Cadia Valley Operations - AEMP

Annual Report 2021 - 2022

Cadia Holdings Pty Limited

15 September 2022

→ The Power of Commitment

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The Power of Commitment

Executive summary

The Newcrest Cadia Valley Operations (CVO) environmental monitoring program includes an Aquatic Ecosystem Monitoring Project (AEMP) implemented biannually since spring 2006. The AEMP focusses on the assessment of macroinvertebrates, fish, and aquatic habitat condition potentially impacted by mine operations, within and surrounding the CVO mine lease area (MLA). This report presents data collected during the spring 2021 and autumn 2022 monitoring periods and includes additional eDNA monitoring for platypus. Major findings in this report are:

- There were several high flow events throughout the 12-month period between July 2021 and May 2022 in response to higher-than-average rainfall.
- Broader scale land-use are likely to be impacting on aquatic ecosystem health independent of mining activities in the catchment. These include elevated salinity or nutrient levels, agricultural pollution, disturbance to riparian zone vegetation and the downstream impacts of dams.
- There was no evidence to suggest mining activities have impacted on water quality of Cadiangullong Creek or Rodd's Creek.
- As found in previous monitoring periods, there was evidence of increased copper in the sediments of Cadiangullong Creek downstream of the mine at sites CC2 and CC3, where concentrations exceeded the upper ANZG (2018) guideline. Due to the geomorphology of CC2, the pool at this site appears to act as a deposition site for sediments containing elevated copper concentrations.
  - Sediment transport from CC2 and CC3 with copper bound to it may occur during higher flow events and appears to be dependent on a) the connectivity between CC2 and downstream reaches, b) the frequency and size of the high flow events, and c) the size of the sediment particles
  - Despite elevated concentrations at CC2 and CC3, copper concentration was lower further downstream at CC4, although remained higher than copper concentrations upstream of the mine
  - The concentration of copper in sediments at site CC4 further downstream is below the upper ANZG (2018) guideline, which indicates lower potential ecological risks.
- There was some evidence that site CC2 supported a less healthy aquatic ecosystem than other sites on Cadiangullong Creek or reference sites. It is likely habitat conditions are more influential on macroinvertebrate community health than water or sediment quality.
- Sediment analytes were not found to be a major factor impacting the macroinvertebrate community. This includes the relatively high copper concentrations at CC2.
- A relatively healthy fish community dominated by the native Mountain Galaxias (*Galaxias olidus*) remains distributed throughout Cadiangullong Creek, along with Flyers Creek and Swallow Creek. Spring recruitment of juveniles indicates a self-sustaining population with adequate recruitment.
- eDNA monitoring for platypus suggest they remain distributed throughout Cadiangullong Creek with the exception of the most downstream site CC4 at Oaky Station, where they have been regularly absent and were only confirmed present since March 2019.

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1. Introduction

1.1 Background

Cadia Valley Operations (CVO) is the largest gold and copper producer in New South Wales (NSW) and is one of Australia's largest gold mining operations. It is located approximately 25 km from the city of Orange in central west NSW and is 250 km west of Sydney. CVO is 100% owned by Newcrest Mining Ltd (Newcrest).

The CVO mine lease area (MLA) and associated land holdings cover over 9000 ha and current operations include the underground mining of copper and gold at 'Cadia East' and an ore processing facility. The Cadia Hill open pit mine ceased operation and has been in a state of care and maintenance since July 2012.

The key activities, both currently and historically, carried out at CVO include:

- Underground block and panel caving mining of copper and gold currently at Cadia East and historically at Ridgeway
- Open pit mining of copper and gold at Cadia Hill – ceased in 2012 now in care and maintenance phase
- Processing of ores
- Waste rock storage
- Tailing storage
- Water storage in Cadiangullong Dam and Rodd's Creek Dam

As part of the Newcrest CVO environmental monitoring program, an Aquatic Ecosystem Monitoring Project (AEMP) is implemented on a biannual basis (spring and autumn). Commencing in spring 2006, this AEMP has focused on the assessment of macroinvertebrate and fish populations, and aquatic habitat condition of streams potentially impacted by mine operations within and surrounding the CVO MLA. GHD Pty Ltd (GHD) was commissioned to conduct the most recent monitoring events for the AEMP from 15 to 18 December 2021 (spring) and 16 to 20 May 2022 (autumn).

1.2 Scope and limitations

This report details the AEMP and documents the field sampling conducted by GHD in spring 2021 and autumn 2022. It describes the methodology, results for the various components of the monitoring program, and discusses these in relation to various assessment criteria (where applicable) and in the context of the mining operation.

This report has been prepared by GHD for Newcrest Mining Ltd and may only be used and relied on by Newcrest Mining Ltd for the purpose agreed between GHD and Newcrest Mining Ltd. GHD otherwise disclaims responsibility to any person other than Newcrest Mining Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible. The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points, and on conditions encountered and information reviewed at the date of preparation of the report. Site conditions at other parts of the mine may be different from the site conditions found at the specific sample points. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

Investigations undertaken in respect of this report are constrained by the particular site conditions. As a result, not all relevant site features and conditions may have been identified in this report. Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

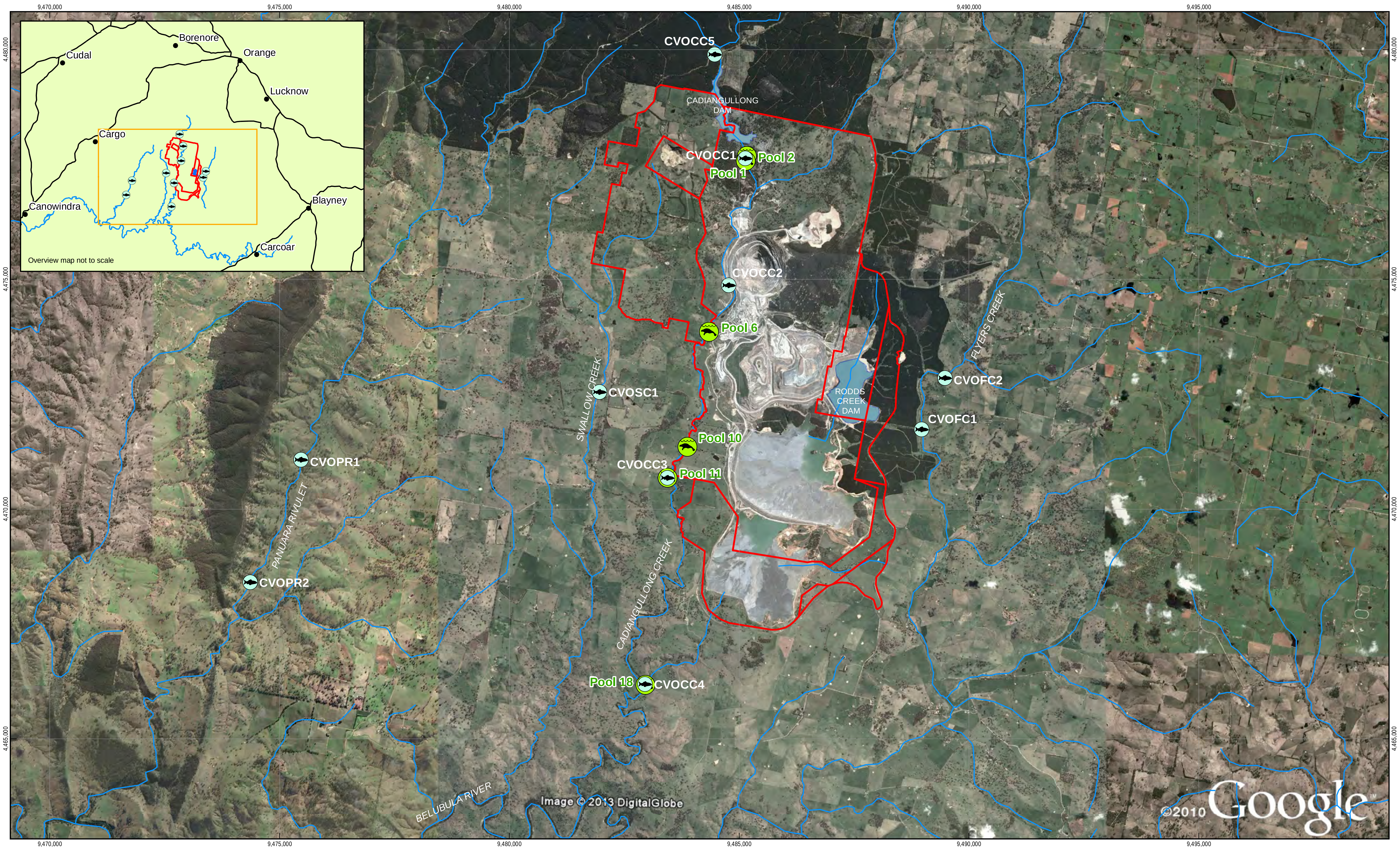
1.3 Rationale for using biological indicators

