APPENDIX F: AQUATIC ECOLOGY ASSESSMENT

Deep Creek Quarry

Response to Submissions Report

IRONSTONE DEVELOPMENTS PTY LTD

DEEP CREEK QUARRY PROPOSAL

DEEP CREEK AQUATIC ECOLOGY BIODIVERSITY STUDY

Figure 1 Looking downstream through pool site at Deep Creek site DC2.

Report Prepared for Wedgetail Project Consulting

Marine Pollution Research Pty Ltd

December 2022

TABLES

FIGURES

1 INTRODUCTION

Wedgetail Project Consulting submitted an EIS on behalf of the proponent *Ironstone Developments Pty Ltd* for a hard rock quarry off The Bucketts Way at Limeburners Creek, NSW in late 2021 (the Deep Creek Quarry (DCQ) EIS). The project is State Significant Development (SSD-11591659). DCQ is located at 279 Deep Creek Road, Limeburners Creek and is within the MidCoast local government area.

In part as a response to the state and local government agency EIS Review Process in December 2021 and early 2022 and in line with the possibility that stormwater discharges may be required, *Wedgetail Project Consulting* requested *Marine Pollution Research Pty Ltd* (MPR) undertake a base-line aquatic ecology survey of tributary drainages and Deep Creek bounding the DCQ footprint and access road, of sites in the downstream Deep Creek receiving environment in the Karuah National Park and at the Karuah River estuary interface. The proposed field aquatic ecological assessments included:

- Deep Creek freshwater stream-health sites sampled for fish and macroinvertebrates.
- Metered water quality and Riparian, Channel and Environment Condition assessments at all sites.
- Field habitat inspections and aerial drone imagery of the estuarine and intertidal vegetation communities and including occurrence of oyster lease infrastructure in the lower estuarine section of Deep Creek and around the river confluence.
- Aquatic habitat assessment including potential threatened and protected species habitats.

1.1 Project Location and Description

DCQ is located within the catchment of Deep Creek, a tributary of the Karuah River. Deep Creek extends from its headwaters located about 2 km west of DCQ to its confluence with the Karuah River about 10 km east - see **Figures 3 & 4** for project location and footprint.

Land use within and immediately surrounding DCQ is primarily agricultural. Further downstream (east of The Bucketts Way) Deep Creek flows through Karuah National Park to its confluence with Karuah River. The creek becomes tidal and estuarine within the National Park boundaries, and Karuah River oyster aquaculture extends up to and past the confluence.

Within the vicinity of DCQ, Deep Creek is a third order watercourse, with a catchment area of about 1,500 ha upstream of The Bucketts Way. The upper catchment areas of Deep Creek are generally steep and forested lands with extensive rock outcropping. The channel sections of Deep Creek are moderately sinuous, with bed and bank materials ranging from large boulders and rock, to alluvial materials that include sections of currently active head-cuts. The Creek is separated from the upper slopes by colluvium deposits that are generally cleared with sporadic tree coverage.

The proposal footprint is shown in **Figure 4** and is described as follows:

- The development and operation of a new single pit gravel quarry of about 31 hectares disturbance area (including an18-hectare pit) extracting up to 500,000 tonnes per year for up to 30 years.
- Provision of on-site crushing facilities, weighbridge, workshop and stockpile areas.
- Pump out septic system for offsite septic disposal.
- Haulage of up to 4,000 tonnes per day during peak sales (125 laden truck movements).
- The construction and operation of a private haul road to link the proposed quarry with The Bucketts Way and inclusive of a crossing of Deep Creek (large culverts). A new intersection will be constructed at The Bucketts Way.
- Water supply will be mainly drawn from on-site dams, in-pit groundwater and a pipeline from a former sawmill dam.
- Without excessively large on-site storage dams, the need for stormwater discharges to Deep Creek cannot be avoided. Site storage has been increased from that initially proposed, but is still expected to require 4-9 discharges each year to maintain sediment basins at a capacity to capture runoff from storm events. In extreme events it is predicted that there could be one uncontrolled discharge (i.e. dam overtopping) on average per year. Controlled discharges would be done via two tributary discharge points to be established in southern tributaries immediately above and below the quarry footprint.
- The progressive and final rehabilitation of the site to a mixture of open grassland and native vegetation.

1.2 Threatened Aquatic Species Review

This assessment includes considerations of threatened aquatic species and key threatening processes listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), *Fisheries Management Act 1999* (FM Act) and *Biodiversity Conservation Act 1995* (BC Act).

Threatened aquatic species, populations and ecological communities listed under the FM Act and EPBC Act that occur, or could potentially occur within the study area were assessed by reviewing the NSW fish communities and threatened fish species distribution maps (see NSW DPI 2016a) and current listings on the databases maintained by the NSW Dept Primary Industry (NSW Fisheries Spatial data portal) and the National Protected Matters Search Tool:

- Sydney hawk dragonflies (*Austrocordulia leonardi*) are aquatic in their early (larval) life-stage, and are listed as endangered under the FM Act and the EPBC Act. Sydney hawk dragonflies have only ever been recorded from large waterways ranging between stream orders of 4 to 7 (Theischinger et al 2009), requiring cool, oxygenated water such as that provided by riffle zones or artificial structures (Grieve & Theischinger 2020), and larvae appear to have specific habitat requirements, being collected from deep river pools, with cooler water and permanent flow (NSW DPI 2016b). Whilst the presence of a viable population of Sydney Hawk Dragonfly (*Austrocordulia leonardi*) is yet to be confirmed from the Karuah River catchment area, a single larva was found by Dr Bruce Chessman in the early 2000's from freshwater habitats in the Karuah River catchment, some 49km upstream from the Deep Creek confluence.
- It is therefore considered unlikely that the Sydney hawk dragonfly occurs in Deep Creek throughout the study area as the aquatic habitats are considered unsuitable, as Deep Creek adjacent to the study area is ephemeral and known to dry up during drought periods, and there are limited sections of open pools with steep rocky sides. There were no *Austrocordulia* larvae or exuviae observed or caught during the aquatic macroinvertebrate sampling for this project.
- Freshwater fish community status is rated as *Fair* for the lower portion of Deep Creek downstream from Bucketts Way bridge crossing, with no rating provided for Deep Creek upstream from the bridge (NSW Fisheries Spatial data portal accessed 5/7/2022).
- The threatened species indicative distribution maps represent river reaches that have a similar suite of environmental variables suitable for those species (NSW DPI 2016a). The southern purple spotted gudgeon indicative distribution map (provided in Appendix B Figure 14) highlights potential occupation in the upper Karuah River catchment, but there are no indications for the Deep Creek catchment. Southern Purple Spotted Gudgeon are a benthic species that can be found in a variety of waterway types such as rivers, creeks and billabongs with slow-moving or still

waters or in streams with low turbidity, and important habitat features include aquatic vegetation, overhanging vegetation from river banks, leaf litter, rocks or snags (NSW DPI 2017).

- Whilst there is suitable southern purple spotted gudgeon habitat present in Deep Creek, the likelihood of occurrence is considered low, as there are no records within the locality, nor were there any specimens caught or observed during net sampling or trapping undertaken for the project.

Threatened aquatic species, populations and ecological communities listed under the BC Act that could occur or within the study area were assessed by reviewing the current listings on the NSW Bionet Atlas database, maintained by the NSW Department of Planning, Industry and Environment:

- Round-leafed Wilsonia (*Wilsonia rotundifolia*) is listed as an endangered saltmarsh species under the BC Act. Round-leafed Wilsonia occurs in coastal saltmarsh and inland saline or brackish lakes south of Sydney, and while there are no occurrence records for the Port Stephens estuary (including the Karuah River) on the NSW Bionet Atlas or on the Atlas of Living Australia websites, additional searches were made for round-leafed Wilsonia throughout the saltmarsh areas around lower Deep Creek, and none were encountered.
- Narrow-leafed Wilsonia (*Wilsonia backhousei*) is listed as a vulnerable saltmarsh species under the BC Act, and occurs around the perimeter of coastal saltmarshes lakes south of Newcastle. There are no records of narrow-leafed Wilsonia for the Port Stephens estuary (including the Karuah River) on the NSW Bionet Atlas or on the Atlas of Living Australia websites. Searches were made for narrow-leafed Wilsonia throughout the saltmarsh areas in lower Deep Creek, and none were encountered.
- Giant dragonflies (*Petalura gigantea*) are aquatic in their larval life-stage, and are listed as an endangered species under the BC Act. Desktop inspections of aerial images undertaken prior to fieldwork suggested that sections of Deep Creek catchment bounding site DC6 may support freshwater swamps (potential habitat of the giant dragonfly), however, field ground-truthing of these sections found no freshwater swamps, and accordingly it is concluded that the project area does not include potential or actual giant dragonfly habitat.

1.3 NSW DPI Fisheries Key Fish Habitat Classifications

The assessment of development proposals by NSW DPI (Fisheries Division) as detailed in the Fisheries Policy and Guideline Document (NSW Fisheries 2013), requires the

consideration of the *sensitivity* of fish habitats, in terms of the importance of the habitat to the survival of fish and the ability of the habitats to withstand disturbance.
The NSW DPI *Fisheries Spatial Data Portal* was accessed to determine the extent of Key Fish Habitat (KFH) within the Deep Creek catchment, which is continuous along the main Deep Creek channel (and ST5SD channel) from the upper catchment limits downstream to Karuah River (**Figure 2** below). It is important to emphasise that the term 'fish' includes all freshwater invertebrates such as crayfish, prawns, shrimps, mussels and insect larvae.

Figure 2 NSW Fisheries Spatial Data Portal Map showing the extent of KFH (blue shading) in relation to the study area (yellow outline).

With regard to the NSW Fisheries waterway *sensitivity* classification scheme as shown in Table 1 of the revised Policy and Guidelines document (NSW Fisheries 2013), the main Deep Creek channel throughout the study area is classified as a Type 1 “Highly sensitive key fish habitat”, owing to the presence of substratum and habitat types consistent with the definitions outlined for Type 1 habitats (gravel beds, boulders and snags).
In addition to the waterway *sensitivity* classification scheme, Deep Creek and its tributaries need to be assessed with regard to *functionality* as a fish habitat (Table 2 of the revised Policy and Guidelines document (NSW Fisheries 2013)):

- Deep Creek between DCUp and Hobarts Forest Rd bridge is regarded as a Class 2 “Moderate key fish habitat”, as it is a named watercourse with clearly defined bed and banks, with semi-permanent to permanent waters present in pools,
- Deep Creek downstream from Hobarts Forest Rd bridge is regarded as a Class 1 “Major Key Fish Habitat” by virtue of it being an estuarine waterway.
- Southern tributaries ST2, ST3 and ST4 and northern tributaries NT5 and NT7 are regarded as Class 3 “Minimal key fish habitat”, as they are unnamed watercourses

with intermittent flow, and sporadic refuge breeding areas for aquatic fauna with semi-permanent pools.

- Northern tributary NT6 is regarded as Class 4 “Unlikely fish habitat”, owing to its lack of definition (or incision) of drainage line, or pool forms capable of sustaining prolonged aquatic habitats.

1.4 Oyster Aquaculture in Karuah River

The Karuah River/Port Stephens Estuary is one of the largest shellfish aquaculture areas in the State with an output of some 592 tonnes of shellfish in 2019/20, the second largest production behind Wallis Lake at 712 tonnes and around 18% of the total NSW production. The main aquaculture shellfish species are Sydney Rock Oysters and Pacific Oysters and Port Stephens is the only estuary in the state that can grow and harvest naturalised Pacific Oysters. There are oyster aquaculture leases in the lower estuarine portion of Deep Creek and in Karuah River up- and down-stream of the Deep Creek confluence, and, as the Deep Creek Quarry proposal includes a need for stormwater discharges from settlement ponds plus the possibility of stormwater pond overflows during high rainfall events, consent or approval under the *Environmental Planning and Assessment Act 1979* (*EP&A Act) requires* the consent or determining authority to consider the potential impacts of the activity on oyster aquaculture areas in the locality. Given the current state of oyster aquaculture in the estuary following the devastating Sydney Rock Oyster losses to QX disease since early 2021, this requirement becomes paramount.

Appendix E provides an overview of oyster aquaculture in Port Stephens/Karuah River and **Section 4.1** provides a review of existing oyster infrastructure in Deep Creek and the immediate Karuah River. In context, the proposed stormwater discharges from the proposal are located between 2 to 3km upstream of The Bucketts Way road-crossing, with an additional 10.4km freshwater to estuarine creek reach to the lower Deep Creek oyster leases.

The NSW DPI publication *Healthy Estuaries for Health Oysters – Guidelines* (HEHO) DPI NSW 2017) provides advice on how to ensure development in close proximity to estuaries is compatible with the requirements of oyster aquaculture and the intended outcome of HEHO is to see development that protects the oyster industry, that estuarine water quality objectives are being met, and that new developments contribute to the objectives being met. HEHO outcomes are designed to both protect the environmental conditions required for healthy oyster production and improved estuarine health, increased amenity for tourism and improved conditions for recreational and commercial fisheries.

2 AQUATIC ECOLOGY SURVEY METHODS

Figures 3 to **5** show the extended Deep Creek study area and sites that were surveyed and **Table 1** provides GPS coordinates for sites sampled, The Deep Creek freshwater aquatic ecology field survey extended over four days between the 19th and 29th April 2022:

- Four in-stream sites sampled in Deep Creek (DCUp, DC1, DC4 and DC6) were sampled for aquatic macroinvertebrates and fish. Metered water quality sampling was undertaken at all four sites.
- An additional 18 sites were sampled for metered water quality in Deep Creek and in unnamed tributaries to Deep Creek bounding the proposed quarry site and access road.
- Overnight or extended period fish trapping was undertaken at three Deep Creek sites in close proximity to the proposed quarry.
- Additional habitat assessments were undertaken of the estuarine vegetation communities and of the distribution of oyster leases in the lower limits of Deep Creek and adjoining the Karuah River on 28th April 2022.

Table 1 Deep Creek Sample Schedule April 2022

Catchment	Site	Coordinates (MGA56)		Autumn 2022 Sampling		
		E	N	SDL	Aq Eco	Fish Trap
Deep Ck	DCUp	397510	6398538		x	
	DC1	397980	6397992		x	x
	DC2	398312	6397503	x		x
	DC4	399541	6396763		x	x
	DC5	399855	6395793	x		
	DC6-u	399226	6394534	x		
	DC6	399340	6394519		x	
	DCHFu	399412	6394066	x		
	DCHFd	399422	6394033	x		
	DC7	400869	6392697	x		
	DCDn	400287	6391728	x		
Northern tributaries	NT5dam	398589	6397589	x		
	NT5	398834	6397531	x		
	NT5d	398692	6397359	x		
	NT6	399138	6397491	x		
	NT7	399396	6397427	x		
Southern tributaries	ST2Up	397710	6398114	x		
	ST2Dn	397848	6398185	x		
	ST3Up	397815	6397792	x		
	ST3Dn	397994	6397943	x		
	ST4Dam	398036	6397578	x		
	ST5SD	398139	6396880	x		

Notes: SDL represents metered water quality readings recorded with a submersible data logger
Aq Eco includes SDL, macroinvertebrate and fish sampling and RCE
Fish trap represents overnight or extended period fish trapping

Appendix A provides a detailed description of the freshwater aquatic ecology sample methodology and macroinvertebrate metrics which are summarised as follows:

- Aquatic macroinvertebrate sampling at sites DCUp, DC1, DC4 and DC6 was undertaken using standard methods (AusRivAS) with sorting undertaken to proscribed identification levels as described in Turak et al (2004).
- The results were used to generate macroinvertebrate taxa metrics including Diversity (richness), SIGNAL and EPT indices where Diversity is the number of taxa per site, SIGNAL and EPT are pollution sensitivity indices with SIGNAL considering taxa at the Family level (see Chessman 2003a) and EPT considering taxa from three pollution sensitive orders (Ephemoptera, Plecoptera and Trichoptera).

