn 2007			Spring 2007					Autumn 2008					Spring 2008																
										Life Stage			26/06	28/06	27/06	19/12	20/12	19/12	19/12	19/12	13/05	14/05	14/05	13/05	13/05	10/12	10/12	10/12	10/12	10/12		N=3	N=5	N=5	N=5	%	%	%	%	SIGNAL Indices		
Phylum	Class	Sub-Class	Order	Sub-Order	Family	Sub-Family	Species	Common nar	Description	L	N	A	GC Up	GC Mid	GC Down	GC Up	GCOC Up	GC Mid	GCOC Down	GC Down	GCUp	GCOC Up	GC Mid	GCOC Down	GC Down	GC Up	GCOC Up	GC Mid	GCOC Down	GC Down	Occur	Au07	Sp07	Au08	Sp08	Au07	Sp07	Au08	Sp08	HU-97	SIG-2	Taxa#
Arthropoda	Insecta		Coleoptera		Dytiscidae			Diving Beetles		x		x		1		1	1	1	1	1		1	1	1	1						10	1	5	4		33	100	80		2	2	1
Arthropoda	Insecta		Coleoptera		Elmidae			Riffle Beetles		x		x				1	1	1	1		1	1	1			1	1	1			10		4	3	3		80	60	60	8	7	2
Arthropoda	Insecta		Coleoptera		Gyrinidae			Whirligig Beetles		x		x					1	1	1	1			1	1			1		1	1	9		4	2	3		80	40	60	5	4	3
Arthropoda	Insecta		Coleoptera		Haliplidae			Crawling Water Beetles		x		x		1																	1	1				33				*	2	4
Arthropoda	Insecta		Coleoptera		Hydrochidae			Scavenger Water Beetles				x				1	1	1						1						1	5		3	1	1		60	20	20	4	4	5
Arthropoda	Insecta		Coleoptera		Hydrophilidae					x		x	1				1		1				1				1		1		6	1	2	1	2	33	40	20	40	4	2	6
Arthropoda	Insecta		Coleoptera		Psephenidae			Water Pennies		x														1							1			1				20		7	6	7
Arthropoda	Insecta		Coleoptera		Scirtidae			Marsh Beetles		x				1						1											2	1	1			33	20			6	6	8
Arthropoda	Insecta		Diptera		Ceratopogonidae			Biting Midges		x			1				1				1				1					4	1	1	1	1	33	20	20	20	5	4	9
Arthropoda	Insecta		Diptera		Chironomida	Chironominae		Bloodworms		x			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	3	5	5	5	100	100	100	100	3	3	10
Arthropoda	Insecta		Diptera		Chironomida	Orthocladiinae				x				1																	1	1				33				3	4	11
Arthropoda	Insecta		Diptera		Chironomida	Tanypodinae				x			1					1			1			1	1	1	1				7	1	1	3	2	33	20	60	40	3	4	12
Arthropoda	Insecta		Diptera		Culicidae			Mosquitoes		x															1	1					2			1	1			20	20	6	1	13
Arthropoda	Insecta		Diptera		Empididae			Dance Flies		x																			1		1				1				20	*	5	14
					Muscidae?					x										1											1		1				20			*	1	15
Arthropoda	Insecta		Diptera		Simuliidae			Black Flies		x			1					1	1	1	1			1	1						7	1	3	3		33	60	60		5	5	16
Arthropoda	Insecta		Diptera		Stratiomyidae			Soldier Flies		x										1							1	1	1	1	5		1		4		20		80	3	2	17
Arthropoda	Insecta		Diptera		Tabanidae			March Flies		x									1				1								2		1	1			20	20		*	3	18
Arthropoda	Insecta		Ephemeroptera		Baetidae			Mayflies			x		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	3	5	5	5	100	100	100	100	7	5	19
Arthropoda	Insecta		Ephemeroptera		Caenidae						x		1			1	1	1	1	1	1		1	1	1	1	1	1	1	1	15	1	5	4	5	33	100	80	100	5	4	20
Arthropoda	Insecta		Ephemeroptera		Leptophlebiidae						x			1		1	1			1	1	1	1	1	1	1	1	1	1		13	1	3	5	4	33	60	100	80	10	8	21
Arthropoda	Insecta		Hemiptera		Belastomatidae			Giant Water Bugs					1																		1	1				33				*	1	22
Arthropoda	Insecta		Hemiptera		Corixidae			Lesser Water Boatmen					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	3	5	5	5	100	100	100	100	3	2	23
Arthropoda	Insecta		Hemiptera		Gerridae			Water Striders								1	1	1	1	1	1	1							1	1	9		5	2	2		100	40	40	7	4	24
