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Aquatic Biodiversity Technical Report
Tahmoor North – Western Domain
Longwalls West 1 and West 2

Prepared for Tahmoor Coal | 11 July 2019

Document control

Project number	Client	Project manager	LGA
4794	Tahmoor Coking Coal Operations	Matthew Russell	Wollondilly Shire

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Enquiries should be addressed to:

Sydney Head Office
Niche Environment and Heritage
02 9630 5658
info@niche-eh.com
PO Box 2443 North Parramatta
NSW 1750 Australia

Glossary and list of abbreviations

Term or abbreviation	Definition
ABTR	Aquatic Biodiversity Technical Report
Aquatic macroinvertebrates	Small animals without a backbone that live for all, or part, of their lives in water. They are a useful indicator of stream health.
AUSRIVAS	Australian River Assessment System
BACI	Before After Control Impact
CEEC	Critically Endangered Ecological Communities
CMA	Corrective Management Action
DoE	Department of Environment
DP&E	Department of Planning and Environment
DPI	Department of Primary Industries
DRE	Division of Resources and Energy
EEC	Endangered Ecological Communities
EPT	Ephemeroptera, Plecoptera, Trichoptera – a macroinvertebrate index of stream health.
ha	Hectare/s
km	Kilometre/s
m	Metre/s
mm	Millimetre/s
Macrophytes	Aquatic vegetation
RCE Inventory	Riparian Channel and Environment Inventory assessment
SIGNAL	'Stream Invertebrate Grade Number – Average Level' is a simple biotic index for macroinvertebrates that uses the pollution tolerance levels of different macroinvertebrate types to create a site score and water quality rating for the river, creek or pond being studied.
Subsidence	The gradual caving in or sinking of an area of land.
TARP	Trigger Action Response Plan
TILs	Trigger Investigation Levels
Upsidence	Is defined as the difference between observed subsidence profiles within valleys and conventional subsidence profiles that would have otherwise been expected in flat terrain.

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1. Introduction

1.1 Background

The Tahmoor Coal Mine (Tahmoor Mine) is an underground coal mine located approximately 80 kilometres (km) south-west of Sydney between the towns of Tahmoor and Bargo, New South Wales (NSW) (refer to Figure 1). Tahmoor Mine produces up to three million tonnes of Run of Mine (ROM) coal per annum from the Bulli Coal Seam. Tahmoor Mine produces a primary hard coking coal product and a secondary higher ash coking coal product that are used predominantly for coke manufacture for steel production. Product coal is transported via rail to Port Kembla and Newcastle for Australian domestic customers and export customers.

The Tahmoor Mine has been operated by Tahmoor Coal Pty Ltd (Tahmoor Coal) since Tahmoor Mine commenced in 1979 using bord-and-pillar mining methods, and via longwall mining methods since 1987. Tahmoor Coal, trading as Tahmoor Coking Coal Operations (TCCO), is a subsidiary within the SIMEC Mining Division (SIMEC) of the GFG Alliance (GFG).

Tahmoor Coal has previously mined 31 longwalls to the north and west of the Tahmoor Mine's current pit top location. Tahmoor Coal is currently mining Longwall 32 in accordance with Development Consents and Subsidence Management Plan Approval.

Tahmoor Coal proposes to extend underground coal mining to the north-west of the Main Southern Railway (referred to as the 'Western Domain') which will include Longwalls West 1 (LW W1) to West 4 (LW W4) at Picton and Thirlmere. The first two longwalls to be mined are LW W1 and Longwall West 2 (LW W2) (collectively referred to as LW W1-W2), which will be the focus of this Aquatic Biodiversity Technical Report (ABTR) (Figure 1, Figure 2).

1.2 Context

Niche Environment and Heritage (Niche) were commissioned by Tahmoor Coal to prepare an ABTR associated with LW W1-W2 to address the Approval Conditions in accordance with DA 67/98 (as modified). This assessment details the predicted impacts in relation to aquatic biodiversity and provides relevant Trigger Actions Response Plans (TARPs) associated with aquatic biodiversity.

1.3 Purpose and Scope

This ABTR LW W1-W2 applies to aquatic flora and fauna potentially impacted as a result of mining within the Study Area (Figure 1). The Study Area applicable to this ABTR consists of a combination of the Predicted 20 millimetre (mm) Total Subsidence Contour and the 35° Angle of Draw Line for LW W1-W2 as shown on Figure 1.

The purpose of this ABTR is to describe the aquatic biodiversity values and assess the significance of the impact of the LW W1-W2 on those values within the Study Area or likely to be impacted by far-field or valley related movements outside the Study Area. This technical report specifically addresses aquatic biodiversity. The document outlines the management strategies, mitigation measures, controls and monitoring programs to be implemented for the management of aquatic flora and fauna from the proposed extraction workings.

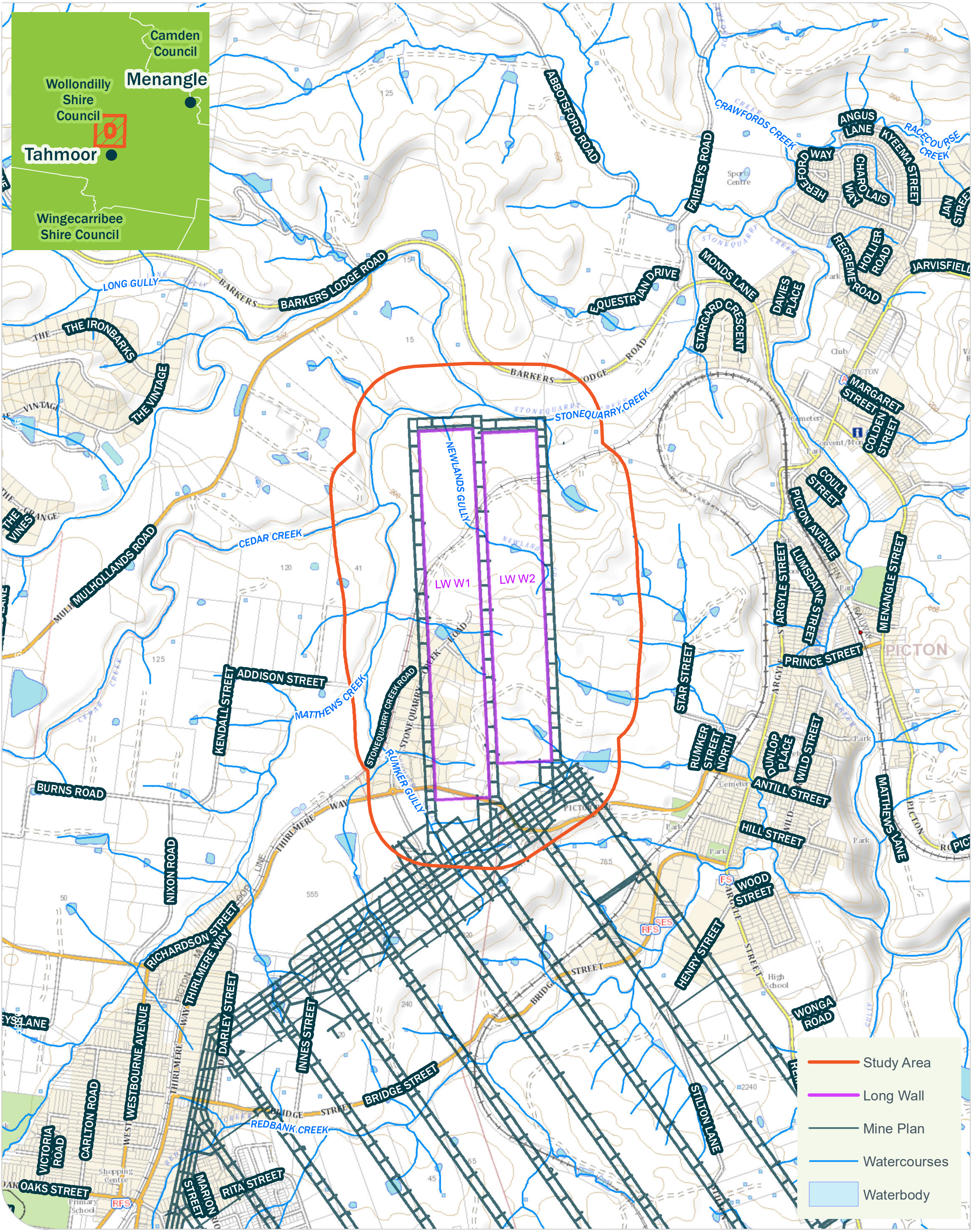
This ABTR includes the following:

- Summary of the baseline data for existing aquatic habitat, aquatic biodiversity, and stream morphology.
- Provisions for the management of potential impacts and environmental consequences of the proposed second workings on aquatic biota and aquatic habitat.
- Provision of a TARP that includes a description of performance indicators to be implemented to ensure compliance with negligible environmental consequences to threatened species, threatened populations and their habitats, and endangered ecological communities; as well as considerations for the management or remediation of any impacts on and/or environmental consequences for aquatic biodiversity.
- Provisions for the inclusion of the monitoring of aquatic biota and aquatic habitat and a description of any adaptive management practices implemented to guide future mining activities in the event of greater than predicted impacts on aquatic habitat.

1.4 Structure of this document

The main text sections and attachments of this ABTR include the following:

Section 1	Provides an introduction to the ABTR for LW W1-W2, including the purpose and scope of the ABTR and the document structure.
Section 2	Describes the regulatory requirements, the subsidence performance measures relevant to this ABTR for LW W1-W2 and a summary of relevant legislation and stakeholder consultation.
Section 3	Describes the existing environment within the Study Area and the results of baseline monitoring.
Section 4	Summarises the predicted subsidence impacts and environmental consequences resulting from the extraction of LW W1-W2.
Section 5	Describes the management, monitoring and evaluation measures that will be implemented and how monitoring data will be used to assess the relevant performance indicators and performance measures.
Section 6	Provides a Contingency Plan to manage any unpredicted impacts and their consequences and Trigger Action Response Plan (TARP).
Appendix A	Aquatic Ecology Baseline Monitoring Report



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GDA 1994 MGA Zone 56

Location and study area

Aquatic Biodiversity Technical Report LW W1-W2

Niche PM: Matthew Russell
Niche Proj. #: 4794
Client: Tahmoor Coal

Figure 1

2. Statuary Requirements

2.1 Project Approval

The proposed LW W1-W2 (the Project) will be operating in the Tahmoor North mining area, and will be operated under Development Consents DA 57/93 and DA 67/98. DA 67/98 provides the conditional planning approval framework for mining activities in the Western Domain to be addressed within an Extraction Plan and supporting management plans and technical reports.

This ABTR LW W1-W2 is a component of the Tahmoor North – Western Domain LW W1-W2 Extraction Plan and has been prepared specifically to address Approval Condition 13H (vii)(d) of DA 67/98 (as modified) (Table 1). The biodiversity requirements as stated in Table 1 are addressed in two separate technical reports – an Aquatic Biodiversity Technical Report (this document) and a Terrestrial Biodiversity Technical Report (Niche 2019b).

Table 1: Development consent conditions (extracted from DA 67/98)

<table>
<tr><th>Condition</th><th colspan="2">Condition Requirement</th><th>Section Addressed Within This Document.</th></tr>
<tr><td colspan="4">SUBSIDENCE
Performance Measures – Natural and Heritage Features etc.</td></tr>
<tr><td>13A</td><td colspan="2">The Applicant must ensure that extraction of LW W1 and subsequent longwalls does not cause any exceedances of the performance measures in Table 1.
Note: The Applicant will be required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this consent.</td><td rowspan="4">Section 5 and Section 6</td></tr>
<tr><td rowspan="3">Excerpt from Table 1</td><td>Feature</td><td>Performance Measure</td></tr>
<tr><td colspan="2">Biodiversity</td></tr>
<tr><td>Threatened species, threatened populations, or endangered ecological communities</td><td>Negligible environmental consequences.</td></tr>
<tr><td>13B</td><td colspan="2">Measurement and monitoring of compliance with performance measures and performance indicators in this consent is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans and monitoring programs. In the event of a dispute over the appropriateness of proposed methods, the Secretary will be the final arbiter.</td><td>Section 5 and Section 6</td></tr>
<tr><td colspan="4">Additional Offsets</td></tr>
<tr><td>13C</td><td colspan="2">If the Applicant exceeds the performance measures in Table 1 and the Secretary determines that:
• It is not reasonable or feasible to remediate the subsidence impact or environmental consequences, or
• Measures implemented by the Applicant have failed to satisfactorily remediate the subsidence impact or environmental consequence.</td><td>Noted.
Performance measures in Table 1 of DA 67/98 are not anticipated to be exceeded.</td></tr>
</table>

Condition	Condition Requirement	Section Addressed Within This Document.
	Then the Applicant must provide a suitable offset to compensate for the subsidence impact or environmental consequence, to the satisfaction of the Secretary.	
13D	The offset must give priority to like-for-like physical environmental offsets, but may also consider payment into any NSW Offset Fund established by OEH, or funding or implementation of supplementary measures such as: • Actions outlined in threatened species recovery programs • Actions that contribute to threat abatement programs • Biodiversity research and survey programs and/or • Rehabilitating degraded habitat. *Note: Any offset required under this condition must be proportionate with the significance of the impact or environmental consequence*	Noted. Performance measures in Table 1 of DA 67/98 are not anticipated to be exceeded.
Extraction Plan		
13H	The Applicant must prepare an Extraction Plan for all second workings in Longwall 33 and subsequent longwalls to the satisfaction of the Secretary. Each Extraction Plan must:	Extraction Plan main document
13H(vi)	• Describe in detail the performance indicators to be implemented to ensure compliance with the performance measures in Table 1 and Table 2, and manage or remediate any impacts and/or environmental consequences.	Section 5.1, Section 5.2, and Section 6
13H(vii)(d)	• Prepare a Biodiversity Management Plan which has been prepared in consultation with OEH, which establishes a baseline data for the existing habitat on the site, including water table depth, vegetation condition, stream morphology and threatened species habitat, and provides for the management of potential impacts and environmental consequences of the proposed second workings on aquatic and terrestrial flora and fauna, with a specific focus on threatened species, populations and their habitats, EECs and groundwater dependent ecosystems.	Consultation detailed in Section 2.3. Monitoring detailed in Section 5. Management detailed in Section 6.
13H(vii)(h)	• Prepare a Trigger Action Response Plan/s addressing all features in Table 1 and Table 2, which contain: ▪ Appropriate triggers to warn of increased risk of exceedance of any performance measure. ▪ Specific actions to respond to high risk of exceedance of any performance measure to ensure that the measure is not exceeded. ▪ An assessment of remediation measures that may be required if exceedances occur and the capacity to implement the measures. ▪ Adaptive management where monitoring indicates that there has been an exceedance of any performance measure in Table 1 or Table 2, or where any such exceedance appears likely.	Section 6.2 and Section 6.3.
13H(vii)(i)	• Provide a Contingency Plan that expressly provides for: ▪ Adaptive management where monitoring indicates that there has been an exceedance of any performance	Section 6, Section 5.3

Condition	Condition Requirement	Section Addressed Within This Document.
	measure in Table 1 and Table 2, or where any such exceedance appears likely. ▪ An assessment of remediation measures that may be required if exceedances occur and the capacity to implement those measures. ▪ Includes a program to collect sufficient baseline data for future Extraction Plans.	

2.2 Relevant Legislation

2.2.1 Biodiversity Conservation Act 2016

The NSW *Biodiversity Conservation Act 2016* (BC Act) provides protection for threatened species native to NSW (excluding fish and marine vegetation). Species, populations and ecological communities listed under Schedule 1 (Endangered) and Schedule 2 (Vulnerable) are considered to be threatened in NSW.

Protection is provided by integrating the conservation of threatened species, endangered populations and Endangered Ecological Communities / Critically Endangered Ecological Communities (EEC/CEECs) into development control processes under the EP&A Act.

The Terrestrial Ecology Assessment (Niche 2014b) applied to the Study Area applied to the Study Area determined that no significant impacts to threatened biodiversity are likely as a result of the extraction of LW W1-W2. The findings of this assessment, and updates based on the MSEC (2019) predications for the Study Area are provided in Section 4. Given the MSEC (2019) do not exceed those addressed in the Biodiversity Impact Assessment (Niche 2014), similar conclusions regarding non-significant impacts to threatened biodiversity listed under the BC Act are likely as a result of the extraction of LW W1-W2.

2.2.2 Fisheries Management Act 1994

The objectives of the *Fisheries Management Act 1994* are to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations. In particular, the objectives of this Act include to:

- Conserve fish stocks and key fish habitats;
- Conserve threatened species, populations and ecological communities of fish and marine vegetation; and
- Promote ecologically sustainable development, including the conservation of biological diversity.

Protection is provided by integrating the conservation of threatened species, endangered populations and EEC/CEECs into development control processes under the EP&A Act. The Aquatic Ecology Impact Assessment (Niche 2014a) applied to the Study Area concluded there was only a very low likelihood of any threatened species, populations or ecological communities listed under the *Fisheries Management Act 1994* to be impacted by the approved disturbance.

2.2.3 Environment Protection and Biodiversity Conservation Act 1999

Under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), approval from the Commonwealth Minister for Department of Environment (DoE) is required for any action that may have a significant impact on Matters of National Environmental Significance (MNES). These matters are:

- Listed threatened species and ecological communities

- Migratory species protected under international agreements
- Ramsar wetlands of international importance
- The Commonwealth marine environment
- World Heritage properties
- National Heritage place
- Great Barrier Reef Marine Park
- Nuclear actions and
- A water resource, in relation to coal seam gas development and large coal mining development.

Threatened species, migratory species and threatened ecological communities listed under the provisions of the EPBC Act were considered within the Study Area and an assessment was made to determine if LW W1-W2 would pose a significant impact on Matters of National Environmental Significance (MNES).

The Aquatic Ecology Impact Assessment applied to the Study Area concluded there was only a very low likelihood of any threatened species, population or ecological community listed under the EPBC Act to be impacted by the approved disturbance.

2.3 Consultation

2.3.1 Consultation with OEH

A meeting with OEH was held with representatives of OEH and representatives of Tahmoor Coal at the OEH Hurstville Office on 21 March 2019. The meeting was an opportunity to outline the proposed LW W1-W2 Extraction Plan and the proposed subsidence monitoring program for the LW W1-W2 Study Area.

OEH inquired if the baseline studies for ecology (amphibian, riparian vegetation and macroinvertebrate) would be publicly available. Tahmoor Coal advised that a copy of the baseline ecology report would be provided as part of the Extraction Plan. No further comments were made by OEH with regard to aquatic biodiversity. A copy of the Aquatic Ecology Baseline Monitoring Report (Niche 2019a) is attached as Appendix A.

3. Existing Environment

3.1 Baseline Monitoring Data Sources

The existing environment has been characterised using baseline studies and ongoing aquatic monitoring in the Study Area. These include:

- Tahmoor North Longwalls 31 to 37 Aquatic Ecology Assessment (Niche 2014a):
  - Riparian Channel and Environment Inventory assessment to rank the relative health of stream condition;
  - AUSRIVAS stream health assessment (including aquatic habitat, macrophytes, *in situ* water quality and macroinvertebrates);
  - Fish survey;
  - Threatened species and key fish habitat assessment;
- Biannual aquatic ecological monitoring for spring 2017, autumn 2018, spring 2018 and autumn 2019 (Niche 2019a):
  - Riparian Channel and Environment Inventory assessment to rank the relative health of stream condition;
  - AUSRIVAS stream health monitoring (including aquatic habitat, macrophytes, *in situ* water quality and macroinvertebrates);
  - Quantitative macroinvertebrate (Before After Control Impact (BACI)) monitoring;
  - Fish survey;
- Tahmoor Coal Pty Ltd - Tahmoor Colliery Longwall Panels 31 to 37 Streams, Dams & Groundwater Assessment, Tahmoor, NSW (GeoTerra, 2014); and
- Extraction Plan LW W1 – W2 - Surface Water Technical Report (HEC 2019).

3.2 Watercourses and Stream Morphology

The Study Area is located in the Stonequarry Creek catchment with the natural waterway features comprising Matthews Creek, Cedar Creek and Stonequarry Creek, as shown in Figure 2. Baseline pool water level and surface water quality data has been collected within and surrounding the Study Area by HEC (2019), which has been incorporated throughout this section.

Matthews Creek and Cedar Creek rise in low hills to the west of the Study Area, with their junction approximately 200 metres (m) west of LW W1. Stonequarry Creek also rises to the west and flows east along the northern boundary of the Study Area, joining Cedar Creek approximately 130 m north of LW W2, before flowing east and south through the town of Picton. Redbank Creek flows into Stonequarry Creek towards the south-east of the Study Area. Stonequarry Creek continues to flow south-east, joining the Nepean River near Maldon (HEC 2019).

3.2.1 Matthews Creek

The headwaters of Matthews Creek lie within the residential area of Thirlmere, with residential development significantly affecting the vegetation and weed growth along the upper reaches of the creek. The catchment comprises mainly rural properties. The creek flows to the north-east on the northern side of Thirlmere (Figure 2). The creek then flows to the north, downstream of Thirlmere, through a rural area with sparse residential development, along with poultry farms, commercial vegetable gardens and a shale quarry. The riparian zone of the creek contains thick native vegetation in this region. The creek in the vicinity of Thirlmere is generally in a poor state, with a high content of weeds and rubbish dumped or washed into it. Downstream of the residential area the creek significantly improves to a more natural state, down to the junction with Cedar Creek. To date, the creek has not been mined beneath, and the headwaters of the creek are located outside of the Study Areas of the previous and current longwalls.

Within the Study Area, Matthews Creek is a 4th order stream system that drains to the north into Cedar Creek, which subsequently flows to Stonequarry Creek, then the Nepean River. The creek flows north, adjacent to the proposed LW W1 in the western portion of the Study Area. Matthews Creek does not overlie any longwalls, however it is within the 20 mm subsidence area for approximately 850 m of its reach.

Within the Study Area, Matthews Creek is relatively incised in Hawkesbury Sandstone, with a steep V-shaped valley and isolated vertical scarps predominating adjacent. Just upstream and at the junction with Cedar Creek, the valley becomes more incised and steeper with more predominant vertical scarps in the basal exposed sandstone of the valley. Overhangs of undercut sandstone are also prevalent in this section. Within the Study Area, Matthews Creek falls approximately 40 m in height over a total length of approximately 1,600 m, with an inferred average gradient of 25 mm/m (MSEC 2014). The stream bed and banks of Matthews Creek are well vegetated and do not show significant erosion or bank instability, principally as it is developed on, or just above, exposed Hawkesbury Sandstone basement.

Water level baseline data for Matthew Creek has been detailed in HEC (2019), which described Matthews Creek as exhibiting 'flashy' responses to rainfall events, and indicates that pools in Matthews Creek within the Study Area experience natural periods of no flow.

Eastern tributary gullies of Matthews Creek flow above proposed LW W1 and LW W2 (HEC 2019). The minor eastern tributaries of Matthews Creek within the Study Area are ephemeral and likely only flow during periods of extended or high rainfall. Surface water runoff from these tributaries has been partially diverted by urban drainage associated with "Stonequarry Estate" housing estate and flows through stormwater detention basins/dams and culverts under the rail line, with runoff from the tributaries likely to contribute to flow in Matthews Creek during periods of extended or significant rainfall only (HEC 2019).