Aquatic macroinvertebrates are widely accepted and used for biological assessment of rivers and streams. The use of macroinvertebrates in ecosystem disturbance studies stems from their high abundance and diversity, sensitivity to changes in water quality, flow regime and habitat conditions, ease of sampling, a good understanding of their taxonomy and ecological requirements, and an ability to detect long-term impacts (DNR 2001). The successful application of macroinvertebrates for biological assessment in the mining industry has been demonstrated both within Australia and overseas (Brycroft et al. 1982; Dudka and Adriano 1997; Norris et al. 1982; Faith et al. 1995; Humphrey et al. 1995). Traditionally, biological indices such as diversity and pollution indices have been used to determine the level of impact (Garcia-Criado et al. 1999).

Fish have been widely used as indicators of water quality throughout the world and were the basis for the North American Index of Biological Integrity (IBI), which has been modified for use in temporary streams and Australian inland rivers. The quantitative monitoring of fish has been applied successfully to the assessment of water quality impacts in temporary waters in Australia. Previous studies of fish populations within streams in the CVO area (Bauer 1995; Goldney 2000; Ecowise Environmental 2007, 2008; ALS 2010, 2011; GHD 2012 to 2021) have identified the occurrence of five species; only one of which, Mountain Galaxias (*Galaxias olidus*), is native to the region. The other four exotic species recorded in past studies include Redfin Perch (*Perca fluviatilis*), Eastern Gambusia (*Gambusia holbrooki*), Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*).

1.4 Study area

Cadiangullong Creek is the main focus of the AEMP as it runs in a southerly direction directly through the mine and is therefore susceptible to impacts from mining operations (Figure 1). Cadiangullong Dam, a key water supply for mining facilities and environmental flow releases (termed '*riparian releases*'), is located upstream of the main CVO mining facilities. A 2.4 km diversion, excavated from igneous rock, was created around open cut mining operations to allow for continuation of water supply to downstream reaches of Cadiangullong Creek. Cadiangullong Creek flows south into the Belubula River, approximately 14 km downstream of the CVO southern lease boundary. Flyers Creek, Swallow Creek, Diggers Creek, Panuara Rivulet and Rodd's Creek are monitored in the AEMP and also flow into the Belubula River.



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Kilometers

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 NSW Lambert

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LEGEND

- Platypus Monitoring Sites
- Aquatic Monitoring Sites
- Cadia Valley Operations MLA
- Water Storage/Reservoir
- Roads
- River/Creek

GHD

Newcrest Pty Ltd
Cadia Valley Operations - Aquatic Ecosystem Monitoring Project

Job Number	23-12540968
Revision	B
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Aquatic Ecosystem Monitoring Sites
Surface Water Features

Figure 1

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Data source: Google/Satellite Imagery, Geoscience Australia/aust250k.gdb, Newcrest Pty Ltd/Cadia Mining Lease_AMG, GHD/Cadia AE Sites. Created by:cjauniau

1.5 Monitoring locations

During spring 2021 and autumn 2022 12 sites were monitored in the AEMP with site locations enabling comparisons of different treatments (Table 1; Figure 1). Representative site photographs for autumn 2021 and autumn 2022 have been included to show changes that have occurred over the last 12 months. Five sites were located on Cadiangullong Creek (CC1 to CC5), the main waterway flowing through the CVO MLA (Plate 1). One site was located on Swallow Creek (SC1) and two sites on Panuara Rivulet (PR1 and PR2) to the west of the MLA (Plate 2). One site was also located on Rodd's Creek (RC1) and Diggers Creek (DG1) (Plate 2). Two sites were located on Flyers Creek (FC1 and FC2) to the east of CVO (Plate 3).

Table 1 Monitoring site locations

Waterway	Site code	Site treatment
Cadiangullong Creek	CC5	Upstream
	CC1	Upstream
	CC2	On-site
	CC3	Downstream
	CC4	Downstream
Flyers Creek	FC2	Reference
	FC1	Reference
Panuara Rivulet	PR1	Reference
	PR2	Reference
Swallow Creek	SC1	Reference
Rodd's Creek	RC1	On-site (downstream tailings dam)
Diggers Creek	DG1	Upstream

In addition to the standard AEMP monitoring components, monitoring of platypus was also undertaken during spring 2021 and autumn 2022 (Figure 1). Under normal conditions, the CVO riparian releases are approximately 2.8 ML/day and are aimed at achieving 0.9 ML/day at Oaky Creek. However, due to a lack of water in Cadiangullong Dam during 2019, CVO applied to the NSW Department of Water and Energy (DWE) for a variation to the riparian release conditions and to temporarily cease the releases into Cadiangullong Creek. To support the DWE application and address specific questions related to ecological risks should the releases cease, GHD prepared a report that recommended a three-stage monitoring program (GHD 2019a). The aims of the program were to determine the current distribution of platypus in Cadiangullong Creek, predict changes during the cease-to-flow period, and identify potential management actions to mitigate against potential impacts.

In a previous monitoring program (GHD 2020a), monitoring of platypus and associated water quality and habitat conditions (generally monthly) was carried out between March 2019 and July 2020 with environmental DNA (eDNA) sampling used to determine platypus presence. The overall findings from the monitoring were that platypus persisted in Cadiangullong Creek, even during the cessation of the riparian releases, and continued to persist once releases were reinstated. The monthly monitoring program ceased in July 2020 although CVO decided to include the eDNA component in the AEMP to continue tracking platypus distribution (between spring 2020 and autumn 2022).

CC1

CC1

CC2

CC2

CC3

CC3

CC4

CC4

CC5

CC5

Plate 1 Cadiangullong Creek site photographs in autumn 2021 (left) and autumn 2022 (right)

RC1 	**RC1** 
SC1 	**SC1** 
DG1 	**DG1** 
PR1 	**PR1** 
PR2 	**PR2** 

Plate 2 ***Reference sites and off-site photographs autumn 2021 (left) and autumn 2022 (right)***

FC1	FC1
	
FC2	FC2
	

Plate 3 Flyers Creek site photographs in autumn 2021 (left) and autumn 2022 (right)

2. Methodology

2.1 Permits and licences

GHD has current NSW Fisheries permits and licences to conduct macroinvertebrate and fish monitoring in NSW rivers and streams and staff operate under a NSW Department of Primary Industries (DPI) Fisheries permit, issued under section 37 of the *Fisheries Management Act 1994* (Permit No: P07/0142-5.0, expiry date 31 Oct 2023).

2.2 Aquatic habitat

The aquatic habitat assessment was undertaken following methods described in the NSW AUSRIVAS Manual (Turak et al. 2004) that includes a range of physical habitat measurements and the Visual Assessment of Disturbance Related to Human Activities (VisAssess). This visual assessment method is an evidence-based approach of grading the degree of anthropogenic impacts at a monitoring site based on four assessment categories:

– Water Quality: odour, water clarity, disruption of the natural hydrology, presence of foam from detergents, oil
– Instream: change in substrate (e.g., rock piles or sedimentation from road construction or other development pipes), rubbish, filamentous algae, alien fish species, invasion by exotic aquatic plants
– Riparian Zone: de-vegetation, exotic plant invasion, bank degradation, point sources
– Catchment: mine, sewage treatment plant, landfill, dam, industry, logging, agriculture, clearing, salinity, grazing, urban development

A ranking of 0 to 4 and an associated description is assigned for each category with a higher score indicating a higher level of anthropogenic impact (Table 2). The Total Visual Assessment Score is the sum of these rankings for each site, which provides an overall assessment of anthropogenic impacts ranging from 0 to 16.