Arthropoda	Insecta		Hemiptera		Hydrometridae			Water Measurers									1														1		1				20			*	3	25
Arthropoda	Insecta		Hemiptera		Notonectidae			Backswimmers					1	1	1	1	1						1			1			1		8	3	2	1	2	100	40	20	40	6	1	26
Arthropoda	Insecta		Hemiptera		Pleidae			Pygmy Backswimmers					1		1																2	2				67				*	2	27
Arthropoda	Insecta		Hemiptera		Veliidae			Small Water Striders					1				1	1	1			1	1	1			1				8	1	3	3	1	33	60	60	20	6	3	28
Arthropoda	Insecta		Lepidoptera		Pyralidae			Moths		x															1					1	2			1	1			20	20	6	3	29
Arthropoda	Insecta		Odonata	Epiproctophora	Aeshnidae			Dragonflies		x								1													1		1				20			7	4	30
Arthropoda	Insecta		Odonata	Epiproctophora	Gomphidae					x												1									1			1				20		6	5	31
Arthropoda	Insecta		Odonata	Epiproctophora	Hemicorduliidae					x			1	1	1						1		1	1	1						7	3		4		100		80		4	5	32
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	18	3	5	5	5	100	100	100	100	2	2	33
Arthropoda	Insecta		Odonata	Zygoptera	Isostictidae					x			1			1					1	1	1			1	1	1	1	1	10	1	1	3	5	33	20	60	100	6	3	34
Arthropoda	Insecta		Odonata	Zygoptera	Megapodagrionidae					x																		1			1				1				20	6	5	35
Arthropoda	Insecta		Odonata	Zygoptera	Protoneuridae					x			1		1						1	1	1	1	1		1		1	1	10	2		5	3	67		100	60	4	4	36
Arthropoda	Insecta		Trichoptera		Atriplectididae			Caddis Flies		x						1	1														2		2				40			*	7	37
Arthropoda	Insecta		Trichoptera		Calamoceratidae					x							1						1			1		1	1	1	6		1	1	4		20	20	80	9	7	38
Arthropoda	Insecta		Trichoptera		Conoesucidae					x			1			1			1												3	1	2			33	40			8	7	39
Arthropoda	Insecta		Trichoptera		Ecnomidae					x				1		1	1		1		1	1	1	1	1		1		1	1	12	1	3	5	3	33	60	100	60	5	4	40
Arthropoda	Insecta		Trichoptera		Hydrobiosidae					x			1											1							2	1		1		33		20		8	8	41
Arthropoda	Insecta		Trichoptera		Hydropsychidae					x								1		1	1										3		2	1			40	20		6	6	42
Arthropoda	Insecta		Trichoptera		Hydroptilidae					x			1		1		1		1		1	1	1	1	1	1		1	1	1	14	2	3	5	4	67	60	100	80	4	4	43
Arthropoda	Insecta		Trichoptera		Leptoceridae					x			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	3	5	5	5	100	100	100	100	7	6	44
Arthropoda	Arachnida		Acarina	Hydracarina				Freshwater Mites					1	1	1	1	1	1		1	1	1		1		1	1	1			13	3	4	3	3	100	80	60	60	*	6	45
Arthropoda	Crustacea	Branchiopod:	Diplostraca	Cladocera				Water Fleas					1									1				1	1	1	1		6	1		1	4	33		20	80	*	*	46
Arthropoda	Crustacea	Copepoda	Calanoida		Centropagidae			Copepods																	1						1			1				20		*	*	47
Arthropoda	Crustacea	Copepoda	Cyclopoida		Cyclopidae								1	1	1	1			1		1	1			1						8	3	2	3		100	40	60		*	*	48
Arthropoda	Crustacea		Decapoda		Atyidae			Freshwater Shrimp					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18	3	5	5	5	100	100	100	100	6	3	49
Arthropoda	Crustacea		Decapoda		Palaemonidae			Freshwater Prawns													1			1	1						3			3				60		*	4	50
Arthropoda	Ostracoda							Seed Shrimps							1			1	1												3	1	2			33	40			*	*	51
Annelida	Hirudinea				Glossiphoniidae			Leeches											1												1		1				20			3	1	52
Annelida	Oligochaeta							Freshwater Worms						1		1	1	1		1	1	1		1		1		1	1	1	12	1	4	3	4	33	80	60	80	*	2	53