In terms of overall facility construction works the proposed quarry access road would follow the approximate course of an existing track, crossing three of the southerly flowing tributaries to Deep Creek along the northern catchment area (**Figure 4**):

- The westernmost second-order creek northern tributary NT5 would contain crossings over two of its upper first order branches, with farm dams present on the upper western branch, including water quality metering site NT5dam on the upstream side of the property fence. During the April 2022 field survey, NT5 contained surface water with trickling flows throughout the inspection area, and water quality metering was undertaken in the upper eastern branch (NT5) and downstream of the upper branch confluence (NT5Dn).
- NT6 is a small first order drainage. Catchment runoff is distributed downstream under the existing track crossing via three pipe culverts, and while the tributary channel was mostly dry, water quality metering was undertaken in an isolated surface pool on the upstream side of the track crossing. There were no indications of incised pools or channels forms capable of sustaining aquatic habitats at NT6.
- NT7 is a second-order tributary. The proposed access road would cross both of its upper first order branches above their confluence. Whereas the western branch was completely dry during the field survey, the eastern branch contained trickling surface flows and aquatic habitats which was for the most part, continuous through to the confluence and downstream. Water quality metering was undertaken upstream in the eastern branch.

There are three tributaries in the southern catchment area that drain to Deep Creek where the quarry surface infrastructure and pit are proposed:

- ST2 is a second order creek which contained intermittent surface flows during the field survey. The proposal includes a gravel road crossing over ST2 drainage channel with piped culverts for ST2 stream flow, located between the quarry pit and stockpile areas just upstream of the existing road crossing. Currently runoff overtops the existing Deep Creek Rd crossing, and water quality metering was undertaken at sites above and below the road (ST2Up and ST2Dn respectively).

Figure 3 SIX Map aerial view of the aquatic ecology Deep Creek catchment study area. Refer to **Figure 4** (Inset 1) and **Figure 5** (Inset 2) below for more detail.

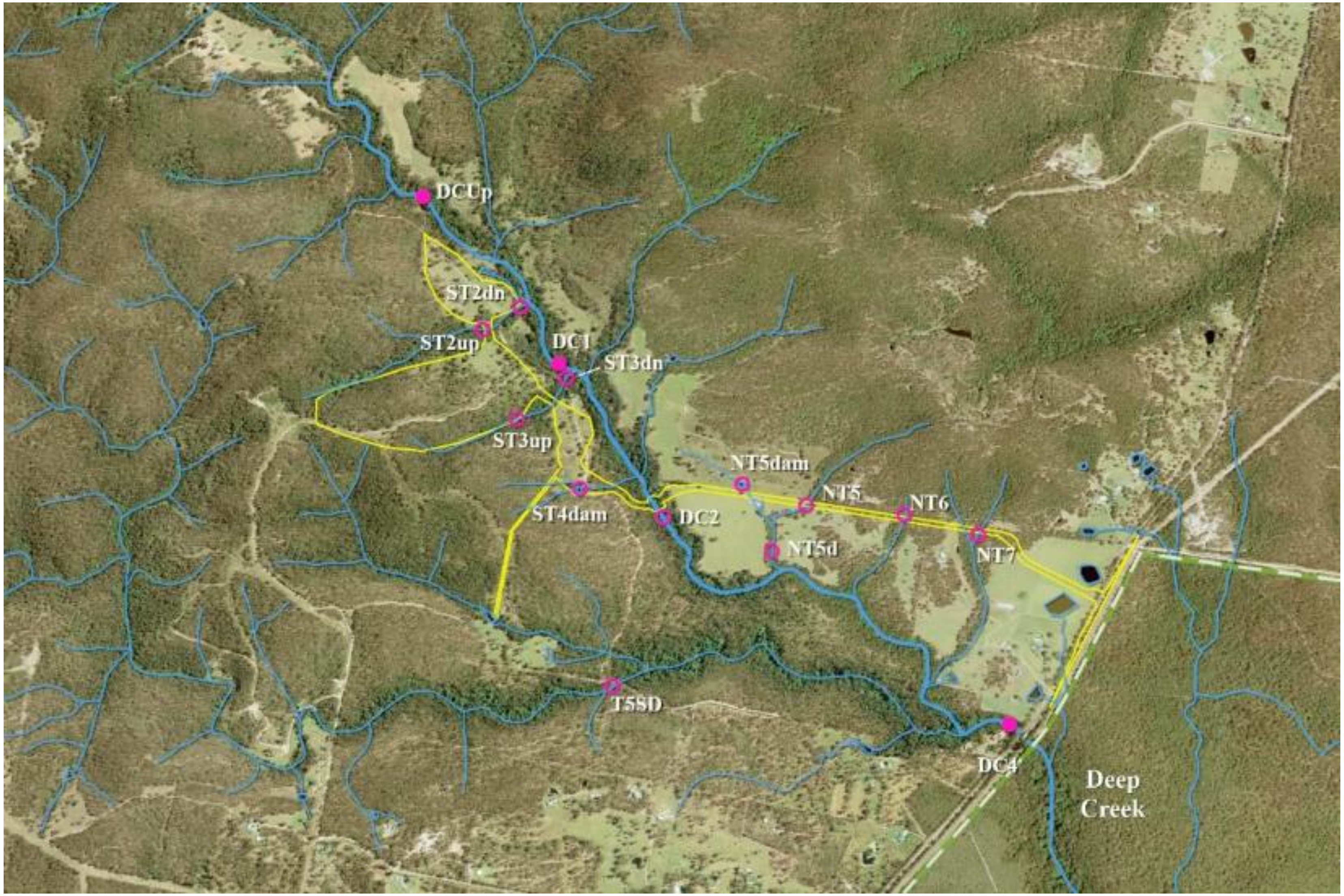

Figure 4 SIX Map aerial view of the upper Deep Creek catchment drainages (blue lines), showing the Deep Creek Quarry project footprint (yellow line), aquatic ecology (pink dots) and water quality metering (pink rings) sites, and Karuah National Park boundary (green dashed line).

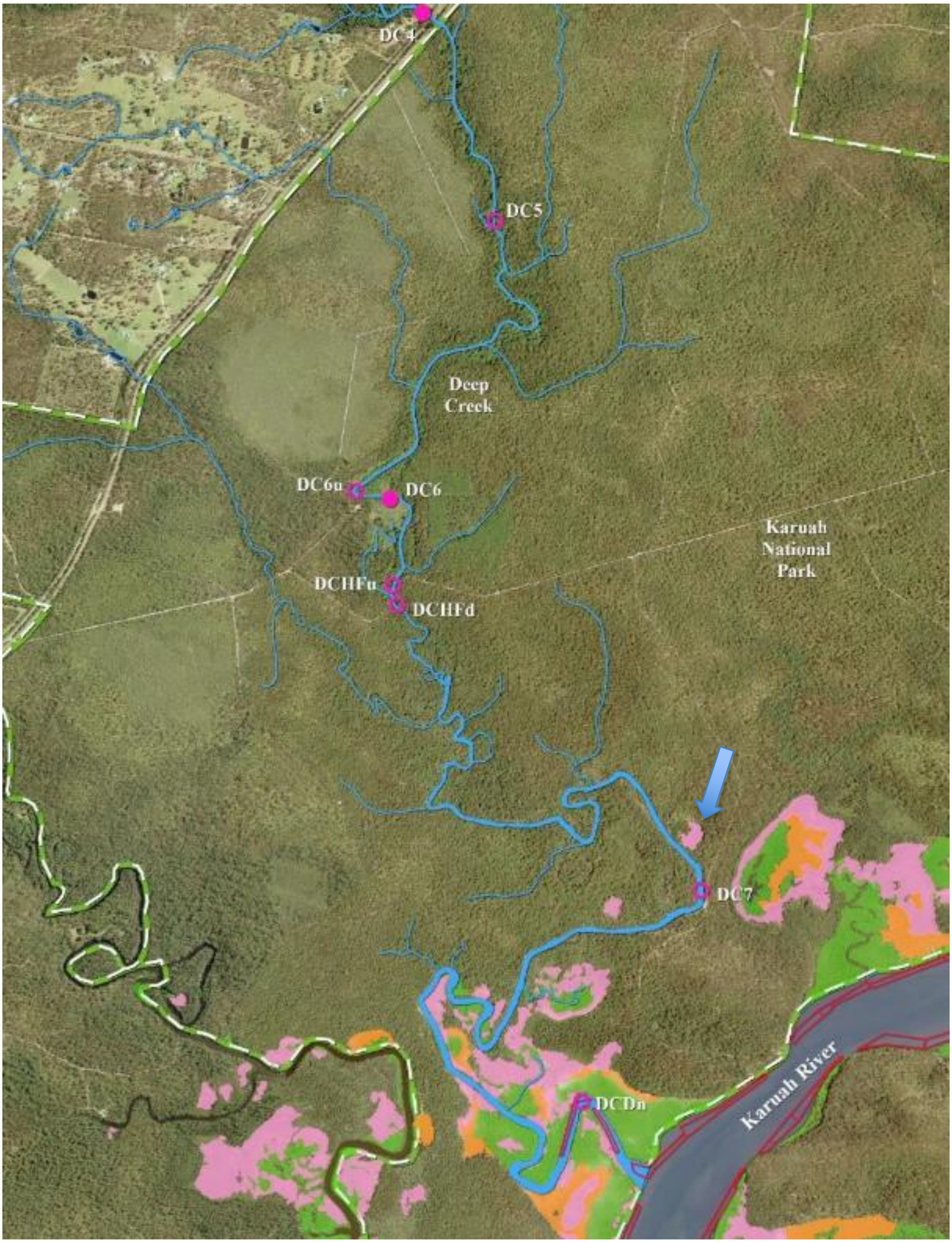

Figure 5 SIX Map aerial view of the lower Deep Creek catchment drainages (blue lines) within the Karuah National Park boundary (green dashed line). The aquatic ecology sites are shown as pink dots and the water quality metering sites are shown as pink rings. NSW Fisheries estuarine vegetation mapping from 2017 include mangrove (green shading), saltmarsh (pink) and mixed mangrove/ saltmarsh (orange) habitats, with blue arrow indicating saltmarsh area not included in the NSW Fisheries mapping. Oyster leases in the lower Deep Creek and Karuah River are shown in red. Note that the mangroves are generally continuous along Deep Creek between DCHF and DCDn.

- ST3 is a first order drainage channel, which supported intermittent surface flows during the April field survey. The proposal includes a gravel road crossing over ST3 drainage channel (upstream of the existing road crossing) with piped culverts for ST3 stream flows, joining the surface infrastructure (office and workshop) to the quarry pit. Currently runoff from the ST3 channel flows over the existing Deep Creek Rd and water quality metering was undertaken at sites above and below the road (ST3Up and ST3Dn respectively).
- ST4 is a small second order drainage. The proposal includes a culvert crossing over ST4 for the sealed quarry access road. There was no indication of incised channel forms upstream from the existing Deep Creek Rd, and currently runoff from the ST4 channel flows over the existing Deep Creek Rd from the inline dam. Water quality metering was undertaken within the dam (ST4dam), as there was no surface water observed upstream from the dam and only minimal water downstream (in small isolated surface pools).

The proposal includes a culvert road crossing over Deep Creek (upstream end of site DC2), with the potential for surface water discharge points to be placed into the Southern Tributaries ST2 and ST3. Accordingly, aquatic ecology sample sites and water quality monitoring was undertaken in Deep Creek upstream of the proposal (DCUp), in between ST2 and ST3 (DC1) and from several sites downstream including the Karuah National Park (DC2 to DCDn).

3 FRESHWATER AQUATIC ECOLOGY SURVEY RESULTS

Appendix B provides the locality rainfall data, the full results of water quality metering including depth profiles, Riparian Channel and Environment Inventory scores and macroinvertebrate and fish monitoring results. **Appendices C** and **D** provides detailed freshwater drainage descriptions, field notes and site photographs for Deep Creek and Tributary sample sites respectively:

- Deep Creek drainage line descriptions are summarised below in **Section 3.2**
- Freshwater habitats, aquatic and riparian condition results are in **Section 3.3**
- Water quality results are presented in **Section 3.4**.
- Aquatic ecology results are presented in **Sections 3.5**

3.1 Prevailing Weather Conditions

The Deep Creek aquatic ecology field survey was over four days between the 19th and 29th April 2022. **Appendix Table B-1** provides rainfall measurements at BOM Clarence town gauge (61010), 10km west of the study area Rainfall leading into the autumn 2022 survey was characterised by below average rainfall with brief dry periods in January to February, followed by consistent wet weather periods in early and late March (totalling 328mm):

- There was 57mm recorded over the two-week period leading into the survey, the majority of which fell 11 days prior to the commencement of sampling.
- A further 25mm was recorded as scattered light showers over the week in between sampling dates, which would have replenished catchment drainages and creek flows.

Surface flows were continuous throughout the length of Deep Creek within the study area (DCUp to DCDn) for the duration of the autumn 2022 survey, and trickling surface flows were noted in several of the tributaries to Deep Creek.

3.2 Deep Creek Drainage Line Descriptions

The study area of the main drainage line of Deep Creek comprises the freshwater sites between DCUp and downstream through DC6, with intertidal creek sections inspected at Hobarts Forest crossing (DCHF) plus DC7 and DCDn. The upper freshwater portion of Deep Creek catchment area above DCQ contains mixed land use with cleared agricultural land and remnant vegetation along the upper catchment areas and the mid upper catchment adjacent DCQ and to The Bucketts Way road crossing comprises mixed agriculture plots plus intact native vegetation along drainage channel riparian corridors.

The freshwater portion of Deep Creek in Karuah National Park extends from The Bucketts Way road crossing to site DCHF (Hobarts Forest Rd bridge) on **Figure 5** which is the tidal limit. The creek and its riparian boundary downstream of DCHF become progressively more estuarine, with estuarine intertidal vegetation (saltmarsh) extending upstream from Karuah River to at least the uppermost saltmarsh patch indicated with a blue arrow in **Figure 5**, and mangroves occurring along both banks of the creek upstream to DCHF (see **Section 4** for more detail).

3.3 Deep Creek freshwater habitats

Surface flows were continuous throughout the length of Deep Creek during the survey period and waters were generally turbid, inhibiting visual assessments of aquatic features (substrates, habitats) in pool areas deeper than 0.3 to 0.4m. For the freshwater creek sections, Deep Creek aquatic and riparian habitats were for the most part, consistent between DCUp downstream to DC5:

- The main drainage channel is meandering with moderately sloped to steep banks with bank undercutting noted throughout the length, incised to depths of 3 to 10m into the surrounding valley floor. The channel pool morphology was characterised by long pools with sluggish flows separated by shallow sandy runs (**Figure 6**). The pools were incised with undercut banks, and the overall pool dimension increased with increasing distance downstream (**Table 2** below).
- Livestock access to the creek channel was documented throughout Deep Creek upstream of DC4, which would likely contribute to reduced bank stability during flow events and contributions of mobile sandy sediments to pool habitats.

Table 2 Deep Creek Site Pool Dimensions

	Width (m)		Depth (m)	
	Max	Mean	Max	Mean
DCUp	4.5	2.5	0.9	0.3
DC1	5	3	1.2	0.5
DC2	5.5	3	1.4	0.6
DC4	8	5	1.8	1.2
DC5	7	3.5	1.5	0.8
DC6	11	6	2.5	1.2

- Bank substrates were comprised of sloped sandy sediments, isolated pockets of exposed clay on bends with localised areas of boulder or cobble rock embedded in that bank walls. The channel sediments were comprised mostly of mobile sandy sediment drifts and sections of gravels, and smaller quantities of bedrock, boulders or cobble riffles (the latter noted from DC4 only) (**Figure 7**).

- The main aquatic habitats that were sampled included undercut banks, trailing bank vegetation (mostly trailing root masses from riparian vegetation) and undercut banks. There were no established aquatic plant communities (macrophytes) observed through the upper freshwater section, with only small amounts of the floating duckweed (*Lemna sp*) noted form DC4.
- The riparian corridors were continuous, and provided a high degree of shading over the creek aquatic habitats (with moss present on edge banks and tree trunks), particularly so for the downstream site DC5 where the riparian corridor was more rainforest like with vines and palm trees (**Figure 8**).
- The channel bank edges supported sparse to moderate coverage of grasses, vines, ferns, mat-rushes (*Lomandra longifolia*) and *Carex* grasses in the understorey and large eucalypts, providing the main source of bank stabilisation from flood event flow scouring.
- There were sections of bank collapse and recently fallen trees observed throughout the freshwater section of Deep Creek, which were a likely result of flooding during the March flood event/s (**Figure 9** below). Log jams and detrital accumulations were present, however there were no large detrital deposits noted sufficient to cause black water environments or sulphur odours when disturbed.
- Most of the sites contained evidence of a high flow event which overtopped the riparian edge banks, in the form of debris accumulations and (recent) bank erosion, which reached between 3 and 6m above the background water levels. Several recent sand deposits were noted on instream bank ledges and on the top off banks bordering the main channel area.
- Orange iron staining and precipitation was present observed on banks and in pool edges at most sites.