Table 2 NSW AUSRIVAS VisAssess ranking categories, descriptions and total scores

Ranking	Description	Total Visual Assessment Score
0	No evidence of disturbance	0 – 2
1	Little disturbance	3 – 5
2	Moderate disturbance	6 – 8
3	High disturbance	9 – 12
4	Extreme disturbance	13 – 16

2.3 Water quality

In situ water quality recordings were made from the surface at each site for the following physico-chemical parameters:

– Temperature (°C)
– pH (pH units)
– Electrical conductivity (EC) (µS/cm)
– Dissolved oxygen (DO) (% saturation and mg/L)
– Turbidity (NTU)
– Alkalinity (mg/L $CaCO_3$)

Temperature, pH, EC and DO dissolved oxygen were recorded at each site using a YSI 556 multi-parameter water quality meter. This meter was calibrated in accordance with QS/QA (Quality System/Quality Assurance) requirements and the manufacturer's specifications. Alkalinity was measured using a Hach Digital Alkalinity Titration kit. Turbidity was measured using a Hach 2100Q portable turbidimeter. The water quality results were compared to ANZG (2018) default guideline values for slightly disturbed upland rivers of south-eastern Australia (previously known as ANZECC 2000).

2.4 Sediment quality

2.4.1 Sampling

Sediment quality has been included in the monitoring program since autumn 2018 to fill a knowledge gap identified following a review of the water quality, environmental and biological data for CVO (GHD 2018). One of the key recommendations from the review was to include sediment monitoring to assess its relationship with benthic macroinvertebrate communities. There was some evidence of a relationship between macroinvertebrate communities and sediment in autumn 2018, so monitoring continued to determine whether there was evidence of seasonal variation in sediment quality.

From a minimum of five locations at each site, sediment was collected and consolidated into a single composite sample. Sediment from multiple locations encapsulates variation associated with different habitats and hydrological units and allows for a more standardised procedure for comparing sediments amongst sites. The sediment samples were analysed for a suite of total metals (Table 3).

Table 3 Analytes – sediment samples

Laboratory analyses	Analytes
Total metals	Aluminium (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Silver (Ag), Zinc (Zn)

2.4.2 Data analysis

In previous seasons, sediment concentrations were compared to ANZECC (2000) interim sediment quality guidelines (ISQG) for 95% level of protection for slightly to moderately disturbed ecosystems. These guidelines have now been reviewed and updated and in this report, sediments concentrations are compared to default guideline values (DGVs) published in ANZG (2018). The sediment DGVs indicate concentrations below which there is a low risk of unacceptable effects occurring in aquatic ecosystems (ANZG 2018). Upper guideline values are also published to provide an indication of concentrations at which toxicity-related adverse effects may be expected (ANZG 2018). The sediment concentrations in this report have been compared to both the DGVs and upper DGVs.

Note that the major toxic effect of metals on the macroinvertebrate communities is due to the dissolved form of metals in an ecosystem (ANZG 2018). As such, the total metal concentrations assessed in this monitoring program over-estimate the fraction that is bioavailable.

Relationships in sediment quality amongst sites were examined using a Principal Components Analysis (PCA), which reduces a large set of variables into a small set that retains most information associated with the large set. In this case, the suite of metals listed in Table 3 were reduced to two principal components (PC1 and PC2). These principal components were used as axes in PCA ordinations to graphically represent sites in ordinal space. Principal component scores explain the percentage of variation in the sediment quality contributed by each axis and linear coefficients define the contribution of each analyte to each axis. Vectors plotted on the PCA ordination superimpose environmental gradients. Prior to performing the PCA, the data was normalised to ensure scale independence. PCA analyses were conducted using PRIMER Version 7 (Clarke and Warwick 2001). Note that where sediment results were presented as below laboratory limits of resolution (LOR), these values were halved (i.e., $<0.5 \div 2 = 0.25$ and $<1 \div 2 = 0.5$ respectively) and retained in the analysis. Antimony, cadmium and silver were removed from analyses as all values were below laboratory detection limits and provided no information about variation.

2.5 Macroinvertebrates

2.5.1 Sampling

Macroinvertebrates were sampled in accordance with the NSW AUSRIVAS Sampling and Processing Manual (Turak et al. 2004). At each site, the littoral or edge habitat was sampled by sweeping the collecting net along the edge of the stream in areas of little or no current. Where present, riffles were sampled using a kick sampling method.

For each sample, the collected material was placed into a sorting tray and macroinvertebrates were '*live picked*' for a minimum of 40 minutes. Live picked macroinvertebrates were preserved in 70% ethanol and labelled with information including site code, site location, habitat, sampling method, date, sampler and picker.

2.5.2 Laboratory processing

Macroinvertebrate samples were examined using Leica M80 or S6 series stereo-dissection microscopes with a minimum of 6.3:1 zoom and a standard magnification of 7.5-60x. Freshwater macroinvertebrates were identified using published taxonomic keys (see Hawking 2000), unpublished working keys and an extensive specimen reference collection maintained by GHD. Based on standard conventions for NSW AUSRIVAS models (Turak et al. 2004) macroinvertebrates were identified to family-level with the following exceptions:

– Chironomidae (Diptera) were identified to Sub-family (e.g., Orthocladiinae, Chironominae and Tanypodinae)
– Groups such as Nematoda, Oligochaeta and Acarina were identified to Class or Order
– Microcrustacea, Ostracoda, Copepoda and Cladocera were identified to the Order

Upon completion of identifications, all samples were returned to 100% ethanol for long-term archiving. This process allows samples to be re-examined if required. This may be important, particularly if taxonomy changes significantly in the future under a long-term monitoring program or for QA/QC purposes. GHD will ensure archived samples are retained for the life of the AEMP. Reference specimens will remain the property of GHD.

2.5.3 Data analysis

The data analyses in this AEMP are designed to achieve the key objective of developing an understanding of macroinvertebrate communities as an indicator of aquatic ecosystem health.

Univariate analyses - Biological indices

The biological indices calculated from the macroinvertebrate data include:

– Taxa Richness
– EPT Taxa Richness
– SIGNAL-2
– NSW AUSRIVAS models: spring, autumn, and combined season edge and riffle where applicable

Taxa Richness

Taxa Richness refers to the number of different taxa (identified to levels outlined in Section 2.5.2) contained in a sample. Taxa Richness can reasonably indicate ecological health, with healthy waterways generally having more taxa.

EPT Taxa Richness

The EPT Taxa Richness index refers to the number of key macroinvertebrate taxa (identified to family level) belonging to the Orders Ephemeroptera, Plecoptera and Trichoptera. These Orders are generally considered to contain pollution–sensitive insects and a loss of families usually indicates some level of disturbance (Plafkin et al. 1989).

SIGNAL-2

SIGNAL-2 (Stream Invertebrate Grade Number Average Level) is a simple scoring system for macroinvertebrates in Australian rivers (see Chessman 2003). SIGNAL-2 is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate taxa at the Order and Family levels. These grades have been derived from published and unpublished information on taxa tolerance to pollutants such as sewage and nitrification (Chessman 1995). Each taxon is assigned a grade from 1 (tolerant) to 10 (sensitive) based on eco-toxicity assessment data.

Not all macroinvertebrate families have been assigned a SIGNAL-2 grade and those without are removed from SIGNAL-2 calculations, which is the average of the grades within a sample. SIGNAL-2 scores only use the presence of taxa and are not weighted with regard to abundance. For easier interpretation, SIGNAL-2 scores and the number of macroinvertebrate taxa are graphed using a bi-plot. The resulting bi-plot is placed into context using a quadrant diagram, which divides the results into four general realms; each realm indicates various factors of site condition that may explain the macroinvertebrate community SIGNAL-2 score (Figure 2).