Mollusca	Bivalvia				Corbiculidae			Basket Shells													1	1									2			2				40		4	4	54
Mollusca	Bivalvia				Sphaeriidae			Pea Shells																				1			1				1				20	5	5	55
Mollusca	Gastropoda				Ancylidae			Freshwater Limpets					1			1					1	1	1		1	1		1			8	1	1	4	2	33	20	80	40	7	4	56
Mollusca	Gastropoda				Lymnaeidae			Freshwater Snails										1	1	1								1		1	5		3		2		60		40	4	1	57
Mollusca	Gastropoda				Physidae								1					1	1	1	1	1	1	1	1	1	1	1	1	1	14	1	3	5	5	33	60	100	100	1	1	58
Platyhelmintl	Turbellaria		Tricladida		Dugesiidae			Flatworms									1					1	1		1						4		1	3			20	60		3	2	59
Porifera					Spongillidae			Sponges									1														1		1				20			*	3	60
Chordata	Amphibia							Tadpoles																								0									*	*	
Chordata	Amphibia				Hylidae		*Litoria fallax*	Dwarf Tree Frog																								0									*	*	
Chordata	Osteichthyes				Anguillidae		*Anguilla reinhardtii*	Long-Finned Eel													1								1		2			1	1			20	20	*	*	
Chordata	Osteichthyes				Cyprinidae			Carp																		1	1		1	1	4				4				80	*	*	
Chordata	Osteichthyes				Eleotridae			Gudgeon							1	1		1		1							1	1			6	1	3		2	33	60		40	*	*	
Chordata	Osteichthyes				Eleotridae		*Philypnodon sp*										1		1											1	3		2		1		40		20	*	*	
Chordata	Osteichthyes				Mugilidae		*Mugil cephalus*	Mullet															1		1		1				3			2	1			40	20	*	*	
Chordata	Osteichthyes				Poeciliidae		*Gambusia holbrooki*	Eastern Gambusia					1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17	2	5	5	5	67	100	100	100	*	*	
Chordata	Osteichthyes				Retropinnidae		*Retropinna semoni*	Australian Smelt								1	1	1	1	1		1				1		1	1	1	10		5	1	4		100	20	80	*	*	
Chordata	Osteichthyes				Either Eel Tailed Catfish or Long-Finned Eel (observed briefly)																			1							1			1				20		*	*	
								Total number of invertebrate taxa per site					26	17	14	22	26	22	23	20	26	24	24	24	23	21	20	21	22	20		34	42	42	34							
								Mean Creek Number of Taxa																								21.9	19.0	22.6	24.2	20.8							
								SE Creek Number of Taxa																								0.7	3.606	0.98	0.49	0.374							
								Site SIGNAL Scores					4.71	4.63	4.50	5.48	5.08	4.71	4.67	4.55	4.96	4.95	5.00	4.71	4.62	5.30	4.95	5.20	4.95	4.65		4.63	4.91	4.85	5.01							
								Mean Creek SIGNAL Score																									4.61	4.90	4.85	5.01							
								SE Site Signal Score																									0.061	0.17	0.077	0.113							
Notes:	* represents those taxa for which SIGNAL-2 scores are not available, or do not apply (including taxa recorded as shell only)																																										

Appendix Table A5.1
Field Water Quality Results & Summary Statistics from Glennies Ck
Sub-catchment Surveys July to Dec 08

Site	Date	Time	Depth M	Temp C	Cond μS/cm	Sal ppt	DO %sat	DO mg/l	pH Units	ORP mv	Turb ntu	#
T3Dam	28/10/08	15:08	0.6	29.22	132	0.08	91.2	7.0	7.71	633	17.8	44
T3.1	03/07/08	10:20	0.1	11.01	127	0.01	77.3	8.5		299	74.3	1
P4	15/10/08	12:34	0.3	16.91	140	0.08	33.9	3.3	6.73	617	26.8	18
P4	15/10/08	12:35	0.6	16.86	149	0.09	11.5	1.1	6.66	617	24.5	19
P4	15/10/08	12:36	1.1	15.47	213	0.13	1.7	0.2	6.33	-40	29.0	20
P4	15/10/08	12:27	0.3	19.50	132	0.08	32.6	3.0	6.88	621	48.3	15