Figure 6 Typical Deep Creek channel forms in the upper study area, showing shallow sandy gravel runs at DCUp (left) and DC2 (right).

Figure 7 Looking downstream through long, deep pool at DC4 (left) and cobble riffle section at DC4 (right).

Figure 8 Looking upstream at Karuah National Park site DC5 (left) and orange bank staining at DC1 (right).

Figure 9 Areas of active bank erosion were commonly encountered throughout the Deep Creek study area (DC1 left and DC4 right).

While adjoining channel sections up and downstream of DC6 contained habitat attributes consistent with the form observed upstream at DC5 (such as channel pool forms and aquatic habitats, edge bank vegetation and riparian canopy cover), site DC6 was sampled in a localised section of Deep Creek which contained different aquatic habitats to that observed upstream:

- The channel form contained one large pool, much broader than pools upstream and the vegetation along the channel banks were made up of sedges, grasses, ferns, with minimal canopy coverage over the waterbody. As a consequence, pool areas were more exposed to sunlight than habitats upstream and the site supported macrophyte growths (**Figure 10**).

Figure 10 Site DC6 contained more open pools and supported an assemblage of emergent and floating macrophyte species.

- The channel floodplain adjacent to the main (incised) creek channel are generally much flatter and broader than that observed upstream. It is likely that under flood conditions, floodwaters would be dispersed over a much large area, with lower velocity and less scouring of instream aquatic habitats than through the narrower V-shaped channel areas upstream. The overall aquatic habitat complexity was higher than sites DCUp to DC5, owing to the extent and composition of detritus (mixture of large woody and fine particulate material) and presence of macrophytes.
- Channel bank edge vegetation included mat-rushes, *Carex* grasses, bracken fern (*Pteridium esculentum*) and dense knotweed (*Persicaria sp*), and the pool macrophyte occurrences are provided below in **Section 3.3.1**.

3.3.1 Aquatic and riparian habitat condition

The overall Aquatic and Riparian Habitat condition - as estimated using the RCE Index - are provided for Deep Creek aquatic ecology sites and tributary inspection sites in **Appendix Table B-3**. **Tables 3** and **4** below provides a summary of the Deep Creek sample site and tributary site RCE results respectively, and the aquatic macrophyte occurrences are shown below in **Table 5**.

All of the inline creek Deep Creek site RCE scores indicate *good* to *very good* aquatic and riparian habitat conditions (at >70%). Each site recorded relatively high scores for the riparian categories, owing the intact and continuous vegetation corridors spanning the channel lengths, and the Karuah National Park sites (DC5 and DC6) recorded the highest values for 'land-use beyond immediate riparian zone' owing to the lack of cleared land adjacent to the creekline.

Table 3 Summary of Deep Creek RCE Results

Category	DCUp	DC1	DC2	DC4	DC5	DC6
Land-use pattern beyond immediate riparian zone	3	3	3	3	4	4
Width of riparian strip-of woody vegetation	4	4	4	4	4	4
Completeness of riparian strip of woody vegetation	4	4	4	4	4	4
Vegetation of riparian zone within 10 m of channel	3.5	3.5	3.5	3.5	4	3.5
Stream bank structure	3	2	3	3	3	3
Bank undercutting	2	2	2	2	2	3
Channel form	4	4	4	4	4	4
Riffle/pool sequence	3	3	3	3	3	2
Retention devices in stream	3	3	3	3	3	3
Channel sediment accumulations	2	2	2	3	2	2
Stream bottom	1	1	1	3	2	2
Stream detritus	4	4	4	4	4	3
Aquatic vegetation	4	4	4	4	4	2.5
Autumn 2022 RCE %:	77.9	81.7	77.9	83.7	82.7	76.9

With regard to channel related categories, bank undercutting was prevalent through most of the Deep Creek study area, and most sites recorded low category scores for 'channel sediment accumulations' due to the dominance of sandy sediments. The upstream sites DCUp to DC2 contained the overall highest proportions of unconsolidated, mobile sandy sediment drifts (estimated at 60 to 90% of site substrate composition), which resulted in the lowest category scores for 'stream bottom'.

All sites between DCUp and DC5 recorded high values for 'stream detritus' and 'aquatic vegetation' categories due to lack of detritus accumulations or aquatic vegetation, and it is possible that flood scouring in March 2022 may have contributed to the loss of detrital deposits.

The Deep Creek tributary scores ranged between 64% at NT5 and 92% at ST5SD (**Table 4**). Southern tributary site ST5SD is a much larger tributary with minimal clearing around the direct riparian zone compared to the other sites, and as such contained features which contributed to the high RCE score, including vegetation continuity and composition (plus lack of weeds), established channel form (frequent alternation of riffles and pools in the lower half) with sections of rocky substrates and lack of fine sediment accumulations.

Table 4 Summary of Deep Creek Tributary RCE Results

Category	NT5	NT5Dn	NT7	ST2up	ST2dn	ST3up	ST3dn	ST4dam	ST5SD
Land-use pattern beyond immediate riparian zone	2	2	3	3	3	4	3.5	3.5	4
Width of riparian strip-of woody vegetation	3	4	4	4	3	4	4	4	4
Completeness of riparian strip of woody vegetation	2	4	4	4	4	4	4	4	4
Vegetation of riparian zone within 10 m of channel	3	3	3	3	3	3	3	3	4
Stream bank structure	3	2.5	3	2.5	2.5	2.5	2.5	3	4
Bank undercutting	2	2	3	3	3	2	2	3	2
Channel form	3	4	2.5	4	4	4	4	2	4
Riffle/pool sequence	2	2	4	2	2	2.5	2	1.5	3.5
Retention devices in stream	2	2	3.5	3	3	3	3	1	3
Channel sediment accumulations	2	2	3	3	3	2.5	3	2	3.5
Stream bottom	2	1	3.5	3	3	3	3	3	4
Stream detritus	3	3	4	4	4	4	4	3	4
Aquatic vegetation	4	4	4	4	4	4	4	2	4
Autumn 2022 RCE %:	63.5	68.3	85.6	81.7	79.8	81.7	80.8	67.3	92.3

Each of the other site catchment areas were much smaller, containing smaller drainage channels and aquatic habitats, and most lacked formal sequencing of riffle and pool forms. Whilst clearing of land around the southern and northern tributary drainages contributed to reduced category scores for 'land use pattern beyond the immediate riparian zone', the immediate riparian corridors are for the most part, continuous and reflected in the other riparian related categories.

Livestock access to creek lines, particularly along the northern drainage lines would have likely influenced the mobilisation of sediments from channel bank walls through trampling and possibly the extent of understorey vegetation, in turn affecting the 'stream bank structure'.

There were no established macrophyte beds observed among the upper Deep Creek sites DCUp to DC4 (**Table 5**). Small quantities of the floating macrophyte duck weed (*Lemna sp*) were observed at DC4, however this may have been transported downstream from upstream sources (tributaries or dams) during flow events. Site DC6 supported several established native macrophytes, including water ribbons (*Cycnogeton sp*), cumbungi (*Typha sp*), jointed twigrush (*Baumea articulata*) and knotweed (*Persicaria sp*) around the pool edges, with smaller amounts of water primrose (*Ludwigia peploides*).

Table 5 Deep Creek Macrophyte Results April 2022

	Jointed Twigrush *Baumea articulata*	Water Ribbons *Cycnogeton sp*	Duckweed *Lemna spp*	Water Primrose *Ludwigia peploides*	Slender Knotweed *Persicaria decipens*	Cumbungi *Typha spp*
DCUp						
DC1						
DC4			1			
DC6	1	1		1	1	1

Macrophyte occurrences at the tributary drainage channel sites were limited to small quantities of knotweed and *Carex* grasses noted from NT5, NT7, ST2 and ST3, and submerged beds of water milfoil (*Myriophyllum sp*) were noted at ST5SD. Several lentic habitats (dams) were inspected, including two dams on NT5 western tributary, southern tributary site ST4dam and a dam located between the proposed stockpile area and Deep Creek (SPdam in **Figure 11** below).

Most of the dams supported peripheral macrophyte growth (**Figure 12** below). The dominant macrophytes included emergent species bulrush (*Schoenoplectiella mucronata*) and tall spikerush (*Eleocharis sphacelata*), with smaller quantities of rushes (*Juncus sp*), knotweed (*Persicaria* sp) and water primrose (*Ludwigia peploides*), frogsmouth (*Philydrum lanuginosum*), water couch (*Paspalum distichum*) and charophytes.

Figure 11 NT5dam showing dense coverage of the small floating macrophyte *Azolla pinnata* smothering the water surface, with emergents tall spikerush in the middle and bulrush around the edges (left), and ST4dam with bulrush stands around the perimeter, among other species.

Figure 12 SPdam supported emergent bulrush stands, cumbungi and water couch (left), and the proposed water supply dam site ST5NDdam photographed during the drought (14/1/2020) supports peripheral growths of cumbungi and water lilies *Nymphaea sp* (right). Photo supplied by Tim Mullaney.

3.4 Water Quality Results

Water quality metering was undertaken along length of the Deep Creek study area and the southern and northern tributary drainages, including intertidal sites downstream in Karuah National Park (DCHF, DC7 and DCDn). Analysis of the Karuah River tidal gauge data (https://tides.willyweather.com.au/nsw/hunter/karuah-river--karuah.html) indicates that the tide was ebbing when intertidal sites were sampled. Depth profile water quality readings were undertaken at all sites to identify potential differences in applicable parameters between surface and bottom layers (e.g., decreases in temperature or dissolved oxygen concentrations, increases in conductivity), and are provided in **Appendix B-4**.

There were no major differences between surface and bottom water quality readings at any location, and for the most part the Deep Creek pool waters were generally well mixed. **Table 6** below provides the results for surface sample water quality readings and includes the ANZG 2018 guideline values for NSW Lowland Rivers. The results are summarised as follows:

- Water temperatures were mostly similar among sites (range of 16.9°C to 19.0°C) however the farm dam site NT5dam produced the overall highest reading of 24.8°C. There is minimal riparian coverage over the waterbody at NT5dam and presumably responds more rapidly to fluctuations in air temperature and exposure to sunlight than lotic sites with riparian cover. Furthermore, the reading at downstream Deep Creek site DCDn (21.2°C) likely indicates the influence of mixing with warmer estuarine waters of the Karuah River.

Table 6 Deep Creek Catchment Surface Water Quality Results

Catchment	Site	Date	Time	Temp °C	Cond μS/cm	Sal ppt	DO %sat	DO mg/L	pH Units	Turb ntu
	ANZG 2018				*200-300		80-110		6.5-8.0	6-50
Deep Creek	DCUp	20/04/22	10:05	17.00	203	0.14	66.9	6.46	6.93	40.7
	DC1	20/04/22	9:26	16.86	209	0.14	61.8	5.99	6.85	55.6
	DC2	20/04/22	12:38	17.24	202	0.13	71.0	6.83	6.97	56.1
	DC4	29/04/22	8:05	17.51	308	0.18	80.9	7.73	7.07	71.9
	DC5	28/04/22	16:07	17.68	235	0.12	89.4	8.52	7.21	72.2
	DC6-u	20/04/22	13:37	18.24	240	0.14	55.2	5.20	6.84	57.7
	DC6	20/04/22	14:15	18.96	229	0.14	54.6	5.07	7.05	57.7
	DCHFu	20/04/22	14:34	18.06	387	0.22	54.6	5.16	6.88	56.5
	DCHFd	20/04/22	14:41	17.71	471	0.27	52.7	5.02	6.99	56.0
	DC7	28/04/22	11:27	19.03	2432	1.25	58.1	5.35	6.11	81.3
	DCDn	28/04/22	13:12	21.16	15480	9.01	66.5	5.61	6.89	32.1
Northern Tribs	NT5Dam	19/04/22	13:51	24.81	65	0.06	23.7	1.96	5.10	22.2
	NT5	19/04/22	13:33	17.85	120	0.08	68.5	6.51	6.21	77.7
	NT5d	19/04/22	14:17	17.12	92	0.07	23.5	2.26	5.76	52.2
	NT6	19/04/22	12:13	18.51	138	0.10	67.8	6.35	5.78	97.8
	NT7	19/04/22	12:25	19.23	151	0.10	63.5	5.87	6.10	35.3
Southern Tribs	ST2Up	20/04/22	10:38	17.63	148	0.11	24.6	2.35	6.51	48.3
	ST2Dn	20/04/22	10:58	17.19	158	0.11	33.4	3.21	6.65	63.8
	ST3Up	19/04/22	16:14	18.69	129	0.09	47.9	4.48	5.76	37.3
	ST3Dn	20/04/22	9:34	17.32	153	0.11	18.2	1.75	6.60	32.8
	ST4Dam	20/04/22	8:43	17.06	98	0.09	14.2	1.37	6.46	141.0
	ST5SD	20/04/22	8:12	16.72	247	0.16	78.3	7.61	7.19	66.5

Note: *Represents ANZG 2018 DGVs for NSW coastal rivers.
Values above ANZG 2018 guideline ranges at shaded orange and values below the range are shaded blue.
ANZG 2018 values were not applied to intertidal sites (DCHF, DC7 or DCDn).

- Water conductivity (EC) values were generally lower among the tributary sites compared to the receiving waters of Deep Creek, with all of the northern tributaries and the southern tributaries ST2, ST3 and ST4 recording values below the ANZG 2018 DGV range for NSW coastal rivers (200 to 300 μS/cm), with a range of 65 to 158 μS/cm. Site ST5SD supported the overall highest tributary EC which was similar to Deep Creek (247 μS/cm).
- EC values were for the most part, within the ANZG 2018 DGV range for the freshwater Deep Creek sites above DCHFu (DCUp to DC6), with single value at DC4 on 29th April being marginally higher (308 μS/cm). EC values were higher at DCHF sites and probably reflected the influence of freshwater runoff within a location subjected to tidal interactions. At the time of metering, the creek was discharging downstream with cascading flows underneath the Hobarts Forest Road bridge crossing at DCHF.
- Salinity values increased between DC7 (1.3ppt) and DCDn (9.0ppt) which is located just upstream from the Karuah River confluence. There was no indication of a salt wedge at the location of water quality metering for either DC7 or DCDn, and the visible downstream movement of water suggested that freshwater and tidal influences were well mixed.
- Surface water dissolved oxygen (DO) concentrations (expressed as % saturation) ranged from fair to good (from 53 to 89% sat) over all the Deep Creek sites, and DC4 and DC5 were the only sites to record values within the ANZ 2018 DGV range of 80 to 110% sat.
- DO values in the tributary sites were variable and mostly lower than values observed in Deep Creek. With the exception of ST5SD (78% sat), the southern tributary sites recorded the overall lowest DO values (range of 14 to 48% sat), and whilst the northern tributary sites NT5, NT6 and NT7 recorded moderate DO values (64 to 69 % sat), the larger pool sites NT5dam and NT5dn contained low DO concentrations (both 24% sat).
- With the exception of DC7 (6.1 pH units), water pH values were consistent across the range of Deep Creek sites, ranging between 6.8 and 7.2 pH units. All of the northern tributary sites recorded pH values below the ANZ 2018 DGV range of 6.5 to 8.0 pH units, varying between 5.1 and 6.2 pH units.
- While site ST5SD supported mildly alkaline surface waters (7.2 pH units), the remainder of southern tributary sites were acidic (5.8 at ST2Up to 6.7 at ST2Dn).
- Water turbidity was generally high, with most of the Deep Creek and tributary sites recording values above the ANZG 2018 range of 6 to 50 NTU.

3.5 Aquatic Ecology of the Study Sites

As described in **Section 2**, sampling and field sorting was undertaken using AusRivAS methods with taxa identified to the AusRivAS taxonomic levels. Multiple baited fish traps were set at each sampling site and left out for at least 1.5 hours, and additional netting plus observations were made for fish at each site. **Appendix Table B-5** provides the full macroinvertebrate and fish occurrence results, and **Table 7** provides the summary macroinvertebrate indices results. Aquatic macroinvertebrate edge sampling was undertaken at four sites along the freshwater length of Deep Creek (**Figures 4** and **5**), including one riffle macroinvertebrate sample at DC4. Fish trapping was undertaken at each macroinvertebrate site plus DC2 (see **Table 1** in **Section 2** for survey schedule).