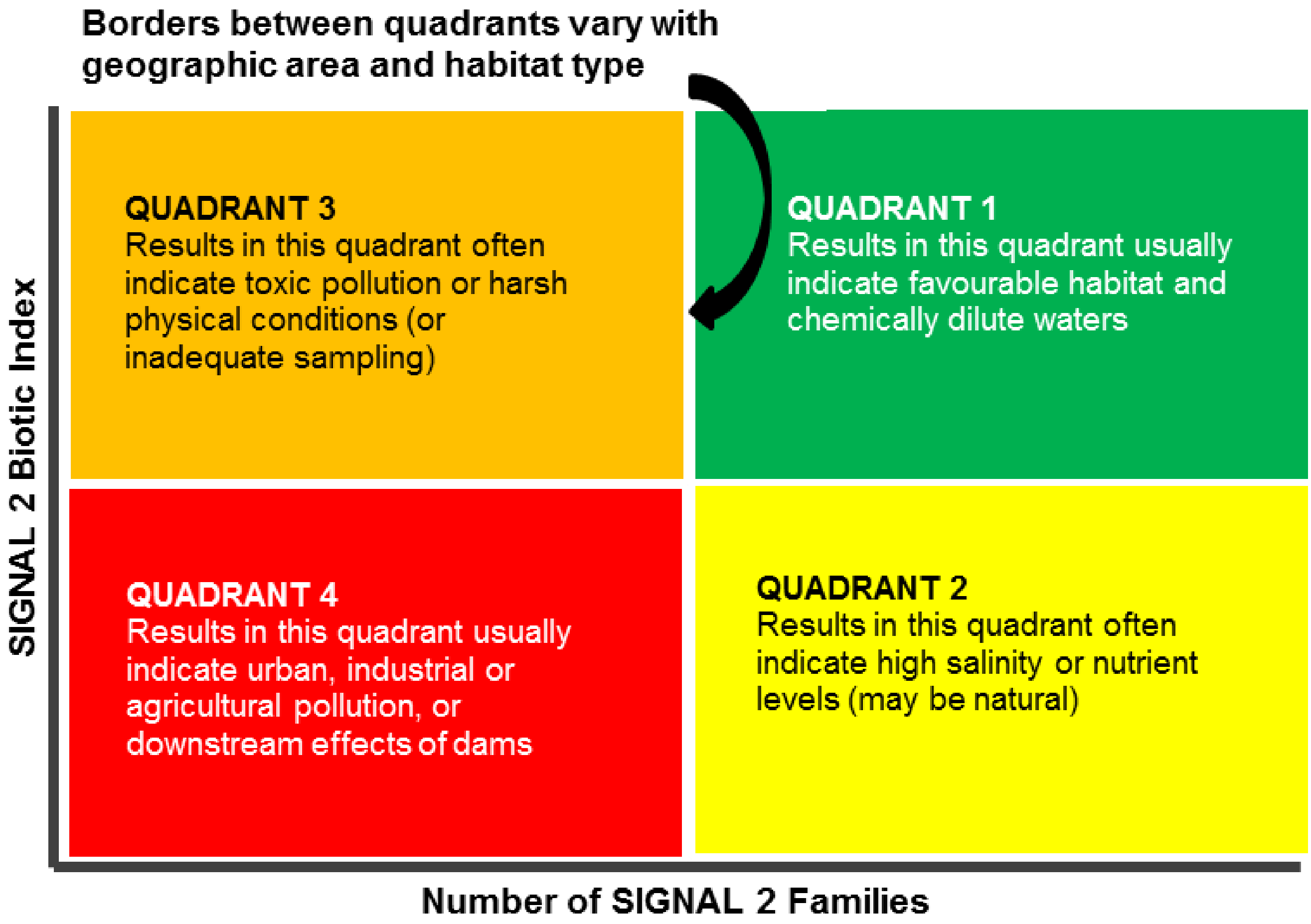

Figure 2 ***SIGNAL-2 bi-plot displaying the four quadrants and explanations of what each indicates***

The SIGNAL-2 quadrant boundaries have been set according to the NSW interim boundaries suggested for sites within the Murray-Darling Basin above 400 m elevation (Chessman 2001). These are:

– A SIGNAL-2 score of 5 and 19 for number of families in edge habitats
– A SIGNAL-2 score of 6 and 17 for number of families in riffle habitats

NSW AUSRIVAS Model

All macroinvertebrate data, water quality parameters and habitat variables required by the AUSRIVAS models were collected according to the NSW AUSRIVAS manual (Turak et al. 2004) and ANZG (2018) Water Quality Guidelines for aquatic ecosystems in south-eastern Australia. NSW AUSRIVAS models and accompanying scores and bandings have been used to detect changes in observed and expected macroinvertebrate communities for sites associated with the AEMP and include:

– NSW - Spring Riffle
– NSW - Spring Edge
– NSW - Autumn Riffle
– NSW - Autumn Edge
– NSW - Combined Seasons Edge
– NSW - Combined Seasons Riffle

AUSRIVAS generates site-specific predictions of the macroinvertebrate fauna expected to be present in the absence of environmental stress. The expected fauna from reference sites with a similar set of physical and chemical characteristics are compared to the observed fauna, and the ratio derived is used to indicate the extent of the impact. This ratio can range from zero (0), when none of the expected taxa are found at a site, to approximately one (1), when all the expected taxa are present. The value can also be greater than one (1) when more families are found at a site than predicted by the model. The ratio scores are placed in bands, which indicate whether the site is richer than reference, reference quality, significantly impaired, severely impaired or extremely impaired. Examples of outputs from the AUSRIVAS models (i.e., O/E 50 upper limits and band descriptions) are demonstrated for the combined season edge and riffle models in Table 4.

Table 4 AUSRIVAS bands, O/E 50 upper limits, and band names and descriptions for the NSW combined season models

Band Label	O/E 50 Upper Limit Edge	O/E 50 Upper Limit Riffle	Band Name	Band Description
Band X	>1.17	>1.14	More biologically diverse than reference sites.	More taxa found than expected. Potential biodiversity hot spot. Possible mild organic enrichment.
Band A	1.17	1.14	Reference condition	Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
Band B	0.82	0.85	Significantly impaired	Fewer families than expected. Potential impact, either on water quality or habitat quality or both, resulting in loss of taxa.
Band C	0.48	0.57	Severely impaired	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
Band D	0.14	0.29	Extremely impaired	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

Multivariate Analysis

Multivariate analyses were performed on the macroinvertebrate data for both spring and autumn separately as strong seasonal differences have previously been identified by the AEMP. Edge and riffle habitats were also analysed separately due to differences in the communities associated with these habitats. The multivariate analyses were utilised to determine if significant differences in the macroinvertebrate community existed spatially. That is, are there significant differences between sites associated with each treatment type (i.e., upstream, on-site, downstream and reference). All multivariate analyses were performed using the PRIMER V7 software package (Clarke and Gorley 2015).

Initially, the macroinvertebrate data was transformed to presence/absence data as the RBA sampling protocol is a semi-quantitative technique. Furthermore, transformation of the macroinvertebrate data increases the influence of rare species and decreases potential sample variability based on the inherent variation associated with different sample collectors.

A similarity matrix was subsequently calculated between all samples based on the Bray-Curtis similarity measure. Non-metric multidimensional scaling (nMDS) was then used to produce an ordination plot as a graphical representation of key spatial and temporal trends in the macroinvertebrate assemblages. The stress value associated with the nMDS ordination was examined to identify the accuracy of the ordination. A stress value <0.2 indicates a potential useful 2-dimensional ordination (Clarke and Warwick 2001).

To test if there were statistically significant differences in the macroinvertebrate communities between each treatment type (see Table 1), permutation-based analyses of variance (ANOSIMs) were used using 999 permutations. If significant differences were detected, taxa analysis was conducted using the similarity percentages (SIMPER) routine to identify the taxa that best discriminate between the treatments. SIMPER quantifies the contribution of each taxon to the average dissimilarity between the two groups of samples, and to the average similarity within a group (Clarke and Warwick 2001).

Sediment / macroinvertebrate relationships

A key focus of the sediment monitoring was to assess if there was an association between sediment quality and macroinvertebrate communities. To investigate this, the RELATE, BEST and DISTLM procedures in the PRIMER V7 software package were used (see Clarke and Gorley 2015). Initially, the RELATE procedure was used to test if there was a correlation between sediment quality and macroinvertebrate communities. That is, to explore if the patterns on the sediment PCA show some correlation to the macroinvertebrate nMDS. Using 999 permutations, RELATE calculates the rank correlation (q) and if the null hypothesis was accepted (significance level $P > 0.05$) no relationship between two data sets is assumed.

The sediment analytes that best explained relationships were identified using the BEST procedure. BEST identifies which analytes are most strongly correlated with the macroinvertebrate communities and was carried out by generating a resemblance matrix (based on Euclidean distance) of normalised sediment analytes and matching it, using a Spearman rank correlation, to the macroinvertebrate data.

The limitation of the BEST procedure is it gives an indication of correlation between sediment analytes and macroinvertebrate communities but does not identify how much of the variation in macroinvertebrates communities is explained by each analyte. This was determined using the distanced based linear modelling (DISTLM) procedure to test if there was a significant correlation, using 999 permutations, between each sediment analyte and the macroinvertebrate communities. DISTLM then identifies the percentage variation in the macroinvertebrate community explained by the analytes.