P4	15/10/08	12:27	0.5	19.19	133	0.08	31.9	3.0	6.87	623	34.9	16
P4	15/10/08	12:28	0.7	18.98	137	0.09	26.3	2.4	6.82	626	32.0	17
P4	15/10/08	13:34	0.3	17.58	155	0.09	16.2	1.5	6.67	554	18.6	21
P4	15/10/08	13:35	0.4	17.51	155	0.09	10.4	1.0	6.62	555	26.0	22
T4.1	15/10/08	13:42	0.5	17.30	149	0.09	12.7	1.2	6.54	583	17.8	23
T4.1	15/10/08	13:44	0.7	17.12	162	0.09	1.6	0.2	6.42	516	27.5	24
T4.2	03/07/08	14:30	0.2	14.16	123	0.01	85.8	8.8		299	600.0	8
T4.3	03/07/08	14:26	0.2	14.62	71	0.01	89.1	9.1		300	30.6	7
T4.4	15/10/08	13:51	0.3	20.10	180	0.10	36.5	3.3	6.61	578	20.1	25
T4.4	15/10/08	13:53	0.6	19.50	187	0.10	25.2	2.3	6.53	587	17.8	26
T4.4	15/10/08	13:54	0.7	19.43	189	0.10	24.5	2.3	6.51	591	17.8	27
T4.5	03/07/08	13:57	0.2	12.14	105	0.01	86.4	9.3		300	187.5	6
T4.6	15/10/08	15:05	0.3	18.88	172	0.10	14.9	1.4	6.56	633	28.3	30
T4.6	15/10/08	15:06	0.6	18.78	183	0.11	6.9	0.6	6.48	637	21.6	31
T4.6	15/10/08	15:07	0.8	18.39	334	0.19	1.4	0.1	6.08	149	29.0	32
T4.7	03/07/08	12:28	0.3	11.95	135	0.03	76.7	8.3		298	27.8	5
T4.8	03/07/08	12:24	0.2	12.75	248	0.07	77.2	8.2		298	34.0	4
T4.9	03/07/08	12:04	0.1	14.75	92	0.01	84.1	8.5		300	533.3	3
T4.10	03/07/08	11:39	0.3	12.40	93	0.01	52.5	5.6		298	27.8	2
T5.1	28/10/08	10:48	0.4	22.98	91	0.06	91.5	7.9	7.40	583	92.2	40
P5	28/10/08	10:52	0.3	18.18	589	0.33	8.0	0.8	6.73	516	98.9	41
P5	28/10/08	10:54	0.6	17.95	593	0.32	6.3	0.6	6.82	532	43.1	42
T5.2	28/10/08	09:27	0.5	18.41	184	0.11	5.6	0.5	6.73	536	59.5	39
T5.3	16/10/08	14:29	0.4	27.58	193	0.11	67.5	5.3	6.98	548	189.6	37
T5.4	16/10/08	14:30	0.3	25.66	93	0.06	84.5	6.9	7.30	530	321.2	38
		Tribs	Min	11.01	71.0	0.01	1.4	0.1	6.08	-40.00	17.8	
		Tribs	Max	29.22	593.0	0.33	91.5	9.3	7.71	637.00	600.0	
		Tribs	Mean	17.91	181.9	0.1	41.0	3.9	6.74	474.7	89.0	
		Tribs	SE	0.8	21.7	0.0	6.1	0.6	0.1	31.0	25.8	
Dam1	14/10/08	17:13	0.4	22.09	300	0.16	35.4	3.1	7.44	440	58.0	9
Dam1	14/10/08	17:13	0.5	20.88	304	0.17	30.4	2.7	7.38	438	64.7	10
Dam1	14/10/08	17:13	0.5	19.53	318	0.17	7.4	0.7	7.30	321	107.1	11
Dam6	15/10/08	10:04	0.3	19.90	92	0.06	41.4	3.8	7.00	557	6.7	12
Dam6	15/10/08	10:05	0.5	19.84	92	0.06	41.1	3.7	6.97	565	5.2	13
Dam6	15/10/08	10:06	0.6	19.85	92	0.06	39.7	3.6	6.93	572	5.9	14
Dam 7	15/10/08	14:53	0.3	19.19	155	0.10	41.7	3.9	6.86	601	24.5	28
Dam 7	15/10/08	14:55	0.5	18.74	153	0.09	15.2	1.4	6.67	607	42.4	29
Dam 8	16/10/08	09:25	0.3	18.58	175	0.11	49.6	4.6	7.11	622	136.8	33
Dam 8	16/10/08	09:28	0.3	17.87	176	0.10	46.2	4.4	7.07	618	136.1	34
Dam9	16/10/08	14:16	0.4	22.91	108	0.06	132.8	11.4	9.19	507	168.8	35
Dam9	16/10/08	14:18	0.4	23.47	111	0.06	142.3	12.1	9.46	480	180.7	36
Dam11	28/10/08	14:08	0.3	32.36	108	0.06	81.1	5.9	7.24	595	386.6	43
Dam12	9/12/08	17:30	0.3	29.74	137	0.07	114.8	8.7	9.09	391	3.7	45
Dam12	9/12/08	17:32	0.5	29.71	137	0.07	112.7	8.6	9.07	391	3.7	46
		Dams	Min	17.87	92	0.06	7.4	0.7	6.67	321.00	3.7	
		Dams	Max	32.36	318	0.17	142.3	12.1	9.46	622.00	386.6	
		Dams	Mean	32.36	163.9	0.1	62.1	5.2	7.65	513.7	88.7	
		Dams	SE	1.2	20.5	0.0	11.2	0.9	0.3	25.2	26.8	

Appendix Table A5.2

Field Water Quality Results from Glennies Ck Sub-catchment Surveys July to Dec 08

Site	Date	Time	Depth	Temp	Cond	Sal	DO	DO	pH	ORP	Turb
			M	C	μS/cm	ppt	%sat	mg/l	Units	mv	ntu