The Deep Creek macroinvertebrate and fish sample results are summarised as follows:

- There was a total of 39 macroinvertebrate taxa recorded from the study area, comprising 30 insect taxa, 3 crustaceans, 2 gastropod and one bivalve mollusc, and one taxa each of mites, worms and flatworms. The individual site diversity (taxa richness) values for edge samples ranged between 15 taxa at DC1 and 22 taxa at DCUp, with 16 taxa were recorded from the DC4 riffle sample.

Table 7 Macroinvertebrate Indices Summary Results

Date	20/4/22	19/4/22	29/4/22	29/4/22	20/4/22
Site	DCUp	DC1	DC4	DC4	DC6
	Edge	Edge	Edge	Riffle	Edge
Diversity	22	15	16	16	18
SIGNAL-2	4.30	4.47	4.69	5.88	4.35
EPT	3	4	3	8	4

- Site SIGNAL-2 values were consistent between the edge sample sites, and ranged between 4.30 (DCUp) and 4.69 (DC4), with the DC4 riffle sample being higher at 5.88. Overall, the SIGNAL-2 values indicate the creek condition to be moderately to mildly impaired.
- The most commonly encountered taxa included families regarded as pollution sensitive; mayfly family Leptophlebiidae (SIGNAL value of 8) and caddisfly families Leptoceridae (SIGNAL 6) and Odontoceridae (SIGNAL 7), plus midge-fly sub-family Chironominae (SIGNAL 3) and diving beetles Dytiscidae (SIGNAL 2), each recorded at all sites.
- There were eight EPT taxa recorded from the study area, including two mayfly families (Baetidae and Leptophlebiidae), one stonefly (Gripopterygidae) and five

caddisflies (Hydrobiosidae, Leptoceridae, Odontoceridae, Philopotamidae and Tasimiidae), all of which were recorded from DC4 riffle sample.

With regards to fish and other invertebrates, there were no fish caught or trapped at upstream Deep Creek site DCUp (**Table 8**).

Table 8 Deep Creek Fish Sampling Results						
		DCUp	DC1	DC2	DC4	DC6
Striped Gudgeon	*Gobiomorphus australis*				x	x
Empire Gudgeon	*Hypseleotris compressa*		x	x	x	
*Eastern Gambusia	*Gambusia holbrooki*					x
Common Jollytail	*Galaxias maculatus*			x		
Fish larva						x
*Note: Represents introduced species						

For the other Deep Creek sites, three native species and one introduced pest species were recorded from the study area**:**

- Empire gudgeons were caught in overnight traps at DC1 (3 fish) and DC4 (7 fish), and in traps left for 4.5 hour during the day at DC2 (7 fish). A single common jollytail was also caught in traps at DC2 (**Figure 13** below).
- Striped gudgeons were retained in sample nets and traps at both DC4 and DC6.
- Plague minnow were caught and observed in small numbers at DC6 only.
- Animal tracks presumed to be Australian water rat, were observed at DC1 (**Figure 13**), and burrow openings were observed at DCUp, DC1 and DC4 (**Appendix C** Plate 5).

Figure 13 Clockwise from top left: empire gudgeon *Hypseleotris* compressa from DC4, common jollytail *Galaxias maculatus* from DC2, probable Australian water rat (*Hydromys chrysogaster*) tracks along the waters' edge at DC1 and empire gudgeons from DC2.

4 DEEP CREEK ESTUARINE HABITATS

The distribution of the major estuarine vegetation communities, as mapped by the NSW DPI Fisheries (2017) in and around the confluence of Deep Creek are shown in **Figure 5**:

- There were small quantities of river mangroves (*Aegiceras corniculatum*) extending up as far as Hobarts Forest Rd bridge crossing (**Figure 14**).
- There were additional areas of estuarine vegetation noted during the field survey that is not included in the NSW Fisheries mapping, including a more or less continuous strip of mangroves along the Deep Creek edge banks from DCHF to DCDn (for example see **Figure 15**), which increases in density with distance downstream.
- There was a patch of saltmarsh on the north-eastern side of Deep Creek, upstream of DC7 (see **Figures 5** and **16**) which is not included in the Fisheries' mapping, with several other small patches along the periphery of Deep Creek around 1km upstream from DC7 (these are yet to be confirmed).

A vast mangrove-saltmarsh vegetation complex occurs around the lower limits of Deep Creek and along the Karuah River (**Figures 5** and **17** to **20** below):

- The Deep Creek channel is incised with heavily undercut, steep banks in the lower tidal portion of the creek (**Figures 17** and **18**), supporting a dense mix of 1.5 to 2.0m high river and grey mangroves, and isolated large grey mangroves 5 to 8m in height.
- The lower Deep Creek saltmarsh areas were mostly vegetated, with smaller patches of exposed bare mudflat, and substrates comprised firm muddy sand around the upper intertidal to soft dark mud towards and along the river banks.
- Runoff from the saltmarsh drains to the main channel via numerous smaller channels of varying degrees of incision.
- The only large mangroves (>5m height) observed were grey mangroves, occurring mostly along the edges of drainage lines in lower Deep Creek and Karuah River, whereas both grey and river mangroves occurred in varying proportions along the edges of Deep Creek and saltmarsh drainage channels. Dense assemblages of mangroves short mangroves were observed over the large flat areas adjacent to the drainage channels, dominated by river mangroves (0.8 to 1.2m height) and scattered grey mangroves (1.0 to 3.0m height).

Figure 14 Looking upstream from Hobarts Forest Rd bridge crossing over Deep Creek (left) and looking downstream (right). This point represents the approximate upstream tidal limit in Deep Creek.

Figure 15 Looking upstream at DC7. This location contained both river mangroves and grey (*Avicennia marina*) mangroves, with a continuous strip confined to the immediate bank edges along the western bank (left) and fragmented growths along the eastern bank. There was no saltmarsh beyond the mangrove strip.

Figure 16 Looking upstream from DC7, showing floodplain saltmarsh adjacent to the main Deep Creek channel. This area was not included on the NSW Fisheries estuarine vegetation mapping.

Figure 17 Aerial image looking west (upstream) in the lower limits of Deep Creek.

Figure 18 Looking downstream along incised and undercut banks at DCDn.

The main features of the lower Deep Creek saltmarsh and mangrove habitats were as follows:

- Epiphytic growth of the red alga *Catenella nipae* were observed in varying quantities growing on grey mangrove structures (pneumatophores and tree trunks) in lower Deep Creek and along the Karuah River.
- Saltmarsh areas supported bands of almost monospecific species occupation, including samphire (*Sarcocornia quinqueflora*), sea rush (*Juncus kraussii*) and sea couch (*Sporobolus virginicus*) dominated saltmarsh bands (**Figures 20** and **21**). Other saltmarsh species present in smaller, localised areas included streaked arrow grass (*Triglochin striata*) and creeping brookweed (*Samolus repens*).
- Two burrowing estuarine crab species were observed on the saltmarsh mudflats and among mangrove habitats: mangrove sesarmid *Parasesarma erythodactyla* and the semaphore crab *Heloecius codiformis* (**Figure 22**).
- The upper edges of the saltmarsh transitioned to swamp paperbark stands on the lower side of eucalypt woodlands.
- There were no vehicular tracks or other major damage to estuarine habitats observed along the northern bank side of Deep Creek.

Figure 19 Aerial image looking east across the lower limits of Deep Creek and the confluence with the Karuah River in the distance.

Figure 20 Deep Creek estuarine vegetation community showing sea couch dominated saltmarsh with isolated outcrops of sea rush.

Figure 21 Samphire saltmarsh estuarine vegetation community in the lower limits of Deep Creek.

Figure 22 Two commonly encountered estuarine crabs in the lower Deep Creek saltmarsh; the red-fingered shore crab (left) and the semaphore crab (right).

In terms of potential seagrass distribution, the extended NSW Fisheries Port Stephens/ Karuah River mapping indicated a few small *Zostera* seagrass patches in the river between Karuah township and the Karuah River discharge to Port Stephens, some 7.2km downstream of Deep Creek confluence. For the present survey there were no seagrasses observed on the lower limit seabed of Deep Creek in the aerial drone imaging and none noted during specific field inspections of the lower creek banks. There was also no seagrass wrack observed along the creek or river bank edges or in the saltmarsh zones, further indicating that there was no seagrass present at the time of the field surveys. Based on the 2017 and earlier Fisheries' mapping none are expected.

4.1 Oyster Aquaculture Infrastructure

Appendix D provides a description of the Port Stephens, Karuah River Oyster Aquaculture Industry including mapping of oyster leases in the Deep Creek lower estuary. NSW Fisheries oyster infrastructure mapping indicates more or less continuous oyster lease infrastructure down each side of the Karuah River from 1.5km downstream of Allworth to the river mouth 18km downstream, and Deep Creek/River confluence infrastructure is located 10km upstream of the river delta.

As noted on **Figure 5,** oyster leases are present in the downstream limits of Deep Creek and Karuah River up and downstream of the Deep Creek confluence. Aerial drone imagery indicates that some of the oyster farm infrastructure was being utilised using stick and tray culture methods at the time of survey, with stock present on leases in the lower Deep Creek and in Karuah River up and downstream of Deep Creek (**Figures 23** and **24**).

Figure 23 Looking upstream in Deep Creek at oyster leases (along the southern bank). Note stock on racks at upper left.

Figure 24 Looking upstream in the Karuah River showing oyster lease infrastructure around the entrance of Deep Creek (blue arrow). Note stock on downstream river leases in lower left corner.

5 BASELINE AQUATIC ECOLOGY SUMMARY AND CONCLUSIONS

The April 2022 survey of Deep Creek was undertaken following consistent above average rainfall over the preceding months with the most recent flood event in March 2022 that left detritus flood lines indicating that water levels reached between 3 and 6m above the background water levels. Deep Creek catchments were saturated and surface water flow was continuous downstream through the length of the Deep Creek study area, from upstream of the proposed quarry and surface infrastructure (site DCUp) downstream through to the Karuah River. Each of the tributaries to Deep Creek which interact with the development footprint (quarry infrastructure along the southern catchment area and access road along the north) contained surface water and intermittent surface flows, in the form of trickling water or seepages, and there were several locations on the catchment slopes with boggy ground. Most of the dams inspected supported seepage discharge.

Large, deep pools are present throughout the length of Deep Creek and pool sizes increase with distance downstream from upstream site DCUp (maximum width/ depth of 4.5m and 0.9m) to downstream site DC6 (11m and 2 to 2.5m). Good potential fish habitats were encountered throughout the length of the Deep Creek study area at the time of survey, and there were four species of fish recorded. There were also fish refuges encountered among the tributary drainages in the form of deep, incised pools, however it is likely they would dry up during extended dry periods. With the exception of ST5, most of the tributary channel confluences with Deep Creek contained drop-offs which represented impassable barriers to the migration of fish upstream into tributary refuge pools upstream. Further, only the southern tributary ST5 and downstream portions of northern tributaries NT5 and NT7 appeared to contain pools capable of withstanding dry periods with recharge in any case.

Three native fish species were captured in Deep Creek study area above Bucketts Way bridge using baited fish traps and released; striped gudgeons, empire gudgeons and common jollytail, and the invasive pest species plague minnow was recorded at DC6. Plague minnow are more or less ubiquitous throughout east-flowing drainages in NSW and are listed as a key threatening process for Australian frogs. In the ecological context, the absence of this species from Deep Creek above Bucketts Way is considered beneficial for the resident native fish population and macroinvertebrates.

Water quality metering undertaken during the aquatic ecology survey provides a snapshot of post-flood conditions. The water quality results indicate that contributions of runoff from the smaller, more ephemeral tributaries (ST2, ST3, ST4, NT5 and NT7) would have lower electrical conductivity (range of 65 to 158 μS/cm) and pH (5.1 to 6.7 pH units) compared to the main Deep Creek channel adjacent the tributaries (conductivity range of 202 to 308

μS/cm and pH range of 6.9 to 7.1 pH units). Furthermore, dissolved oxygen results were lower and more variable in the tributary pools compared to Deep Creek, and surface waters were generally turbid at all sites, likely reflecting mobilisation of the finer particle fractions (clays) present in the channel walls and substrates from recent high flow events. These results are consistence with the observations that there was no flow consistency for the tributary channels over the survey period, and it is considered that tributary flow consistency only occurs during flood events.

Surface waters had elevated metered turbidity results, in line with the fact that Deep Creek and its tributaries support tannin-stained backwater aquatic habitats, resulting from mineralisation of organic material (from riparian vegetation deposits in pools) that produce dissolved organic matter, particularly during periods of lower flow. This, combined with other localised factors (high overhanging riparian vegetation coverage and flash-flood flow events), limit the potential for macrophyte establishment in Deep Creek habitats upstream of the Bucketts Way. Further downstream at site DC6) macrophytes thrive in the absence of overhanging riparian vegetation.

The pool biota aquatic habitats were limited to detrital accumulations and log jams, undercut banks and trailing bank vegetation (most root masses and sedge or edge rush trailing leaves). While most of the channel areas upstream of DC6 contained log jams and localised debris accumulations, the overall presence of detrital deposits was low, with many channel substrates being free of any particulate or coarse material. This was assumed to be a result of flood event scouring of the stream channel in March 2022.

Noting that fish passage was continuous through the length of Deep Creek between DC4 up to DCUp during the field survey, and on the conclusions from the study that stream connectivity and/or deeper pool waters would be maintained during baseflow conditions, the absence of fish from upstream site DCUp and the observations that most pool habitats and substrates between DCUp and DC4 were devoid of detrital accumulations supports the possibility that flooding contributed to some scouring and loss (or movement) of macroinvertebrates and fish downstream from the study area during peak flow velocities.

Whilst Deep Creek macroinvertebrate assemblages may also have been impacted by scouring effects from March floodwaters, individual site edge sample diversity ranged from 15 to 22 taxa per site, and are still considered to represent a reasonably diverse assemblage for the study period, with a total of 39 aquatic macroinvertebrate taxa recorded from the four Deep Creek freshwater study sites.

Accordingly, the combined Diversity, SIGNAL, EPT indices for the aquatic macroinvertebrate assemblage and their site habitat RCE condition indices provide a good preliminary aquatic ecology baseline condition against which potential project construction and operational impacts could be assessed.

6 AQUATIC ECOLOGY IMPACT AVOIDANCE

This Base-line aquatic ecology and oyster aquaculture report has highlighted the present viability and good condition of the freshwater aquatic ecology of Deep Creek, the good condition of the lower estuarine intertidal habitats in Deep Creek and the use of the lower Deep Creek estuary for commercial cultivation of oysters.

As noted in **Section 1.1** the proposal is for development and operation of a new single pit gravel quarry of about 31 hectares disturbance area extracting up to 500,000 tonnes per year for up to 30 years with progressive and final rehabilitation of the site to a mixture of open grassland and native vegetation. Operation will require on-site crushing facilities and stockpile areas and haulage of up to 4,000 tonnes per day during peak sales (125 laden truck movements) on a new private haul road that includes a Deep Creek crossing and a new intersection constructed at The Bucketts Way. Operation of the quarry will also require a pump out septic system for offsite septic disposal.

Section E-4 of **Appendix E** provides a synopsis of Karuah River water quality in relation to oyster aquaculture and this indicates that Karuah River waters during stormwater events have excessive nutrient and sediment levels, elevated heavy metal concentrations and elevated faecal coliform levels. The project Surface Water Impact Assessment (Appendix J for the project EIS), provides an assessment of existing site water quality that indicates existing tributary and dam water quality has natural low pH characteristics, occasional elevated nutrients, and occasional elevated heavy metals (copper, lead and zinc) and high iron concentrations, consistent with overall river water quality results.

Stormwater modelling has indicated that excessively large on-site storage dams would be needed to contain all stormwaters and that stormwater management is better achieved with smaller detention dams plus controlled discharges to Deep Creek, and it is anticipated that the project will require 4 to 9 controlled discharges to Deep Creek each year to maintain the modelled sediment basins at a capacity to capture runoff from storm events. In extreme events it is predicted that there could be one uncontrolled discharge (i.e. dam overtopping) on average per year. The project design includes two controlled discharges to two tributary discharge points to be established in southern tributaries immediately above and below the quarry footprint.