3.2.2 Cedar Creek

The catchment area of Cedar Creek contains rural properties including a number of poultry farms, while the upper reaches are timbered and the head of the catchment lies within the Nattai National Park (HEC, 2019). The riparian zone of the creek contains thick native vegetation. To date, the creek has not been mined beneath, and the headwaters of the creek are located outside of the Study Areas of the previous and current longwalls. The creek does not directly overlie the proposed longwalls however it is located approximately 50 m north of LW W1 for approximately 300 m upstream of its confluence with Stonequarry Creek (Figure 2).

Cedar Creek lies within the Study Area from the Stonequarry Creek confluence to approximately 500 m upstream of its confluence with Matthews Creek, adjacent to the northern boundary of the Study Area (Figure 2). Within the Study Area, Cedar Creek is a 5th order stream system that drains to the west then north to Stonequarry Creek, which subsequently flows to the Nepean River. Cedar Creek joins with Stonequarry Creek adjacent to the northern boundary of LW W2 and has an estimated catchment area of 27 km^2.

Within the Study Area, Cedar Creek is distinctly incised in Hawkesbury Sandstone, and has a steep valley with prominent, although discontinuous, vertical sandstone ledges in the lower elevations of the valley. Overhangs of undercut sandstone are prevalent in the mid study reach of the creek. Near the junction with Matthews Creek, it has a wider base, although remains deeply incised in a steep sided valley with an exposed sandstone base. Further downstream the valley floor is wider, although there are less undercut sandstone overhangs. In this reach, and downstream to the junction with Stonequarry Creek, the creek remains in a steep sided valley, which opens up with an elongated permanent pool present at the junction. The creek within the Study Area is in a natural state to the junction with Stonequarry Creek. The creek's bed and banks are well vegetated and do not show erosion or bank instability, principally as it is developed on, or just above, exposed Hawkesbury Sandstone basement.

Groundwater seepage has been observed to occur at the junction of Cedar Creek and Matthews Creek based on high iron hydroxide precipitation within this reach (Niche 2014a).

A minor tributary gully of Cedar Creek flows from east to west over the northern portion of LW W1 and LW W2. The minor tributary of Cedar Creek within the Study Area is ephemeral and likely only flows during periods of extended or high rainfall. Surface water runoff from the headwater of this tributary is predominately captured by a farm dam with runoff from the tributary likely to contribute to flow in Cedar Creek during periods of extended or significant rainfall only. Flow in the tributary passes through a culvert under the Picton Mittagong Loop Line before flowing to Cedar Creek (HEC 2019).

Water level baseline data for Cedar Creek has been detailed in HEC (2019). As described by HEC (2019), Cedar Creek monitoring sites were fairly consistent during the monitoring period with subdued small peaks in water level recorded during rainfall periods. Sharp increases in water level were recorded at the most upstream monitoring sites following rainfall events followed by steep recessions, however, the water level was below the cease to flow level for the majority of the monitoring period prior to rising above the cease to flow level following rainfall in late January 2019 and again in March (HEC 2019).

3.2.3 Stonequarry Creek

The catchment area of Stonequarry Creek upstream of the Study Area comprises mainly rural properties and farmland with localised housing development (HEC 2019). The headwaters of Stonequarry Creek lie to the north and west of Cedar Creek. Stonequarry Creek flows in a southerly direction immediately upstream of its junction with Cedar Creek, then to the east downstream of the junction through a rural area with sparse residential development, along with poultry farms, commercial vegetable gardens and a shale quarry. The riparian zone of the creek contains thick native vegetation and high weed growth in the Study Area. To date, the creek has not been mined beneath, and the headwaters are located outside of the Study Areas of the previous and current longwalls.

Within the Study Area, Stonequarry Creek is a 5th order stream system, and is the northern most creek which flows to the Nepean River. Stonequarry Creek flows along the northern boundary of the Study Area and has an estimated catchment area of 44 km^2 to the downstream boundary of the Study Area. Cedar Creek joins Stonequarry Creek near the northern edge of LW W1-W2 (Figure 2). Stonequarry Creek subsequently flows to the east, downstream of LW W2.

The creek bed has a low gradient in the Study Area, with a predominance of rock bar, boulder and rock shelf constrained pools in its upper reaches, which are predominantly overgrown with weeds. An extended rock shelf is present approximately 175 m (and further) downstream of LW W2, which is maintaining the long upstream pool water level. The bed and banks of the creek are well vegetated and do not show significant erosion or bank instability, principally as it is developed on, or just above, exposed Hawkesbury Sandstone basement.

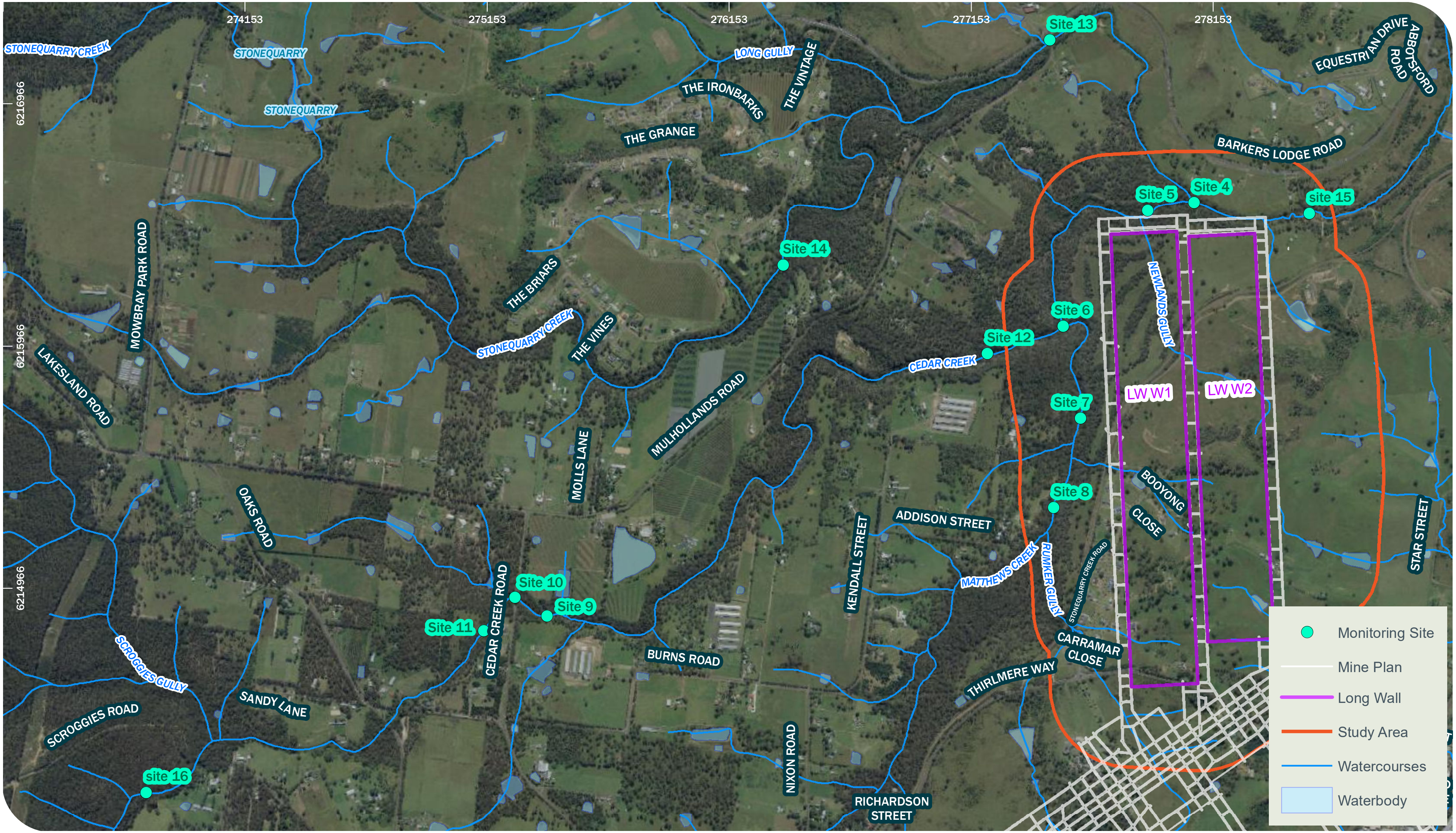
Stonequarry Creek is not particularly incised, although it is predominantly based on Hawkesbury Sandstone in the upstream section of the Study Area, with low valley sides. Downstream of the junction with Cedar Creek it has a wider channel and contains a long permanent pool.

A minor tributary of Stonequarry Creek flows from south to north adjacent to the proposed LW W2. Stonequarry Creek then flows east outside the boundary of the Study Area, through the town of Picton, joining the Nepean River near Maldon. The minor tributary of Stonequarry Creek within the Study Area is ephemeral and likely only flows during periods of extended or high rainfall. Surface water runoff from the headwater of the tributary is predominately captured by a farm dam with runoff from the tributaries likely to contribute to flow in Stonequarry Creek during periods of extended or significant rainfall only. Flow in the tributary passes through a culvert under the Picton-Mittagong Loop Line before flowing to Stonequarry Creek (HEC 2019).

Baseline data by HEC (2019) has indicated that water level at Stonequarry Creek remained above the cease to flow (CTF) level for the duration of the monitoring period, while the water level at downstream sites regularly fell below the CTF level, exhibiting 'flashy' responses to rainfall events followed by steeper recessions (HEC 2019).

3.3 Riparian Vegetation

Vegetation along the upper banks of Stonequarry Creek has been mapped as Cumberland Shale Sandstone Transition Forest (PCT1395) with a small section of Cumberland River-flat Forest (PCT835) occurring to the north of the longwalls. The vegetation along the banks of Matthews Creek and Cedar Creek has been mapped as Hinterland Sandstone Gully Forest (PCT1181). The condition of the vegetation communities varied depending on grazing, historic clearing and invasion by introduced species. Cumberland River-flat Forest (PCT835) contained a greater number of introduced species. The headwaters of Matthews Creek lie within the residential area of Thirlmere, with the condition of the creek significantly degraded by residential development.



Environment and Heritage

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Monitoring sites
Aquatic Biodiversity Technical Report LW W1-W2

Niche PM: Matthew Russell
Niche Proj. #: 4645
Client: Tahmoor Coal

Figure 2

3.4 Aquatic Biodiversity

Aquatic baseline monitoring includes an initial stream health assessment conducted in 2015 and monitoring primarily based on AUSRIVAS and quantitative macroinvertebrate sampling biannually since spring 2017 (Attachment A). The baseline monitoring program was conducted in November 2017, April 2018, November 2018 and May 2019 and employed the following survey methods:

- Aquatic habitat assessment comprising:
  - The Australian River Assessment System (AUSRIVAS);
  - Riparian Channel and Environment (RCE) Inventory;
- Macroinvertebrate survey comprising:
  - AUSRIVAS macroinvertebrate sampling;
  - A quantitative benthic macroinvertebrate monitoring program (to be updated when samples have been identified and analysed);
- Water quality sampling; and
- Fish sampling.

The baseline monitoring is primarily focused on macroinvertebrate monitoring regimes including AUSRIVAS and quantitative Before After Control Impact (BACI) design. In AUSRIVAS macroinvertebrate samples are compared to modelled reference sites and is a rapid assessment based on presence/absence of invertebrates. This provides of before /after impact monitoring of the sites through time.

The quantitative macroinvertebrate program compares potential impacts sites with upstream control sites and contains community assemblage data, which can be used to determine quantitative changes in fauna abundance, richness and structure that may be otherwise be missed by a rapid assessment approach. This approach takes into account the natural variability of the stream through the comparison to upstream control sites through time.

Collected habitat and water quality data is used to aid the interpretation of macroinvertebrate monitoring; to determine the likely drivers behind any changes in stream health indicators.

The monitoring locations for the current monitoring program are shown in Figure 2, summarised below in Table 2 and detailed in Table 10.

Table 2: Monitoring site summary

Site number	Site code	Watercourse	Sampling method
Potential impact sites – baseline (not yet impacted)			
Site 4	SQC4	Stonequarry Creek	Aquatic habitat assessment AUSRIVAS and Quantitative macroinvertebrate sampling Water quality sampling Fish sampling.
Site 5	CC5	Cedar Creek	
Site 6	CC6	Cedar Creek	
Site 7	MC7	Matthews Creek	
Site 8	MC8	Matthews Creek	
Site 15	SQC15	Stonequarry Creek	Quantitative macroinvertebrate sampling Water quality sampling Fish sampling.
Control sites			
Site 9	CC9	Cedar creek	Quantitative macroinvertebrate sampling

Site number	Site code	Watercourse	Sampling method
Site 10	CC10	Cedar Creek	Water quality sampling Fish sampling.
Site 11	CC11	Cedar Creek	
Site 12	CC12	Cedar creek	
Site 13	SQC13	Stonequarry Creek	
Site 14	SQC14	Stonequarry creek	
Site 16	CC 16	Cedar Creek	

3.5 Conclusions

The major results and conclusions from the baseline aquatic monitoring are provided in Table 3. For more details analysis of baseline results refer to Attachment A.

Table 3: Summary of results and conclusions of baseline studies

Indicator	Parameter	Results	Conclusion
Stream condition/ aquatic habitat	Stream condition	Matthews Creek, Stonequarry Creek and Cedar Creek were found to be in moderate to good stream/riparian condition with the best habitat located within the gorge along Matthews/Cedar Creek above Stonequarry Creek.	Stream are generally in moderate to good condition however low flows places natural stress on the aquatic environment and the availability and quality of aquatic habitat. Iron floc occurring in CC6 is natural and may indicate groundwater influencing benthic habitat at the location.
	Aquatic habitat	Habitat availability varied among seasons, particularly at MC8, which was dry on two occasions and could not be sampled. Macrophyte diversity was low with in the gorge and greatest downstream (CC5 and SC4). Iron staining was observed at CC6.	
Water quality	Electrical conductivity	The water quality results showed high salinity (approximately 1000 µS/cm) within and upstream the Study Area.	This indicated that electrical conductivity is naturally elevated above ANZECC guidelines in and upstream of the Study Area and resident fauna are likely to be adapted to these relatively high concentrations.
	Dissolved oxygen	Low dissolved oxygen was characteristic of all sites	Low dissolved oxygen is considered normal for stream pools exhibiting low- to no-flow conditions.
	pH	The pH was generally within ANZECC guidelines in spring	This reduction may be related to low rainfall,

		2017 and autumn 2018 however appear to decrease below ANZECC guidelines in spring 2018 and autumn 2019.	less surface water flow and increase in groundwater water influence.
	Alkalinity	Alkalinity was generally low in all streams	Indicating a low buffering capacity against changes in pH.
Macroinvertebrates	AUSRIVAS	Most sites on all sampling occasions were different to modelled reference sites scoring in Band B and Band C. Only two occasions of scores in Band A (close to reference condition) in MC7 and SQC4.	Low stream health scores and indices that were observed in the baseline study can be considered natural characteristics of drying intermittent/low flow streams.
	SIGNAL	Most sites had low signal score (<4).	
	EPT	EPT scores were generally low with Cedar Creek CC5 having the highest score. Most common pollution sensitive EPT taxa included Calamoceridae, Leptoceridae and Leptophlebiidae.	
	Assemblage data	The results showed that assemblages were temporally and spatially variable. Site 11 was an outlier.	Temporal variability between surveys is likely related to change in flow/habitat quality. Spatial differences are likely to be related to morphological and hydrological differences in streams. Site 11 should be excluded from further monitoring.
Fish	Fish identification and counts	Few fish were observed. Most common in the Study Area and upstream sites was introduced *Gambusia Holbrooki*. One native fish was identified with in the study area *Gobiomorphus coxii. Galaxias olidus* was found in Cedar Creek upstream of the Study Area.	Fish are unlikely to be a good indicator of environmental impact.

3.5.1 Threatened species

No aquatic threatened species are considered likely to occur (Table 4), and therefore aquatic threatened species are unlikely to be impacted by longwall mining as part of the extraction of LW W1-W2. No threatened species have been identified as part of the baseline monitoring.

Table 4: Threatened species likelihood of occurrence

Threatened Species	FM Act	BC Act	EPBC Act	Likelihood of Occurrence
Macquarie Perch (*Macquaria australasica*)	Endangered	-	Endangered	No (Does not occur or have habitat in Study Area, however there are records downstream in the Nepean River)
Sydney Hawk Dragonfly (*Austrocordulia leonardi*)	Endangered	-	-	No (Does not occur or have habitat in Study Area however there are records downstream in the Nepean River)
Adam's Emerald Dragonfly (*Archaeophya adamsi*)	Endangered	-	-	No (Does not occur or have habitat in Study Area)
Giant Dragonfly (*Petalura gigantean*)	-	Endangered	-	No (Does not occur or have habitat in Study Area)

4. Predicted Subsidence Impacts and Environmental Consequences

4.1 Subsidence Impacts and Environmental Consequences

In accordance with the findings of the Southern Coalfield Inquiry (Hebblewhite 2009):

- Subsidence effects are defined as the deformation of ground mass, such as horizontal and vertical movement, curvature and strains;
- Subsidence impacts are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata; and
- Environmental consequences are then identified, for example, as a loss of surface water flows and standing pools.

Predictions were revised by MSEC (2019) to account for the revised Mine Plan for LW W1-W2. The maximum predicted subsidence, upsidence and closure in mm are provided in Table 5. The predicted subsidence impacts for LW W1-W2 are provided in Section 4.2 and the environmental consequences in Section 4.3.

Table 5: Subsidence, upsidence and closure predictions for Matthews, Cedar and Stonequarry creeks

Site	Subsidence (mm)	Upsidence (mm)	Closure (mm)
Matthews Creek	90	90	170
Cedar Creek	60	160	180
Stonequarry Creek	60	90	60

4.2 Potential Subsidence Impacts

Potential subsidence impacts are discussed below and summary of potential subsidence impact to each waterway provided in Table 6.

4.2.1 Creeks

Tahmoor Coal has designed the layout of LW W1-W2 to avoid mining directly beneath Matthews, Cedar and Stonequarry Creeks. The purpose of the design is to substantially reduce the severity and extent of impacts on surface water flows within these creeks, compared to impacts that would occur if the longwalls were extracted directly beneath them (MSEC 2019).

MSEC (2019) predict that it is unlikely that Matthews, Cedar and Stonequarry Creeks would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks nor due to changes in stream alignment.

The maximum predicted total closure for Matthews, Cedar and Stonequarry Creeks due to the extraction of the proposed longwalls is 180 mm. The predicted rate of impact for the pools along these creeks due to the extraction of the proposed longwalls, therefore, is less than 10%. Impacts are more likely to occur near the commencing ends of LW W1-W2, where Cedar and Stonequarry Creeks are located closest to these longwalls, and where Cedar and Matthews Creeks are located closest to the tailgate of LW W1. The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls (MSEC 2019).

No gas emissions or consequential changes in water quality have been reported over Tahmoor Colliery in the Bargo River, Redbank Creek or Myrtle Creek. Where gas releases occur into the water column there is insufficient time for any substantial amount of gas to dissolve into the water. The majority of the gas is released into the atmosphere and is unlikely to have an adverse impact on water quality (MSEC 2019). It is possible, though rare, for substantial gas emissions at the surface to cause localised vegetation die-back. Previous occurrences of vegetation dieback due to gas emissions were limited to small areas of vegetation, local to the points of emission, and when the gas emissions declined, the affected areas were successfully restored (MSEC 2019).

4.2.2 Tributaries

The predicted mining-induced changes in grade are small when compared with the natural grades of the tributaries. It is unlikely that the tributaries would experience adverse impacts due to increased levels of ponding, increased levels of scouring of the banks nor changes in stream alignment (MSEC 2019).

Fracturing could develop along the tributaries located within the Study Area. The fracturing could predominately occur where the tributaries are located directly above LW W1-W2, but could also occur at distances up to approximately 400 m from the longwalls (MSEC 2019).

The mining-induced compression due to valley closure effects can also result in dilation and the development of bed separation in the topmost bedrock, as it is less confined. This additional dilation due to valley closure is expected to develop predominately within the top 10-20 m of the bedrock. Compression can also result in buckling of the topmost bedrock, resulting in heaving in the overlying surface soils (MSEC 2019).

Surface water flow diversions could occur along the tributaries that are located directly above LW W1-W2. In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds. The tributaries are ephemeral and, therefore, surface water flows only occur during, and for short periods after, rain events (MSEC 2019).

4.2.3 Surface water

The maximum predicted total closure for Matthews, Cedar and Stonequarry Creeks due to the extraction of the proposed longwalls is 180 mm. The predicted rate of impact for the pools along these creeks due to the extraction of the proposed longwalls, therefore, is less than 10 %. Impacts are more likely to occur near the commencing ends of LW W1-W2, where Cedar and Stonequarry Creeks are located closest to these longwalls, and where Cedar and Matthews Creeks are located closest to the tailgate of LW W1. The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls (MSEC 2019).

As Stonequarry Creek, Matthews Creek and Cedar Creek are outside the proposed longwall alignment, it is considered likely that streambed cracking will occur in less than 10% of pools with most impacts occurring near the commencing end of LW W1-W2.

Subsidence impacts are predicted to be relatively greater in the south, with Matthews Creek predicted to experience greater subsidence effects than Stonequarry Creek and Cedar Creek. Flow diversion and pool water level impacts are expected to be minimal (HEC 2019).

Although there may be some temporary loss of flow (diversion) from the surface water systems in the event of cracking, connectivity between the groundwater and surface water systems is not predicted (HEC 2019).

The minor tributary gullies overlying LW W1-W2 are predicted to experience minimal change in gradient and as such it is unlikely that there will be increased ponding upstream of the gullies or increased potential for scour and erosion (HEC 2019).

The impacts due to the proposed subsidence associated with the western domain on the three creeks in flood conditions are predicted to be negligible (HEC 2019).

4.2.4 Water quality

Isolated, episodic pulses in salinity, iron, manganese, zinc and nickel may occur in Stonequarry Creek, Matthews Creek and Cedar Creek due to subsidence induced changes in surface water runoff, through flow and baseflow discharging to these surface water systems. However, as Stonequarry Creek, Matthews Creek and Cedar Creek will not be directly mined beneath, the subsidence related impacts to water quality are likely to be less than that recorded previously in Redbank Creek following mining of LW 25 to LW 32 (HEC, 2019).

Groundwater seepage has been observed at the junction of Cedar Creek and Matthews Creek based on high iron hydroxide precipitation within this reach (GeoTerra 2014). As such, subsidence related impacts to water quality may be more pronounced at this location. Ferruginous deposition is prevalent in Cedar Creek and may be exacerbated by subsidence induced emergence of ferruginous springs (HEC 2019).