T3Dam	28/10/08	15:08	0.6	29.22	132	0.08	91.2	7.0	7.71	633	17.8
T3.1	03/07/08	10:20	0.1	11.01	127	0.01	77.3	8.5		299	74.3
P4	15/10/08	12:34	0.3	16.91	140	0.08	33.9	3.3	6.73	617	26.8
P4	15/10/08	12:27	0.3	19.50	132	0.08	32.6	3.0	6.88	621	48.3
P4	15/10/08	13:34	0.3	17.58	155	0.09	16.2	1.5	6.67	554	18.6
T4.1	15/10/08	13:42	0.5	17.30	149	0.09	12.7	1.2	6.54	583	17.8
T4.2	03/07/08	14:30	0.2	14.16	123	0.01	85.8	8.8		299	600.0
T4.3	03/07/08	14:26	0.2	14.62	71	0.01	89.1	9.1		300	30.6
T4.4	15/10/08	13:51	0.3	20.10	180	0.10	36.5	3.3	6.61	578	20.1
T4.5	03/07/08	13:57	0.2	12.14	105	0.01	86.4	9.3		300	187.5
T4.6	15/10/08	15:05	0.3	18.88	172	0.10	14.9	1.4	6.56	633	28.3
T4.7	03/07/08	12:28	0.3	11.95	135	0.03	76.7	8.3		298	27.8
T4.8	03/07/08	12:24	0.2	12.75	248	0.07	77.2	8.2		298	34.0
T4.9	03/07/08	12:04	0.1	14.75	92	0.01	84.1	8.5		300	533.3
T4.10	03/07/08	11:39	0.3	12.40	93	0.01	52.5	5.6		298	27.8
T5.1	28/10/08	10:48	0.4	22.98	91	0.06	91.5	7.9	7.40	583	92.2
P5	28/10/08	10:52	0.3	18.18	589	0.33	8.0	0.8	6.73	516	98.9
T5.2	28/10/08	09:27	0.5	18.41	184	0.11	5.6	0.5	6.73	536	59.5
T5.3	16/10/08	14:29	0.4	27.58	193	0.11	67.5	5.3	6.98	548	189.6
T5.4	16/10/08	14:30	0.3	25.66	93	0.06	84.5	6.9	7.30	530	321.2
		Tribs	Min	11.01	71.0	0.01	5.6	0.5	6.54	298.00	17.8
		Tribs	Max	29.22	589.0	0.33	91.5	9.3	7.71	633.00	600.0
		Tribs	Mean	17.80	160.2	0.1	56.2	5.4	6.90	466.2	122.7
		Tribs	SE	1.2	24.5	0.0	7.2	0.7	0.1	32.1	38.2
Dam1	14/10/08	17:13	0.4	22.09	300	0.16	35.4	3.1	7.44	440	58.0
Dam6	15/10/08	10:04	0.3	19.90	92	0.06	41.4	3.8	7.00	557	6.7
Dam 7	15/10/08	14:53	0.3	19.19	155	0.10	41.7	3.9	6.86	601	24.5
Dam 8	16/10/08	09:25	0.3	18.58	175	0.11	49.6	4.6	7.11	622	136.8
Dam9	16/10/08	14:16	0.4	22.91	108	0.06	132.8	11.4	9.19	507	168.8
Dam11	28/10/08	14:08	0.3	32.36	108	0.06	81.1	5.9	7.24	595	386.6
Dam12	9/12/08	17:30	0.3	29.74	137	0.07	114.8	8.7	9.09	391	3.7
		Dams	Min	18.58	92	0.06	35.4	3.1	6.86	391.00	3.7
		Dams	Max	32.36	300	0.16	132.8	11.4	9.19	622.00	386.6
		Dams	Mean	32.4	153.6	0.1	71.0	5.9	7.7	530.4	112.2
		Dams	SE	2.0	26.8	0.0	14.9	1.2	0.4	33.2	51.8

Appendix Table A6 Field Comments – Spring 2008 Survey		
Date	Site	Comments
14/10/08	Dam1	Dam adjacent Glennies Creek site GCOCUp. Length 15m, maximum width 15m, max depth ~1.2m. No flow in or out, water level moderate (0.4m to overflowing), water slightly turbid. Surrounding land use all pasture with cattle access to dam, riparian vegetation consisting of grass with some sedges. Main edge aquatic habitats sampled were floating pondweed (*Potamogeton sulcatus*) beds and submerged bank vegetation. Charophytes present. Yabby *Cherax destructor* shell retained in traps and sample net. Long necked turtle (*Chelodina longicollis*) and tadpoles present. Filamentous green algae present in moderate to abundant amounts. Substrate mainly fine muddy silt/ clay and sand.
15/10/08	Dam6	Offline dam adjacent house on T4. Fence through middle of dam. Length 20m, max width 15m, depth to 1.5m. No flow in or out of dam, water level moderate to high (0.5m to overflow), water clear. Surrounding land use all pasture with cattle access to dam, riparian vegetation consisting of grass with some sedges. Waternymph (*Najas tenuifolia*) abundant throughout dam. Floating pondweed, emergent grass (*Paspalum spp*?), blunt pondweed (*Potamogeton ochreatus*), sedge (Eleocharis spp) and swamp lily (*Ottelia ovalifolia*) also present but in smaller amounts. Main edge aquatic habitats sampled were macrophyte beds and submerged bank vegetation. Tadpoles present. Filamentous green algae present in moderate to abundant amounts. Substrate soft muddy.