2.6 Fish

2.6.1 Sampling

Electrofishing was conducted in accordance with the Australian Code of Electrofishing Practice (SCFFA 1997) and GHD's Fauna Survey Standard Operating Procedure to ensure all safety requirements were met prior to commencing work. At each site, the total reach surveyed was defined as 10 x bank-full width. Electrofishing was undertaken using an E-fish 500 W Backpack System in areas where the depth, instream habitat, and water quality was suitable for safe operation.

Due to stream depth, elevated conductivity or turbidity electrofishing could not be conducted at CC5 and SC1. At these sites, eight baitfish traps (250 mm x 250 mm x 450 mm; 5 mm mesh) were set using a stratified approach to cover all habitat types within the reach. Traps were baited with dry cat biscuits and left overnight for approximately 12 hours. Fish surveys are not conducted at Rodd's Creek (RC1) or Diggers Creek (DG1).

2.6.2 Identification and processing

At each site, fish collected were identified to species using published keys (e.g., Allen et al. 2002; Lintermans 2007; Kuiter 2013) and their total length (TL) to the nearest millimetre (mm) recorded. Native species were returned unharmed to the stream. Non-native species were euthanized and disposed of in accordance with ethics permit requirements. All by-catch fauna (e.g., *Cherax* sp. (Yabbies)) were noted and immediately returned to the stream.

2.7 Platypus

2.7.1 Sampling

Platypus were monitored using environmental DNA (eDNA) sampling used to determine presence. At each site, samples were collected in duplicate by passing 200-500 mL water through a 0.22 μm filter (Sterivex) on site. Filters were stored on ice for a maximum of 48 hrs before being transported to the laboratory (EnviroDNA) for processing.

2.7.2 Laboratory processing

DNA was extracted from the filters using a commercially available DNA extraction kit (Qiagen DNeasy Blood and Tissue Kit). Real-time quantitative Polymerase Chain Reaction (qPCR) assays were used to amplify the target DNA, using a species-specific marker targeting a small region of the mitochondrial DNA, previously developed and assessed for specificity and sensitivity by EnviroDNA (Weeks et al. 2015; Lugg et al. 2018). Assays were performed in triplicate on each sample. Negative controls were included for the DNA extraction and qPCR steps. At least two positive PCR's (out of six assays performed for each site) were required to classify the site as positive for the presence of platypus.

3. Results

3.1 Rainfall and hydrology

During the six months prior to the spring 2021 monitoring in December, total monthly rainfall in the surrounding catchments of the CVO was higher than the long-term average (Table 5), except for October. Monitoring in December occurred in a month with total rainfall less than the long-term average. Prior to the May 2022 monitoring, total rainfall was greater than the long-term average in January and April but was less in February and March. Overall, rainfall between June 2021 and May 2022 (1,434 mm) was higher than for the same period between 2020 and 2021 (1,080 mm), and much higher than between 2019 and 2020 (688 mm).

Table 5 Monthly rainfall and temperature recorded at Orange Airport (63303) from June 2021 to May 2022 and long-term means from 1996 to 2022 (sourced from BOM 2022)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Total rainfall (mm)	141	172	113	79	61	317	65	171	38	44	131	102
Long-term mean rainfall (mm)	79	76	84	78	71	88	86	69	77	75	45	52
Mean maximum temperature (°C)	10.1	9.0	11.3	14.4	17.0	18.1	23.2	24.9	24.2	22.6	18.2	13.7
Long-term mean maximum temperature (°C)	10.9	9.8	11.2	14.9	17.4	21.8	24.9	27.4	25.9	22.9	18.6	14.0

The hydrograph for Cadiangullong Creek upstream of Cadiangullong Dam (CC5) reflected the pattern in rainfall with an increase in mean daily flow following increased rainfall. The peaks in the hydrograph at CC5 correspond to intense rainstorms in July, August and November (Figure 3). Downstream of Cadiangullong Dam at CC1, similar increases in flow due to rainfall were observed, although the lower magnitude flows in July indicates the higher flows in this month were captured by Cadiangullong Dam. Sites CC3 and CC4 downstream of the CVO MLA followed rainfall patterns more closely than CC1 as they receive additional runoff from tributaries. Runoff peaks were observed from July to September and from November to January in response to rainfall.

There was little runoff in the Swallow Creek reference site (SC1) throughout the year. However, there were peaks associated with high rainfall in August and from November to January. The Flyers Creek reference site (FC1) had more consistent flow from August to January than both Swallow Creek and Cadiangullong Creek. There was a downward trend in baseflow in Flyers Creek from October to March.

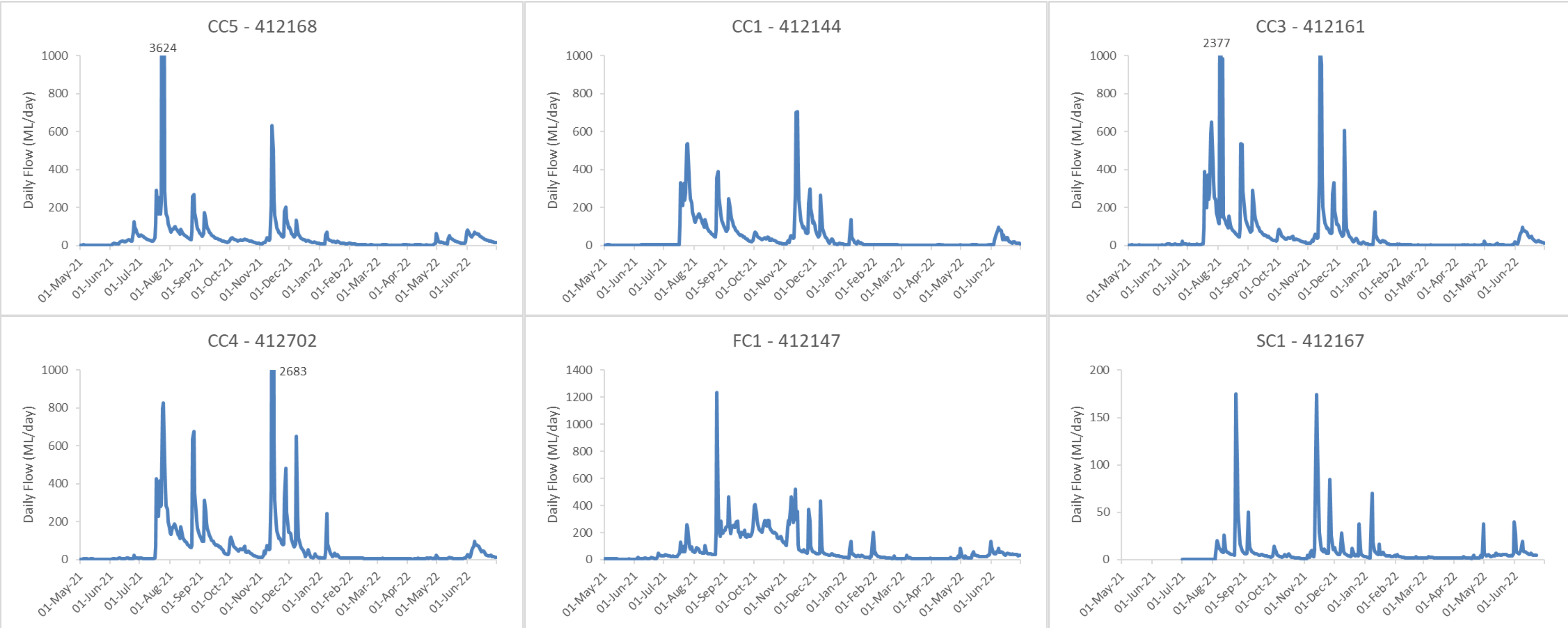

Figure 3 ***Hydrographs from Swallow Creek (SC), Flyers Creek (FC) and Cadiangullong Creek (CC) for the period 1 May 2021 to 30 June 2022***

3.2 Aquatic habitat

Following the NSW AUSRIVAS Visual Assessment of Disturbance Related to Human Activities, the majority of sites on the Cadiangullong Creek were assessed as ‘high disturbance’ (Table 6). Site CC2, which is located on-site at CVO, was categorised as ‘extreme disturbance’ during spring, with water quality being the only disturbance assessment criteria that did not score the maximum value.