Table 6: Predicted water chemistry and geomorphological impacts of Cedar, Matthews and Stonequarry Creeks from the Extraction Plan Layout

Watercourse	Attribute	Predicted impacts (MSEC 2019; HEC 2019)
Cedar Creek	Grade reversal	Grade change negligible (MSEC 2019).
	Ponding	Adverse impacts due to increased levels of ponding unlikely (MSEC 2019).
	Flow	Impacts from fracturing are more likely to occur near the commencing ends of LW W1-W2, where Cedar Creek is located closest to these longwalls, and where Cedar Creek is located closest to the tailgate of LW W1. The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls (MSEC 2019). Has the potential to occur in less than 10% of pools. Although there may be some loss of flow (diversion) from the surface water systems in the event of cracking, connectivity between the groundwater and surface water systems is not predicted (HEC 2019).
	Scour	Adverse impacts due to increased levels of scouring of the banks unlikely (MSEC 2019).
	Pool holding capacity	Less than 10% of pools may be impacted such that there is an observable impact to pool water levels and pool connectivity (HEC 2019).
	Water quality changes	Isolated, episodic pulses in salinity, iron, manganese, zinc and nickel may occur. Potential subsidence related impacts to water quality at the junction of Cedar Creek and Matthews Creek. Existing ferruginous deposition may be exacerbated by subsidence induced emergence of ferruginous springs.
Matthews Creek	Grade reversal	Grade change negligible (MSEC 2019).
	Ponding	Adverse impacts due to increased levels of ponding unlikely (MSEC 2019).

Watercourse	Attribute	Predicted impacts (MSEC 2019; HEC 2019)
	Flow	Impacts from fracturing are more likely to occur where Matthews Creek is located closest to the tailgate of LW W1. The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls (MSEC 2019). Although there may be some temporary loss of flow (diversion) from the surface water systems in the event of cracking, connectivity between the groundwater and surface water systems is not predicted (HEC 2019).
	Scour	Adverse impacts due to increased levels of scouring of the banks unlikely (MSEC 2019).
	Pool holding capacity	Less than 10% of pools may be impacted such that there is an observable impact to pool water levels and pool connectivity (HEC 2019).
	Water quality changes	Isolated, episodic pulses in salinity, iron, manganese, zinc and nickel may occur. Potential subsidence related impacts to water quality at the junction of Cedar Creek and Matthews Creek.
Stonequarry Creek	Grade reversal	Grade change negligible (MSEC 2019).
	Ponding	Adverse impacts due to increased levels of ponding unlikely (MSEC 2019).
	Flow	Impacts from fracturing are more likely to occur near the commencing ends of LW W1-W2, where Stonequarry Creek is located closest to these longwalls. The likelihoods of fracturing and surface flow diversions reduce with distance away from the proposed longwalls (MSEC 2019). Although there may be some temporary loss of flow (diversion) from the surface water systems in the event of cracking, connectivity between the groundwater and surface water systems is not predicted (HEC 2019).
	Scour	Adverse impacts due to increased levels of scouring of the banks unlikely (MSEC 2019).
	Pool holding capacity	Unlikely that streambed cracking will occur or that the predicted change in gradient will result in an observable impact to pool water levels, pool connectivity or stream bed erosion (HEC 2019).
	Water quality changes	Isolated, episodic pulses in salinity, iron, manganese, zinc and nickel may occur.
Tributaries	Grade reversal	Predicted mining-induced changes in grade are small compared with the natural grades of the tributaries. It is unlikely that the tributaries would experience adverse impacts due to changes in stream alignment (MSEC 2019).
	Ponding	It is unlikely that the tributaries would experience adverse impacts due to increased levels of ponding (MSEC 2019).
	Flow	Surface water flow diversions could occur along the tributaries that are located directly above LW W1-W2. In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds.
	Scour	It is unlikely that the tributaries would experience adverse impacts due to increased levels of scouring of the banks (MSEC 2019).

Watercourse	Attribute	Predicted impacts (MSEC 2019; HEC 2019)
	Pool holding capacity	The tributaries are ephemeral and, therefore, surface water flows only occur during, and for short periods after, rain events (MSEC 2019).
	Water quality changes	Not expected.

4.3 Environmental Consequences

The environmental consequences of the potential subsidence impacts are summarised in Table 7.

Table 7: Environmental consequences of changing aquatic values

Aquatic value	Predicted impact	Environmental consequence
Aquatic habitat	Matthews Creek	Potential reduction in pool habitat near LW W1, less than 10% reduction in overall pool habitat and increase in iron floc smothering the benthos at Cedar/Matthews Creek junction.
	Cedar Creek	Potential reduction in pool habitat near LW W1, less than 10% reduction in overall pool habitat and increase in iron floc further smothering the benthos at Cedar/Matthews Creek junction.
	Stonequarry Creek	Unlikely to have reduction in pool habitat.
Riparian Vegetation	Matthews Creek	Potential localised impacts from gas emissions, low likelihood.
	Cedar Creek	Potential localised impacts from gas emissions, low likelihood.
	Stonequarry Creek	Potential localised impacts from gas emissions, low likelihood.
Macrophytes	Matthews Creek	Potential localised reduction in available wetted habitat.
	Cedar Creek-	Potential localised reduction in available wetted habitat.
	Stonequarry Creek	Unlikely.
Macroinvertebrates	Matthews Creek	Potential reduction in available habitat and macroinvertebrate biomass. Reduction of sensitive macroinvertebrate species at Cedar Creek/Matthews Creek junction. Potential localised temporal change in community composition from episodic changes in water quality.

Aquatic value	Predicted impact	Environmental consequence
	Cedar Creek	Potential localised reduction in available habit and macroinvertebrate biomass. Reduction of sensitive macroinvertebrate species at Cedar Creek/Matthews Creek junction. Potential localised temporal change in community composition from episodic changes in water quality
	Stonequarry Creek	Potential localised temporal change in community composition from episodic changes in water quality.
Fish	Matthew Creeks-	Potential localised temporal reduction in fish passage in low flows when there is naturally limited fish passage.
	Cedar Creek-	Potential localised temporal reduction in fish passage in low flows when there is naturally limited fish passage.
	Stonequarry Creek	Unlikely.
Threatened species	Matthew Creeks	Unlikely.
	Cedar Creek	Unlikely.
	Stonequarry Creek	Unlikely.

5. Management Monitoring and Evaluation

5.1 Subsidence Performance Measures and Indicators

This ABTR outlines the management strategies, controls and monitoring programs to be implemented for the management of aquatic flora and fauna regarding potential environmental impacts from the proposed LW W1-W2 extraction workings.

Biodiversity performance measures were defined in DA 67/98 Condition 13A Table 1, and are repeated in Table 8 below. Tahmoor Coal must ensure that there is no exceedance of the subsidence impact performance measures for biodiversity as provided in Table 8, and have contingencies if these performance measures are exceeded.

A monitoring program will be implemented to measure any impacts to aquatic biodiversity. This monitoring program is described in Section 5.2 and provided in Table 9.

To establish compliance with the performance measures outlined in Table 8, a TARP has been developed to inform the operations if the performance measures are likely to be exceeded during secondary extraction within the Study Area, and to provide management/corrective actions for implementation if a risk is triggered. The TARP is described in Section 6.2 and provided in Table 11 of this ABTR.

Table 8: Biodiversity subsidence performance measures and performance indicators

Biodiversity feature	Subsidence performance measure for consent	Adopted subsidence performance indicators
Threatened species, threatened populations, or endangered ecological communities	Negligible environmental consequences	This performance indicator will be considered to be triggered if: • Changes in macroinvertebrate and stream health indicators are statistically significant; and • If visual assessment of aquatic habitat identifies mining subsidence induced impacts.

5.2 Monitoring

5.2.1 Subsidence monitoring program

The monitoring program outlined below will be implemented to monitor the impacts of subsidence effects to aquatic biodiversity within the Study Area and surrounding areas likely to be impacted by far-field movements. As subsidence effects are predicted to be small in magnitude, the monitoring program outlined below reflects the magnitude of these expected impacts.

5.2.2 Aquatic biodiversity monitoring program

Monitoring for aquatic biodiversity would address stream health indicators and measure relevant water quality variables at appropriate spatial and temporal scales. This will enable changes to water quality, aquatic habitats and biota resulting from mining related subsidence to be distinguished from natural variability and other catchment influences.

Monitoring will be conducted in an adaptive management framework and be in accordance with the current monitoring program methods and protocols (see baseline monitoring report for details - Niche 2019).

Sampling has been conducted in spring and autumn for two years prior to the commencement of mining in order to establish a baseline condition and will be conducted in spring and autumn every year during and for a period of three to five years after mining to detect any changes to the aquatic environment and its biota that could be attributed to mining activities. Monitoring will employ a range of techniques including:

- Physiochemical water quality sampling;
- Aquatic habitat observations;
- AUSRIVAS macroinvertebrate sampling; and
- Quantitative macroinvertebrate sampling.

Detailed recommendations for monitoring including laboratory methods and data analysis are provided in Niche (2019a). The sampling regime and locations are provided in Table 9, Table 10 and Figure 2.

AUSRIVAS monitoring will allow monitoring of the sites through time with a before/after comparison. Quantitative sampling of macroinvertebrates will allow statistical testing of any change to family richness, density and macroinvertebrate assemblages in a BACI experimental design through temporal comparison of impact sites to upstream controls.

Reporting will be completed annually or as required by the TARP.

5.3 Baseline Monitoring for Future Extraction Plans

The monitoring program going forward should aim to be consistent with baseline monitoring conducted in 2017-2019 (Niche 2019a) (Table 9, Table 10). The program should also adapt to changing priorities, mine design and/or include improvements to overall design of the monitoring program. This may involve addition or removal of sites and/or indicators as necessary to streamline and detect meaningful ecological change. The program should be reviewed particularly after the completion of the first longwall (W1), to ascertain whether survey effort is effectively monitoring stream health and anthropogenic induced changes and inform future mine layout.

Table 9: Monitoring program for aquatic biodiversity values

Feature	Monitoring Component / Location	Monitoring		
		Prior to Mining	During Mining	Post Mining
Water quality	Physio chemical water quality sampling at all sites	Completed as part of baseline monitoring.	Bi-annually (first occurring in spring 2019)	Bi-annually (spring and autumn for 3-5 years)
Aquatic habitat	Aquatic habitat observations at Sites 4-8 (SQC4, CC5, CC6, MC7, MC8)			
Macroinvertebrates	AUSRIVAS macroinvertebrate sampling at Sites 4-8 (SQC4, CC5, CC6, MC7, MC8)			
	Quantitative macroinvertebrate sampling at Sites 4-16 (Table 10)			

Table 10: Location of monitoring sites

Site number	Site code	Location	Sampling method	Stream	Longwall	Easting	Northing
Potential impact sites – baseline (not yet impacted)							
Site 4	SQC4	Confluence of Stonequarry and Cedar creeks	Aquatic habitat assessment AUSRIVAS and Quantitative macroinvertebrate sampling Water quality sampling Fish sampling.	Stonequarry Creek	North of Longwall W2	278049	6216448
Site 5	CC5	Upstream of Stonequarry Creek confluence		Cedar Creek	North LW W1	277883	6216526
Site 6	CC6	At confluence of Cedar and Matthews creeks		Cedar Creek	West of LW W1	277534	6216048
Site 7	MC7	Upstream of Cedar Creek confluence		Matthews Creek	West of LW W1	277606	6215667
Site 8	MC8	Most upstream site		Matthews Creek	West of LW W1	277494	6215298
Site 15	SQC15	Stonequarry Creek downstream	Quantitative macroinvertebrate sampling Water quality sampling.	Stonequarry Creek	Downstream of longwalls	278551	6216513
Control sites							
Site 9	CC9	Cedar Creek at Weir	Quantitative macroinvertebrate sampling Water quality sampling.	Cedar creek	Upstream control	275401	6214851
Site 10	CC10	Cedar Creek at Bridge		Cedar Creek	Upstream control	275268	6214927
Site 11	CC11	Cedar Creek upstream		Cedar Creek	Upstream Control	275140	6214789

Site number	Site code	Location	Sampling method	Stream	Longwall	Easting	Northing
Site 12	CC12	Cedar Creek upstream of Matthews Creek		Cedar Creek	Upstream Control	276643	6215875
Site 13	SQC13	Stonequarry creek at bridge		Stonequarry Creek	Upstream Control	277479	6217229
Site 14	SQC14	Stonequarry Creek at Vintage		Stonequarry creek	Upstream control	276376	6216300
Site 16	CC 16	Cedar Creek at Scroggies Lane		Cedar Creek	Upstream control	273744	6214122

6. Contingency Plan

6.1 Adaptive Management

As part of the aquatic biodiversity management, Tahmoor Coal recognises the need to adapt to unforeseeable impacts or changes associated with the Project. Tahmoor Coal will implement the contingencies outlined in Section 6.2 and the TARP (Table 11).

An Adaptive Management Framework provides for flexible decision making, adjusted to consider uncertainties as management outcomes are understood. Through feedback to the management process, the management procedures are changed in steps until monitoring shows that the desired outcome is obtained. The monitoring program has been developed so that there is statistical confidence in the outcome.

In adaptive management the goal to be achieved is set, so there is no uncertainty as to the outcome, and conditions requiring adaptive management do not lack certainty, but rather they establish a regime which would permit changes, within defined parameters, to the way the outcome is achieved.

Adaptive management involves:

- Planning – identifying performance measures and indicators, developing management strategies to meet performance measures and establishing programs to monitor against the performance measures;
- Implementation – implementing monitoring programs and management strategies;
- Review – reviewing and evaluating the effectiveness of monitoring and management strategies;
- Contingency Response – implementing the contingency plan in the event that a subsidence impact performance measure in relation to surface water resources has been exceeded; and
- Adjustment – adjusting management strategies to improve performance.

An adaptive management response would be detailed in an Investigation Report prepared as a response to issues identified in the monitoring program. A management response may be developed and would be based on the monitoring data as supplemented by expert advice, if sought.

6.2 Trigger Action Response Plans (TARPs)

TARPs are used to set out response measures for unpredicted subsidence impacts and have been developed for potential impacts to sensitive biodiversity features, such as aquatic habitat and macroinvertebrates.

The monitoring results will be used to assess the impacts of mining in the Western Domain against the performance indicators and performance measures using the TARPs.

The frequency of assessment against the TARPs and the proposed method of analysis is summarised in Table 9 and Table 10 for each potential impact to aquatic biodiversity. The impact assessment triggers and proposed response/action plans are detailed in Table 11. The terms “normal”, “within prediction” and “exceeds prediction” are used for consistency with other Tahmoor Coal TARPs.

Table 11. TARPs associated with aquatic biodiversity

Potential impact	Trigger	Action
Decline or significant negative change in macroinvertebrate indicators. These indicators include: • Density • Family richness • Community assemblages • EPT index • SIGNAL score • AUSRIVAS score	Normal	
	Monitoring macroinvertebrate indicators are within range of baseline data as supported by statistical analysis.	• No action required • Continue subsidence monitoring program. • Continue biodiversity monitoring program.
	Within prediction	
	One or more macroinvertebrate indicators are not within range of baseline data as supported by statistical analysis. AND ONE OR BOTH OF THE FOLLOWING: • Subsidence monitoring program identifies potential for impact to watercourse parameters associated with aquatic habitat areas compared to baseline e.g. cracking. • Subsidence monitoring program identifies potential impacts to hydrology/water quality parameters compared to baseline.	• Review and confirm monitoring data, cross check aquatic biodiversity monitoring data against other related environmental data (e.g. control sites and benchmark data) and subsidence monitoring upon identification of the potential trigger. • Undertake further investigations as appropriate to confirm the potential issue and analyse data with the aim of determining whether the exceedance is likely to be mining related. • Assess need for any increase to monitoring frequency or additional monitoring where relevant. • Continue monitoring programs.
	Exceeds prediction	
	Monitoring indicates that three or more macroinvertebrate indicators are not within range of baseline data as supported by statistical analysis. AND ONE OR BOTH OF THE FOLLOWING: • Subsidence monitoring identifies mining induced impacts compared to baseline watercourse parameters associated with aquatic habitat e.g. cracking.	• Implement Adaptive Management process as detailed within the Extraction Plan. • Notify OEH and relevant stakeholders within 7 days of current findings and proposed approach for investigation upon identification of the potential trigger. • Take all necessary steps to ensure that the exceedance ceases and does not recur. • Convene Tahmoor Coal Environmental Response Group to review response. • Implement remediation measures to the satisfaction of the Secretary. • Review of mining design / predictions against mine design criteria. • Written reporting as per consent and relevant approvals.

	• Subsidence monitoring identifies significant impacts to hydrology/water quality that exceed predictions compared to baseline.	

Potential impact	**Trigger**	**Action**
Reduction in aquatic habitat though loss of pools or associated reduction in water quality (AUSRIVAS habitat assessment).	Normal	
	Visual monitoring indicates aquatic habitat parameters are similar to baseline observations at aquatic ecology monitoring sites.	• No action required • Continue subsidence monitoring program. Continue aquatic biodiversity monitoring program.
	Within prediction	
	Visual monitoring indicates potential change in aquatic habitat compared to baseline observations at aquatic ecology monitoring sites. AND ONE OR BOTH OF THE FOLLOWING: • Subsidence monitoring identifies potential for impact to watercourse parameters associated with macroinvertebrate indicators compared to baseline. Subsidence monitoring program identifies potential for impact to hydrology/water quality parameters compares to baseline.	• Review and confirm monitoring data, cross check aquatic biodiversity monitoring data against other related environmental data (e.g. control sites and benchmark data) and subsidence monitoring upon identification of the potential trigger. • Undertake further investigations as appropriate to confirm the potential issue and analyse data with the aim of determining whether the exceedance is likely to be mining related. • Assess need for any increase to monitoring frequency or additional monitoring where relevant. • Continue monitoring programs.
	Exceeds prediction	
	Visual monitoring indicates a significant change in aquatic habitat compared to baseline observations at aquatic ecology monitoring sites. AND ONE OR BOTH OF THE FOLLOWING:	• Implement Adaptive Management process as detailed within the Extraction Plan. • Notify OEH and relevant stakeholders within 7 days of current findings and proposed approach for investigation upon identification of the potential trigger. • Take all necessary steps to ensure that the exceedance ceases and does not recur. • Convene Tahmoor Coal Environmental Response Group to review response. • Implement remediation measures to the satisfaction of the Secretary. • Review of mining design / predictions against mine design criteria.

	• Subsidence monitoring identifies that macroinvertebrate indicators exceed prediction compared to baseline. • Subsidence monitoring identifies significant impacts to hydrology/water quality that exceed predictions.	• Written reporting as per consent and relevant approvals.

6.3 Contingency Measures

Due to the minimal subsidence and mine design criteria presented in section 5, the need to implement remediation measures for potential impacts are considered unlikely. However, in the event that remediation is required, Tahmoor Coal will undertake remediation in consultation with the relevant landholders and NSW Government Agencies. A Response Strategy will be adopted if a significant impact is detected as a result of mining activities within the Study Area.

Standard management measures will be implemented for negligible impacts to aquatic biodiversity where those impacts occur as a result of mining. These measures include, continuation of the approved monitoring program and reporting.

Management measures for aquatic biodiversity will be employed where more than negligible impacts resulting from subsidence occur (e.g. 'within prediction' and 'exceeds prediction' as described in the TARPs). Management measures include implementation of the standard management measures as well as the involvement of relevant stakeholders, agencies and specialists to investigate and report on the changes that are identified.

Assessment of biodiversity impacts by an Accredited Ecologist would be undertaken once an impact is confirmed. Additional monitoring would be undertaken with specialists providing updates on the investigation process and the relevant stakeholders and agencies would be provided with investigation results. In the event that the impacts of mine subsidence on aquatic habitats are greater than predicted, the following mitigation measures would also be considered, in consultation with key stakeholders:

- Should significant impacts on aquatic biodiversity occur that are considered to be outside of the Performance Measures of the approval conditions, Tahmoor Coal would review future longwalls configurations;
- Implementing stream remediation measures, such as backfilling or grouting in areas where fracturing of controlling rock bars and/or stream bed leads to diversion of stream flow and drainage of pools; and
- Implementing appropriate erosion/sedimentation control measures to limit the potential for deposition of eroded sediment into affected streams.

7. References

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8. Appendix A

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AQUATIC ECOLOGY BASELINE MONITORING REPORT
TAHMOOR NORTH - WESTERN DOMAIN

2017- 2019

Prepared for Tahmoor Coal | 5 July 2019

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Document control

Project number	Client	Project manager	LGA
4645	Tahmoor Coal	Matthew Russell	Wollondilly

Version	Author	Review	Status	Date
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Enquiries should be addressed to:

Sydney Head Office
Niche Environment and Heritage
02 9630 5658
info@niche-eh.com
PO Box 2443 North Parramatta
NSW 1750 Australia

Executive summary

Project outline

Tahmoor Coal Pty Ltd (Tahmoor Coal) proposes to extent underground coal mining to the north-west of the Main Southern Railway (referred to as the 'Western Domain') which will include Longwalls West 1 (LW W1) to West 4 (LW W4) at Picton and Thirlmere. Niche Environment Heritage Pty Ltd (Niche) were engaged by Tahmoor Coal to conduct baseline monitoring of aquatic ecology within the area potentially affected by longwall mining. This report documents the aquatic ecology of two years of biannual (spring/autumn) monitoring within the study area and surrounds.

Methods

The monitoring program was conducted in November 2017, April 2018, November 2018 and May 2019 and employed the following survey methods:

- Aquatic habitat assessment comprising:
  - The Australian River Assessment System (AUSRIVAS);
  - Riparian Channel and Environment (RCE) Inventory;
- Macroinvertebrate survey comprising:
  - AUSRIVAS macroinvertebrate sampling;
  - A quantitative benthic macroinvertebrate monitoring program (to be updated when samples have been identified and analysed);
- Water quality sampling; and
- Fish sampling.

Results and conclusions

The baseline study identified the following environmental characteristics of the streams in the study area:

- Matthews Creek, Stonequarry Creek and Cedar Creek were found to be in moderate to good condition with the best habitat located within gorges along Matthews Creek and Cedar Creek upstream of Stonequarry Creek;
- There was variation in habitat availability, particularly at site MC 8 which was dry on two occasions and could not be sampled;
- The water quality had high salinity (approximately 1000 µS/cm) within the study area. This indicated that electrical conductivity is naturally elevated above ANZECC guidelines in and upstream of the study area and resident fauna are likely to be adapted to these relatively high concentrations;
- Low dissolved oxygen was characteristic of all sites and considered normal for stream pools exhibiting low to no flow conditions;
- The pH was generally within Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines in spring 2017 and autumn 2018 however appear to decrease below Default Trigger Levels (DTVs) in spring 2018 and autumn 2019. This reduction may be related to low rainfall, less surface water flow and increase in groundwater water influence;
- Alkalinity was generally low in all streams indicating a low buffering capacity against changes to pH;
- Stream health, as indicated by AUSRIVAS and Stream Invertebrate Grade Number – Average Level (SIGNAL), showed impairment of macroinvertebrates (that is, sites that are missing families expected to occur at the site naturally) and generally consisted of pollution tolerant macroinvertebrate families. Overall, this indicated that streams are in poor stream health which is likely due to a number of factors including natural environmental stresses, driven by low stream flow;

- There are however pollution sensitive invertebrates that inhabit these environments. The mayfly Leptophlebiidae (SIGNAL 8), and caddis flies Leptoceridae and Calamoceridae are taxa that are vulnerable to pollution but common among sites in the study area; and
- Low stream health scores and indices that were observed in the baseline study can be considered natural characteristics of drying intermittent/low flow streams.