The EIS Appendix J Surface Water Report provides a Conceptual Water Management System and a proposed WMS that would form the basis of a site Water Management Plan (WMP) to be developed prior to construction, that will outline how the WMS is to be operated to meet EPL conditions within the requirements of the POEO Act, taking account of both historical and current water qualities in the surrounding watercourses, and current and future downstream water users. The WMP will include both water quality and aquatic ecology monitoring linked to a Trigger-Action-Response Plan (TARP).

As detailed in **Section 1.4** the WMP must be developed with consideration of avoiding potential impacts of the activity on downstream oyster aquaculture areas, under SEPP (Primary Production) 2021 Part 2.5 Sustainable Aquaculture Division 4. NSW DPI (2017) publication *Healthy Estuaries for Health Oysters – Guidelines* (HEHO 2017) provides advice on how to ensure water quality from developments in close proximity to estuaries is compatible with the requirements of oyster aquaculture.

With the implementation of a suitable WMP (developed in consultation with NSW DPI) the quarry is unlikely to 'have an adverse effect on oyster aquaculture development or a priority oyster aquaculture area. As such, the Consent Authority is able to determine the application consistent with Division 4 of the State Environmental Planning Policy (Primary Production) 2021.

7 REFERENCES

Adlard, R.D., Nolan, M.J (2015)
Elucidating the life cycle of *Marteilia sydneyi*, the aetiological agent of QX disease in the Sydney rock oyster (*Saccostrea glomerata*), International Journal for Parasitology

Chessman, B. C (1995)
Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology* 20, pp. 122-129.

Chessman, B. C., Growns, J. E. and Kotlash, A. R. (1997)
Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales. *Marine & Freshwater Research* 48, pp. 159-172.

Chessman, B. C. (2003a)
New Sensitivity grades for Australian river macroinvertebrates. *Marine & Freshwater Research* 54, pp. 95 - 103.

Chessman, B. C., (2003b)
SIGNAL 2 – A Scoring System for Macro-invertebrate (‘Water Bugs’) in Australian Rivers, Monitoring River Heath Initiative Technical Report no 31, Commonwealth of Australia, Canberra

DPI NSW 2021
NSW Oyster Industry Sustainable Aquaculture Strategy Forth Edition 2021

Grieve, A. and Theischinger, G. (2020)
A new record and microhabitat of *Austrocordulia leonardi* (Anisoptera, Libelluloidea incertae sedis). *Agrion* 24 (1): 45-47.

Haine et al (2011)
An ecological health assessment of the Karuah River. Report prepared for Great Lakes Council by NSW Office of Environment and Heritage.

NSW DPI (2016a)
Fish communities and threatened species distributions of NSW. NSW Department of Primary Industries, June 2013.

NSW DPI (2016b)
Primefact 184 2nd Edition. Threatened Species in NSW Sydney Hawk Dragonfly *Austrocordulia leonardi*.

NSW DPI (2017)
Primefact 1275 2nd Edition. Threatened Species in NSW Southern Purple Spotted Gudgeon *Mogurnda adspersa*.

NSW Fisheries (2013)
Policy and Guidelines for Fish Habitat Conservation and Management (2013 update), NSW Department of Primary Industries, June 2013.

Rubio A; Frances J; Coad P; Stubbs J; Guise K, (2013).
The onset and termination of the QX disease window of infection in Sydney rock oyster (*Saccostreaglomerata*) cultivated in the Hawkesbury River, NSW, Australia. Journal of Shellfish Research, 32(2):483-496.

Theischinger, G., Miller, J., Miller, R. & Krogh. M. (2009)
Rediscovery of Austrocordulia leonardi (Sydney Hawk) in the suburbia of Sydney. *Agrion* 13 (2): 50-53.

Turak, E, Waddell, N Johnstone, G. (2004)
New South Wales Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual. Department of Environment and Conservation, Sydney.

APPENDIX A

AQUATIC ECOLOGY SAMPLING METHODS

APPENDIX A

Field sampling encompasses overall aquatic and riparian habitat assessment, sampling for aquatic macroinvertebrates and fish and obtaining metered stream water quality data. MPR is licensed to conduct surveys in aquatic ecosystems under NSW Fisheries Scientific Collection Permit (Permit No. P12/0008-3.0).

1 Macroinvertebrate Sampling Methods

The aquatic macroinvertebrate assemblages are determined using the standardised National River Process and Management Program River Bio-assessment Manual methods (NRPMP 1994) as adapted for the National River Health Program (the AusRivAS method (Turak et al 2004, Chessman 2003b). 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. 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", and riffle samples collected from broken waters with only pebble, gravel, sand or bedrock substratum may not produce reliable results.
- Edge habitat is "an area along the creek with little or no current".

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

1.1 Field methods for macroinvertebrate sampling

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 reaches. Net samples were then placed into white sorting trays for in situ live sorting 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.

Rarer specimens for which positive identification could be made in the field (e.g., water scorpions), 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 that 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. Notes are also kept of the presence of burrows and holes that are present in the site aquatic habitats (i.e., as indications of yabbies or burrowing dragonflies). All retained specimens are placed in sample jars 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. Additionally, searches for exuviae of listed threatened species are made during the course of sampling and habitat assessments, and any potential findings are collected for later confirmation.

1.2 Laboratory methods for macroinvertebrate samples

In the laboratory, taxonomic identifications were undertaken using a Leica MZ95 binocular microscopes and taxonomic guides such as; CSIRO, Land and Water Resources & Environment Australia (1999), Hawking & Smith (1997), Hawking & Theischinger (1999), Theischinger (2009) and Williams (1980).

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

1.3 Site SIGNAL index & EPT Index calculations

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

SIGNAL indices may be regionally specific (e.g. SIGNAL HU-97 developed for the Hunter Valley Catchment (Chessman 1997), or applicable Australia wide (e.g. SIGNAL-2, Chessman 2003a).
Each macroinvertebrate Family has been assigned a SIGNAL score ranging from 10 (very pollution intolerant) to 1 (very pollution tolerant). For the present study SIGNAL-2 scores are applied. Taxa with no published SIGNAL score are excluded from the site SIGNAL analysis.

Once taxa SIGNAL indices have been applied individual site SIGNAL indices are calculated (as the mean) from all site taxa with SIGNAL scores. Creek SIGNAL scores are calculated as the mean of all taxa SIGNAL value occurrences recorded within each creek system for a survey. Site and creek SIGNAL scores are then summarised and compared across each survey and between surveys. As a general guide site SIGNAL Indices are graded into the following categories (Chessman *et al*. 1997):

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

However, as the intent of this study is to assess site condition relative to other sites over time, the site scores are used for these comparison purposes rather than as overall study area condition indices. That is, the overall changes in site indices over time are of greater interest than the basic and generalised 'health' scores (as per Chessman et al 1997).

The combined number of Ephemoptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddis-fly) families present per site (the EPT index) is used to supplement the taxa richness (diversity) and SIGNAL index as an indicator of stream health.

1.4 Field Sampling Methods for Fish and Other Vertebrates

At each macroinvertebrate sampling site, four fish bait traps (dimensions 250 mm by 250 mm by 400 mm, 4 - 5 mm mesh size and 50 mm diameter entrance) are set at suitable locations. These are left in the stream either overnight, or for the duration of the combined macroinvertebrate sampling and live picking survey (minimum 1.5 hours) and then retrieved. Captured fish are identified i*n situ* using Allen *et. al*., (2002) and McDowall (1996).and immediately released. Fish caught or observed as part of the macroinvertebrate dip net sampling are also identified, noted and released.

Dead fish specimens and any fish that cannot be positively identified in the field are taken to the Australian Museum for confirmation of species identification.
These specimens with capture details are then incorporated into the Australian Museum collection as appropriate. 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. Specimens are not kept or identified.

The presence of birds, reptiles and turtles that utilise the aquatic habitats are noted, and notes are made of the potential for the study area habitats to support platypus or Australian water rats where appropriate.

1.5 Field Water Quality Metering

A submersible Yeo-Kal 618 water quality data logger is used to record water depth, temperature, dissolved oxygen concentration and saturation, pH, conductivity and turbidity at all aquatic ecology sampling sites. At some sites, depth profiles of water quality may also be made to test for layering/mixing. Physical observations are also taken in the field to highlight any aquatic habitat variations (e.g. recent rain, subsequent infilling, detritus in water column or on benthos, scum or flocculates in or on water body etc.) and the presence of fresh yabbie holes are also noted.

1.6 Aquatic Habitat Condition (RCE Index)

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

APPENDIX B

RAINFALL DATA

FIELD SAMPLE DATA:

FIELD NOTES

WATER QUALITY

RCE

MACROINVERTEBRATE AND FISH

AUTUMN 2022

Appendix Table B-1 BOM Clarencetown Rain Gauge Records May 2021 to April 2022												
Year	2021								2022			
Date	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1st	0	0	0.2	0	0.2	0	0	0	0	0	3.4	19
2nd	0	0	1.2	0.4	0	2.2	0	0	0	1	11	2.2
3rd	0	0	0.2	0.4	0	0	0	0	3.6	9.8	26	0
4th	0	4.6	0	0	0	0	0	0.6	0	15.6	81.4	0
5th	3.2	0	0	0	2.8	0	1	1.4	6.4	6.6	17.6	0
6th	9.2	0	0	0	0	0	0	0	1.6	4.4	13	0
7th	15.4	0	0	0	0	0	0	4.4	0	2	5.2	0
8th	0.4	0	0	0	0	0	15.4	0	24	1.8	7.4	44
9th	0	4	0.8	0	0	0	0	29.8	1	3	16	1.4
10th	0	0	3.4	0	0	0	0	5.4	0	0	0	0
11th	0	1.8	6.2	0	0	15.2	7.2	0	0	0	0	0
12th	0	0	1.4	0	0	4.6	8.8	0	3	21.2	0	0
13th	0	0	1	0	0	8.6	0	0	0	0	0	6.4
14th	0	0	0.2	0	19	1.8	0	0	0	0	0	5.2
15th	0	0	0	0	2.4	1.8	0.4	0	0	0	0	0
16th	0.2	0	11.4	0	0	0	0	0	3	0	0	0
17th	0	1.6	3.4	0	0	0	0	0.8	0	0	0	0
18th	0	0	0	0	0	0	0	0	0	8.4	0	0
19th	0	0	0	0	0.2	0	0	0	18.4	0	0	0
20th	0	9.2	0	0	0	0.2	0.2	0.6	19	0	0	0
21st	0	6.8	0	0.2	0	1.2	15.2	0	0	0	0	0
22nd	7.8	0.2	0	0	2.6	4.4	27.8	0	0	0	0	16.8
23rd	0	0.2	0.2	0	0	0	7.8	0	0	2.4	0	2.8
24th	0	0.4	0	12.4	0	12	2.2	3.4	5	6.6	29	1
25th	0	1.6	0	6.6	0	0	4.2	1.2	0	9.4	34	4.4
26th	0	0	0	0	0.2	0	11.2	0	0	0	27	0
27th	0	0	0	0	0	0	23.2	0.2	0	2.4	9.4	0
28th	0	0	0	0	0	0	12	0.6	0	0	1.4	1.4
29th	0	3.8	0.4	0	0	0	0	0.8	0		3	0
30th	0.4	0.8	0	0	3.4	0	0	0.6	0		9	0
31st	0		0	0		0.2		0.2	0		13.2	
Highest Daily	15.4	9.2	11.4	12.4	19	15.2	27.8	29.8	24	21.2	81.4	44
Monthly Total	36.6	35	30	20	30.8	52.2	136.6	50	85	94.6	307	104.6
Mean	40.4	80.9	36.9	33.4	41.2	54	82.5	59.2	104.9	111.6	126.2	99.9
Note: Sample dates are shown in yellow.												

Table B-2 Field Comments –Deep Creek Aquatic Ecology Sample Sites April 2022		
Date	Site	Comments
20/4/22	DCUp	Surface water turbid with flow continuous throughout site length. Localised seepages coming in along bank edges with small amounts of orange precipitate. Maximum pool width to 4.5m and average width 2.5m, maximum depth 0.9m and average depth 0.3m. The site channel is meandering and incised 3 to 7m into the surrounding valley floor. Banks stabilised mainly by tree roots but very sandy, unstable and actively eroding in parts (particularly on bends), undercut banks present throughout site length, *Lomandra longifolia* present along channel edge banks. Moss present on site banks. High canopy cover over channel area. Signs of recent bank collapse, and evidence of recent high flow water levels breaching the top of banks (reaching 4m above background creek water levels). The riparian corridor is comprised mainly of native tree species with some weeds (lantana and privet). Overall, the aquatic habitats sampled included detritus, undercut banks and trailing bank vegetation (mostly root masses), however the pool basins were relatively devoid of detrital accumulations. No macrophytes observed. Site substrates dominated by sands, with smaller quantities of pebbles, gravels and cobbles. Possible Australian water rat burrow observed in channel banks (around 2m above water level). No Filamentous green alga observed.
20/4/22	DC1	Surface water turbid/ tannin stained with flow continuous throughout site length. Maximum pool width to 5m and average width 3m, maximum depth 1.2m and average depth 0.5m. Evidence of high flow water levels to 3 to 4m, with banks scoured free of detrital material. Channel banks sandy, steep and undercut, signs of recent banks collapse. Moss present on site banks. Site aquatic habitats consisting of long pools separated by shallow runs and constricted log jams. The aquatic habitats sampled included detritus, undercut banks and trailing bank vegetation (mostly root masses), however the pool basins were relatively devoid of detrital accumulations. The channel substrates were made up of mobile sandy sediments with isolated patches of gravels and pebbles. No macrophytes observed, and submerged end emergent logs present throughout site pools. *Lomandra longifolia* present along channel edge banks. Australian water rat tracks observed along instream sand banks, and possible burrow observed in channel banks (around 2 to 3m above water level). No filamentous green alga observed.
29/4/22	DC4	Water turbid and flowing through site length, sluggish in pool areas with broken water in downstream shallow constricted riffles. Maximum pool width to 8m and average width 5m, maximum depth 1.8m and average depth 1.2m. Evidence of flows to 5 to 6m above background water levels. High degree of canopy cover over waterbody. Site length drainage channel consisting of an incised long, deep pool with riffle section downstream. Banks steep, undercut throughout length and lined with *Lomandra longifolia,* eucalypts and water gums (*Tristaniopsis laurina*). Moss present on site banks. Channel pool basins generally free of detrital accumulations or particulate matter. The aquatic edge habitats sampled included detritus, undercut banks and trailing bank vegetation (mostly root masses), and the riffle samples were undertaken among cobble riffles downstream. The channel substrates were made up of bedrock, mobile gravelly sands with sections of cobbles, exposed clay in some sections of bank walls. Possible Australian water rat burrow observed in channel bank. No filamentous green alga observed.

20/11/20	DC6	Water brown and flowing through site, however mostly sluggish flow through deeper pool areas. Maximum pool width to 11m and average width 6m, maximum depth 2.5m and average depth 1.2m. Evidence of flows to 3m above background flow water levels, indications of floodwaters (debris accumulations) breaching floodplain banks. Pools broader than upstream, with narrow constricted channel areas (similar to other Deep Creek sites DCUp to DC4) up and downstream. Banks lined with *Lomandra longifolia, Carex* grasses, bracken fern (*Pteridium esculentum*) and dense knotweed (*Persicaria sp*). Small amounts of purple top (*Verbena bonariensis*) and *Bidens pilosa* on riparian floodplain banks. Aquatic macrophytes present throughout site pools, including water ribbons (*Cycnogeton sp*), cumbungi (*Typha sp*), jointed twigrush (*Baumea articulata*) and knotweed (*Persicaria sp*) around the pool edges, with small amounts of water primrose (*Ludwigia peploides*). The aquatic edge habitats sampled included macrophytes, detritus and trailing bank vegetation. The channel substrates were comprised mainly of sands with smaller quantities of gravels and pebbles, though difficult to determine the overall composition due to the amount of detritus accumulated in pool basins. Filamentous green alga present in small to moderate amounts.

Appendix Table B-3

Modified Riparian, Channel and Environment (RCE) Inventory (after Chessman et al 1997).