15/10/08	P4	In line pool in tributary 4. Pool length around 25m, max width 5m, average width 2m, max depth 1.6m. No flow in or out of pool, however surface water present within channel immediately up and downstream of site. Channel scoured, with exposed clay walls in some parts of site. Next pool downstream is a 0.6m drop below end of T4. Surrounding land use all pasture. Riparian vegetation mainly casuarina trees. Water primrose (*Ludwigia peploides*) and sedges present in very small amounts. Edge habitat sampled consisted mostly of trailing bank vegetation and floating pondweed. New cumbungi (*Typha spp*) shoots emergent in next pool downstream. Long necked

		turtle and tadpoles observed. Filamentous green algae present in moderate to abundant amounts. Substrate soft muddy clay with some sand.
15/10/08	Dam7	Dam on small tributary to T4. Max length 20m, maximum width 20m, max depth ~2m. No flow in or out, water level moderate (0.4m to overflowing), water slightly turbid. Surrounding land use all pasture with cattle access to dam, riparian vegetation consisting of grass with some sedges. Main macrophyte present is floating pondweed, with swamp lily and blunt pondweed present in smaller amounts. Edge habitat areas sampled were floating pondweed beds, plus trailing bank vegetation. New cumbungi shoots also present. Tadpoles retained in sample. Filamentous green algae present in moderate to abundant amounts. Substrate soft muddy clay with some sand.
16/10/08	Dam8	Dam on T3. Max length 20m, max width 15m, max depth ~1.2m. No flow in or out, however 10m soak at upstream end of pool occupied by emergent grass (Paspalum spp?). No flow in or out of dam. Water level moderate with turbid water, 0.2m to overflow. No riparian trees or shrubs just pasture. Cattle access to dam. Floating pondweed, blunt pondweed, sedge, emergent grass and swamp lily present and sampled as edge habitat. Tadpoles present. Filamentous green algae present in small amounts. Substrate soft muddy clay with some sand. Small in-line pool sampled approximately 50m below in-line dam on T5. Pool length 15m x 4m max width, max depth 1.4m. No flow in or out of pool, dry channel upstream to dam and around 50m downstream of site. Water slightly turbid. No riparian trees. Upstream end of pool filled with cumbungi, downstream half with floating pondweed, small amounts of blunt pondweed present also. Perimeter of pool occupied by emergent grass (Paspalum spp?). Edge habitat sampled consisted of trailing bank vegetation and floating pondweed and around sub merged logs. Cattle access throughout length of creekline within fenceline. Numerous green reed frogs *Litoria fallax* observed within cumbungi. Long-necked turtle, and eastern water dragon observed in dam 50m upstream. Filamentous green algae present in small amounts. Substrate soft muddy clay with some sand.