Recommendations

Further monitoring will be required to assess and track any further impacts and/or subsequent recovery as longwall mining takes place. The monitoring should focus on using macroinvertebrates as indicator of ecological stream health. Responses to impacts should be measured primarily through the analysis of AUSRIVAS and changes in macroinvertebrate biomass, community composition and indicator species using quantitative data in accordance with BACI (Before After Control Impact) design.

Glossary and list of abbreviations

Term or abbreviation	Definition
SIGNAL	Stream Invertebrate Grade Number Average Level
BACI	Before After Control Impact experimental design
DTV	Default Trigger Level
AUSRIVAS	Australian Rivers Assessment System
RCE	Riparian Channel and Environment Inventory Assessment
FM Act	*Fisheries Management Act 1994* (NSW)
DPI	The NSW Department of Primary Industries
ANZECC	Australian and New Zealand Environment and Conservation Council
Modal Width	The width which appears most often in a specified length of stream channel

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1. Introduction

1.1 Background and need for the project

The Tahmoor Coal Mine (Tahmoor Mine) is an underground coal mine located approximately 80 kilometres (km) south-west of Sydney between the towns of Tahmoor and Bargo, New South Wales (NSW) (Figure 1). Tahmoor Mine produces up to three million tonnes of Run of Mine (ROM) coal per annum from the Bulli Coal Seam. Tahmoor Mine produces a primary hard coking coal product and a secondary higher ash coking coal product that are used predominantly for coke manufacture for steel production. Product coal is transported via rail to Port Kembla and Newcastle for Australian domestic customers and export customers.

Tahmoor Coal proposes to extent underground coal mining to the north-west of the Main Southern Railway (referred to as the 'Western Domain') which will include Longwalls West 1 (LW W1) to West 4 (LW W4) (collectively referred to as LW W1-W4) at Picton and Thirlmere. Niche Environment Heritage Pty Ltd (Niche) were engaged by Tahmoor Coal to conduct baseline monitoring of aquatic ecology within the area potentially affected by longwall mining.

1.1.1 Purpose and objectives of this report

This document details baseline aquatic ecological monitoring for LW W1-W4, incorporating two years of biannual monitoring including spring 2017, autumn 2018, spring 2018 and autumn 2019. The monitoring data will also support the Aquatic Biodiversity Technical Report for the mining of LW W1-W2, the Biodiversity Management Plan and Extraction Plan.

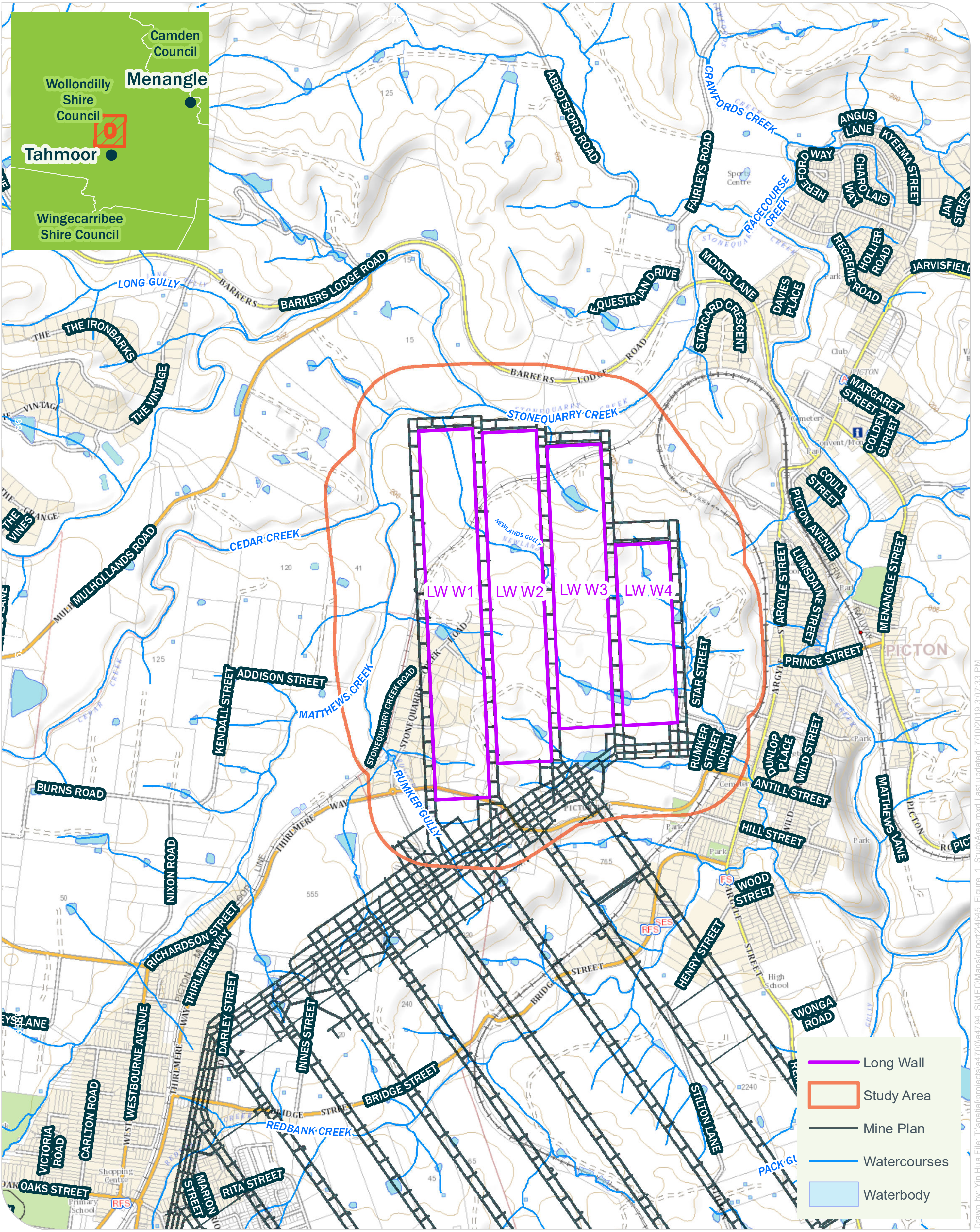
The purpose of the aquatic ecological monitoring is to establish background conditions; a baseline to which future monitoring can be compared during and post extraction. Ongoing monitoring will provide information regarding the effectiveness of the management of the aquatic environment and assist in adaptive management of the extraction process to limit and or mitigate environmental impacts.

1.2 Previous studies

In 2014, Niche Environment and Heritage conducted an aquatic impact assessment of Cedar Creek, Matthews Creek and Stonequarry Creek to determine the risk to aquatic ecology from longwall mining from LW W1-W4. The assessment used AUSRIVAS and SIGNAL to assess stream health. The study found that:

- The sites are reflective of generally good riparian native vegetation, with the absence of weeds, rubbish, visual pollution, and a healthy channel morphology that provides substantial aquatic habitat;
- Streams had low alkalinity indicating less buffering capacity against changes in pH. Cedar Creek near the Stonequarry Creek confluence had a low pH;
- Electrical conductivity and turbidity was low and generally within ANZECC DTVs;
- Dissolved oxygen was generally below and outside of ANZECC DTVs however this is common for low flow intermittent streams in the area;
- The macroinvertebrate communities in these habitats generally consist of families that are good dispersers; particularly those that aerially disperse; can cope with poor water quality (e.g. low dissolved oxygen, low alkalinity/pH, extremes in temperature); as well as variable flow conditions including extended periods of no flow or complete drying out;
- Mostly the faunal composition includes those of low SIGNAL scores that indicate pollution tolerance. A low SIGNAL2 score in this instance can be considered natural in drying ephemeral streams; and
- There are pollution sensitive invertebrates that inhabit these environments in the study area. The mayfly Leptophlebiidae (SIGNAL score 8) are most vulnerable to pollution. The family is common

among the ephemeral/semi-permanent streams in the area and its absence may indicate streams under natural or anthropogenic stress.



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0 500 m

GDA 1994 MGA Zone 56

Location and study area

Aquatic Baseline Monitoring Tahmoor Longwalls West 1-4

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Niche Proj. #: 4794
Client: Tahmoor Coal

Figure 1

2. Methods

2.1 Study Area

The proposed LW W1-W4 are located to the west of the township of Picton, between Matthews, Cedar and Stonequarry Creeks, the Main Southern Railway and the currently active longwall series. The layouts of the proposed longwalls at the mine are shown in Figure 1 and Figure 2.

The Study Area is defined as the surface area that could be affected by the mining of LW W1-W4 as determined by Mining Subsidence Engineering Consultants (MSEC 2019) on behalf of Tahmoor Coal. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- A 35° angle of draw from the extents of LW W1-W4;
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of LW W1-W4; and
- Features that could experience far-field or valley related movements and could be sensitive to such movements.

The Study Area includes a number of natural features and surface infrastructure. Of relevance to this baseline study are Matthews, Cedar and Stonequarry creeks (Figure 2).

Most of the Study Area consists of rural residential development, with vegetated land concentrated along the riparian zones of watercourses. Topography varies within the Study Area from gently undulating flats on higher altitude areas to steep incised gullies within lower areas of exposed Hawkesbury Sandstone.

Stonequarry Creek, Matthews Creek and Cedar Creek are the main natural waterway features within the Study Area (Figure 2) and will be the focus of the monitoring program. The monitoring includes control sites located upstream of the 20 mm subsidence contour.

2.2 Summary of survey methods

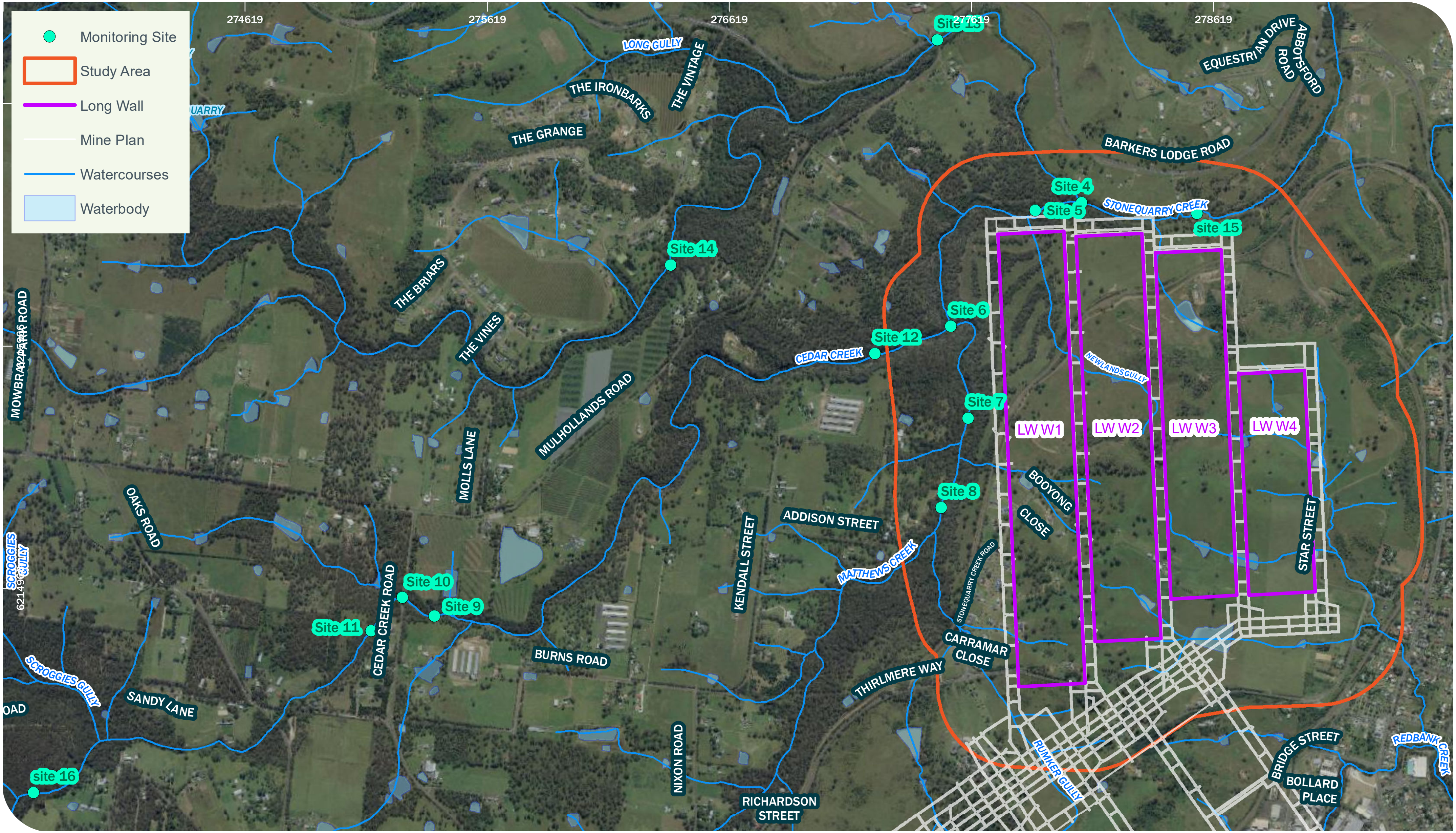
The monitoring program conducted in November 2017, April 2018, November 2018 and May 2019 and employed the following survey methods:

- Aquatic habitat assessment comprising:
  - The Australian River Assessment System (AUSRIVAS);
  - Riparian Channel and Environment (RCE) Inventory;
- Macroinvertebrate survey comprising:
  - AUSRIVAS macroinvertebrate sampling;
  - A quantitative benthic macroinvertebrate monitoring program (to be updated when samples have been identified and analysed);
- Water quality sampling; and
- Fish sampling.

The baseline monitoring is primarily focused on macroinvertebrate monitoring regimes including AUSRIVAS and quantitative Before After Control Impact (BACI) design. In AUSRIVAS macroinvertebrate samples are compared to modelled reference sites and is a rapid assessment based on presence/absence of invertebrates. The quantitative macroinvertebrate program compares potential impacts sites with upstream control sites and contains community assemblage data, which can be used to determine quantitative changes in fauna abundance, richness and structure that may otherwise be missed by a rapid assessment approach. The suite of methods used at each site is detailed in Table 1.

2.3 Sampling locations

All creeks subject to potential future impacts from longwall mining were surveyed including Cedar Creek, Matthews Creek and Stonequarry Creek (Figure 2). Control sites were established upstream of the Study Area along the same creeks to be impacted. In total, thirteen locations were sampled comprising of six impact sites and seven control sites. A summary of sampling sites and methods for spring 2017 to autumn 2019 is provided in Table 1.



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Monitoring sites
Aquatic Baseline Monitoring Tahmoor Longwalls West 1-4

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Client: Tahmoor Coal

Figure 2

Table 1: Location of monitoring sites

Site Number	Site Code	Location	Sampling method	Stream	Reason for site selection	Easting	Northing
Potential impact sites – baseline (not yet impacted)							
Site 4	SQC4	Confluence of Stonequarry and Cedar creeks	Aquatic habitat assessment AUSRIVAS and Quantitative macroinvertebrate sampling Water quality sampling Fish sampling	Stonequarry Creek	North of LW W2	278049	6216448
Site 5	CC5	Upstream of Stonequarry Creek confluence		Cedar Creek	North LW W1	277883	6216526
Site 6	CC6	At confluence of Cedar and Matthews creeks		Cedar Creek	West of LW W1	277534	6216048
Site 7	MC7	Upstream of Cedar Creek confluence		Matthews Creek	West of LW W1	277606	6215667
Site 8	MC8	Most upstream site		Matthews Creek	West of LW W1	277494	6215298
Site 15	SQC15	Stonequarry Creek downstream	Quantitative, water quality and fish sampling	Stonequarry Creek	Downstream of longwalls. This site was included to have two impact sites on Stonequarry Creek as part of the quantitative monitoring.	278551	6216513
Control sites							
Site 9	CC9	Cedar Creek at Weir	Quantitative macroinvertebrate Water quality sampling Fish Sampling	Cedar creek	Upstream control	275401	6214851
Site 10	CC10	Cedar Creek at Bridge		Cedar Creek	Upstream control	275268	6214927
Site 11	CC11	Cedar Creek upstream		Cedar Creek	Upstream Control	275140	6214789
Site 12	CC12	Cedar Creek upstream of Matthews Creek		Cedar creek	Upstream Control was added in autumn 2018 to be closer to study area.	276643	6215875
Site 13	SQC13	Stonequarry creek at bridge		Stonequarry Creek	Upstream Control	277479	6217229
Site 14	SQC14	Stonequarry Creek at Vintage		Stonequarry creek	Upstream control	276376	6216300

Site Number	Site Code	Location	Sampling method	Stream	Reason for site selection	Easting	Northing
Site 16	CC 16	Cedar Creek at Scroggies Lane		Cedar Creek	Upstream control was added in spring 2018 as other control sites were dry.	273744	6214122

Note: No control sites were established in Matthews Creek due to limited access and available habitat however potential monitoring sites were identified towards the end of the baseline study that could be incorporated into the future monitoring program.

2.4 Aquatic habitat assessment

Visual assessment of aquatic habitat was conducted using the AUSRIVAS method. The survey is a rapid assessment to describe habitat based on the following parameters:

- Geomorphology;
- Channel diversity;
- Bank stability;
- Riparian vegetation and adjacent land use;
- Water quality;
- Macrophytes; and
- Local impacts and land use practices.

This was complimented by an RCE Inventory assessment to rank the relative health of stream condition. The RCE Inventory (Chessman et al., 1997) provides a comparative measure of stream condition by assessing both the stream and its riparian environment in terms of habitat diversity, habitat condition and the degree of human-induced disturbance. Thirteen categories each receive a score between 1 and 4 based their condition, resulting in an accumulated score of between 13 and 52. The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) indicates a heavily channelled stream without any riparian vegetation. This assessment provided a score the general condition of the stream and must be interpreted accordingly.

2.5 Macroinvertebrate survey

2.5.1 AUSRIVAS

The AUSRIVAS method of sampling both pools and riffles were modified to suit the site conditions, as no suitable in-stream riffle features were present. Samples were collected from pool edges for a length of 10 m either side as a continuous line or in disconnected segments. Sampling in segments was undertaken to ensure the sampling of sub-habitats such as macrophyte beds, bank overhangs, submerged branches and root mats. Segmented sampling was also employed where pool length was short and it was logistically difficult to sample in a continuous line (e.g. due to the presence of in-stream logs). A 250 micrometre (μ/m) dip net was drawn through the water with short sweeps towards the bank to dislodge benthic fauna while scraping submerged rocks and debris, sides of the stream bank and the bed substrate. Further sweeps in the water column targeted the suspended fauna.

Each sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps, pipettes and/or paint brushes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour or until no new specimens had been found. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous or slow. The animals collected at each site were placed into a labelled jar containing 70% ethanol.

The chemical and physical variables required for running the AUSRIVAS predictive model were also recorded: i.e. alkalinity, modal depth and width of the stream, percentage bedrock, boulder or cobble along with latitude and longitude. Distance from stream source, altitude, land-slope and rainfall were also calculated.

2.5.2 Quantitative benthic macroinvertebrate sampling

Macroinvertebrates were sampled from three random pool edges at each site. Pool-edge samples were collected from depths of 0.2 - 0.5 m within 2 m of the bank. A suction sampler described by Brooks (1994) was placed over the substrate and operated for one minute at each sampling location. The sample was washed thoroughly over a 500 µm mesh sieve. All material retained on the 500 µm mesh sieve was preserved in 70% ethanol for laboratory sorting. Samples that contained few invertebrates were not subsampled.

2.5.3 Laboratory methods-invertebrate identification

Macroinvertebrate samples were identified to family level with the exception of Oligochaeta (to class), Polychaeta (to class), Ostracoda (to subclass), Nematoda (to phylum), Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Small crustaceans Ostrocoda, Copapoda and Cladocera were not included as part of the analysis. Identification keys used included:

- Dean, J., Rosalind, M., St Clair, M., and Cartwright, D. (2004) Identification keys to Australian families and genera of caddis-fly larvae (Trichoptera) Cooperative Research Centre for Freshwater Ecology;
- Gooderham, J. and Tsyrlin, E. (2002). The Waterbug Book: A guide to the Freshwater Macroinvertebrates of Temperate Australia, CSIRO Publishing;
- Hawking and Theischinger (1999) A guide to the identification of larvae of Australian families and to the identification of ecology of larvae from NSW;
- Madden, C. (2010) Key to genera of Australian Chironomidae. Museum Victoria Science Reports 12,1-31;
- Madden, C. (2011) Draft identification key to families of Diptera larvae of Australian inland waters La Trobe University;
- Smith, B. (1996) Identification keys to the families and genera of bivalve and gastropod molluscs found in Australian inland waters Murray Darling Freshwater Research Centre; and
- Website - http://www.mdfrc.org.au/bugguide/.

2.5.4 Data analysis

AUSRIVAS

Samples collected using AUSRIVAS protocol were analysed using the predictive models for NSW pool edge habitats (Turak et al., 2004). The AUSRIVAS model predicts the aquatic macroinvertebrate fauna expected to occur at a site in the absence of environmental stress, such as pollution or habitat degradation. The AUSRIVAS NSW autumn and spring models were used for the data collected. Observed to expected ratio (OE50), SIGNAL (Stream Invertebrate Grade Number Average Level), and number of taxa were the indices used to interpret stream health.

OE50

The Observed to Expected ratio is the ratio of the number of invertebrate families observed at a site (NTC50) to the number of families expected (NTE50) at that site. Only macroinvertebrate families with a greater than 50% predicted probability of occurrences are used by the model. OE50 provides a measure of biological impairment at the test site. Bands derived from the OE50 indicate the level of impairment of the assemblage. The OE50 ratios are divided into bands representing different levels of impairment (Table 2).

Table 2: AUSRIVAS band interpretation

Band	Interpretation
Band X	Represents a more biologically diverse community than reference
Band A	Is considered similar to reference condition
Band B	Represents sites significantly impaired
Band C	Represents sites in a severely impaired condition
Band D	Represents sites that are extremely impaired

SIGNAL (Stream Invertebrate Grade Number Average Level) scores

The revised SIGNAL2 biotic index developed by Chessman (2003) was also used to determine the “environmental quality” of sites. This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their response to a range of environmental conditions (Table 3). The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site.

Table 3: SIGNAL Grade and the Level of Pollution Tolerance

SIGNAL Grade	Pollution Tolerance
10-8	Indicates a greater sensitivity to pollution
7-5	Indicates a sensitivity to pollution
4-3	Indicates a tolerance to pollution
2-1	Indicates a greater tolerance to pollution

Table 4 provides a broad guide for interpreting the health of the site according to the SIGNAL 2 score of the site.

Table 4: Guide to interpreting the SIGNAL 2 scores

SIGNAL 2 Score	Habitat quality
Greater than 6	Healthy habitat
Between 5 and 6	Mild pollution
Between 4 and 5	Moderate pollution
Less than 4	Severe pollution

*Note that SIGNAL2 scores are indicative only and that pollution does not refer to just anthropogenic pollution. Environmental stress may result in poor water quality occurring naturally in waterways. Low family richness and the occurrence of pollution tolerant invertebrates can give a low SIGNAL score even though they are natural condition.