The site PR1 on the Panuara Rivulet reference site also recorded levels of ‘extreme disturbance’ in both seasons. Rodd’s Creek reference site (RC1) recorded levels of ‘extreme disturbance’, though this was limited to just autumn. These results were primarily due to the conditions of the riparian zone although catchment conditions also impacted Rodd’s Creek.

In general, sites on the Cadiangullong Creek, Swallow Creek, Flyers Creek, Panuara Rivulet and Rodd’s Creek had ‘high disturbance’ ranks due to the impacts to riparian zone vegetation and broader catchment scale land-use which, aside from mining and associated operations, is heavily influenced by grazing in the mid to lower catchment areas as well as pine plantations in the upper catchment.

Common disturbance of the waterways unrelated to mining activities includes erosion and sedimentation that contributes to increased turbidity in Cadiangullong Creek, excessive algal growth in Panuara Rivulet due in part to agricultural land use and nutrients inputs, and the presence of exotic fish species (Plate 4).

Plate 4 ***Increased turbidity in Cadiangullong Creek following high rainfall in spring 2021, filamentous algal growth in Panuara Rivulet in spring 2020, and Redfin Perch in Cadiangullong Creek autumn 2022***

Table 6 Results of the NSW AUSRIVAS visual assessment of disturbance

Site	Season	Water Quality	Instream	Riparian Zone	Catchment	Total Score	Rank
CC5	Spring	2	2	3	2	9	High disturbance
	Autumn	2	2	3	2	9	High disturbance
CC1	Spring	2	1	2	2	7	Moderate disturbance
	Autumn	3	2	2	2	9	High disturbance
CC2	Spring	2	4	3	4	13	Extreme disturbance
	Autumn	2	3	4	4	13	Extreme disturbance
CC3	Spring	2	3	3	3	11	High disturbance
	Autumn	2	2	3	3	10	High disturbance
CC4	Spring	2	3	3	3	11	High disturbance
	Autumn	2	3	3	3	10	High disturbance
FC1	Spring	2	2	4	3	11	High disturbance
	Autumn	2	3	4	3	12	High disturbance
FC2	Spring	2	2	3	3	10	High disturbance
	Autumn	2	3	3	3	11	High disturbance
PR1	Spring	3	4	4	3	14	Extreme disturbance
	Autumn	3	3	4	3	13	Extreme disturbance
PR2	Spring	2	2	3	3	10	High disturbance
	Autumn	2	2	3	2	9	High disturbance
SC1	Spring	2	3	4	2	11	High disturbance
	Autumn	2	3	4	2	11	High disturbance
RC1	Spring	2	2	4	4	12	High disturbance
	Autumn	2	3	4	4	13	Extreme disturbance
DG1	Spring	2	2	4	3	11	High disturbance
	Autumn	2	2	4	3	11	High disturbance

3.3 Water quality

Results for the *in situ* water quality variables collected in spring 2021 and autumn 2022 are presented in Table 7 and are compared to the relevant ANZG (2018) DGVs. The results are also displayed in graphs in Figure 4, which allows for comparison between seasons and sites.

Table 7 Results of in-situ water quality for the CVO aquatic ecosystems sites sampled in spring 2021 and autumn 2022. Red values exceed ANZG (2018) DGVs

Site code	Season	Temp. (°C)	DO (mg/L)	DO (%Sat.)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	Alkalinity (mg/L)
ANZG (2018) DGVs[1]		NA	NA	90-110	350	6.8-8.0	25	NA
CC5	Spring	15.9	6.7	67.5	85	8.2	29	60
	Autumn	13.1	9.0	94.4	51	7.3	19	30
CC1	Spring	21.4	7.3	81.3	69	7.6	33	80
	Autumn	11.1	10.7	105.7	71	7.6	14	65
CC2	Spring	18.0	4.7	49.5	143	8.3	23	80
	Autumn	12.0	10.3	103.3	167	7.6	9	80
CC3	Spring	19.4	6.9	75.1	254	6.9	25	100
	Autumn	9.6	12.4	116.4	316	8.1	4	100
CC4	Spring	19.9	6.8	73.7	366	7.7	25	120
	Autumn	12.4	11.8	117.3	464	8.3	5	60
DG1	Spring	22.3	5.2	59.8	538	8.1	20	140
	Autumn	11.8	10.1	100.5	380	7.6	13	85
FC2	Spring	16.3	6.6	67.3	208	7.5	13	140
	Autumn	13.2	10.5	108.2	183	8.2	25	110
FC1	Spring	18.8	7.9	85.9	233	7.6	16	140
	Autumn	13.6	10.6	110.8	190	8.1	13	110
PR1	Spring	20.4	9.2	102.6	515	8.8	12	160
	Autumn	7.8	14.0	124.0	421	8.6	3	260
PR2	Spring	18.5	8.9	94.7	529	8.4	19	160
	Autumn	10.3	12.8	120.0	457	8.6	3	260
RC1	Spring	18.3	6.0	63.6	1,591	7.8	24	480
	Autumn	11.9	9.2	91.5	1,136	8.1	5	560
SC1	Spring	18.4	4.3	45.6	1156	7.6	11	280
	Autumn	8.8	9.3	85.3	885	7.7	4	360

[1] ANZG (2018) default guideline values (DGVs) are for upland rivers in south-eastern Australia.

Temperature – There was a consistent seasonal pattern in temperature, with all sites having higher values during spring compared to autumn, (Table 7, Figure 4). This pattern is related to differences in air temperature between the seasons, with higher average maximums during the spring monitoring in 2021 (Table 5). Any differences amongst sites within a season are likely due to the time-of-day when recordings were taken. There is no ANZG (2018) DGV for temperature.

Dissolved oxygen – There was a consistent seasonal pattern in DO, with all sites having higher values during autumn (Table 7, Figure 4). This seasonal variation is related to the cooler water temperatures during autumn that allows for a greater amount of oxygen to be dissolved. During spring, the DO at most sites was below the ANZG (2018) guideline range (90 to 110%) except for the two sites on Panuara Rivulet (PR1 and PR2). This is likely due to high algal growth often observed at these Panuara sites (see Plate 4). Most sites complied with the guideline range in autumn although high DO was recorded at CC3 and CC4 on Cadiangullong Creek and at both sites on Panuara Rivulet, while low DO was recorded at Swallow Creek (SC1).

Electrical conductivity – There was no consistent pattern in EC amongst seasons, with higher values at some sites during spring and during autumn at others (Table 7, Figure 4). In Cadiangullong Creek there was a consistent EC gradient with levels increasing downstream. However, only the most downstream site, CC4, exceeded the ANZG (2018) guideline value of 350 µS/cm. Flyers Creek (FC1) remained below the guideline in both seasons while Diggers Creek (DC1), Panuara Rivulet (PR1 and PR2), Rodd’s Creek (RC1) and Swallow Creek (SC1) were consistently above the guideline. Rodd’s Creek and Swallow Creek were noticeably more saline than all other waterways in both seasons, particularly in spring.

pH – There was no consistent pattern in pH amongst seasons with higher values at some sites during spring and during autumn at others (Table 7, Figure 4). All sites were above the minimum ANZG (2018) DGV of 6.8 in both spring and autumn. However, a number of sites exceeded the maximum ANZG (2018) guideline value of 8.0, particularly at the Panuara Rivulet sites (PR1 and PR2) in both seasons.

Turbidity – Turbidity remained below the ANZG (2018) guideline value of 25 NTU at most sites in both seasons (Table 7, Figure 4). The guideline was exceeded at CC5 and CC1 on Cadiangullong Creek during spring, which is likely due to the elevated flow in this season. Turbid water and increased flow were recorded and observed at several sites during spring (Plate 5).

CC2

CC3

CC4

Plate 5 ***Increased turbidity and flow at select sites in Cadiangullong Creek following high rainfall in spring 2021***

Alkalinity – Alkalinity is water’s capacity to resist changes in pH and is influenced by the soil and bedrock through which it passes as well as by rainfall. Alkalinity can also be influenced by acids from mining runoff, which may decrease alkalinity. There was no major seasonal pattern for alkalinity on Cadiangullong Creek (CC) or Flyers Creek (FC). However, alkalinity was higher in spring at Panuara Rivulet (PR1 and PR2), Rodd’s Creek (RC1) and Swallow Creek (SC1) in autumn. The change in alkalinity might be caused by the different flow rates in spring compared to autumn. There is no ANZG (2018) DGV for alkalinity.