Descriptor			Deep Creek						Northern Tributaries			Southern Tributaries					
	Category	Value	DCUp	DC1	DC2	DC4	DC5	DC6	NT5	NT5Dn	NT7	ST2up	ST2dn	ST3up	ST3dn	ST4dam	ST5SD
1	Land-use pattern beyond immediate riparian zone																
	Undisturbed native vegetation	4					4	4						4			4
	Mixed native vegetation and pasture/exotics	3	3	3	3	3					3	3	3		3.5	3.5	
	Mainly pasture, crops or pine plantation	2							2	2							
	Urban, some vegetation	1															
	Industrial, little vegetation	0															
2	Width of riparian strip-of woody vegetation																
	More than 30 m	4	4	4	4	4	4	4				4		4	4	4	4
	Between 5 and 30 m	3							3	4	4		3				
	Less than 5 m	2															
	No woody vegetation	1															
	No Vegetation	0															
3	Completeness of riparian strip of woody vegetation																
	Riparian strip without breaks in vegetation	4	4	4	4	4	4	4		4	4	4	4	4	4	4	4
	Breaks at intervals of more than 50 m	3															
	Breaks at intervals of 10-50 m	2							2								
	Breaks at intervals of less than 10 m	1															
	No riparian strip at all	0															
4	Vegetation of riparian zone within 10 m of channel																
	Native tree and shrub species	4					4										4
	Mixed native and exotic trees and shrubs	3	3.5	3.5	3.5	3.5		3.5	3	3	3	3	3	3	3	3	
	Exotic trees and shrubs	2															
	Exotic grasses/weeds	1															
	No vegetation at all	0															
5	Stream bank structure																
	Banks fully stabilized by trees, shrubs, concrete	4															4
	Banks firm but held mainly by grass and herbs	3	3		3	3	3	3	3		3					3	
	Banks loose, partly held by sparse grass, rubble	2		2						2.5		2.5	2.5	2.5	2.5		
	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															
	Only on curves and at constrictions	3						3			3	3	3			3	
	Frequent along all parts of stream	2	2	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	4	4	4	4		4		4	4	4	4		4
	Medium; width:depth ratio 8:1 to 15:1	3							3								
	Shallow; width:depth ratio greater than 15:1	2									2.5					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	3										3.5
	Natural channel without riffle/pool sequence	2						2	2	2		2	2	2.5	2		
	Artificial channel; some riffle/pool sequence	1														1.5	
	Artificial channel; no riffle/pool sequence	0															
9	Retention devices in stream																
	Many large boulders and/or debris dams	4															
	Rocks/logs present; limited damming effect	3	3	3	3	3	3	3			3.5	3	3	3	3		3
	Rocks/logs present but unstable; no damming	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		3.5
	Bars of sand and silt common	2	2	2	2		2	2	2	2				2.5		2	
	Braiding by loose sediment	1															
	Complete in-filled muddy channel	0															
11	Stream bottom																
	Mainly clean stones with obvious interstices	4															4
	Mainly stones with some cover of algae/silt	3				3					3.5	3	3	3	3	3	
	Bottom heavily silted but stable	2					2	2	2								
	Bottom mainly loose and mobile sandy sediment	1	1	1	1					1							
	Bottom mainly loose and mobile muddy sediment	0															
12	Stream detritus																
	Mainly unsilted wood, bark, leaves	4	4	4	4	4	4				4	4	4	4	4		4
	Some wood, leaves, etc. with much fine detritus	3						3	3	3						3	
	Mainly fine detritus mixed with sediment	2															
	Little or no organic detritus, mainly sandy	1															
	No organic detritus, mainly mud	0															
13	Aquatic vegetation																
	Little or no macrophyte or algal growth	4	4	4	4	4	4		4	4	4	4	4	4	4		4
	Substantial algal growth; few macrophytes	3															
	Substantial macrophyte growth; little algal growth	2						2.5								2	
	Substantial macrophyte and algal growth	1															
	Total cover of macrophytes plus algae	0															
	RCE Score		40.5	39.5	40.5	43.5	43.0	40.0	33.0	35.5	44.5	42.5	41.5	42.5	42.0	35.0	48.0
	RCE %age		77.9	76.0	77.9	83.7	82.7	76.9	63.5	68.3	85.6	81.7	79.8	81.7	80.8	67.3	92.3

Appendix Table B-4 Deep Creek Catchment Water Quality Results

Catchment	Site	Date	Time	Depth	Temp	Cond	Sal	DO	DO	pH	Turb
				M	°C	µS/cm	ppt	%sat	mg/L	Units	ntu
Deep Ck	DCUp	20/04/22	10:05	0.1	17.00	203	0.14	66.9	6.46	6.93	40.7
	DCUp	20/04/22	10:05	0.3	17.01	203	0.14	66.7	6.44	6.93	40.6
	DCUp	20/04/22	10:05	0.4	17.00	208	0.14	66.6	6.44	6.94	40.8
	DC1	20/04/22	9:26	0.1	16.86	209	0.14	61.8	5.99	6.85	55.6
	DC1	20/04/22	9:26	0.3	16.85	210	0.14	62.1	6.02	6.64	58.9
	DC2	20/04/22	12:38	0.1	17.24	202	0.13	71.0	6.83	6.97	56.1
	DC2	20/04/22	12:39	0.3	17.07	218	0.14	67.6	6.53	7.00	56.8
	DC2	20/04/22	12:40	0.5	17.01	227	0.14	65.1	6.29	6.99	64.1
	DC4	29/04/22	8:05	0.1	17.51	308	0.18	80.9	7.73	7.07	71.9
	DC4	29/04/22	8:06	0.3	17.48	313	0.18	80.6	7.71	6.94	72.2
	DC4	29/04/22	8:06	0.5	17.48	316	0.19	80.3	7.68	6.93	68.5
	DC5	28/04/22	16:07	0.1	17.68	235	0.12	89.4	8.52	7.21	72.2
	DC5	28/04/22	16:08	0.3	17.67	217	0.12	88.3	8.42	7.20	72.7
	DC5	28/04/22	16:08	0.6	17.67	247	0.13	87.7	8.36	7.21	72.2
	DC6-u	20/04/22	13:37	0.1	18.24	240	0.14	55.2	5.20	6.84	57.7
	DC6-u	20/04/22	13:38	0.3	18.22	245	0.14	54.9	5.17	6.90	58.1
	DC6-u	20/04/22	13:38	0.5	18.22	270	0.15	54.7	5.15	6.95	58.4
	DC6	20/04/22	14:15	0.1	18.96	229	0.14	54.6	5.07	7.05	57.7
	DC6	20/04/22	14:16	0.3	18.44	228	0.14	54.7	5.14	7.05	58.3
	DC6	20/04/22	14:16	0.6	17.34	251	0.15	51.1	4.90	7.08	61.2
	DCHFu	20/04/22	14:34	0.1	18.06	387	0.22	54.6	5.16	6.88	56.5
	DCHFu	20/04/22	14:34	0.3	17.88	396	0.22	49.1	4.65	6.90	56.3
	DCHFu	20/04/22	14:34	0.5	17.86	427	0.24	48.9	4.64	6.97	56.6
	DCHFd	20/04/22	14:41	0.1	17.71	471	0.27	52.7	5.02	6.99	56.0
	DCHFd	20/04/22	14:41	0.3	17.70	483	0.27	52.2	4.97	6.99	55.7
	DCHFd	20/04/22	14:41	0.5	17.69	524	0.29	52.0	4.95	7.01	55.6
	DC7	28/04/22	11:27	0.1	19.03	2432	1.25	58.1	5.35	6.11	81.3
	DC7	28/04/22	11:27	0.3	18.99	2358	1.21	57.1	5.26	6.23	81.2
	DC7	28/04/22	11:28	0.5	18.97	2324	1.19	56.9	5.25	6.27	82.5
	DC7	28/04/22	11:29	0.7	18.96	2280	1.17	56.7	5.23	6.32	82.1
	DC7	28/04/22	11:30	0.9	18.97	2357	1.21	56.6	5.22	6.33	80.7
	DCDn	28/04/22	13:12	0.1	21.16	15480	9.01	66.5	5.61	6.89	32.1
	DCDn	28/04/22	13:13	0.3	21.11	15320	8.92	65.7	5.55	6.93	31.9
	DCDn	28/04/22	13:13	0.5	21.02	15260	8.87	65.4	5.54	6.94	32.2
	DCDn	28/04/22	13:14	0.6	21.02	15390	8.96	65.1	5.51	6.95	34.0
	DCDn	28/04/22	13:14	0.8	21.07	15380	8.95	65.2	5.51	6.96	35.0
	DCDn	28/04/22	13:15	1.2	21.12	15500	9.03	65.3	5.51	6.97	39.1
Northside Tribs	NT5Dam	19/04/22	13:51	0.1	24.81	65	0.06	23.7	1.96	5.10	22.2
	NT5Dam	19/04/22	13:51	0.3	24.14	64	0.06	20.9	1.76	5.10	21.5
	NT5	19/04/22	13:33	0.1	17.85	120	0.08	68.5	6.51	6.21	77.7
	NT5	19/04/22	13:33	0.3	18.35	120	0.08	67.7	6.36	6.20	77.4
	NT5d	19/04/22	14:17	0.1	17.12	92	0.07	23.5	2.26	5.76	52.2
	NT5d	19/04/22	14:17	0.3	18.18	104	0.07	24.5	2.32	5.83	51.2
	NT6	19/04/22	12:13	0.1	18.51	138	0.10	67.8	6.35	5.78	97.8
	NT7	19/04/22	12:25	0.1	19.23	151	0.10	63.5	5.87	6.10	35.3
	NT7	19/04/22	12:25	0.3	19.20	151	0.10	63.3	5.85	6.11	34.8
Southside Tribs	ST2Up	20/04/22	10:38	0.1	17.63	148	0.11	24.6	2.35	6.23	48.3
	ST2Up	20/04/22	10:38	0.2	17.41	148	0.11	19.1	1.83	6.23	48.6
	ST2Dn	20/04/22	10:58	0.1	17.19	158	0.11	33.4	3.21	6.65	63.8
	ST2Dn	20/04/22	10:59	0.3	17.11	158	0.11	32.4	3.13	6.62	63.4
	ST3Up	19/04/22	16:14	0.1	18.69	129	0.09	47.9	4.48	5.76	37.3
	ST3Up	19/04/22	16:15	0.2	18.33	128	0.09	45.2	4.26	5.77	36.8
	ST3Up	19/04/22	16:16	0.3	17.81	129	0.09	33.0	3.13	5.77	38.0
	ST3Up	19/04/22	16:17	0.4	17.64	134	0.10	38.8	3.71	5.83	37.6
	ST3Up	19/04/22	16:17	0.5	17.61	142	0.10	40.8	3.89	5.87	37.5
	ST3Dn	20/04/22	9:34	0.1	17.32	153	0.11	18.2	1.75	6.60	32.8
	ST3Dn	20/04/22	9:34	0.3	17.32	153	0.11	18.0	1.73	6.60	32.8
	ST4Dam	20/04/22	8:43	0.1	17.06	98	0.09	14.2	1.37	6.46	141.0
	ST4Dam	20/04/22	8:44	0.2	17.07	97	0.09	12.7	1.23	6.26	125.9
	ST4Dam	20/04/22	8:44	0.4	17.08	98	0.09	11.8	1.14	6.33	145.6
	ST4Dam	20/04/22	8:45	0.7	17.07	99	0.09	10.6	1.03	6.35	148.2
	ST5SD	20/04/22	8:12	0.1	16.72	247	0.16	78.3	7.61	7.19	66.5
	ST5SD	20/04/22	8:12	0.4	16.72	250	0.16	77.3	7.52	7.05	65.9

Appendix Table B-5 Deep Creek Karuah Macroinvertebrate and Fish Sample Results												Sample Site and Sample Date						
									Life Stage			20/4/22	19/4/22	29/4/22	29/4/22	20/4/22		
Phylum	Class	Sub-Class	Order	Sub-Order	Family	Sub-Family	Genus/spp	Common name	L	N	A	DCUp	DC1	DC4	DC4-R	DC6	Occurrence	SIG-2
Arthropoda	Insecta		Coleoptera		Dytiscidae			Diving Beetles	x		x	1	1	1		1	4	2
Arthropoda	Insecta		Coleoptera		Gyrinidae			Whirligig Beetles	x		x	1					1	4
Arthropoda	Insecta		Coleoptera		Hydrophilidae			Scavenger Water Beetles			x	1	1				2	2
Arthropoda	Insecta		Coleoptera		Psephenidae			Water Pennies	x			1			1		2	6
Arthropoda	Insecta		Coleoptera		Scirtidae			Marsh Beetles	x			1	1	1			3	6
Arthropoda	Insecta		Diptera		Athericidae			Snipe Flies	x					1			1	8
Arthropoda	Insecta		Diptera		Ceratopogonidae			Biting Midges	x					1	1		2	4
Arthropoda	Insecta		Diptera		Chironomidae	Chironominae		Bloodworms	x			1	1	1	1	1	5	3
Arthropoda	Insecta		Diptera		Chironomidae	Tanypodinae		Bloodworms	x			1		1		1	3	4
Arthropoda	Insecta		Diptera		Simuliidae			Black Flies	x				1	1	1	1	4	5
Arthropoda	Insecta		Diptera		Tipulidae			Crane Flies	x						1		1	5
Arthropoda	Insecta		Ephemeroptera		Baetidae			Mayflies		x					1		1	5
Arthropoda	Insecta		Ephemeroptera		Leptophlebiidae			Mayflies		x		1	1	1	1	1	5	8
Arthropoda	Insecta		Hemiptera		Gelastocoridae			Toad Bugs						1			1	5
Arthropoda	Insecta		Hemiptera		Gerridae			Water Striders				1	1	1			3	4
Arthropoda	Insecta		Hemiptera		Hydrometridae			Water Measurers					1	1			2	3
Arthropoda	Insecta		Hemiptera		Notonectidae			Backswimmers				1				1	2	1
Arthropoda	Insecta		Hemiptera		Pleidae			Pygmy Backswimmers						1		1	2	2
Arthropoda	Insecta		Hemiptera		Veliidae			Small Water Striders				1	1	1			3	3
Arthropoda	Insecta		Megaloptera		Corydalidae			Dobsonflies	x			1			1		2	7
Arthropoda	Insecta		Odonata	Epiproctophora	Cordulephyidae			Dragonflies	x			1					1	5
Arthropoda	Insecta		Odonata	Epiproctophora	Corduliidae			Dragonflies	x							1	1	5
Arthropoda	Insecta		Odonata	Zygoptera	Argiolestidae			Damselflies	x			1	1	1		1	4	5
Arthropoda	Insecta		Odonata	Zygoptera	Coenagrionidae			Damselflies	x				1			1	2	2
Arthropoda	Insecta		Plecoptera		Gripopterygidae			Stoneflies		x			1		1	1	3	8
Arthropoda	Insecta		Trichoptera		Hydrobiosidae			Caddis Flies	x						1		1	8
Arthropoda	Insecta		Trichoptera		Leptoceridae			Caddis Flies	x			1	1	1	1	1	5	6
Arthropoda	Insecta		Trichoptera		Odontoceridae			Caddis Flies	x			1	1	1	1	1	5	7
Arthropoda	Insecta		Trichoptera		Philopotamidae			Caddis Flies	x						1		1	8
Arthropoda	Insecta		Trichoptera		Tasimiidae			Caddis Flies	x						1		1	8
Arthropoda	Arachnida		Acarina	Hydracarina				Freshwater Mites				1				1	2	6
Arthropoda	Crustacea	Branchiopoda	Diplostraca	Cladocera				Water Fleas				1				1	2	*
Arthropoda	Crustacea	Copepoda	Cyclopoida		Cyclopidae			Copepods				1					1	*
Arthropoda	Crustacea		Decapoda		Atyidae			Freshwater Shrimp				1	1			1	3	3
Annelida	Oligochaeta							Freshwater Worms				1			1		2	2
Mollusca	Bivalvia				Sphaeriidae			Pea Shells								1	1	5
Mollusca	Gastropoda				Ancylidae			Freshwater Limpets							1		1	4
Mollusca	Gastropoda				Planorbidae			Freshwater Snails								1	1	2
Platyhelminthes	Turbellaria		Seriata		Dugesiidae			Flatworms				1					1	2
Chordata	Osteichthyes				Eleotridae		*Gobiomorphus australis*	Striped Gudgeon					1	1		1	3	*
Chordata	Osteichthyes				Eleotridae		*Hypseleotris compressa*	Empire Gudgeon						1			1	*
Chordata	Osteichthyes				Poeciliidae		*Gambusia holbrooki*	Eastern Gambusia								1	1	*
								Total number of invertebrate taxa per site:				22	15	16	16	18	39	37
								Site SIGNAL2 Scores:				4.30	4.47	4.69	5.88	4.35		
Notes:	* Represents those taxa for which SIGNAL-2 scores are not available, or do not apply										EPT:	3	4	3	8	4	8	

APPENDIX C

AQUATIC ECOLOGY SITE

SITE PHOTOGRAPHS

AUTUMN 2022

PLATES 1 TO 17

Plate 1: Looking upstream along steep channel bank at DCUp.