28/10/08	T3Dam	In-line dam sampled on T3 above Glennies Road in commons. Dam length 60m x 45 max width,, max depth estimated at ~2.5m. No flow in or out of dam, water slightly turbid, 0.2-0.3m to overflowing. 20m

28/10/08	T3Dam	In-line dam sampled on T3 above Glennies Road in commons. Dam length 60m x 45 max width,, max depth estimated at ~2.5m. No flow in or out of dam, water slightly turbid, 0.2-0.3m to overflowing. 20m soak at upstream end of pool occupied by emergent grass (Paspalum spp?). Upstream half of dam with dense floating pondweed and abundant filamentous green algae, mostly shallow (to 1.5m deep but mostly <0.8m. Downstream deeper half with floating pondweed beds and smaller amounts of swamp lily. Main habitat sampled was floating pondweed and amongst sedges on dam edges. Single water primrose. Five long necked turtles observed. Plague minnow *Gambusia holbrooki* observed in shallows around dam edges. Substrate soft muddy clay with some sandier sections.
9/12/08	Dam12	Large dam located south of New England highway in middle of T4 catchment (private property). Dam length ~50m x 75 max width, max depth 3-5m (?) in middle. Water clear with no flow in or out of dam, 0.5m to overflowing. Dam perimeter occupied mainly by cumbungi and *Schoenoplectus mucronatus*. Floating pondweed and blunt pondweed also present but in smaller amounts. Filamentous green algae and charophytes abundant. Edge habitat sampled consisted of submerged and emergent macrophyte beds, very little detritus or submerged logs available. The dam was stocked with around

Appendix Table A7																								
Seasonal Macroinvertebrate and Fish Data for Sub-catchment Monitoring Sites													Spring 2008											
										Life Stage			15/10/08	28/10/08	28/10/08	14/10/08	15/10/08	15/10/08	16/10/08	09/12/08		SIGNAL Indices		Taxa
Phylum	Class	Sub-Class	Order	Sub-Order	Family	Sub-Family	Genus	Common na	Description	L	N	A	P4	P5	T3 dam	Dam 1	Dam 6	Dam 7	Dam 8	Dam 12	Occur	HU-97	SIG-2	No
Arthropoda	Insecta		Coleoptera		Dytiscidae			Diving Beetles		x		x	1	1	1	1	1	1	1	1	8	2	2	1
Arthropoda	Insecta		Coleoptera		Gyrinidae			Whirligig Beetles		x		x	1								1	5	4	2
Arthropoda	Insecta		Coleoptera		Hydraenidae			Scavenger Water Beetles				x								1	1	5	3	3
Arthropoda	Insecta		Coleoptera		Hydrophilidae					x		x	1	1		1			1	1	5	4	2	4
Arthropoda	Insecta		Coleoptera		Scirtidae			Marsh Beetles		x			1								1	6	6	5
Arthropoda	Insecta		Diptera		Ceratopogonidae			Biting Midges		x			1			1		1			3	5	4	6
Arthropoda	Insecta		Diptera		Chaoboridae			Phantom Midges		x									1		1	*	2	7
Arthropoda	Insecta		Diptera		Chironomida	Chironominae		Bloodworms		x			1	1	1	1	1	1	1	1	8	3	3	8
Arthropoda	Insecta		Diptera		Chironomida	Orthocladiinae				x									1		1	3	4	9
Arthropoda	Insecta		Diptera		Chironomida	Tanypodinae				x				1	1		1	1		1	5	3	4	10
					Muscidae?					x			1								1	*	1	11
Arthropoda	Insecta		Ephemeroptera		Baetidae			Mayflies			x			1	1	1	1	1	1		6	7	5	12
Arthropoda	Insecta		Ephemeroptera		Caenidae						x				1		1	1			3	5	4	13
Arthropoda	Insecta		Ephemeroptera		Leptophlebiidae						x		1	1							2	10	8	14