Figure 4 *In situ water quality for CVO sites monitored spring 2021 and autumn 2022. Red lines are ANZG (2018) default guideline values*

3.4 Sediment quality

Comparisons of total metals concentrations in sediments against the ANZG (2018) DGVs are shown in Table 8. Concentrations of antimony, cadmium, silver and all but one of mercury and selenium were below laboratory limits of reporting (LOR) at all sites in both seasons. Of the metals that have DGVs published, only arsenic, chromium, copper and nickel exceeded guidelines, with only copper also exceeding the upper DGV in Cadiangullong Creek (CC2 and CC3 in both seasons). The chromium DGV was only exceeded in Flyers Creek during spring.

PCA based on the sediment quality was carried out for two sets of sites:

1. All monitoring sites to identify major differences in sediment quality between the different waterways
2. Cadiangullong Creek sites only, to identify site differences within Cadiangullong Creek

For the PCA ordination of all monitoring sites, the two principal components accounted for over 51% of the variation in sediment metal concentrations (Figure 5). The most noticeable pattern is that the Flyers Creek site FC1 is clearly separated from all other sites in autumn (to the bottom of the ordination along PC2). The vectors on the PCA ordination and the metals with the highest loadings on PC2 (see Table 9) suggest this was due to a combination of relatively higher concentrations of selenium, mercury, manganese and barium. Contrasting this with the raw sediment data in Table 8 indicates that selenium and mercury were slightly higher than all other sites as FC1 was the only site where these metals were not below LOR. However, there were only minor increases in selenium and mercury at FC1 during autumn, so these do not represent major differences between the waterways. Likewise, barium was not noticeably higher at FC1 than many other sites. Manganese was clearly elevated at FC1 although the reason for this is not clear, especially given 1) FC2, that is upstream of FC1, did not have elevated manganese and 2) the increase at FC1 was not observed in spring.

The PCA ordination of all monitoring sites also indicates that both Flyers Creek reference sites (FC2 and FC1) and Cadiangullong Creek within the mine (CC2) are more separated from other sites in both seasons (to the right-hand side of the ordination along PC1) (Figure 5). The vectors on the PCA ordination and the metals with the highest loadings on PC1 (see Table 9) suggest this was due to a combination of relatively higher concentrations of nickel, zinc, cobalt, iron, aluminium and copper. Alternatively, Rodd’s Creek downstream of the tailings dam (RC1) and the reference sites on Panuara Rivulet (PR1 and PR2) were more towards the right-hand side of the ordination with relatively lower concentrations of these metals (Figure 5).

For the PCA ordination of the Cadiangullong Creek sites, the two principal components accounted for over 64% of the variation in sediment metal concentrations (Figure 6). The main aim of this PCA is to examine patterns in sediment quality amongst sites within Cadiangullong Creek. The site within the mine (CC2) is towards the top left-hand side in both seasons and the vectors on the PCA ordination and the metals with the highest loadings on PC1 and PC2 (see Table 9) suggest this was due to a combination of relatively higher concentrations of several metals including cobalt, lead, arsenic, molybdenum, copper, manganese, zinc, barium and aluminium. Alternatively, sites upstream of the mine (CC5 and CC1) had lower concentrations of these metals while CC3 and CC4 were intermediate between the upstream and downstream sites. Other patterns on this PCA includes the separation of CC3 from all other sites during autumn (towards the bottom left-hand side). This was predominantly due to increases in chromium, arsenic and iron. CC5 was also separated from all other sites in autumn (towards the top right-hand side) due to higher concentrations of beryllium and barium.

Table 8 Comparisons of total metals (mg/kg) against the ANZG (2018) DGVs for sediment. Orange values exceeded the DGV and red the upper DGV

Site	Season	Aluminium	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Zinc
DGVs		NA	2	20	NA	NA	1.5	80	NA	65	NA	50	NA	0.15	NA	21	NA	1	200
Upper DGVs		NA	25	70	NA	NA	10	370	NA	270	NA	220	NA	1	NA	52	NA	4	410
CC5	Spring	9790	<5	8	80	2	<1	35	14	19	46000	8	664	<0.1	<2	11	<5	<2	84
CC5	Autumn	19500	<5	6	160	5	<1	28	16	33	40300	8	1900	<0.1	<2	15	<5	<2	136
CC1	Spring	15000	<5	7	100	2	<1	40	14	30	44700	11	581	<0.1	<2	13	<5	<2	77
CC1	Autumn	10500	<5	15	70	<1	<1	46	36	94	27900	8	691	<0.1	<2	24	<5	<2	65
CC2	Spring	18300	<5	14	130	<1	<1	32	58	966	47500	15	2720	<0.1	4	19	<5	<2	134
CC2	Autumn	23000	<5	13	100	<1	<1	40	30	783	48400	13	884	<0.1	6	19	<5	<2	119
CC3	Spring	10400	<5	13	50	<1	<1	37	18	474	44400	10	400	<0.1	4	14	<5	<2	77
CC3	Autumn	12000	<5	21	60	<1	<1	70	21	474	90800	10	372	<0.1	4	17	<5	<2	76
CC4	Spring	17500	<5	11	140	1	<1	34	20	133	42300	9	1540	<0.1	<2	17	<5	<2	70
CC4	Autumn	30700	<5	14	180	<1	<1	43	20	214	63500	9	810	<0.1	<2	26	<5	<2	113
DG1	Spring	10900	<5	40	60	<1	<1	17	5	41	26600	27	154	<0.1	2	8	<5	<2	81
DG1	Autumn	11800	<5	68	120	<1	<1	17	11	51	36400	22	932	<0.1	<2	13	<5	<2	149
FC2	Spring	18400	<5	26	130	<1	<1	93	36	80	63900	28	1620	<0.1	<2	33	<5	<2	158
FC2	Autumn	19600	<5	24	130	<1	<1	80	29	83	57400	23	1520	<0.1	<2	26	<5	<2	151
FC1	Spring	11300	<5	45	70	1	<1	103	26	67	63700	16	1110	<0.1	<2	28	<5	<2	103
FC1	Autumn	16200	<5	20	190	<1	<1	42	22	43	41200	13	6140	0.1	<2	17	8	<2	76
PR1	Spring	10900	<5	6	110	<1	<1	15	8	21	19400	13	634	<0.1	<2	10	<5	<2	42
PR1	Autumn	16300	<5	10	190	<1	<1	26	11	29	30600	17	600	<0.1	<2	14	<5	<2	72
PR2	Spring	8910	<5	7	100	<1	<1	18	10	21	20600	14	422	<0.1	<2	13	<5	<2	47
PR2	Autumn	8400	<5	8	80	<1	<1	18	9	14	26600	10	530	<0.1	<2	11	<5	<2	53
RC1	Spring	8401	<6	8	80	<1	<1	18	9	14	26600	10	530	<0.2	<3	12	<5	<2	54
RC1	Autumn	13800	<5	<5	90	<1	<1	17	9	41	21800	<5	1320	<0.1	<2	8	<5	<2	50
SC1	Spring	14700	<5	20	80	<1	<1	31	10	68	31600	10	401	<0.1	<2	13	<5	<2	72
SC1	Autumn	18100	<5	26	180	<1	<1	34	20	67	34600	11	1610	<0.1	<2	16	<5	<2	70