Plate 2: Looking upstream through shallow pool at DCUp.

Plate 3: Plate Looking upstream at DCUp through shallow gravel run.

Plate 4: Looking upstream at undercut banks stabilised by tree roots at DCUp.


Plate 5: Possible Australian water rat burrow in DCUp bank.


Plate 6: Looking upstream through incised pool in DC1.

Plate 7: Looking upstream at DC1.

Plate 8: Looking upstream through section of sand and gravel banks at DC1.

Plate 9: Australian water rat tracks at DC1.

Plate 10: Looking upstream through open pool section at DC4.

Plate 11: Looking downstream at DC4.

Plate 12: Looking downstream towards Bucketts Way bridge at DC4.

Plate 13: Looking downstream through constricted cobble and gravel riffle section at DC4.

Plate 14: Looking upstream at open channel pool habitats at DC6.

Plate 15: Looking downstream at DC6.

Plate 16: Looking upstream through open pool with macrophytes (water ribbons and knotweed).


Plate 17: Looking upstream at BC6.

APPENDIX D

DEEP CREEK TRIBUTARY

SITE FIELD NOTES AND

PHOTOGRAPHS

AUTUMN 2022

PLATES 1 TO 46

Appendix D

Southern Tributary 2 (ST2) **20/4/2022**

ST2 is a 2nd order tributary to Deep Creek which covers a linear distance of 970m from source to confluence with Deep Creek. Surface waters were brown coloured with some isolated areas of orange precipitation, and there was a low trickle flow present throughout the channel sections at ST2up and ST2Dn, with some (infrequent) isolated dry sections between pools. Evidence of storm flow event runoff (debris accumulations, slanted vegetation) indicate that recent water levels reached around 1m above the current water levels (Plates 1 and 2).

The stream channel is incised and meandering with regular alternation of shallow runs and pools supporting undercut banks, maximum pool depths reached 0.5m however most pools were shallow (<25cm depth) and the maximum pool widths reached 2m. The stream channel banks were generally exposed sandy clays containing sparse to moderate amounts of leaf litter, and the instream channel substrates consisted mostly of mobile sands, cobbles and gravels.

The riparian vegetation corridor was dense and continuous along the stream channel length providing a high degree of cover, with *Carex* grasses, *Lomandra longifolia*, knotweed (*Persicaria sp*), sedges (*Gahnia sp*), ferns and mosses growing along channel edges, and patches of lantana were noted mostly in the lower ST2 limits downstream from the track crossing. There were no aquatic macrophytes observed.

Plate 1: Looking upstream through open pool area at ST2Up.

Plate 2: Looking downstream through transition from pool to shallow run at ST2Up, note the slanted sedges along the stream edges indicative of recent flow events.

Plate 3: Looking downstream at steeply incised bank at ST2Up.

Plate 4: Looking upstream at ST2 Deep Creek Rd crossing.

Plate 5: Looking downstream through shallow pools separated by earthen runs and trickling flows.

Plate 6: Water metering site pool at ST2Dn.

Appendix D

Southern Tributary 3 (ST3) **19-20/4/2022**

ST3 is a 1st order tributary covering a distance of around 790m from the upper catchment boundary to its confluence with Deep Creek. Surface waters were generally turbid grey or brown coloured. Surface flows were intermittent throughout the channel between ST3Up downstream to Deep Creek confluence, trickle flows were observed in some shallow runs however other sections of the tributary channel contained isolated pools separated by dry channel (Plate 10). Water was trickle flowing over Deep Creek Rd crossing, and pools downstream of the road crossing were mostly shallow (<30cm deep), with a fish barrier present (in the form of a drop) at the junction with Deep Creek.

The channel area contained some deep, incised pools (Plate 9) separated by narrow and shallowly incised, meandering earthen runs, the maximum pool depth was around 0.9m and the maximum pool width was 3m. Some pools were formed from logs jams and detrital accumulation (Plate 14). Sections of the channel banks were actively eroding and had recently slumped, bank undercutting prevalent through site. The channel sediments comprised mostly cobbles and gravelly sands, with some boulders.

The riparian corridor was dense and overgrowing the channel pools in parts, moss was present along the channel banks and on logs, with *Carex* grasses, *Lomandra longifolia*, sedges (*Gahnia sp*), ferns and mosses growing along the channel edges. No macrophytes observed.

Plate 7: Looking upstream at ST3 up water quality metering pool.

Plate 8: Looking downstream from ST3Up water quality metering pool.

Plate 9: Looking downstream through incised pool just downstream from ST3Up.

Plate 10: Looking upstream through dry section of channel in ST3, note the lack of channel incision.

Plate 11: Looking upstream through shallow incised surface pool in ST3 drainage channel.


Plate 12: Looking upstream from the Deep Creek Rd crossing.


Plate 13: Looking downstream from Deep Creek Rd crossing.


Plate 14: Looking upstream at ST3Dn water quality metering pool.

Appendix D

Southern Tributary 4 (ST4) **20/4/2022**

Southern Tributary drainage ST4 is a small second order tributary which flows for around 530m from the upper catchment boundary to its confluence with Deep Creek. A farm dam exists midway down the tributary, just above the Deep Creek Rd crossing (water quality metering site ST4dam). There was no channel incision or channel forms capable of sustaining aquatic habitats (e.g., incised pool basins) observed upstream or downstream of the dam. Upstream of the dam rainfall runoff is likely to occur as sheet flow or via multiple shallow streams across the broad flat swale (Plate 15), and whilst there was no surface water observed upstream of the dam, it was boggy underfoot. Several aquatic plants were noted in the dam, primarily bulrush *Schoenoplectiella mucronata*, with smaller quantities of rushes (*Juncus sp* and *Eleocharis spp*), frogsmouth (*Philydrum lanuginosum*), water primrose (*Ludwigia peploides*), water couch (*Paspalum distichum*) and charophytes.

A small seepage flow was present in one of the dam outlet drains (along the western edge), however there was no surface flow over the road crossing (Plate 18). Downstream from the road crossing, the drainage becomes more channelised, with a series of incised pools separated by dry channel runs.

Plate 15: Looking upstream from dam at broad shallow drainage swale.

Plate 16: Water quality metering site ST4dam.

Plate 17: Looking downstream toward Deep Creek Rd crossing from ST4dam.

Plate 18: Looking east at Deep Creek Rd crossing.

Plate 19: Looking downstream from Deep Creek Rd crossing.

Plate 20: Typical scour pool in the channel area downstream of Deep Creek Rd crossing in ST4.

Plate 21: Looking downstream in drainage channel in ST4.

Appendix D

Southern Tributary 5 Southern Drainage (ST5SD) **20/4/2022**

The southern arm of the Southern Tributary Drainage ST5 is a larger fifth order creek entering Deep Creek just upstream from the Bucketts Way bridge. From its headwaters, ST5SD runs for around 8.4km to its junction with Deep Creek. A small second order northern sub-catchment tributary (referred to as ST5ND) that drains to ST5SD just below the Deep Creek Rd crossing contains a farm dam which had been proposed as a water supply dam.

The ST5SD creek drainage was assessed up and downstream of Deep Creek Rd crossing. The drainage is characterised by an incised channel, with long pool upstream of the crossing (Plate 22) which leads into a meandering series of constricted riffles and shallow pools underneath the crossing, which is continued downstream. Maximum pool width reached 8m and the maximum depth was around 1.3m. Channel substrates included sections of cobbles and boulders/ bedrock and gravelly sands. Surface flows were continuous throughout the inspection area and waters were generally turbid, with evidence of high flow event water levels reaching 3m above the background water levels (and 30m in width), which would have overtopped the bridge crossing.

Water milfoil (*Myriophyllum sp*), whirligig beetles (family Gyrinidae) and water striders (family Gerridae) observed. The riparian corridor was continuous and provided a high degree of cover over the aquatic habitats, and the channel edge bank woody vegetation was comprised mostly of water gums (*Tristaniopsis* laurina) with some melaleuca present, and *Lomandra longifolia* lined the edge banks above the water line.

Plate 22: Looking upstream through long pool in ST5SD upstream of Deep Creek crossing.

Plate 23: Looking upstream through riffle section at ST5SD.

Plate 24: Macrophyte growth on the upstream side of Deep Creek Rd crossing (Milfoil *Myriophyllum sp*).

Plate 25: Looking downstream from the Deep Creek Rd crossing.

Plate 26: Looking downstream in ST5SD.

Appendix D

Northern Tributary 5 (NT5) **19/4/2022**

NT5 is the largest of the three northern tributaries to Deep Creek along the northern catchment boundary within the study area footprint. NT5 is a second order tributary covering a distance of around 970m from its upper catchment boundary to its confluence with Deep Creek. There are two inline dams in the upper first order branch to the west, including one upstream of the property boundary fence (water quality metering site NT5dam) (Plate 27), and an additional dam around 50m upstream from the upper branch confluence (Plate 29). There was no surface water upstream of NT5dam. The upstream dam contained dark tannin stained water and supported dense macrophyte growths, including tall spikerush (*Eleocharis sphacelata*), bulrush *Schoenoplectiella mucronata* and ferny azolla (*Azolla pinnata*), with smaller quantities of rushes (*Juncus sp*), knotweed (*Persicaria* sp) and water primrose (*Ludwigia peploides*), however the lower dam was mostly devoid of macrophyte growth (Plate 29). A thinly incised channel joins the two dams and continues downstream to the confluence with the eastern upper branch.

The upper eastern branch contained trickle flows throughout its length and downstream to Deep Creek during the April fieldwork, however there were infrequent sections where surface flows retreated underground (sub-surface alluvial) and there was no downstream connection with Deep Creek as a 1m stepped cascade occurs at the bottom of NT5 presenting a barrier to fish migration, however upstream migration into NT5 would be possible during periods of higher increased water levels. Surface waters were generally brown and turbid, maximum pool widths reached 3.5m, and maximum depth was around 1.0m, the average depths were shallower around 0.4m.

Throughout the site length (NT5 to NT5dn), channel incision increases in depth. The channel forms consisted of a chain of (incised) ponds separated by shallow and narrow sloped earthen runs and cascades or sediment deposits, with frequently occurring undercut banks. As noted in NT7, a headcut exists in the eastern upper branch just upstream from the upper branch confluence, whereby a shallow, narrow and meandering stream run drops into a heavily incised, sunken (to 2m depth) channel which is for the most part, continuous downstream tom Deep Creek (Plate 32). Bank undercutting is frequent through the lower length of tributary with sections of observed bank collapse. The substrates were comprised of sandy gravels lesser quantities of cobbles, large sandy sediment deposits were distributed along the length and small sections of bedrock.

Melaleucas were prevalent along the channel bank edges, also other commonly observed species along the bank edges included *Carex* grasses, sedges (*Gahnia sp*), knotweed (*Persicaria sp*), *Lomandra longifolia*. The riparian corridor is continuous for most of the main channel at NT5, increasing in width and canopy cover with distance downstream with mosses growing along channel edges, and bordered by cleared agricultural lands on both sides of the drainage. There is cattle access to the NT5 channel area throughout the study area length.

Plate 27: Looking north at the upstream dam on the upper western branch of NT5 tributary (water quality metering site NT5dam).

Plate 28: Looking downstream from NT5dam through shallow channel area

Plate 29: Looking south across the lower dam on the upper western branch of NT5 tributary.

Plate 30: Looking upstream from the property boundary fence in the upper first order eastern branch of NT5 (water quality metering location NT5).

Plate 31: Looking downstream through incised channel pools in NT5.

Plate 32: Looking upstream at the upstream limits of the deeply incised, sunken channel headcut.

Plate 33: Looking upstream through the typical meandering, incised channel form in the lower section of NT5. Note the undercut banks and active erosion.

Plate 34: Looking downstream at deep pool in NT5.

Plate 35: Looking upstream in lower limits of NT5.

Appendix D

Northern Tributary 6 (NT6) **19/4/2022**

NT6 is a 1st order tributary spanning around 670m in total length (from the upper catchment slopes to Deep Creek. Small, isolated surface pools were present on upstream and downstream side of the track crossing however there was no other surface water observed up or downstream for a distance of 50m (Plate 31). A constructed track exists across the drainage swale with runoff distributed downstream through 3 x 450mm pipe culverts (Plate 37).

Overall, the NT6 drainage was indistinct, with no areas of channel incision or channel forms capable of sustaining prolonged aquatic habitats. Some minor accumulation of storm flow debris was observed in isolated sections downstream. There were no signs of semi-permanent water as indicated by algae or decomposing detrital material. The catchment area upstream of the boundary fence is steep, and becomes flatter with distance downstream, and supports open eucalypt woodlands spanning the width of the intact riparian corridor with agricultural land beyond. Ponded surface water and boggy ground was present along the ridgeline between NT6 and NT7 however there was no real change in the vegetation community at this location (Plate 40).

Plate 36: Looking upstream from fence boundary in NT6.

Plate 37: Looking west along the constructed track crossing over NT6, showing the small surface pool on the upstream side of the pipe culverts.

Plate 38: NT6 pipe culverts on the downstream side of the constructed track.


Plate 39: Looking downstream from the track crossing at NT6.


Plate 40: Boggy seepages along the ridge between NT6 and NT7 (MGA56: 399220/6397466).

Appendix D

Northern Tributary 7 (NT7) **19/4/2022**

NT7 is a 2^{nd} order tributary of around 930m distance from source to its confluence with Deep Creek. No water present in the upper western branch of tributary from the Haul Rd downstream to the junction of the upper eastern branch, and large bedrock bench present at the downstream limits of the upper western branch (around 80cm height). The eastern branch of NT7 supported a trickle flow through section from the upstream limits (property boundary fence- Plate 41) downstream through upper branch confluence and downstream, with infrequent sections where surface flows retreated underground. Surface waters were tannin stained with regular observations of orange (iron) precipitation on substrates and along pool edges.

The topography was generally steep upstream of the upper branch confluence, with the eastern branch channel comprising a distinct creekline, incised from 0.3m to 1.3m into the V-shaped valley basin, with regular alternation of rock cascades and incised pools with a mix of gravelly sands, bedrock, cobble and boulder substrates (Plates 41 to 43). Mayflies (*Atalophlebia* sp of the family Leptophlebiidae), water pennies (*Sclerocyphon sp* of the family Psephenidae) and charophytes were observed in the upper eastern branch, indicating some degree of relative water permanence. The riparian corridor comprised mostly open eucalypt forest with small quantities of lantana.

Downstream from the upper branch confluence, the valley basin broadens with the flow channels becoming dispersed into multiple, shallow and indistinct flow paths across the broader (and flatter) channel area, reaching 30m in width, with surface flow retreating into the sandy alluvium, supporting a cover of native grasses (*Carex sp*) (Plate 44). Some of the valley basin edges were boggy with visible surface water, and were likely contributing to creek water levels. At around 80m downstream from the confluence the channel drops into an incised channel (Plate 45). Surface water was trickle flowing into the pool at the upstream end of the incised channel over a 60 to 70cm cascade, representing a considerable fish barrier. Eastern water dragon (*Intellagama lesueurii*) and dwarf green frog *Litoria fallax* observed along the pool edges.

Plate 41: Looking upstream of the property boundary fence in the upper eastern branch at NT7.

Plate 42: Looking upstream through incised channel pool in the upper eastern Tributary 7 branch.

Plate 43: Looking upstream through water quality site pool in the upper eastern NT7 branch.

Plate 44: Looking downstream in NT7 towards the upper end of the incised channel.

Plate 45: Looking upstream in T7 at upper limits of incised channel.

Plate 46: Looking downstream through incised channel pool at T7.