Arthropoda	Insecta		Hemiptera		Corixidae			Lesser Water Boatmen					1	1	1	1	1	1	1	1	8	3	2	15
Arthropoda	Insecta		Hemiptera		Gerridae			Water Striders					1								1	7	4	16
Arthropoda	Insecta		Hemiptera		Hydrometridae			Water Measurers					1	1				1			3	*	3	17
Arthropoda	Insecta		Hemiptera		Nepidae			Needle Bugs						1						1	2	*	3	18
Arthropoda	Insecta		Hemiptera		Notonectidae			Backswimmers					1	1	1	1	1	1	1	1	8	6	1	19
Arthropoda	Insecta		Hemiptera		Pleidae			Pygmy Backswimmers												1	1	*	2	20
Arthropoda	Insecta		Hemiptera		Veliidae			Small Water Striders					1						1		2	6	3	21
Arthropoda	Insecta		Odonata	Epiproctoph	Aeshnidae			Dragonflies		x				1	1	1	1	1	1	1	7	7	4	22
Arthropoda	Insecta		Odonata	Epiproctoph	Hemicorduliidae					x							1	1	1		3	4	5	23
Arthropoda	Insecta		Odonata	Epiproctoph	Libellulidae					x			1		1	1	1	1		1	6	4	4	24
Arthropoda	Insecta		Odonata	Zygoptera	Coenagrionidae			Damselflies		x			1	1	1	1	1	1	1	1	8	2	2	25
Arthropoda	Insecta		Odonata	Zygoptera	Lestidae					x			1	1	1	1	1	1	1		7	*	1	26
Arthropoda	Insecta		Trichoptera		Ecnomidae			Caddis Flies		x										1	1	5	4	27
Arthropoda	Insecta		Trichoptera		Hydroptilidae					x										1	1	4	4	28
Arthropoda	Insecta		Trichoptera		Leptoceridae					x			1	1	1	1	1	1	1	1	8	7	6	29
Arthropoda	Arachnida		Acarina	Hydracarina				Freshwater Mites					1	1	1	1	1	1	1	1	8	*	6	30
Arthropoda	Crustacea	Branchiopod	Diplostraca	Cladocera				Water Fleas					1	1	1	1	1	1	1		7	*	*	31
Arthropoda	Crustacea	Copepoda	Calanoida		Centropagidae			Copepods					1					1			2	*	*	32
Arthropoda	Crustacea	Copepoda	Cyclopoida		Cyclopidae								1	1	1	1	1		1		6	*	*	33
Arthropoda	Crustacea		Decapoda		Atyidae			Freshwater Shrimp						1				1			2	6	3	34
Arthropoda	Crustacea		Decapoda		Parastacidae		*Cherax destructor*	Yabbies								1					1	*	4	35
Arthropoda	Ostracoda							Seed Shrimps					1	1	1	1	1	1	1		7	*	*	36
Annelida	Hirudinea				Glossiphoniidae			Leeches									1		1		2	3	1	37
Annelida	Oligochaeta							Freshwater Worms								1				1	2	*	2	38
Mollusca	Bivalvia				Sphaeriidae			Pea Shells							1					1	2	5	5	39
Mollusca	Gastropoda				Ancylidae			Freshwater Limpets					1	1				1			3	7	4	40
Mollusca	Gastropoda				Bithyniidae			Freshwater Snails											1		1	*	3	41
Mollusca	Gastropoda				Lymnaeidae												1	1		1	3	4	1	42
Mollusca	Gastropoda				Physidae										1					1	2	1	1	43
Mollusca	Gastropoda				Planorbidae														1		1	5	2	44
Mollusca	Gastropoda				Thiaridae											1				1	2	2	4	45
Chordata	Amphibia							Tadpoles					1			1	1	1	1	1	6	*	*	
Chordata	Amphibia				Hylidae		*Litoria fallax*	Dwarf Tree Frog						1							1	*	*	
Chordata	Osteichthyes				Poeciliidae		*Gambusia holbrooki*	Eastern Gambusia							1						1	*	*	
Chordata	Reptilia		Testudines		Chelidae		*Chelodina longicollis*	Long Necked Turtle					1		1	1					3	*	*	
								Total number of invertebrate taxa per site					23	20	18	19	19	22	21	21	20.4	0.6		
									Site SIGNAL Scores				4.63	4.71	4.13	4.06	4.19	4.47	4.11	3.81	4.26	0.11		
Notes:	* represents those taxa for which SIGNAL-2 scores are not available, or do not apply (including taxa recorded as shell only)																							