Taxa Richness

The richness of macroinvertebrate families (or class/orders if not identified to family level) was calculated as an indicator of stream health. The higher the number, the healthier the aquatic ecosystem.

EPT Index

The EPT (Ephemeroptera, Plecoptera and Tricoptera) index is based on the insect orders that contain a majority of pollution sensitive taxa (Lenat, 1988). All genera of Ephemeroptera, Plecoptera and Tricoptera were identified and the number of distinct taxa were counted as an indicator of ecosystem health. The higher the number, the healthier the aquatic ecosystem.

Statistical Analysis

Statistical analysis was performed on the macroinvertebrate assemblage data collected using the suction sampler using the PERMANOVA+ for Primer statistical software package (Anderson et al 2008). For the baseline survey a two staged analysis of the data was used to investigate, firstly to review the similarity between different assemblages and secondly to identify statistical differences between factors of interest.

Non-metric MDS (Multi-Dimensional Scaling) was used to investigate the similarity of different assemblages based on their species composition (Anderson *et al* 2008). The analysis was based on Bray-Curtis similarities computed from (transformed) species abundance values. The data was transformed using the fourth-root function to normalise the distribution of the data. MDS plots were used to review the data projected for each factor with emphasis on the similarity of baseline data at control treatment sites with the treatment sites. Where control treatment sites were found to be potential statistical outliers and have little relevance to potential impact sites (overlap in data), they were removed from further analysis and value in the program reviewed.

Both multivariate (many variables) and univariate (single variable) analyses can be undertaken using PERMANOVA. In both cases, the significance level was set at $p < 0.05$ for all statistical tests undertaken for this report. In the case where the number of unique permutations for a particular test was less than 100, Monte Carlo probability values were used to assess the significance of the test as outlined in Anderson *et al.* (2008). Data was examined for spatial and temporal differences in macroinvertebrate assemblages using the following design:

- Survey: A fixed factor combining Year and Season and with four levels:
  - Spring 2017
  - Autumn 2018
  - Spring 2018
  - Autumn 2019
- Creek: A fixed factor with three levels:
  - Stonequarry Creek
  - Cedar Creek
  - Matthews Creek
- Site: A fixed factor nested within Stream with various sites.

The multivariate analysis was based on Bray-Curtis similarities computed from (transformed) species abundance values. The data was transformed using the fourth-root function to normalise the distribution of the data. For the univariate analysis the following parameters were investigated using the Euclidean distance matrix:

- Taxonomic Richness
- Abundance

2.6 Water quality sampling

Surface water quality was measured in situ using a Yeokal 611 water quality probe at each site. The following variables were measured:

- Temperature (°C);
- Conductivity (µS/cm);
- pH;
- Alkalinity measured with a standard titration kit (mg $CaCO_3$/L);
- Dissolved Oxygen (DO) (% saturation and mg/L); and
- Turbidity (NTU).

2.7 Fish sampling

Fish sampling was undertaken at impact and control sites. Fish surveys using bait traps were undertaken at each sample site once per season. Five bait traps were deployed in slow flowing pools at each site for one hour. Additionally, fish at each site collected as part of the AUSRIVAS macroinvertebrate sampling were identified and counted. All captured fish and large crustaceans were immediately transferred to a bucket of water for identification and release. Fish were identified in the field using Field Guide to the Freshwater Fishes of Australia (Allen *et al*. 2002). Any individuals that could not be identified were preserved using 70% ethanol for later identification.

Fish sampling was done in accordance with an Animal Research Authority (Fauna Surveys: Terrestrial and Aquatic) and a Scientific Collection Permit (No. P10/0027-3.0) issued by the NSW Department of Primary Industries.

Water quality data were compared with the ANZECC (2000) default trigger values for physical and chemical stressors for protection of slightly disturbed lowland aquatic ecosystems in south-eastern Australia.

3. Results

3.1 Aquatic habitat

In general, the aquatic habitat within the Study Area and at control sites consists predominately of pools with little to no riffles present. RCE scoring indicated that most sites have moderate to good riparian and channel health (Annex 1). In the Study Area, Matthews Creek and Cedar Creek are situated within the gorge and controlled by the sandstone geology. Bedrock was a common component of the stream's morphology in the area. Cedar Creek at Site 5 (CC5) contains mostly boulder type benthos and becomes sandy near its confluence with Stonequarry Creek at Site 4 (SQC4). Site SQC4 was dominated by a sandy benthos and characterised by much wider deeper pools.

Macrophyte occurrence varied between sites but was generally low in abundance and diversity upstream (Matthews Creek and Cedar Creek MC6, MC 7 and MC8), with Cedar Creek at Site 5 (CC5) and SQC4 further downstream the most diverse and abundant. Typical species included *Potamogeton sulcatus, Myriophyllum salsugineum, Elantine gratioloides* and *Juncus* spp. at Cedar Creek at Site 5 (CC5) and Stonequarry Creek Site 4 (SQC4).

There was low rainfall in 2018 (Figure 3) which limited aquatic habitat available, particularly at Matthews Creek at Site 8 (MC8) which was dry on two occasions. Three control sites CC10, CC11 and SQC13 were also dry in 2018 surveys. An additional monitoring site CC16 which has perennial pools was included as part of the monitoring program.

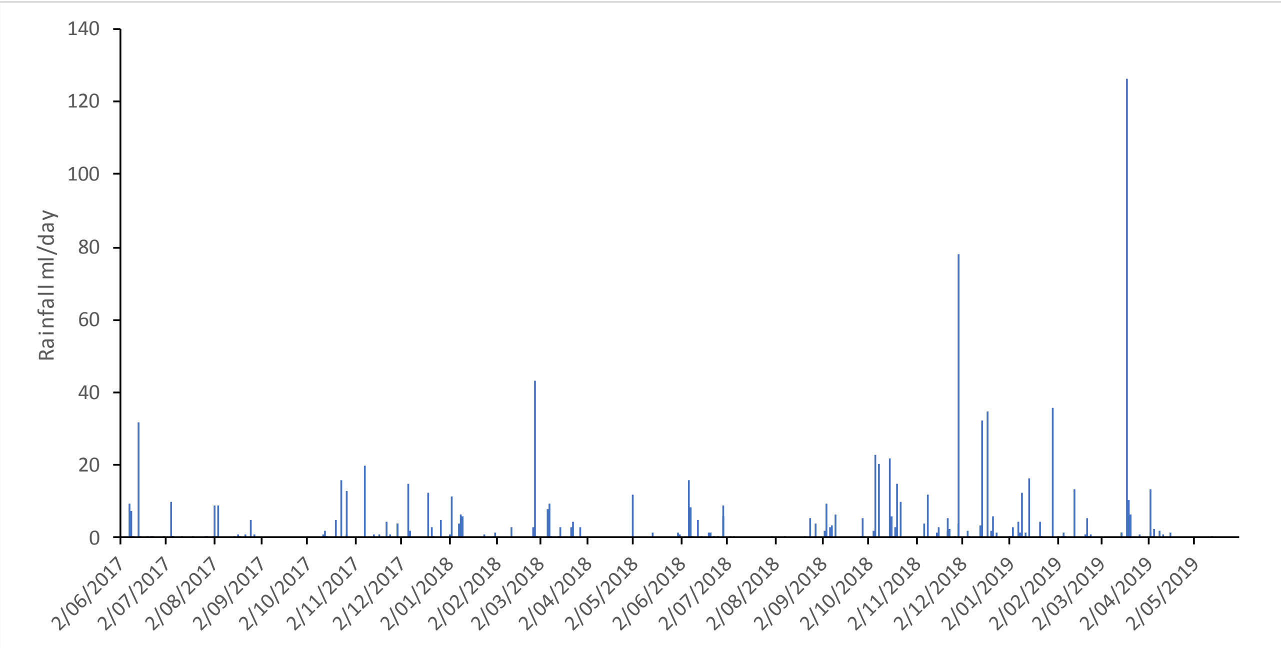

Figure 3: Daily rainfall June 2017-Feburary 2019 (source - Bureau of Meteorology (BOM)).

3.2 Water quality

Water quality results for spring 2017, autumn 2018, spring 2018 and autumn 2019 are presented in Table 5 to Table 8, respectively. Sites MC8, CC10, CC11, and SQC13 were dry during 2018 autumn and spring surveys and were not sampled. Results showed that temperature ranged from 9.7– 23.35°C. Conductivity ranged from 196-1883 µ/cm, exceeding ANZECC trigger values (DTV's) of 30-350µS/cm at most sites with the exception of Matthews Creek (MC8) and Cedar Creek (CC10 and CC11) in spring 2017, Cedar creek

(CC6) and Matthews Creek (MC7) in autumn 2018, Matthews Creek (MC7) and Cedar Creek (CC16) in spring 2018 and Cedar Creek (CC10) in autumn 2019. Stonequarry Creek (SCQ14) recorded the highest electrical conductivity in autumn 2019. Turbidity was variable with most exhibiting low turbidity below or moderately exceeding DTVs. However there were high exceedances particularly in autumn 2018 at Cedar (CC6 and CC12) and Matthews Creek (MC7) (Table 6).

Dissolved oxygen ranged between 21.6 – 108.1% saturation. Most sites were below ANZECC DTVs (85%-110% dissolved oxygen) on most sampling occasions. The pH ranged 3.8-8.7 and was generally variable. The pH however was within DTVs in spring 2017 and autumn 2018 however exceeded DTVs at several sites in spring 2018 and spring 2019. With exception of one site on one occasion, most exceedances were below pH 6.5. Alkalinity was generally low and ranged between 10-60 mg$CaCO_3$/L. The lower the alkalinity, the less buffering capacity (i.e. the capacity of the stream to neutralise acid) a stream has and therefore less capacity to resist to changes in pH. Low alkalinity therefore indicates that river health is potentially sensitive to disturbance.

Table 5: Water quality results spring 2017

Season	Spring 2017												
Site	SQC4	CC5	CC6	MC7	MC8	CC9	CC10	CC11	CC12	SQC13	SQC14	SQC15	CC16
Temperature °C	11.11	17.92	17	18.38	15.2	23.35	20.18	19.59	N/A*	19.02	16.86	14.2	N/A*
Electrical conductivity (µS/cm) ANZECC	**838**	**786**	**835**	**284**	308	**543**	302	338	N/A*	**1269**	**1473**	**1004**	N/A*
Turbidity (NTU)	3.5	1.7	**30.1**	3.7	13.2	**31**	**60**	**100.6**	N/A*	**99**	6.7	18.6	N/A*
Dissolved oxygen (% sat)	**27.0**	**37.0**	**21.6**	**28.3**	**21.9**	**45.2**	**32.2**	**22.2**	N/A*	**24**	**32.5**	**42**	N/A*
pH	6.94	6.98	6.55	7.1	7.63	6.87	6.5	6.54	N/A*	7.01	6.44	7.20	N/A*
Alkalinity (mg $CaCO_3$/L)	40	10	10	30	30	20	20	20	N/A*	50	10	20	N/A*

NOTES: ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-7.5), Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

* Not sampled.

Table 6: Water quality results autumn 2018

Season	Autumn 2018												
Site	SQC4	CC5	CC6	MC7	MC8	CC9	CC10	CC11	CC12	SQC13	SQC14	SQC15	CC16
Temperature °C	12.3	9.7	16.98	19.33	dry	19.01	Dry*	Dry*	16.66	Dry*	12.2	13.78	N/A*
Electrical conductivity (µS/cm) ANZECC	**1075**	**1037**	271	340	dry	**400**	Dry*	Dry*	**1388**	Dry*	**1308**	**1071**	N/A*
Turbidity (NTU)	9	2.7	**1967**	**850**	dry	24	Dry*	Dry*	**600**	Dry*	1.5	18	N/A*
Dissolved oxygen (% sat)	**38.5**	92.6	**32.4**	**61.6**	dry	**60.0**	Dry*	Dry*	**47.5**	Dry*	**75**	**87**	N/A*

Season	Autumn 2018												
Site	SQC4	CC5	CC6	MC7	MC8	CC9	CC10	CC11	CC12	SQC13	SQC14	SQC15	CC16
pH	7.28	6.87	6.91	7.59	dry	6.7	Dry*	Dry*	**5.07**	Dry*	6.56	7.62	N/A*
Alkalinity (mg $CaCa_3$/L)	40	20	60	60	dry	20	Dry*	Dry*	20	Dry*	20	40	N/A*

NOTES: ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-7.5), Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

* Not sampled.

Table 7: Water quality results spring 2018

Season	Spring 2018												
Site	SQC4	CC5	CC6	MC7	MC8	CC9	CC10	CC11	CC12	SQC13	SQC14	SQC15	CC16
Temperature °C	20.69	16.76	18.35	18.05	dry	25.2	Dry*	Dry*	16.85	Dry*	17.21	21.55	18.2
Electrical conductivity (µS/cm) ANZECC	**940**	**899**	**932**	196	dry	**815**	Dry*	Dry*	**1020**	Dry*	**898**	**951**	201
Turbidity (NTU)	14.1	**90**	17.9	**42**	dry	**87.1**	Dry*	Dry*	**29**	Dry*	**35.8**	**27.9**	**39**
Dissolved oxygen (% sat)	**78.1**	**70.0**	**58.3**	**32.5**	dry	108.1	Dry*	Dry*	**52.3**	Dry*	91	91.8	**63.2**
pH	**6.41**	**5.8**	**4.84**	6.58	dry	6.7	Dry*	Dry*	**3.80**	Dry*	**3.88**	6.57	**5.81**
Alkalinity (mg $CaCa_3$/L)	20	20	10	60	dry	20	Dry*	Dry*	10	Dry*	20	20	20

NOTES: ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-7.5), Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

* Not sampled.

Table 8: Water quality results autumn 2019

Season	Autumn 2019												
Site	SQC4	CC5	CC6	MC7	MC8	CC9	CC10	CC11	CC12	SQC13	SQC14	SQC15	CC16
Temperature °C	11.75	10.89	12.52	11.15	12.12	9.95	10.71	Dry*	11	11.34	11.77	13.55	11.48
Electrical conductivity (µS/cm) ANZECC	**797**	**848**	**860**	**388**	**471**	**488**	322	Dry*	**814**	**1092**	**1883**	**699**	**486**
Turbidity (NTU)	5.2	2.9	**173.3**	7	**54.4**	**30.9**	3.1	Dry*	16.2	**27.9**	4.0	5.0	8.2
Dissolved oxygen (% sat)	**59.1**	**83.6**	**32.9**	**51.5**	**40.4**	**57.5**	**44.5**	Dry*	**44.7**	**43.4**	**41.5**	**70.8**	**43.2**
pH	7.6	7.88	**4.9**	7.95	7.62	**8.7**	6.81	Dry*	**6.1**	**6.39**	**3.9**	7.45	**3.97**
Alkalinity (mg $CaCa_3$/L)	20	60	20	40	40	20	20	Dry*	20	60	10	40	20

NOTES: ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-7.5), Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

* Not sampled.

3.3 AUSRIVAS and SIGNAL

AUSRIVAS spring 2017 and autumn 2018, spring 2018 and autumn 2019 results are presented in Table 9 - Table 10 respectively, with raw data provided in Annex 2. Overall, 52 different taxa were collected from all sampling occasions. The number of taxa ranged from 6-24 among sites. Low numbers of macroinvertebrates were recorded in Matthews Creek in autumn 2018 (6) and spring 2018 (7) (Table 10 and Table 11).

Overall, AUSRIVAS sampling showed some impairment at all sites with sites scoring in Band B and Band C over the four sampling occasions (Table 9-Table 12). This indicates that sites have fewer families than was expected and were therefore categorised as significantly to severely impaired. Sites scored close to reference condition (Band A) on two occasions. These were Stonequarry Creek (SQC4) in autumn 2018 and Matthews Creek (MC8) in spring 2019. On average higher AUSRIVAS scores were observed in autumn when compared with spring (Figure 4 and Figure 5).

The SIGNAL scores for all sites and seasons were varied but were mostly low (<4) which may indicate severe pollution or extreme environmental stress (Table 4, Table 9-Table 12). The lowest scores were recorded in Cedar Creek (CC6) scoring 3.1 and 3 in autumn 2018, spring 2018 and autumn 2019. The low scores in general reflect the dominance of pollution tolerant macroinvertebrates and presence of few pollution sensitive taxa. The low scores were also reflected in EPT index which showed that few sensitive families of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) were represented at most sites. Matthews Creek (MC7) and Cedar Creek (CC6) overall had the lowest EPT scores (1-3), while Cedar Creek CC5 had the highest (4-7). Sensitive families observed in the Study Area include: mayfly Leptophlebiidae (SIGNAL 8), and caddis flies Leptoceridae (SIGNAL 6), Odontoceridae (SIGNAL 7), Calamoceridae (SIGNAL 7), Atriplectidae (SIGNAL 7), Heliocopsychidae (SIGNAL 8) and Phioloreithidae (SIGNAL 8). The most common of these families observed among sites were Leptoceridae, Calamoceridae and Leptophlebiidae which are typically found in streams in the area.

Overall the indicators show that the waterway is under natural or anthropogenic stress. It is likely that low flow conditions have contributed to the scores observed.

Table 9: AUSRIVAS results spring 2017

Season	**Spring 2017**				
Site	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
No of taxa	14	17	11	11	10
OE 50	0.55	0.6	0.52	0.64	0.47
SIGNAL	3.43	4.41	4.64	4.18	4
Band	B	B	B	B	C
EPT	3	5	3	3	2

Table 10: AUSRIVAS results autumn 2018

Season	**Autumn 2018**				
Site	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
No of taxa	10	20	21	6	dry
OE 50	0.77	0.49	0.71	0.26	dry
SIGNAL	4.3	4.4	3.10	3.67	dry

Season	Autumn 2018				
Site	SQC4	CC5	CC6	MC7	MC8
Band	B	B	B	C	dry
EPT	4	5	1	1	dry

Table 11: AUSRIVAS results spring 2018

Season	Spring 2018				
Site	SQC4	CC5	CC6	MC7	MC8
No of taxa	17	15	9	7	dry
OE 50	0.86	0.49	0.45	0.4	dry
SIGNAL	3.23	4.15	3	3.86	dry
Band	A	C	C	C	dry
EPT	3	4	3	2	dry

Table 12: AUSRIVAS results autumn 2019

Season	Autumn 2018				
Site	SQC4	CC5	CC6	MC7	MC8
No of taxa	10	24	11	15	17
OE 50	0.39	0.64	0.44	0.71	0.82
SIGNAL	3.5	4.27	3.1	3.92	3.76
Band	C	B	C	B	A
EPT	1	7	1	1	3

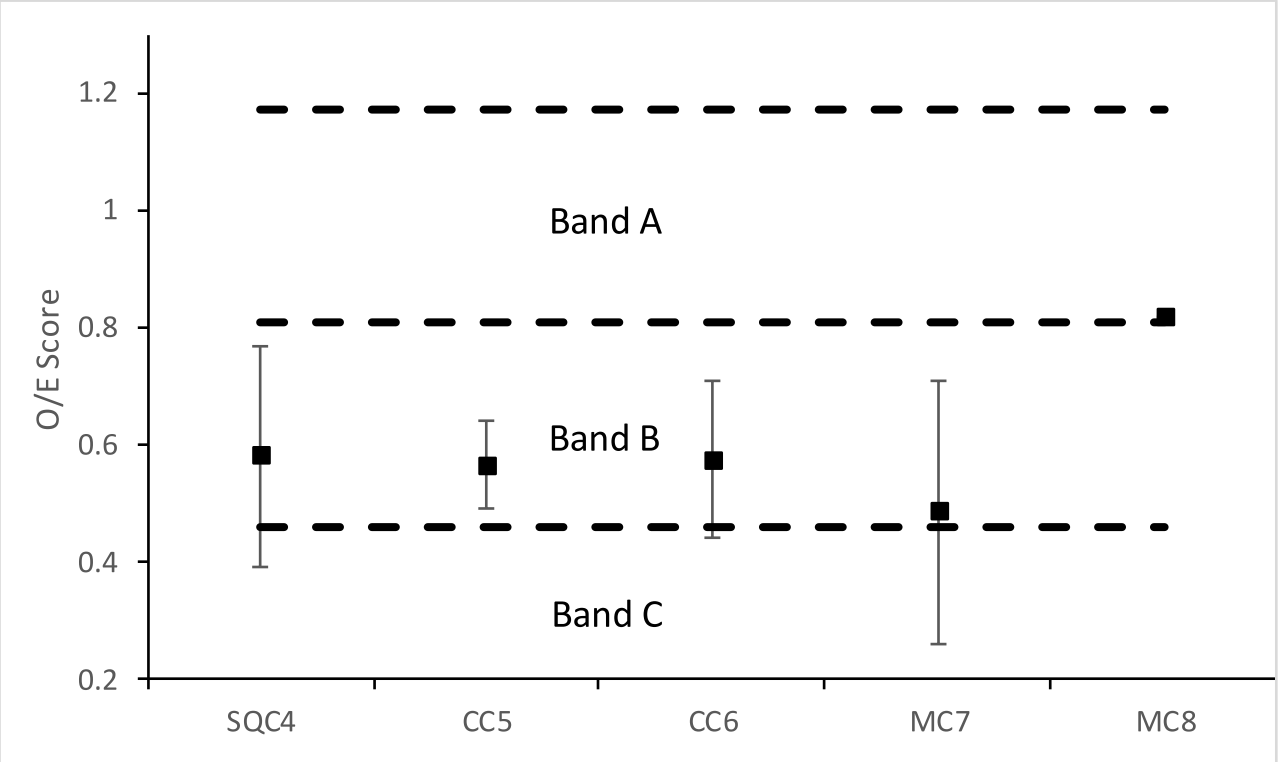

Figure 4: Average O/E50 scores for autumn. Error bars =standard error. Dotted line = AUSRIVAS bandwidths for autumn edge habitat.