APPENDIX E
OYSTER FARMING IN KARUAH RIVER/PORT STEPHENS

E-1 Introduction

The Karuah River/Port Stephens Estuary is one of the largest shellfish aquaculture areas in the state with an output of some 592 tonnes of shellfish in 2019/20, the second largest production behind Wallis Lake at 712 tonnes and around 18% of the total NSW production. The main aquaculture shellfish species are Sydney Rock Oysters (SROs) and Pacific Oysters (POs) and Port Stephens is the only estuary in the state that can grow and harvest naturalised Pacific Oysters.

Oyster aquaculture output from the estuary was drastically reduced from mid 2021 to at least mid 2022 following devastating SRO losses to QX disease which was first confirmed in SROs in Port Stephens on 27 August 2021 and was still present in oysters in March 2022 (see below).

E-2 Legislative Controls on Oyster Farming and Harvesting

NSW Department of Primary Industries (DPI) estimates that the sustainable production level for oysters in NSW estuaries is around 7,500 tonnes, and, under the NSW Oyster Industry Sustainable Aquaculture Strategy (OISAS), currently 4th edition - DPI NSW (2021, the principal aim is to establish the regulatory environment within which the industry can grow to this level. This is achieved in the first instance by identifying suitable ‘priority’ areas for edible oyster aquaculture for all oyster growing estuaries in the state. Management and operational boundaries for Priority Oyster Aquaculture Areas (POAAs) are established in a regularly updated set of best practice standards within OISAS, which are supported by a commitment to environmentally sustainable practices.

As oyster farming comes with both internal and external environmental risks, oyster farming in estuaries was previously undertaken against voluntary Environmental Management Systems (EMS, e.g., the Tilligerry Ck Oyster Farmers EMS 2014). However, as shellfish are filter feeders that can accumulate pollutants which can become a threat to human health, all oyster farming is now undertaken against statutory quality assurance programs under the NSW Shellfish Program as specified in the OISAS and administered by NSW Food Authority. This program incorporates the *Australian Shellfish Quality Assurance Program (ASQAP)* as a minimum standard.

These standards are designed to both ensure that health risks associated with human consumption of oysters and risks of loss of stock to farmers from adverse water quality conditions are minimised.

The ASQAP is a compulsory, joint industry and government funded program that classifies harvest areas on the basis of water quality and pollution source risks; establishes harvest management plans, and mandates post-harvest handling procedures. Under these programs specific lease areas are classified by the NSW Food Authority for harvesting of oysters for human consumption as either *conditionally approved* for direct harvest or as *conditionally restricted*:

- *Conditionally approved* status allows oyster growers to directly harvest from their lease areas (i.e. no depuration required) when water quality monitoring results fall within strict parameters.
- *Conditionally restricted* status recognises that there may be some local issues with water quality, but at levels low enough to be removed from shellfish via depuration. Depuration is a statutory process that requires oysters to be placed in a sterilised recirculation tank for 36 hours. During this process the oysters self-cleanse in recirculated water, which is sterilised using ultraviolet light.

The *NSW Shellfish Program* oversees the open and closed status of harvest areas. Harvest areas may temporarily close for a number of reasons, for example, when localised rainfall produces runoff that pollutes the estuary. To achieve and maintain classification, water and meat quality from oysters to be harvested are assessed every two weeks, with additional bio- toxin assessments conducted once a month. This rigorous sampling regime ensures that immediate action can be taken should pollution levels threaten the health of the river and the viability of oyster stocks.

Figure E-1 shows the extent of POAA oyster lease infrastructure in Port Stephens/Karuah River and these oyster leases are used for the range of oyster growth requirements from spat collection and juvenile growth through grow-out, fattening to maturity and eventually sale. Note that the figure also shows the spatial relationship of the proposed quarry activities to the lower Deep Creek estuarine oyster leases. There are 12 named areas in the Port Stephens estuary that are classified by NSW Food Authority for the harvesting of oysters for human consumption:

- Four (Corrie Island, Swan Bay, Oyster Cover and Cromarty Bay) are classified as *conditionally approved*

- The remaining eight, (Tea Gardens, Pindimar, Bundabah, Carrington Bay, Little Swan Bay, Tilligerry Creek, Lemon Tree Passage and Oakley Island), are classified as *conditionally restricted*.
- The lower Karuah River estuary below Allworth - including sections of Deep Creek, Limeburner's Creek and The Branch River are declared priority oyster aquaculture areas in *NSW* OISAS *2021* and are used as nursery areas for oysters, prior to moving them to the Port Stephens declared shellfish harvest areas**.**

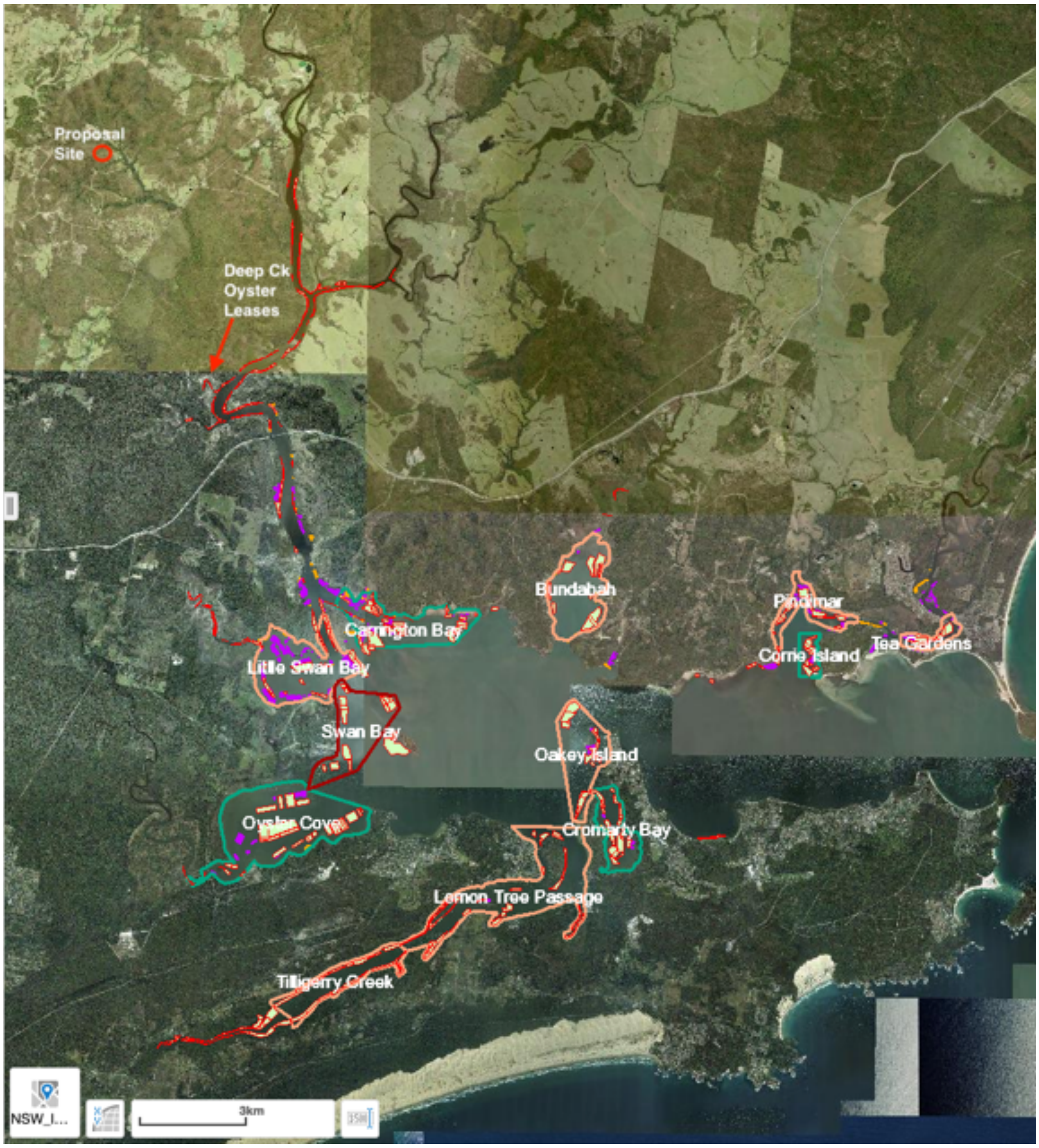

Figure E-1 Designated POAA Oyster Cultivation Leases in Karuah River/Port Stephens. The named POAA lease areas are classified Shellfish Harvest Areas (see text). The proposed quarry site (red circle) is located some 12.5km upstream from the Deep Creek leases.

E-3 Post Stephens QX Disease Outbreak

The Sydney rock oyster (SRO; *Saccostrea glomerata*) is native to Australia, where it is the most intensively cultivated oyster species, however, the NSW SRO industry has been significantly impacted by a disease called QX (Queensland Unknown Disease), which has caused annual losses of SRO stocks of up to 100% in some cultivation regions. QX disease was first detected in the late 1960s in Moreton Bay Queensland. Since the late 1970s, QX has extensively spread across Queensland and southwards into several New South Wales estuaries. The disease is caused by a spore-forming protozoan parasite called *Marteilia sydneyi* that over several weeks, migrates through connective tissue to the digestive gland, undergoes sporulation, causing blockage in the digestive gland and resulting in oyster starvation and death. In Port Stephens QX was first confirmed in Sydney Rock Oysters on 27 August 2021. In February 2022, QX was reconfirmed in both the Karuah River and Tilligerry Creek growing regions following reports of unexplained mortalities and oysters showing clinical signs suggestive of QX disease. During a March 2022 surveillance sampling program run by DPI testing 300 oysters form 10 zones to determine presence/absence of QX in various regions of the Port, QX was again detected in multiple western growing areas. QX was detected in both wild and cultivated oysters across multiple size classes (see **Figure E-2** below).

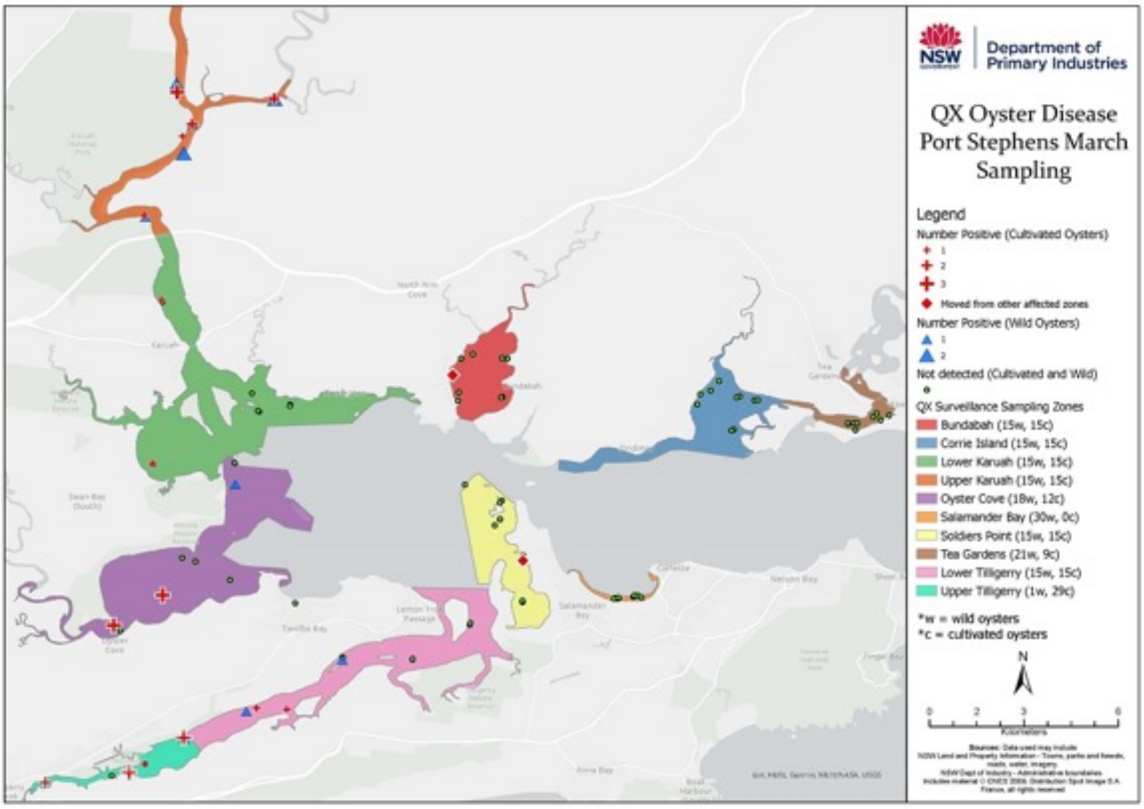

Figure E-2 QX Monitoring by DPI Fisheries (Aquaculture Branch) in March 2022.

Notably, the presence of *M. sydneyi* within an SRO farming estuary does not necessarily result in a QX disease outbreak, indicating that other factors, beyond the presence of the pathogen, are important for infection or progression of disease, and infection is thought to require an intermediate host(s) plus, as with other oyster diseases, QX disease is likely driven by a convergence of environmental (e.g. water chemistry, salinity, temperature, host-specific (e.g. immunity, microbiota biome structure and stress levels) and pathogen-specific factors). QX disease is seasonally recurrent, generally occurring in summer or autumn (depending on the location) and low seawater salinity is considered a major contributing factor.

The relationship of QX presence and varying stream discharge environmental conditions can be noted in the March 2022 patterns shown in **Figure D-2,** where higher positive QX presence was recorded in the upper Karuah River POAA area, closer to the Twelve Mile Creek discharge to Swan Bay and in the upper Tilligerry Creek estuary.

E-4 Synopsis of Karuah River Water Quality in relation to Oyster Aquaculture

Great Lakes Council (2015) Karuah River Catchment Management Plan provides a synopsis of water quality in Karuah River, summarised below:

- In 2011 the Karuah River estuary and Catchment was assessed as being in a moderate ecological condition, but with some significant threats to the system (Haine et al 2011).
    - Turbidity and nutrients including ammonia, total nitrogen, total phosphorus and faecal coliforms are regularly elevated.
    - Subsequent Mid-Coast Water 'State of the Environment' report cards typically rate key environmental indicators within the Karuah River as fair to very poor due to elevated turbidity and/or faecal coliforms.
- Monitoring by Duralie Coal has occasionally observed total aluminium, total manganese and total zinc levels in excess of ANZECC water quality trigger levels.
    - Water quality monitoring undertaken in the Karuah River Catchment by the Gloucester Water Study Project, Baseline Water Survey during 2014 likewise found elevated manganese, aluminium and iron levels, as well as elevated turbidity levels in Wards River and Mammy Johnsons River.
    - These metals are naturally occurring within the landscape associated with the underlying geology and soils types of the catchment and are likely exported to the river bound to sediment.

- OEH water quality monitoring in the estuarine zone of the catchment in 2007, 2011 and 2013 has shown trends that partially correlate with weather conditions:
    - Base flow turbidity and suspended solid levels tend to be lower and usually within the range of ANZECC trigger values.
    - Following periods of intense rain events or higher than average rainfall, turbidity and suspended solid levels spike considerably and climb into unacceptable ranges. This is also consistent with anecdotal evidence from oyster growers in the catchment, particularly for The Branch sub-catchment where storm events result in a significant pulse of sediment within freshwater flows. Silting of the lower estuary has also been observed by oyster farmers operating in the Karuah River.
    - Nutrient levels are regularly elevated, including ammonia, total nitrogen, total phosphorus and there are also high faecal coliforms loads, generally correlated with diffuse rural runoff.
    - Micro or planktonic-algae (diatoms and the like) need both light and nutrients to grow, and given the high nutrient levels recorded in the river, periods of low turbidity can result in algal blooms levels as high levels of nutrients combined with clear and warm water stimulate the growth of algae. Conversely during periods of high rainfall, algae growth is limited by light availability from turbidity/suspended solid levels.
    - Some algae blooms reach levels which are detrimental to fish, humans and aquaculture, consistent with the occasional blue-green algae high alerts issued by the NSW Office of Water (NoW).

MARINE POLLUTION RESEARCH **PTY LTD**

Marine, Estuarine and Freshwater Ecology, Sediment and Water Quality Dynamics

A.B.N. 64 003 796 576

25 RICHARD ROAD SCOTLAND ISLAND NSW 2105

PO BOX 279 CHURCH POINT NSW 2105

TELEPHONE (02) 9997 6541 E-MAIL panink@bigpond.com