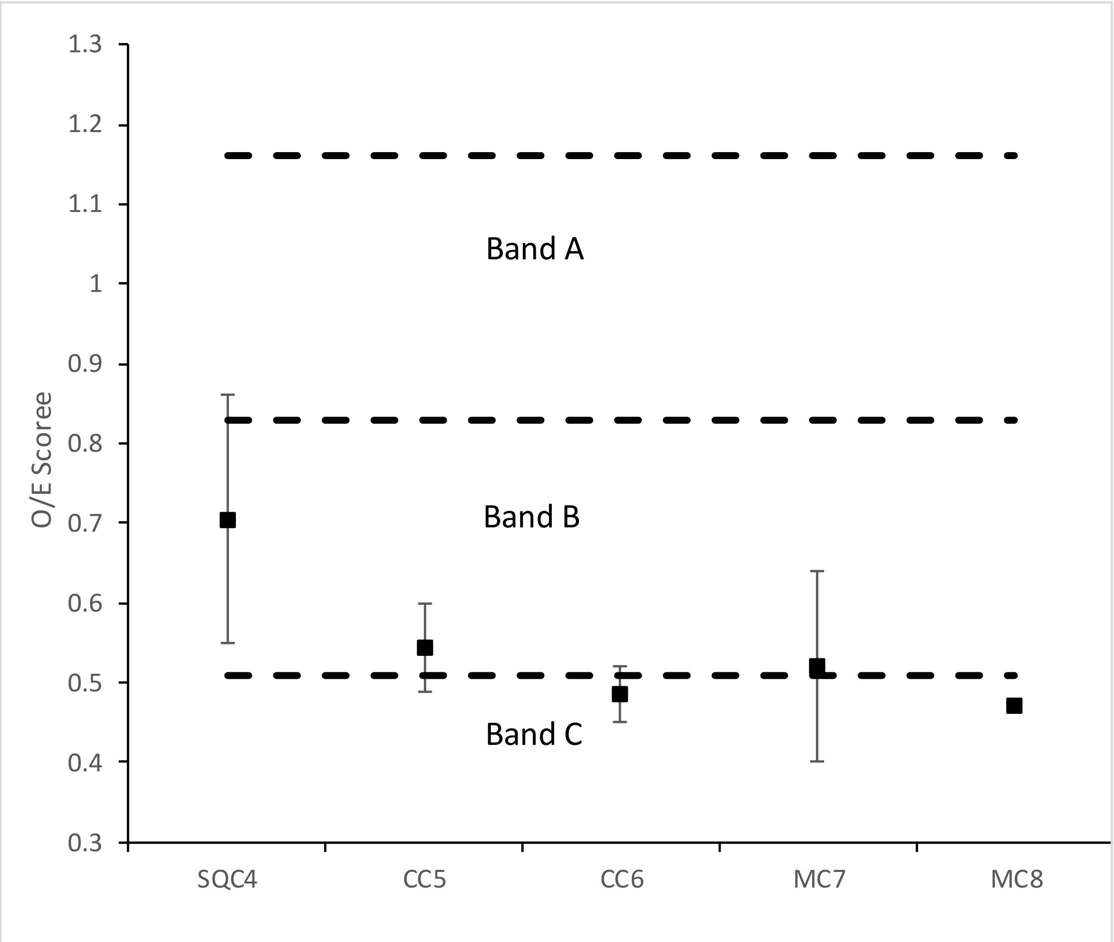

Figure 5: Average O/E50 scores for spring. Error bars =standard error. Dotted line = AUSRIVAS bandwidths for spring edge habitat

3.4 Macroinvertebrate assemblages

Review of the macroinvertebrate assemblages sampled using the suction sampler found that the considerable overlap in data occurred in regard to Survey and Stream, while groupings were clearer at the Site level. Visualisation of these Site differences in data using the MDS graph indicated that only Site 11 has no overlapping data with the potential impact sites (Figure 6). This site also lacked data (with only data from one Survey) to provide a sufficient baseline measure for this program. Given this, Site 11 was excluded from further analysis of statistical differences between Surveys, Streams and Sites.

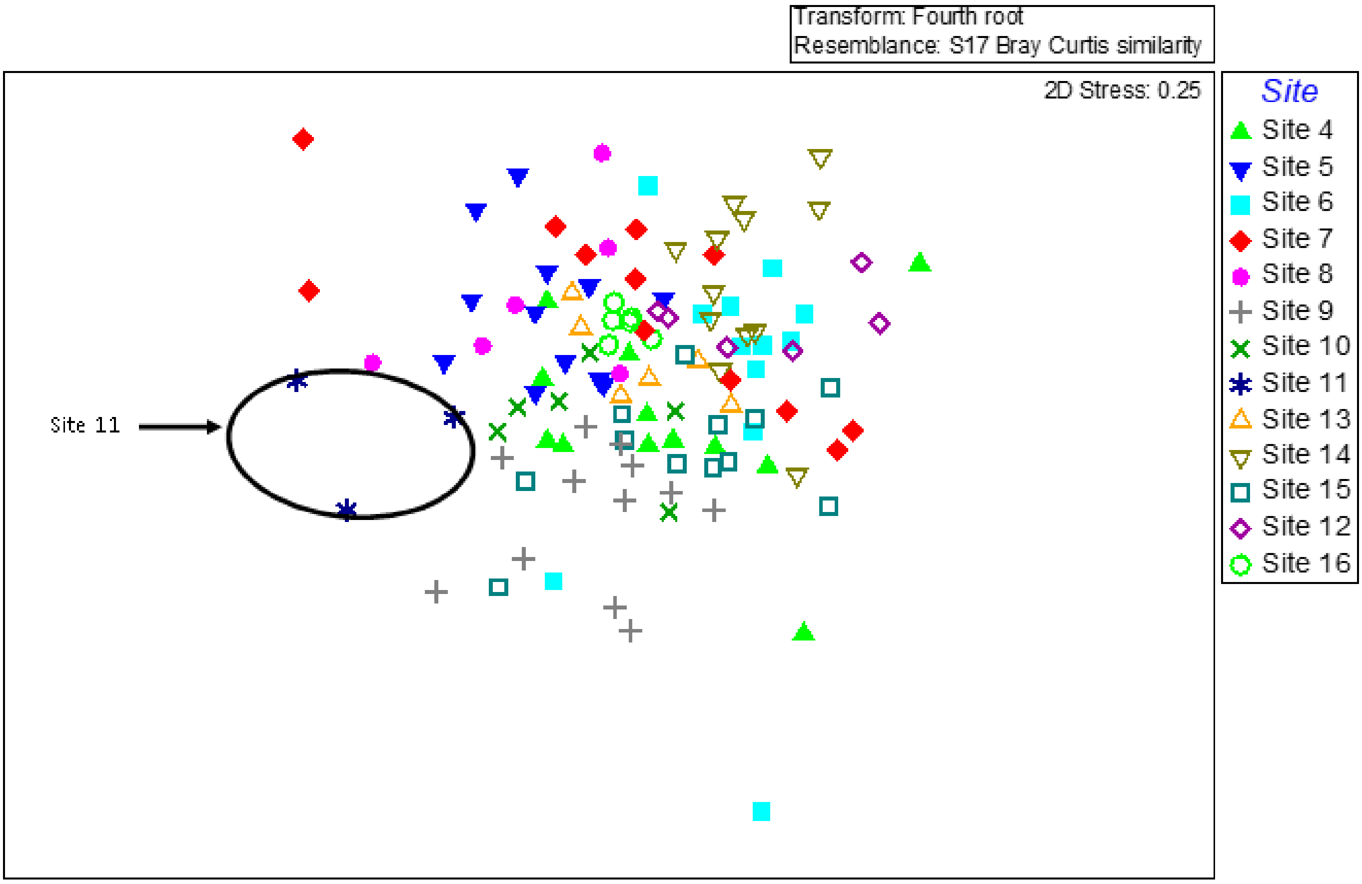

Figure 6: MDS Graph showing groupings of Sites among the macroinvertebrate assemblages.

Analysis of the differences within the macroinvertebrate assemblage using PERMANOVA detected that significant differences for the interaction terms of Survey x Stream, and Survey x Site (nested in Stream) occurred (Annex 2). Further investigation of the Survey x Stream interaction found that within each Stream all Surveys were significantly different, while within each Survey all Streams were significantly different except for Stonequarry and Matthews Streams in autumn 2019. For the Survey x Site (nested in Stream) interaction, significant differences were dependent on Sites within each Stream for differences between Surveys and Surveys for differences between Sites within each Stream (Annex 2).

Analysis of differences in abundance of macroinvertebrates between assemblages detected that significant differences were due to differences between surveys irrespective of other factors (Stream or Site) with the highest abundances recorded from the most (Figure 7). For Taxonomic Richness significant differences for the interaction terms of Survey x Stream, and Survey x Site (nested in Stream) occurred (Annex 3). Further investigation of the Survey x Stream interaction found that these differences were dependent on Stream for differences between Surveys and Surveys for differences between Streams. For the Survey x Site (nested in Stream) interaction, significant differences were dependent on Sites within each Stream for differences between Surveys and Surveys for differences between Sites within in each Stream (Annex 3). Mean taxonomic richness of Streams for each Survey is provided in Figure 8.

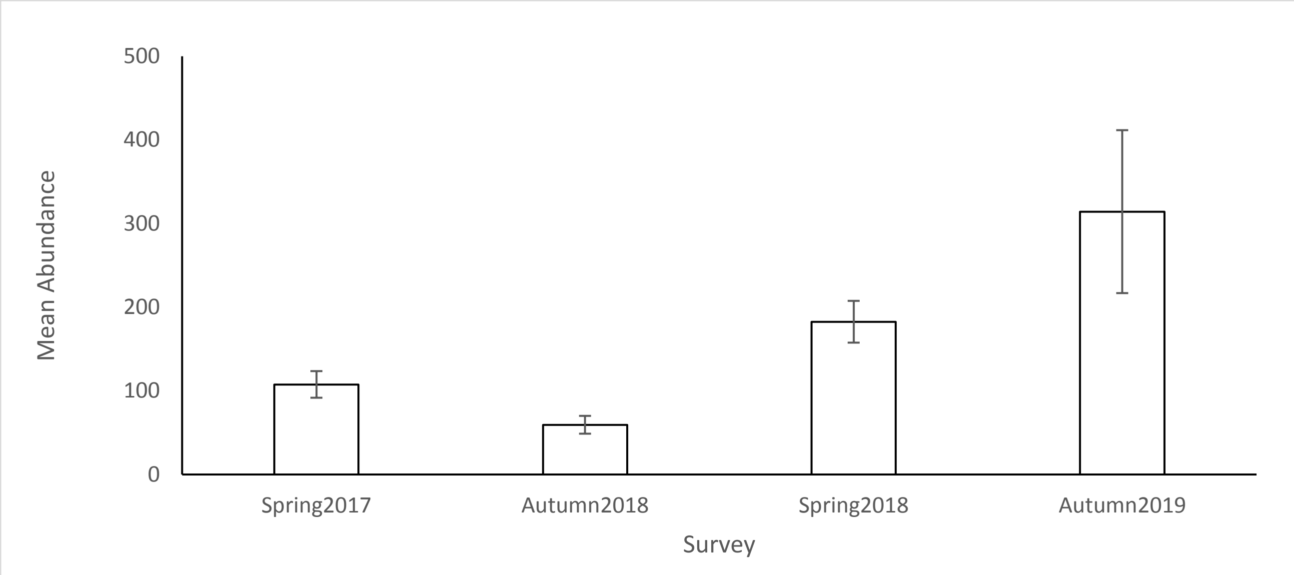

Figure 7: Graph showing differences in mean abundance (+/- SE) between surveys.

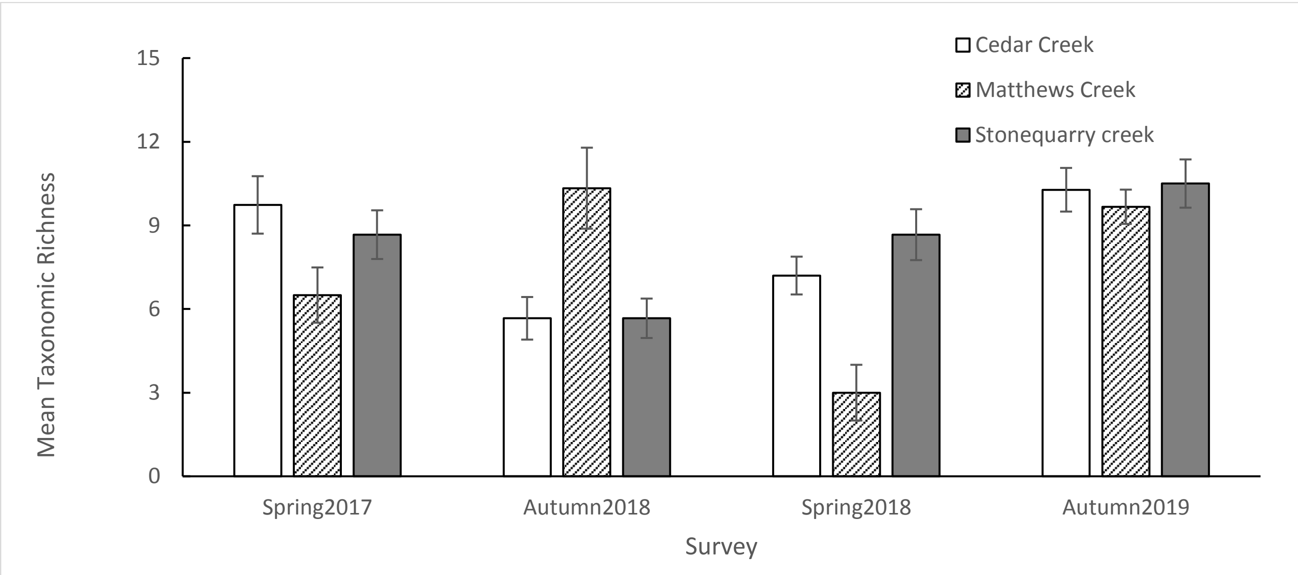

Figure 8: Graph showing differences in mean taxonomic richness (+/- SE) between Streams for each survey

3.5 Fish results

Few fish were caught as part of the fish surveys in spring 2017, autumn 2018, spring 2018 and autumn 2019 (Table 13). Introduced Mosquito Fish *Gambusia holbrooki* were observed in Cedar Creek, Stonequarry Creek and Matthews Creek. Mountain Galaxid (*Galaxias olidus*) was observed in Cedar Creek upstream of Matthews Creek (MC12) on one occasion and Cox's Gudgeon (*Gobiomorphus coxii*) was observed on one occasion in Matthews Creek (MC7).

Table 13: Table of fish results

Season	Site												
	SQC4	CC5	CC6	MC7	MC8	CC9	CC10	CC11	CC12	SQC13	SQC14	SQC15	SQ16
Spring 2017													
Gambusia holbrooki						1					20		
Autumn 2018													
Gamnusia holbrooki	7	5				1						4	
Galaxias olidus									1				
Spring 2018													
Gambusia holbrooki	57												
Gobiomorphus coxii				1									
Autumn 2019													
Gambusia holbrooki	7	15											

4. Discussion

4.1 Discussion of results

In general, the baseline monitoring data showed similar results to the initial impact assessment surveys conducted in 2014 (Niche, 2014a) which found sites in Matthews Creek, Stonequarry Creek and Cedar Creek to be in moderate to good condition with the best habitat located within gorges along Matthews Creek and Cedar Creek upstream of Stonequarry Creek. Most of the sites in the study area were located in sandstone bedrock controlled streams (Site 6 (CC6), Site 7 (MC7) and Site 8 (MC8)) with site SQC4 consisting of a more open landscape and sandy substrate. Cedar Creek (CC5) seems to be a transition between these habitat types as the stream becomes broader towards the eastern end of the Study Area. The habitat within the Study Area is considered good to moderate with stable banks, thick native riparian vegetation and limited anthropogenic disturbance. During the sampling there was a variation in habitat availability, particularly at Matthews Creek (MC 8) which was dry on two occasions and could not be sampled. Sites also showed reduction in habitat availability as part the quantitative macroinvertebrate monitoring program, with control sites SQC13, CC10 and CC11 not being able to sampled on two occasions in autumn 2018.

The water quality had high salinity (approximately 1000 µS/cm) within the Study Area and at upstream control sites sampled as part of the quantitative macroinvertebrate monitoring program. This indicated that electrical conductivity is naturally elevated above ANZECC guidelines in and upstream of the Study Area and fauna are likely to be adapted to these relatively high concentrations. Low dissolved oxygen was characteristic of all sites and was considered normal for stream pools exhibiting low to no flow conditions. The pH was generally within ANZECC guidelines in spring 2017 and autumn 2018, however appear to decrease below DTVs in spring 2018 and autumn 2019. This reduction may be related to low rainfall, less surface water flow and increased groundwater influence. Alkalinity was generally low in all streams indicating a low buffering capacity against changes to pH. As such, it appear that pH can naturally fluctuate between below and within ANZECC guidelines and may indicate that the streams are sensitive to disturbance. Despite the low pH measurements, there does not appear to be a noticeable change in stream health. It should also be noted that red ferruginous deposits were observed at Cedar Creek, particularly near the confluence of Matthews Creek. This is likely a natural occurrence and may indicate significant contribution of groundwater at these locations. This was also observed at some control sites in Cedar Creek (CC16) and Stonequarry Creek (SQC14).

Stream health, as indicated by AUSRIVAS and SIGNAL, showed impairment of macroinvertebrates (that is, sites that are missing families expected to occur at the site naturally) and generally consisted of pollution tolerant macroinvertebrate families. Overall, this indicated that streams are in poor stream health which is likely due to a number of factors including natural environmental stresses, driven by low stream flow. There are however pollution sensitive invertebrates that inhabit these environments. The mayfly Leptophlebiidae (SIGNAL 8), and caddis flies Leptoceridae (SIGNAL 6) and Calamoceridae (SIGNAL 7) are taxa that are vulnerable to pollution. Studies in the area have found that these families are very common in local ephemeral/semi-permanent streams and are present in streams that are close to reference condition (Niche, 2014b). These can be used as indicators of stream health and useful for future stream impact monitoring.

Review of data collected to date indicates that Site 11, which is a reference site for Cedar Creek and was established during low flow periods when Site 10 was dry, has limited macroinvertebrate assemblage data. Furthermore, data collected indicates it may be substantially different in macroinvertebrate assemblage composition to the potential impact sites. Thus, there appears little value in continuing to monitor Site 11. Cedar Creek includes four other potential reference sites. Site 12 is critical to the program as it provides a measure of background condition at the bottom of the Cedar Creek catchment before it enters the project area. Sites 9 and 10 are in close proximity to each other midway between the most upstream site of Site 16 and the project area. Two reference sites on Cedar Creek are likely sufficient in relation to experimental design, however given the waterways vulnerability to low flow conditions, the continued monitoring of up to two additional reference sites on Cedar Creek may be prudent for the future monitoring program. The statistical analysis showed that temporal variation between surveys and those differences between the different streams were major drivers of differences. This suggests that sampling of both the autumn and spring seasons has value in detecting impacts for this program. However, given the streams are vastly different and should utilise a continued approach using a nested design to statistical analysis be implemented, the lack of reference sites (above the project area) on Matthews Creek will present limitations in the future programs ability to detect any impacts on Matthews Creek. Thus, it is recommended that two reference sites be established, if possible, on Matthews Creek, of which one site should be in close proximity to the project area boundary. A potential site was identified towards the end of the baseline study near Addison Street that could potentially be used for the program, however it is acknowledged that access to perennial pool habitat in Matthew's Creek upstream of the study area is generally limited.

Future analysis of monitoring data during the operational / development phase will obviously require the addition of a Treatment factor (reference and potential Impact) to the experimental design. Given that impacts from longwall mining should they occur on streams are most likely to be small in spatial scale, the monitoring program should focus on investigations of changes at the site level.

Few fish were caught as part of the monitoring program which may be due to the sampling methods used or the low abundance of native fish in the waterways. As such, fish sampling is not a useful indicator within the monitoring program and is not recommend that targeted survey be undertaken in future monitoring.

4.2 Conclusion and recommendations

Low flow/intermittent streams undergo natural fluctuations in hydrology, habitat availability and water quality, which ultimately influences faunal composition spatially and temporally. The fauna that use these habitats are thus adapted to the resulting stress of these natural fluctuations. The macroinvertebrate communities in the studied habitats generally consist of families that are good dispersers (particularly those that aerially disperse) which can cope with localised poor water quality (e.g. low dissolved oxygen, low alkalinity/pH, extremes in temperature) and variable flow conditions including extended periods of no flow or complete drying out. Mostly the faunal composition recorded included those of low SIGNAL and EPT scores (Table 7 and Table 8) that indicate pollution tolerance. Low stream health scores in this instance can be considered natural in drying intermittent/low flow streams.

Further monitoring will be required to assess and track any further impacts and/or subsequent recovery as longwall mining takes place. The monitoring should focus on using macroinvertebrates as indicator of ecological stream health. Responses to impacts should be measured primarily through the analysis of AUSRIVAS and changes in macroinvertebrate biomass, community composition, and indicator species using quantitative data in accordance with BACI design.

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Annex 1: AUSRIVAS Aquatic habitat at potential impact sites

Stonequarry Creek SQC4

The aquatic habitat of Stonequarry Creek at confluence of Stonequarry Creek and Cedar Creek site (Plate 1) at the time of the spring 2017, autumn 2018, spring 2017 and autumn 2019 monitoring surveys is detailed in Table 14.

Table 14: SQC4 Stream characteristics

	Attribute	
	Photograph	Plate 1
Riparian	RCE	36
	Vegetation	Canopy vegetation was dominated *Eucalyptus punctata*. The mid-storey was dominated by *Bursaria spinulosa*, *Acacia parramattensis* and *Acacia floribunda*. Groundcover by dominated by *Microleana stipodes*, *Persicaria sp*., and *Viola hederacea*
	Stream shading	Moderate
	Exotic vegetation	Native and exotic
Stream characteristics	Modal width (m)	4.5m
	Substrate	The stream substrate consisted of sand
	Flow/depth	little flow/>1m
	Macrophytes/algae	There were significant macrophytes beds observed at this site consisting mostly of submerged species. Filamentous algae also covered most of the benthos and aquatic vegetation at this location. *Potamogeton sulcatus*, *Myriophyllum salsugineum*, and *Juncus* spp were common macrophtyes. Other submerged macrophytes were also present.
	Water quality observations	Low flow, turbid in autumn 2018, slightly more water in 2019
Comments		Reasonable condition, more open stream, less tree canopy.

Spring 2017

Autumn 2018

Spring 2018

Autumn 2019

Plate 1: Stonequarry Creek (SQC4) at confluence of Stonequarry Creek and Cedar Creek

Cedar Creek CC5

The aquatic habitat of Cedar Creek Upstream of Stonequarry Creek confluence (Plate 2) at spring 2017, autumn 2018, spring 2018 and autumn 2019 monitoring surveys is detailed in Table 15.

Table 15: Cedar Creek CC5

	Attribute	
	Photograph	Plate 2
Riparian	RCE	42
	Vegetation	Canopy vegetation was dominated by *Eucalyptus punctata*. The mid-storey was dominated by *Melaleuca sp*. and groundcover dominated by *Microleana stipoides*, *Viola hederacea*, *Lomandra longifolia* and *Dianella caerulea*.
	Stream shading	Moderate to high
	Exotic vegetation	Native
Stream characteristics	Modal width (m)	2.5m
	Substrate	The stream substrate consisted of a mix of bedrock, boulder, cobble, pebble and sand
	Flow/depth	No flow/<1m
	Macrophytes/algae	There were macrophytes beds observed at this site consisting mostly of submerged species *Potamogeton sulcatus, Myriophyllum salsugineum and Elantine gratioloides*. Filamentous algae also covered most of the benthos and aquatic vegetation at this location.
	Water quality observations	Low flow on all sampling occasions
Comments		Generally good condition, well shaded and variety of benthic habitat.

Spring 2017

Autumn 2018

Spring 2018

Autumn 2019

Plate 2: Cedar Creek CC5 upstream of Stonequarry Creek confluence

Cedar Creek CC6

The aquatic habitat of Cedar creek at confluence with Matthews Creek (Plate 3) at spring 2017, autumn 2018, spring 2018 and autumn 2019 monitoring surveys is detailed in Table 16.

Table 16: Cedar Creek CC6

	Attribute	
	Photograph	Plate 3
Riparian	RCE	51
	Vegetation	Canopy vegetation was dominated by *Eucalyptus piperita*. The mid-storey was dominated by *Callicoma serratifolia, Leucopogon lanceolatus, Clematis aristata* and *Tristaniopsis laurina*. The groundcover was dominated by *Viola hederacea, Lomandra longifolia*, and *Pratia purpurascens*.
	Stream shading	Moderate to high
	Exotic vegetation	Native
Stream characteristics	Modal width (m)	4m
	Substrate	The stream substrate consisted of a mix mainly bedrock with some boulders
	Flow/depth	little flow/1-2m
	Macrophytes/algae	No macrophytes were present
	Water quality observations	Iron floc present at site and often increased turbidity.
Comments		Iron floc, but good riparian vegetation and habitat.

Spring 2017

Autumn 2018

Spring 2018

Autumn 2019

Plate 3: Cedar Creek (CC6) at confluence with Matthews Creek

Matthews Creek MC7

The aquatic habitat of Matthews Creek upstream of cedar creek confluence (Plate 4) at spring 2017, autumn 2018, spring 2018 and autumn 2019 monitoring surveys is detailed in Table 17.

Table 17: Matthews Creek MC7

	Attribute	
	Photograph	Plate 4
Riparian	RCE	51
	Vegetation	Canopy vegetation was dominated by *Eucalyptus punctata*. The mid-storey was dominated by *Backhousia myrtifolia, Persoonia linearis* and *Tristaniopsis laurina*. The groundcover was dominated by *Lomandra longifolia, Schoenus melanostachys, Callicoma serratifolia*, and *Oplismenus aemulus*.
	Stream shading	Moderate to high
	Exotic vegetation	Native
Stream characteristics	Modal width (m)	3m
	Substrate	The stream substrate consisted of mostly bedrock, with occasional boulders and pockets of sand and silt
	Flow/depth	Little flow/~1m
	Macrophytes/algae	No macrophytes were present
	Water quality observations	Low flow almost dry in autumn 2018.
Comments		Low flow conditions on all sampling occasions. Good habitat.

Spring 2017

Autumn 2018

Spring 2018

Autumn 2019

Plate 4: Matthews Creek MC7 upstream of Cedar Creek Confluence

Matthews Creek MC8

The aquatic habitat of Matthews Creek most upstream site (Plate 5) at spring 2017, autumn 2018, spring 2018 and autumn 2019 monitoring surveys is detailed in Table 18.

Table 18: Matthews Creek MC8

	Attribute	
	Photograph	Plate 5
Riparian	RCE	47
	Vegetation	Canopy vegetation was dominated by *Eucalyptus punctata*, *Ceratopetalum apetalum* and *Backhousia myrtifolia*. The mid-storey was dominated by *Callicoma serratifolia*, *Clematis aristata* and *Tristaniopsis laurina*. The groundcover was dominated by *Lomandra longifolia, Blechnum cartilagineum* and *Oplismenus aemulus*
	Stream shading	Moderate
	Exotic vegetation	Native
Stream characteristics	Modal width (m)	1.5m
	Substrate	The stream substrate consisted of bedrock, boulder and silt
	Flow/depth	Little flow/<0.5m
	Macrophytes/algae	No macrophytes were present
	Water quality observations	Low flow and dry in autumn and spring 2018.
Comments		Low flow but good habitat.

Spring 2017

Autumn 2018

Spring 2018

Autumn 2019

Plate 5: Matthews Creek MC8 Most upstream site

Stonequarry Creek SQC15

The aquatic habitat of Stonequarry Creek most downstream site (Plate 6) at spring 2017, autumn 2018, spring 2018 and autumn 2019 monitoring surveys is detailed in Table 19.

Table 19: Stonequarry Creek SQC15

	Attribute	
	Photograph	Plate 6
Riparian	RCE	45
	Vegetation	Canopy vegetation was dominated *Eucalyptus punctate* and introduced *Salix sp*.. The mid-storey was dominated by *Bursaria spinulosa*, *Acacia* sp.. Groundcover by dominated by *Microleana stipodes* and exotic paddock grasses.
	Stream shading	Low
	Exotic vegetation	Native and exotic
Stream characteristics	Modal width (m)	10m
	Substrate	The stream substrate consisted of bedrock, boulder, sand and silt
	Flow/depth	Little flow but deep pool >1m
	Macrophytes/algae	There were significant macrophytes beds observed at this site consisting mostly of submerged species. Filamentous algae also covered most of the benthos and aquatic vegetation at this location. *Potamogeton sulcatus*, *Myriophyllum salsugineum*, *Typha* sp. *Eleocharis acuta* and *Juncus* spp were common macrophtyes.
	Water quality observations	Perennial pool.
Comments		Long deep pool and large rock bar.

Spring 2017

Autumn 2018

Spring 2018

Autumn 2019

Plate 6: Stonequarry Creek SQ15 most downstream site

Annex 2: Macroinvertebrates recorded at survey sites

AUSRIVAS spring 2017

Spring 2017	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Turbellaria	0	2	0	0	0
Sialidae	0	0	0	0	0
Pyralidae	1	0	0	0	0
Physidae	1	0	0	0	1
Corbiculidae	0	11	2	0	8
Oligochaeta	0	1	0	0	0
Acarina	1	0	3	1	0
Cladocera	0	0	0	1	0
Ostracoda	0	1	8	3	0
Ceinidae	0	0	0	0	0
Atyidae	10	6	0	0	2
Parastacidae	0	0	0	1	0
Dytiscidae	16	4	4	1	5
Gyrinidae	0	0	0	0	0
Haliphidae	0	0	0	0	0
Scirtidae	0	2	0	0	3
Dixidae	0	0	0	0	0
Stratiomiyidae	0	0	0	0	0
Culicidae	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0
Tanypodinae	0	2	1	1	0
Orthocladiinae	0	1	0	0	0
Chironominae	12	9	37	2	1
Baetidae	2	0	0	0	0
Leptophlebiidae	0	39	16	27	11
Caenidae	0	3	0	1	0
Mesoveliidae	0	0	0	0	0
Veliidae	0	0	0	2	0
Gerridae	0	0	0	0	0
Corixidae	1	0	0	0	0
Notonectidae	0	0	1	2	0
Pleidae	0	0	0	0	1
Coenagrionidae	2	0	0	0	0
Isostictidae	1	0	0	0	0
Megapodagrionidae	0	4	11	0	0

Spring 2017	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Synlestidae	0	0	0	0	0
Aeshnidae	0	1	0	0	0
Gomphidae	0	0	0	0	0
Hemicorduliidae	1	0	1	1	1
Libellulidae	2	1	0	0	0
Polycentropodidae	0	0	0	0	0
Hydroptilidae	1	0	0	0	0
Ecnomidae	0	0	0	0	0
heliocopsychidae	0	0	0	0	0
Odontoceridae	0	3	1	0	0
Atriplectididae	0	0	0	0	0
Calamoceratidae	0	4	0	0	0
Leptoceridae	8	22	45	7	37

AUSRIVAS autumn 2018

Autumn 2018	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Turbellaria	0	0	1	0	dry
Sialidae	1	2	0	0	dry
Pyralidae	0	0	0	0	dry
Physidae	0	0	0	0	dry
Corbiculidae	0	3	3	0	dry
Oligochaeta	0	1	3	0	dry
Acarina	0	1	4	0	dry
Cladocera	1	0	1	0	dry
Ostracoda	0	0	0	0	dry
Ceinidae	0	1	1	0	dry
Atyidae	0	1	9	0	dry
Parastacidae	0	0	0	9	dry
Dytiscidae	0	4	3	10	dry
Gyrinidae	0	0	1	0	dry
Haliphidae	0	0	4	0	dry
Scirtidae	0	0	0	0	dry
Dixidae	0	0	0	0	dry
Stratiomiyidae	0	0	1	0	dry
Culicidae	0	0	1	0	dry
Ceratopogonidae	0	1	0	0	dry
Tanypodinae	0	3	5	0	dry

Autumn 2018	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Orthocladiinae	0	0	0	0	dry
Chironominae	13	21	9	0	dry
Baetidae	1	0	2	0	dry
Leptophlebiidae	1	41	0	23	dry
Caenidae	0	0	0	0	dry
Mesoveliidae	0	0	0	0	dry
Veliidae	0	0	5	0	dry
Gerridae	0	0	0	0	dry
Corixidae	2	9	3	1	dry
Notonectidae	1	10	3	8	dry
Pleidae	0	0	0	0	dry
Coenagrionidae	1	0	18	0	dry
Isostictidae	0	2	0	0	dry
Megapodagrionidae	0	9	1	0	dry
Synlestidae	0	0	0	0	dry
Aeshnidae	0	0	0	0	dry
Gomphidae	0	1	1	0	dry
Hemicorduliidae	0	0	7	2	dry
Libellulidae	2	0	0	0	dry
Polycentropodidae	0	0	0	0	dry
Hydroptilidae	0	0	0	0	dry
Ecnomidae	0	0	0	0	dry
Helicopsychidae	0	1	0	0	dry
Odontoceridae	0	0	0	0	dry
Atriplectididae	0	1	0	0	dry
Calamoceratidae	6	2	0	0	dry
Leptoceridae	21	33	0	0	dry

AUSRIVAS Spring 2018

Spring 2018	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Sialidae	0	0	0	0	dry
Pyralidae	0	0	0	2	dry
Physidae	0	0	0	6	dry
Corbiculidae	0	0	0	3	dry
Oligochaeta	7	1	1	0	dry
Acarina	0	0	0	0	dry
Cladocera	1	0	1	0	dry

Spring 2018	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Ostracoda	0	0	0	0	dry
Atyidae	0	0	0	3	dry
Parastacidae	0	0	0	0	dry
Dytiscidae	1	18	7	19	dry
Hydrophilidae	0	0	0	1	dry
Hydraenidae	0	0	0	0	dry
Scirtidae	0	0	0	1	dry
Culicidae	5	0	1	0	dry
Ceratopogonidae	0	0	0	0	dry
Tanypodinae	0	0	1	1	dry
Orthocladiinae	0	0	0	0	dry
Chironominae	18	83	23	3	dry
Chaoboridae	1	0	0	0	dry
Baetidae	0	4	1	4	dry
Leptophlebiidae	0	0	2	0	dry
Veliidae	0	2	0	0	dry
Corixidae	0	3	1	1	dry
Notonectidae	0	3	96	1	dry
Hydrometridae	0	0	0	0	dry
Pleidae	0	0	0	1	dry
Gomphidae	0	0	0	0	dry
Telephlebiidae	0	0	0	1	dry
Synthemistidae	0	1	0	0	dry
Hemicorduliidae	0	0	0	4	dry
Cordulephyidae	0	0	0	2	dry
Austrocorduliidae	0	0	0	0	dry
Libellulidae	0	0	0	0	dry
Hydroptilidae	0	0	0	0	dry
Odontoceridae	0	0	0	0	dry
Leptoceridae	0	0	2	18	dry

Autumn 2019

Autumn 2019	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Nematoda	0	0	0	0	0
Turbellaria	0	0	0	0	0
Sialidae	1	7	0	1	0
Ancylidae	0	0	0	0	0

Autumn 2019	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Pyralidae	0	0	0	0	0
Physidae	0	1	0	0	3
Planorbidae	0	0	0	0	0
Corbiculidae	0	6	0	2	3
Oligochaeta	0	3	1	4	0
Acarina	0	0	0	0	3
Cladocera	0	0	0	1	0
Ostracoda	1	0	0	1	0
copapoda	1	0	0	0	0
Ceinidae	0	1	0	0	0
Atyidae	7	4	0	1	12
Parastacidae	0	0	0	0	1
Dytiscidae	2	5	1	5	0
Elmidae	0	1	0	0	0
Scirtidae	0	0	0	2	1
Culicidae	0	0	0	0	1
Ceratopogonidae	0	1	0	0	0
Tanypodinae	0	1	0	0	0
Orthocladiinae	0	0	0	0	0
Chironominae	8	16	12	7	11
Chaoboridae	0	0	0	0	0
Baetidae	1	0	0	0	0
Leptophlebiidae	0	37	0	0	15
Caenidae	0	0	0	0	1
Mesoveliidae	0	0	0	0	0
Veliidae	0	0	8	13	8
Gerridae	0	0	0	2	1
Corixidae	0	1	0	0	9
Notonectidae	0	0	1	0	5
Hydrometridae	0	0	1	2	1
Coenagrionidae	6	3	4	0	0
Isostictidae	1	4	0	0	0
Megapodagrionidae	0	10	23	5	4
Aeshnidae	0	0	4	0	0
Gomphidae	0	2	0	0	0
Hemicorduliidae	5	3	7	4	0
Libellulidae	0	0	0	0	0
Ecnomidae	0	1	0	0	0
Philorheithridae	0	1	0	0	0

Autumn 2019	Site				
Macroinvertebrates	**SQC4**	**CC5**	**CC6**	**MC7**	**MC8**
Helicopsychidae	0	1	0	0	0
Odontoceridae	0	11	0	0	0
Calamoceratidae	0	4	0	0	0
Leptoceridae	0	62	9	6	1

Quantitative macroinvertebrate results

Spring 2017

	SQ C4	SQ C4	SQ C4	CC 5	CC 5	CC 5	CC 6	CC 6	CC 6	M C7	M C7	M C7	M C8	M C8	M C8	CC 9	CC 9	CC 9	CC 10	CC 10	CC 10	CC 11	CC 11	CC 11	CC 13	CC 13	CC 13	CC 14	CC 14	CC 14	SQC 15	SQC 15	SQC 15
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Gordiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Tricladida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbriculidae	11	22	2	7	1	0	1	1	0	1	1	0	6	8	5	85	68	46	103	14	11	13	1	9	30	79	6	1	1	0	4	7	1
Ceindae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Atyidae	3	1	0	1	1	1	0	0	0	0	0	0	0	0	0	4	8	7	1	0	4	3	0	2	0	0	1	0	0	0	0	4	2
Paratacidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Corbiculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	8	10	0	0	0	0	0	0	0	0	0	0	4	1	2	5	30	6	54	41	8	0	1	2	0	0	0	0	0	0	12	1	0
Ancylidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Planorbidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	9	14	28	0	0	0	0	0	0	0	0	0	0	0	0	3	5	5	1	2	4	6	0	0	1	0	1	0	0	0	0	7	15
Caenidae	3	1	0	2	1	26	0	0	0	0	0	0	0	0	0	0	0	0	2	9	3	2	0	0	0	0	0	0	0	0	2	0	2
Coloburiscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptophlebiidae	1	1	5	34	31	28	0	0	1	1	24	13	9	7	30	1	0	0	22	25	35	55	20	10	0	1	2	1	0	0	0	0	1
Coenagrionidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Diphlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Magapodagrionidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Aeshnidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	0	0	1	0	0	0	0	0
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hemicorduliidae	0	0	0	0	0	1	0	0	1	0	0	2	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Synthemistidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Micronectidae	0	0	0	0	1	4	0	0	0	2	0	0	0	0	0	2	0	0	1	4	0	3	1	0	1	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	3	6	7	0	1	13	0	0	1	0	0	0	0	0	0
Haliphilidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Curculionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	1	2	0	2	0	0	0	0	6	2	6	1	0	1	0	2	3	1	2	3	1	1	2	0	0	0	1	3	2	0	0	0	1
Gyrinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haliphilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Athericidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	1	2	0	0	1	1	0	0	0	0	0	0	0	0	0	4	3	1	0	2	0	0	0	1	0	1	0	0	0	3	0	0
chironominae	19	10	3	33	1	8	121	46	13	4	0	0	1	0	2	1	0	1	48	7	3	1	0	0	339	106	260	139	133	191	16	0	9
Tanipodinae	6	4	2	6	2	12	20	8	5	2	0	0	2	0	1	23	59	36	15	14	11	1	0	0	2	10	11	80	64	47	67	14	1
Orthocladinae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syrphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	1	1	1	0	0	0	0	0	0	0	0	0	7	4	1	1	0	3	1	3	3	0	0	0	0	0	0	0	1	3	0	0	0
Limnephilliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odontoceridae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Philorheithridae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
Glossiphoniidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

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	SQC 4	SQC 4	SQC 4	CC 5	CC 5	CC 5	MC 7	MC 7	MC 7	CC 9	CC 9	CC 9	CC12	CC12	CC12	SQC 14	SQC 14	SQC 14	SQC 15	SQC 15	SQC 15	SQC 4	SQC 4	SQC 4	CC 5	CC 5	CC 5	MC 7	MC 7	MC 7
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Lumbriculidae	5	2	1	0	13	0	0	0	0	5	0	12	9	3	14	1	3	1	40	41	160	2	30	7	0	0	0	2	34	1
Ceindae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	2	0	0	6	3	0	0	0	0	0	0
Corbiculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	3	27	0	0	0	0	0	0	0	0	0
Baetidae	1	0	0	1	4	0	2	4	15	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
Caenidae	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	2
Coloburiscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Leptophlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	6	14	7	0	1	3	0	0	0	0	0	0	0	0	0	0	1	0
Coenagrionidae	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diphlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Isostictidae	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magapodagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	2	1	0	0	0	0	0	0	1	1	1	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	13	35	12	0	0	0	1	0	0	8	5	0	0	0	0	0	3	0	0	0	1	0	0	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13	0	0	0	0	0	0	0	2	4	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Notonectidae	1	0	1	0	2	0	0	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Dytiscidae	0	0	2	0	0	0	0	2	12	0	0	0	0	1	0	0	0	1	0	3	0	0	0	0	0	0	0	2	1	0
Gyrinidae	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	2	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	3	0
chironominae	0	1	0	4	0	0	109	103	54	1	13	4	3	1	7	33	9	70	3	0	1	0	0	15	14	152	90	15	37	21
Tanipodinae	0	0	0	5	0	0	19	76	28	0	1	4	1	1	3	17	8	13	0	0	0	0	7	21	53	0	9	3	0	1
Orthocladinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Choaboridae	15	254	54	23	15	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	1	12	5	3
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	2	0	0	1	3	6	3	2	10	0	1	0	0	0	0	0	1	1	0	0	0
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Acarina	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0

Spring 2018

Site	SQC 4	SQC 4	SQC 4	CC 5	CC 5	CC 5	CC 6	CC 6	CC 6	MC 7	MC 7	MC 7	CC 9	CC 9	CC 9	CC1 2	CC1 2	CC1 2	SQC1 4	SQC1 4	SQC1 4	SQC1 5	SQC1 5	SQC1 5	CC 16	CC 16	CC 16
Replicate	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Nematoda	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tricladida	0	0	0	0	0	0	0	0	0	0	0	0	5	20	7	0	0	0	0	0	0	0	0	0	0	0	0
Lumbriculidae	55	43	24	15	8	10	1	1	0	4	7	9	8	9	28	0	0	1	7	7	28	8	1	31	58	55	38
Atyidae	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Sphaeriidae	0	0	0	2	14	0	0	0	0	0	0	0	66	7	11	0	0	0	0	0	0	0	9	0	0	0	0
Physidae	1	3	1	0	0	0	0	0	0	0	0	0	0	17	4	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	1	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Caenidae	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0
Leptophlebiidae	0	0	0	2	6	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	6	25	9
Coenagrionidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
Hemicorduliidae	0	1	0	0	0	2	1	0	1	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	2	2	3
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Micronectidae	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	1	0	0	0	0	2	1	0
Dytiscidae	2	8	4	0	0	0	2	1	0	0	0	0	0	3	0	0	0	0	4	16	9	1	1	0	2	8	2
Elmidae	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0
Ceratopogonidae	22	7	8	0	2	0	3	2	2	0	1	0	4	4	0	8	4	13	0	2	0	0	1	2	2	0	0
chironominae	31	27	30	153	235	183	426	399	229	34	37	28	9	181	29	94	11	135	93	367	115	19	22	54	181	361	109
Tanipodinae	30	35	25	17	9	21	8	17	34	0	0	0	4	10	91	0	1	2	9	1	1	0	14	23	12	3	3
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Choaboridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Tipulidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Calamoceratidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecnomidae	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	4	8	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	6	1	1	4	4	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	0	0	0

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Site	SQ C4	SQ C4	SQ C4	CC 5	CC 5	CC 5	CC 6	CC 6	CC 6	M C7	M C7	M C7	M C8	M C8	M C8	CC 9	CC 9	CC 9	CC 10	CC 10	CC 10	CC 12	CC 12	CC 12	SQ C1 3	SD QC 13	SQ C1 3	SQ C1 4	SQ C1 4	SQ C1 4	SQ C1 5	SQ C1 5	SQ C1 5	CC 16	CC 16	CC 16
Replicate	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3						
Nematoda	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricladida	1	4	0	0	0	0	0	0	0	0	0	0	1	2	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Lumbriculidae	2	12	6	0	26	14	3	2	5	15	1	7	9	0	84	251	53	72	72	70	29	251	154	118	10	71	11	6	2	15	21	4	5	65	57	21
Phreatoicidae/ carallidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Paratacidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	5	0	0	34	31	2	0	0	0	0	0	0	0	0	0	15	15	10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
Ancylidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Baetidae	6	5	4	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	9	32	3	0	0	0	13	10	3	1	0	0	1	0	2	2	0	1
Caenidae	6	12	9	1	0	1	0	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	1	1	15	0	0	0
Leptophlebiidae	4	5	0	14	25	5	0	0	0	0	1	3	26	17	50	0	1	0	1	0	1	2	1	0	155	22	10	0	0	0	0	0	0	15	3	7
Coenagrionidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	5	1	3	0	0	0	1	0	0	0	0	0	0	1	3	1	0	3	1
Isostictidae	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	3	6	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3	0	2	0	0	0	10	3	0	0	0	4	1	4
Lindeniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	1	0	1	10	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0

Libellulidae	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	7	4	0
Hemicorduliidae	4	2	0	1	1	1	0	6	0	0	1	4	0	2	0	0	0	0	4	1	0	6	7	3	8	2	0	0	3	1	0	2	7	6	0	6
Sialidae	0	0	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	8	0	0	0	1	0	0	0
Micronectidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1	1	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Dytiscidae	3	0	0	0	0	0	0	0	0	8	5	11	0	0	0	0	1	3	3	6	1	1	7	0	5	0	0	0	0	0	0	0	4	1	2	0
Elmidae	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hydraenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Psephenidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ceratopogonidae	2	2	3	5	1	2	142	59	13	10	0	1	0	1	3	17	21	28	0	1	1	13	20	18	0	10	1	2	1	4	0	2	6	1	9	3
chironominae	13	85	27	4	129	9	53	27	75	75	66	170	60	3613	87	29	94	40	160	81	197	65	206	309	117	114	87	16	50	139	459	225	408	180	100	101
Tanipodinae	33	72	8	6	34	9	6	5	35	9	19	3	13	2	16	1	3	9	3	0	0	51	79	60	6	14	2	0	68	1	1	2	10	8	4	3
Orthocladinae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0

Calamoceratidae	1	0	0	11	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecnomidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0
Leptoceridae	3	4	0	9	27	2	0	1	0	0	2	2	1	0	1	0	1	3	1	0	0	0	0	0	1	1	0	0	6	1	0	2	9	0	9	2
Limnephilliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odontoceridae	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glossiphoniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0

Annex 3: Macroinvertebrate assemblage analysis

Note: 'Stream' factor has been abbreviated to Cr.
PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Su	3	17344	5781.4	7.5226	0.0001	9888
Cr	2	8917.3	4458.6	5.8014	0.0001	9915
Si(Cr)	9	43487	4831.8	6.287	0.0001	9824
SuxCr	6	22550	3758.3	4.8902	**0.0001**	9887
SuxSi(Cr)**	17	31312	1841.9	2.3966	**0.0001**	9805
Res	76	58409	768.54			
Total	113	1.8829E5				

PAIR-WISE TESTS

Term 'SuxCr' for pairs of levels of factor 'Survey'

Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	1.9273	**0.0013**	9947	0.0059
Spring2017, Spring2018	1.7561	**0.0017**	9947	0.0117
Spring2017, Autumn2019	1.5678	**0.0196**	9934	0.0311
Autumn2018, Spring2018	1.823	**0.0049**	9944	0.0157
Autumn2018, Autumn2019	1.9455	**0.0045**	9947	0.0088
Spring2018, Autumn2019	1.8207	**0.0061**	9939	0.0133

Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	2.1553	**0.0007**	9945	0.0029
Spring2017, Spring2018	2.5937	**0.0002**	9942	0.0004
Spring2017, Autumn2019	2.4152	**0.0001**	9936	0.0004
Autumn2018, Spring2018	3.138	**0.0001**	9958	0.0004
Autumn2018, Autumn2019	2.8254	**0.0001**	9944	0.0001
Spring2018, Autumn2019	2.5755	**0.0001**	9955	0.0001

Within level 'Matthews Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	2.5137	**0.005**	830	0.0082
Spring2017, Spring2018	3.0385	**0.0025**	830	0.0058
Spring2017, Autumn2019	2.5412	**0.0028**	8888	0.0042
Autumn2018, Spring2018	3.0875	0.1023	10	0.0084
Autumn2018, Autumn2019	1.5998	**0.014**	830	0.0639
Spring2018, Autumn2019	2.3053	**0.0047**	830	0.009

Term 'SuxCr' for pairs of levels of factor 'Stream'

Within level 'Spring2017' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	1.5463	**0.0164**	9937	0.042
Stonequarry creek, Matthews Creek	3.1192	**0.0007**	9953	0.0003
Cedar Creek, Matthews Creek	2.9974	**0.001**	9939	0.0005

Within level 'Autumn2018' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	2.4979	**0.0011**	9961	0.0019
Stonequarry creek, Matthews Creek	1.5545	**0.0446**	9227	0.0678
Cedar Creek, Matthews Creek	2.0804	**0.0051**	9112	0.0087

Within level 'Spring2018' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	2.5901	**0.0001**	9945	0.0002
Stonequarry creek, Matthews Creek	2.6242	**0.0064**	9166	0.0037
Cedar Creek, Matthews Creek	3.3483	**0.0017**	9933	0.0002

Within level 'Autumn2019' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	1.8111	**0.0053**	9929	0.0086
Stonequarry creek, Matthews Creek	1.3927	0.0759	9940	0.0912
Cedar Creek, Matthews Creek	1.9739	**0.001**	9936	0.003

Term 'SuxSi(Cr)' for pairs of levels of factor 'Survey'

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 4' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	1.7161	0.0957	10	0.0695
Spring2017, Spring2018	2.0376	0.1039	10	**0.0383**
Spring2017, Autumn2019	1.2846	0.2948	10	0.222
Autumn2018, Spring2018	2.0165	0.0963	10	**0.0351**
Autumn2018, Autumn2019	1.791	0.0992	10	0.0666
Spring2018, Autumn2019	1.8408	0.102	10	0.058

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 13' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2019	1.2767	0.3016	10	0.2237

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 14' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	1.4016	0.1983	10	0.1713
Spring2017, Spring2018	1.8385	0.1046	10	0.0693
Spring2017, Autumn2019	1.5726	0.1005	10	0.117
Autumn2018, Spring2018	2.1054	0.1035	10	**0.0271**
Autumn2018, Autumn2019	1.4851	0.1013	10	0.1462
Spring2018, Autumn2019	1.4268	0.0974	10	0.1571

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 15' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	1.3766	0.099	10	0.1939
Spring2017, Spring2018	0.86189	0.8078	10	0.5625
Spring2017, Autumn2019	1.2178	0.1957	10	0.2563
Autumn2018, Spring2018	0.84736	0.8964	10	0.582
Autumn2018, Autumn2019	1.8983	0.098	10	**0.048**
Spring2018, Autumn2019	1.3266	0.0961	10	0.1967

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 5' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	2.0471	0.1005	10	**0.04**
Spring2017, Spring2018	2.1792	0.0964	10	**0.0259**
Spring2017, Autumn2019	2.342	0.1026	10	**0.0205**
Autumn2018, Spring2018	1.871	0.1052	10	**0.0489**
Autumn2018, Autumn2019	2.0509	0.1052	10	**0.0315**
Spring2018, Autumn2019	2.0899	0.0947	10	**0.0375**

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 6' of factor 'Site'

Unique

Groups	t	P(perm)	perms	P(MC)
Spring2017, Autumn2018	1.4728	0.1052	10	0.1544
Spring2017, Spring2018	1.1842	0.301	10	0.2913
Spring2017, Autumn2019	1.4237	0.0975	10	0.1704
Autumn2018, Spring2018	2.0756	0.1025	10	0.0512
Autumn2018, Autumn2019	1.6694	0.1016	10	0.0929
Spring2018, Autumn2019	1.8276	0.1047	10	0.0602

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 9' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	1.6828	0.1016	10	0.0783
Spring2017, Spring2018	2.4709	0.1031	10	**0.0172**
Spring2017, Autumn2019	1.7721	0.1002	10	0.0657
Autumn2018, Spring2018	2.2592	0.0972	10	**0.0201**
Autumn2018, Autumn2019	1.6157	0.1027	10	0.1005
Spring2018, Autumn2019	1.7738	0.1014	10	0.0541

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 10' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2019	2.6359	0.0983	10	**0.0202**

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 12' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2018, Autumn2019	2.7422	0.1023	10	**0.0139**

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 16' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2018, Autumn2019	1.8357	0.0995	10	0.0517

Within level 'Matthews Creek' of factor 'Stream'
Within level 'Site 7' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	2.2584	0.0954	10	**0.0275**
Spring2017, Spring2018	2.7799	0.0971	10	**0.019**
Spring2017, Autumn2019	1.9257	0.0962	10	0.0561
Autumn2018, Spring2018	3.0875	0.0984	10	**0.0078**
Autumn2018, Autumn2019	1.7553	0.0953	10	0.0651
Spring2018, Autumn2019	2.7492	0.1008	10	**0.0139**

Within level 'Matthews Creek' of factor 'Stream'
Within level 'Site 8' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2019	2.2835	0.0991	10	**0.0243**

SuxSi(Cr)' for pairs of levels of factor 'Site'

Within level 'Spring2017' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 13	1.8501	0.0995	10	0.0519
Site 4, Site 14	2.3695	0.0993	10	**0.02**
Site 4, Site 15	0.93833	0.7067	10	0.4936
Site 13, Site 14	1.8549	0.1059	10	0.0533
Site 13, Site 15	1.4405	0.1041	10	0.1266
Site 14, Site 15	1.8181	0.1059	10	0.0623

Within level 'Spring2017' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	1.9581	0.1014	10	**0.0479**
Site 5, Site 9	2.8676	0.1029	10	**0.0083**
Site 5, Site 10	2.0649	0.101	10	**0.0284**
Site 6, Site 9	2.7461	0.1073	10	**0.013**
Site 6, Site 10	2.7277	0.1024	10	**0.0129**
Site 9, Site 10	1.8466	0.0992	10	0.0518

Within level 'Spring2017' of factor 'Survey'
Within level 'Matthews Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 7, Site 8	1.8272	0.0976	10	0.0647

Within level 'Autumn2018' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 14	1.7311	0.102	10	0.0791
Site 4, Site 15	1.5325	0.1061	10	0.1296
Site 14, Site 15	2.656	0.1078	10	**0.0146**

Within level 'Autumn2018' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	1.6391	0.1018	10	0.1044
Site 5, Site 9	2.5094	0.1008	10	**0.0174**
Site 6, Site 9	1.5345	0.0979	10	0.1181

Within level 'Spring2018' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 14	2.7794	0.101	10	**0.013**
Site 4, Site 15	1.4184	0.1013	10	0.1626
Site 14, Site 15	1.1325	0.4955	10	0.315

Within level 'Spring2018' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	2.3168	0.1043	10	0.0215
Site 5, Site 9	2.0634	0.0994	10	**0.0304**
Site 5, Site 12	2.777	0.1009	10	**0.0115**
Site 5, Site 16	2.2531	0.1032	10	**0.0253**
Site 6, Site 9	2.6491	0.0984	10	**0.0167**
Site 6, Site 12	1.784	0.0949	10	0.076
Site 6, Site 16	2.7284	0.0958	10	**0.0101**
Site 9, Site 12	2.7179	0.0972	10	**0.0131**
Site 9, Site 16	2.7176	0.0985	10	**0.0116**
Site 12, Site 16	3.0895	0.1004	10	**0.0071**

Within level 'Autumn2019' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 13	1.3171	0.1028	10	0.1981
Site 4, Site 14	1.4426	0.1989	10	0.156
Site 4, Site 15	1.6435	0.0978	10	0.0996
Site 13, Site 14	1.3551	0.1009	10	0.1802
Site 13, Site 15	1.5817	0.102	10	0.0979
Site 14, Site 15	1.384	0.1036	10	0.1693

Within level 'Autumn2019' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)

Site 5, Site 6	2.5875	0.1015	10	**0.0116**
Site 5, Site 9	2.3602	0.1053	10	**0.0157**
Site 5, Site 10	3.1848	0.0976	10	**0.0064**
Site 5, Site 12	2.9087	0.097	10	**0.0115**
Site 5, Site 16	2.1667	0.1069	10	**0.0243**
Site 6, Site 9	1.8353	0.1021	10	**0.0491**
Site 6, Site 10	2.4271	0.1003	10	**0.0222**
Site 6, Site 12	1.8568	0.1002	10	0.0536
Site 6, Site 16	1.856	0.0994	10	**0.0456**
Site 9, Site 10	2.1115	0.0965	10	**0.0318**
Site 9, Site 12	2.0762	0.1001	10	**0.0326**
Site 9, Site 16	1.8959	0.0995	10	**0.0462**
Site 10, Site 12	2.4155	0.1011	10	**0.0172**
Site 10, Site 16	1.6547	0.0974	10	0.0806
Site 12, Site 16	1.8513	0.0975	10	**0.0468**

Within level 'Autumn2019' of factor 'Survey'
Within level 'Matthews Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 7, Site 8	1.5254	0.0994	10	0.1099

Macroinvertebrate Abundance

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Su	3	1.2547E6	4.1824E5	3.8025	**0.0457**	9946
Cr	2	4.5001E5	2.25E5	2.0457	0.1583	9934
Si(Cr)	9	1.2215E6	1.3572E5	1.2339	0.2837	9946
SuxCr	6	1.0216E6	1.7026E5	1.548	0.1507	9937
SuxSi(Cr)**	17	1.6278E6	95755	0.87058	0.6756	9914
Res	76	8.3592E6	1.0999E5			
Total	113	1.3777E7				

PAIR-WISE TESTS

Term 'Su'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	0.91213	0.3644	9814	0.3695
Spring2017, Spring2018	2.8864	**0.0071**	9831	0.0064
Spring2017, Autumn2019	2.4045	**0.0078**	9876	0.0194
Autumn2018, Spring2018	3.3984	**0.0013**	9849	0.0016
Autumn2018, Autumn2019	0.69492	0.4676	9797	0.4914
Spring2018, Autumn2019	0.38401	0.6802	9805	0.7085

Macroinvertebrate Taxonomic Richness

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Su	3	126.88	42.294	10.215	0.0001	9953
Cr	2	1.1766	0.58829	0.14209	0.8655	9941
Si(Cr)	9	369.52	41.058	9.9165	0.0001	9944
SuxCr	6	158.62	26.436	6.385	**0.0001**	9957
SuxSi(Cr)**	17	191.91	11.289	2.7265	**0.0021**	9929
Res	76	314.67	4.1404			
Total	113	1307.6				

PAIR-WISE TESTS

Term 'SuxCr' for pairs of levels of factor 'Survey'

Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	3.3731	**0.0059**	9771	0.0047
Spring2017, Spring2018	0.54835	0.5861	9774	0.5895
Spring2017, Autumn2019	1.6973	0.1105	9533	0.1118
Autumn2018, Spring2018	3.429	**0.0064**	6829	0.0045
Autumn2018, Autumn2019	3.6527	**0.0034**	9686	0.0029
Spring2018, Autumn2019	1.1593	0.2711	8273	0.2719

Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	3.2214	**0.0069**	9755	0.0063
Spring2017, Spring2018	0.64194	0.5347	9792	0.5221
Spring2017, Autumn2019	0.48656	0.6361	9792	0.6356
Autumn2018, Spring2018	3.2697	**0.0049**	9361	0.005
Autumn2018, Autumn2019	5.625	**0.0001**	9664	0.0001
Spring2018, Autumn2019	4.8779	**0.0001**	9833	0.0002

Within level 'Matthews Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	3.6244	**0.006**	398	0.012
Spring2017, Spring2018	1.2769	0.2787	83	0.2488
Spring2017, Autumn2019	3.6566	**0.0078**	4032	0.0062
Autumn2018, Spring2018	4.1576	0.0997	6	**0.0134**
Autumn2018, Autumn2019	0.86603	0.4287	182	0.4159
Spring2018, Autumn2019	4.7001	**0.0016**	246	0.0024

Term 'SuxCr' for pairs of levels of factor 'Stream'

Within level 'Spring2017' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	1.3363	0.1968	9717	0.2018
Stonequarry creek, Matthews Creek	2.0059	0.0676	9144	0.0653
Cedar Creek, Matthews Creek	3.4651	**0.0058**	9584	0.0059

Within level 'Autumn2018' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	Negative			
Stonequarry creek, Matthews Creek	3.2998	**0.0137**	3835	0.0111
Cedar Creek, Matthews Creek	3.8829	**0.0045**	3200	0.0036

Within level 'Spring2018' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	2.1642	**0.0444**	9778	0.0478
Stonequarry creek, Matthews Creek	4.9075	**0.0051**	763	0.0019
Cedar Creek, Matthews Creek	4.2475	**0.0023**	8545	0.0014

Within level 'Autumn2019' of factor 'Survey'

Groups	t	P(perm)	Unique perms	P(MC)
Stonequarry creek, Cedar Creek	0.24759	0.8085	9745	0.8142
Stonequarry creek, Matthews Creek	0.67116	0.5174	9199	0.5105
Cedar Creek, Matthews Creek	0.67319	0.5211	9569	0.5173

Term 'SuxSi(Cr)' for pairs of levels of factor 'Survey'

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 4' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2018	3.8341	0.099	7	**0.0186**
Spring2017,	Spring2018	0.2132	1	4	0.8407
Spring2017,	Autumn2019	0.3873	0.8985	6	0.725
Autumn2018,	Spring2018	6.3246	0.0975	5	**0.0031**
Autumn2018,	Autumn2019	2.5981	0.1026	7	0.0598
Spring2018,	Autumn2019	0.31623	0.8982	6	0.7747

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 13' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2019	2.7386	0.1005	8	0.052

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 14' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2018	1.1767	0.399	6	0.3053
Spring2017,	Spring2018	Negative			
Spring2017,	Autumn2019	0.42426	0.8026	6	0.6921
Autumn2018,	Spring2018	1.3416	0.296	5	0.2526
Autumn2018,	Autumn2019	1.2728	0.2836	5	0.2674
Spring2018,	Autumn2019	0.45227	0.9002	5	0.6789

Within level 'Stonequarry creek' of factor 'Stream'
Within level 'Site 15' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2018	1.066	0.5972	3	0.3553
Spring2017,	Spring2018	0.75593	0.6045	3	0.495
Spring2017,	Autumn2019	1.3229	0.3016	4	0.2544
Autumn2018,	Spring2018	0.17678	1	5	0.866
Autumn2018,	Autumn2019	2.1213	0.1966	7	0.1072
Spring2018,	Autumn2019	1.7844	0.202	7	0.1513

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 5' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2018	1.0426	0.6021	4	0.3553
Spring2017,	Spring2018	0.44721	1	2	0.6737
Spring2017,	Autumn2019	3.9001	0.0985	7	**0.0166**
Autumn2018,	Spring2018	0.90453	0.6036	3	0.4143
Autumn2018,	Autumn2019	6.957	0.0985	7	**0.0021**
Spring2018,	Autumn2019	7.1813	0.1029	6	**0.0025**

Within level 'Site 6' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2018	0.90453	0.5986	3	0.419
Spring2017,	Spring2018	0.89443	0.5961	5	0.4234
Spring2017,	Autumn2019	2.4749	0.1945	4	0.0728
Autumn2018,	Spring2018	1.6977	0.2993	4	0.1585
Autumn2018,	Autumn2019	4.4721	0.1014	5	**0.0107**
Spring2018,	Autumn2019	0.80178	0.5987	4	0.47

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 9' of factor 'Site'

Groups		t	P(perm)	Unique perms	P(MC)
Spring2017,	Autumn2018	3.9279	0.0979	6	**0.0178**
Spring2017,	Spring2018	1.6059	0.2972	5	0.1838
Spring2017,	Autumn2019	0.71429	0.699	5	0.5066
Autumn2018,	Spring2018	2.75	0.0992	5	0.0521
Autumn2018,	Autumn2019	1.9167	0.2939	3	0.1294
Spring2018,	Autumn2019	0.30151	1	5	0.77

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 10' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2019	2.2136	0.2014	8	0.092

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 12' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2018, Autumn2019	3.25	0.1008	5	**0.0302**

Within level 'Cedar Creek' of factor 'Stream'
Within level 'Site 16' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2018, Autumn2019	3.6181	0.0995	6	**0.0249**

Within level 'Matthews Creek' of factor 'Stream'
Within level 'Site 7' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2018	3.0052	0.0957	8	**0.041**
Spring2017, Spring2018	1.066	0.4997	5	0.3456
Spring2017, Autumn2019	2.6	0.2001	6	0.064
Autumn2018, Spring2018	4.1576	0.0998	6	**0.0132**
Autumn2018, Autumn2019	0.71842	0.6072	6	0.5144
Spring2018, Autumn2019	3.9279	0.1028	7	**0.0173**

Within level 'Matthews Creek' of factor 'Stream'
Within level 'Site 8' of factor 'Site'

Groups	t	P(perm)	Unique perms	P(MC)
Spring2017, Autumn2019	4.2426	0.1011	4	**0.012**

Term 'SuxSi(St)' for pairs of levels of factor 'Site'

Within level 'Spring2017' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 13	2.1651	0.1982	8	0.0965
Site 4, Site 14	2.744	0.2026	6	**0.0473**
Site 4, Site 15	1.6432	0.2012	6	0.1764
Site 13, Site 14	0.15811	1	6	0.8801
Site 13, Site 15	1	0.3984	5	0.3652
Site 14, Site 15	1.4924	0.3036	5	0.2037

Within level 'Spring2017' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	3.1277	0.0954	6	**0.0362**
Site 5, Site 9	1.5119	0.2982	4	0.2032
Site 5, Site 10	2.3016	0.1984	6	0.0854
Site 6, Site 9	5.2766	0.1022	8	**0.0063**
Site 6, Site 10	5.4805	0.0955	9	**0.0057**
Site 9, Site 10	1.0445	0.4074	6	0.3615

Within level 'Spring2017' of factor 'Survey'
Within level 'Matthews Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 7, Site 8	2.9399	0.1027	5	**0.0419**

Within level 'Autumn2018' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 14	0.2132	1	3	0.8454
Site 4, Site 15	1.4924	0.2078	5	0.208
Site 14, Site 15	1.5689	0.2088	6	0.1857

Within level 'Autumn2018' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	3.9196	0.094	5	**0.0174**
Site 5, Site 9	1.25	0.3977	4	0.2725
Site 6, Site 9	2.2188	0.2969	3	0.0886

Within level 'Spring2018' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 14	5.3033	0.1005	6	**0.0061**
Site 4, Site 15	2.6833	0.0996	7	0.0534
Site 14, Site 15	0.58835	0.7984	4	0.5871

Within level 'Spring2018' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	2.1828	0.2955	4	0.0921
Site 5, Site 9	0.90453	0.7081	3	0.4206
Site 5, Site 12	5.3033	0.1002	4	**0.0076**
Site 5, Site 16	0.30151	1	3	0.7725
Site 6, Site 9	2.6833	0.2024	6	0.0608
Site 6, Site 12	1.4552	0.2922	5	0.2141
Site 6, Site 16	1.7889	0.3093	5	0.1481
Site 9, Site 12	5.4272	0.1044	6	**0.0064**
Site 9, Site 16	1.069	0.4965	4	0.3464
Site 12, Site 16	4.2212	0.1103	6	**0.0121**

Within level 'Autumn2019' of factor 'Survey'
Within level 'Stonequarry creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 4, Site 13	0.46291	0.7992	6	0.6711
Site 4, Site 14	1.1471	0.4965	6	0.3095
Site 4, Site 15	0.13131	1	7	0.9036
Site 13, Site 14	2.0555	0.1963	7	0.1092
Site 13, Site 15	0.4264	0.8989	5	0.684
Site 14, Site 15	1.4699	0.2987	6	0.2185

Within level 'Autumn2019' of factor 'Survey'
Within level 'Cedar Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 5, Site 6	12.5	0.1052	5	**0.0001**
Site 5, Site 9	2.2136	0.205	7	0.0897
Site 5, Site 10	3.6244	0.1007	8	**0.0212**
Site 5, Site 12	5.4222	0.0988	8	**0.0038**
Site 5, Site 16	3.0237	0.0974	5	**0.0397**
Site 6, Site 9	1.7844	0.3014	4	0.1456
Site 6, Site 10	1.7889	0.2956	4	0.1463
Site 6, Site 12	1.1094	0.4974	4	0.3297
Site 6, Site 16	7.6026	0.1052	5	**0.0023**
Site 9, Site 10	0.40089	0.7989	5	0.7117
Site 9, Site 12	1	0.4979	6	0.3733
Site 9, Site 16	0.93704	0.5935	6	0.4057
Site 10, Site 12	0.71842	0.603	6	0.5148
Site 10, Site 16	1.8766	0.2016	6	0.1329
Site 12, Site 16	3.25	0.1028	5	**0.0316**

Within level 'Autumn2019' of factor 'Survey'

Within level 'Matthews Creek' of factor 'Stream'

Groups	t	P(perm)	Unique perms	P(MC)
Site 7, Site 8	1.1094	0.4933	4	0.333

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Contact Us

Niche Environment and Heritage
02 9630 5658
info@niche-eh.com

NSW Head Office – Sydney
PO Box 2443 North Parramatta
NSW 1750 Australia

QLD Head Office – Brisbane
PO Box 540 Sandgate
QLD 4017 Australia

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Aboriginal heritage
Historical heritage
Conservation management
Community consultation
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Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
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Niche Environment and Heritage
02 9630 5658
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NSW Head Office – Sydney
PO Box 2443 North Parramatta
NSW 1750 Australia

QLD Head Office – Brisbane
PO Box 540 Sandgate
QLD 4017 Australia

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