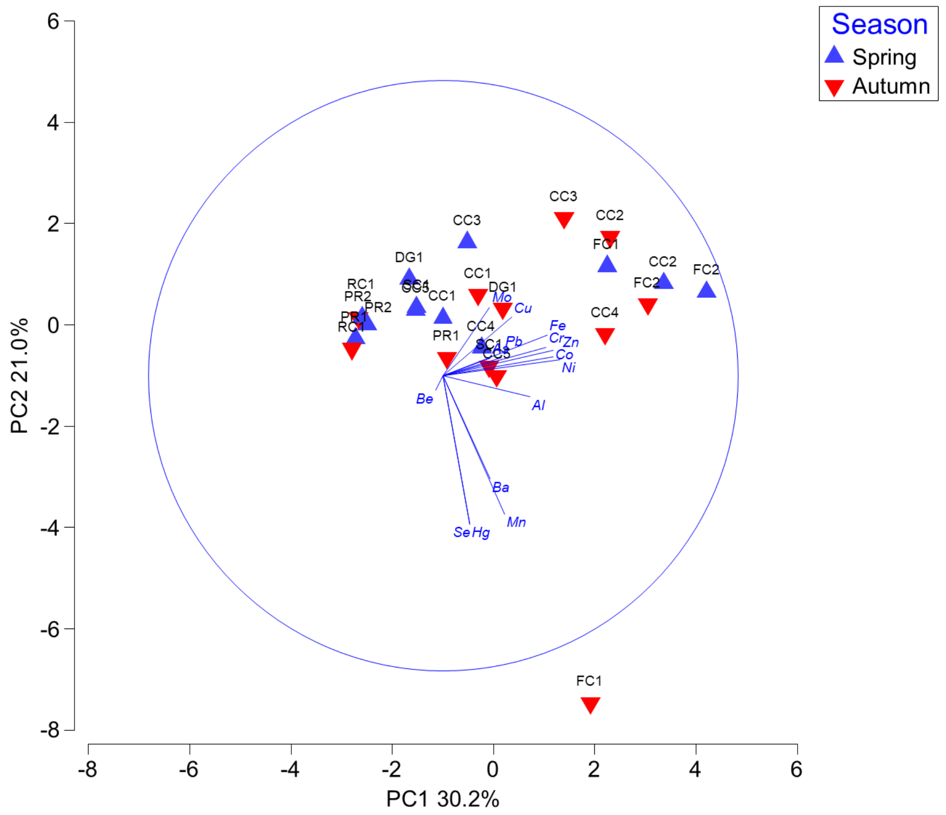

Figure 5 *PCA ordination showing relationship between sediment concentrations and monitoring sites for all sites*

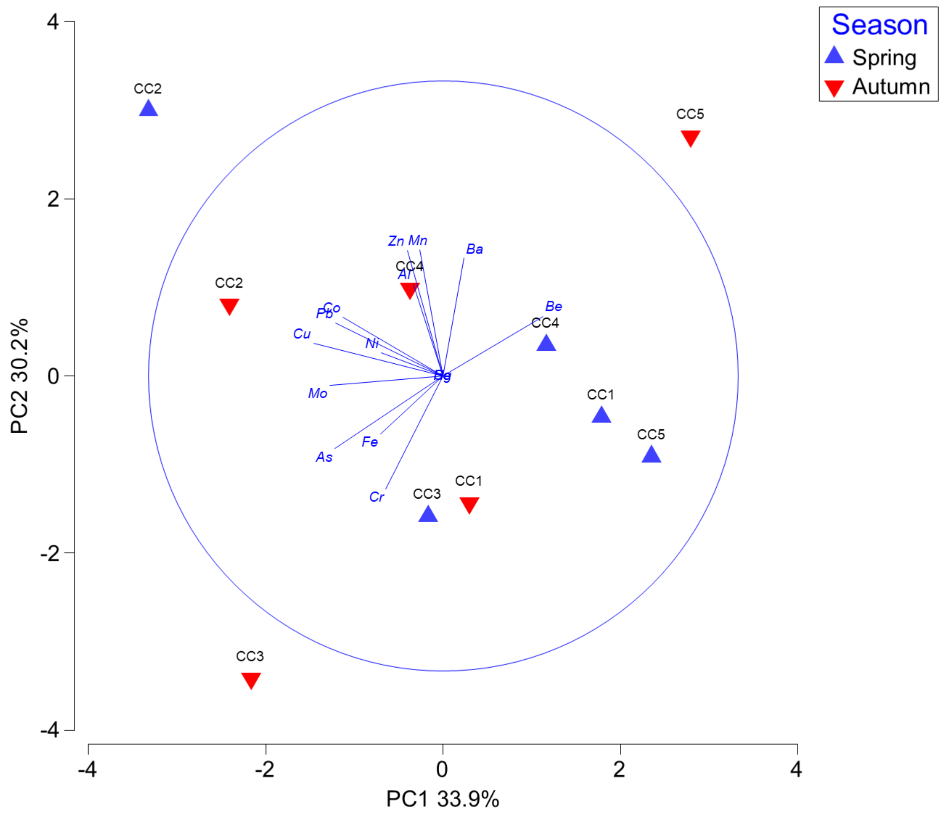

Figure 6 *PCA ordination showing the relationship between sediment concentrations and monitoring sites for Cadiangullong Creek only*

Table 9 Coefficients in the linear combinations of variables making up the principal components

Variable	PC1	PC2	PC1	PC2
	All sites		Cadiangullong Creek sites	
Aluminium	0.294	-0.071	-0.102	0.313
Arsenic	0.160	0.058	-0.368	-0.246
Barium	0.160	-0.348	0.071	0.400
Beryllium	-0.024	-0.050	0.340	0.202
Chromium	0.350	0.097	-0.194	-0.383
Cobalt	0.373	0.063	-0.339	0.199
Copper	0.233	0.199	-0.438	0.110
Iron	0.355	0.137	-0.212	-0.196
Lead	0.198	0.062	-0.364	0.180
Manganese	0.208	-0.469	-0.079	0.429
Mercury	0.090	-0.504	0.000	0.000
Molybdenum	0.158	0.232	-0.385	-0.031
Nickel	0.395	0.054	-0.208	0.078
Selenium	0.090	-0.504	0.000	0.000
Zinc	0.374	0.085	-0.121	0.424

3.5 Macroinvertebrates

A summary of the macroinvertebrate biological indices is presented in Table 10. AUSRIVAS results are coloured according to the Banding scheme presented in Table 4. Combined season AUSRIVAS model bands are included in the final column of Table 10.

3.5.1 Taxonomic richness and EPT

In Cadiangullong Creek, taxa richness in spring 2021 was generally lower in at the downstream sites compared with the upstream sites in both the edge and riffle habitats (Figure 7). In autumn 2022 the pattern was reversed; the downstream sites generally had higher taxa richness than the upstream sites in both the edge and riffle habitats. Taxonomic richness of Cadiangullong Creek, and downstream of the tailings dam on Rodd's Creek (RC1), was similar to that observed at the reference sites in Flyers Creek, Panuara Rivulet and Swallow Creek. The exception to this was riffle habitat in spring 2021, where taxa richness at the Cadiangullong Creek sites was higher than the reference sites.

EPT richness varied between sites on Cadiangullong Creek. There was no consistent pattern to suggest sites downstream of CVO had lower EPT richness than sites upstream. For example, in spring 2021 EPT richness was higher at upstream site CC5 and downstream site CC3 but lower at upstream site CC1 and mine site CC2. In autumn 2022, EPT was slightly higher at the downstream sites. EPT was similar for riffle habitat upstream and downstream in both spring and autumn. The EPT richness of Cadiangullong Creek, and downstream of the tailings dam on Rodd's Creek (RC1), was similar to that observed at the reference sites.

3.5.2 AUSRIVAS

There was no clear pattern indicating AUSRIVAS scores were lower at the downstream sites on Cadiangullong Creek compared with the upstream sites. For single season edge habitats, the upstream site CC5 was classified as Band A in spring, suggesting it was similar to reference conditions (Table 10). In autumn it was classified as Band B, indicating fewer families than expected due to potential impacts from water quality and/or habitat quality. Edge habitat at the other upstream site, CC1, was categorised as Band B in spring and 'outside the experience of the model' in autumn. AUSRIVAS scores at the downstream sites were more variable than the upstream sites but did not suggest poorer environmental condition than the upstream sites. A greater proportion of sites were classified as Band A, although one site (CC4 edge habitat in spring 2021) was classified as Band C, which suggests a loss of families due to moderate to severe impacts on water and/or habitat quality. Riffle habitat at site CC2, located onsite at CVO, was also classified as Band C in spring 2021.

There was also substantial variation in the AUSRIVAS Bands between the reference sites on Flyers Creek, Panuara Rivulet and Swallow Creek. The majority of sites were classified as Band B in both seasons for both edge and riffle habitat. An exception was edge habitat at site FC1 on Flyers Creek, which scored Band A in autumn and Band X in spring, with more families found than expected which potentially represents a biodiversity 'hot spot' due mild organic enrichment. In contrast, riffle habitat at FC1 was categorised as Band B in spring and Band C in autumn. The results at CVO and the downstream sites on Cadiangullong Creek (CC2, CC3 and CC4) do not suggest impairment compared to other sites.

3.5.3 SIGNAL-2

In spring 2021, SIGNAL-2 scores were higher at the downstream sites (CC3 and CC4) compared to the upstream sites (CC5 and CC1) in both edge and riffle habitat. In autumn 2022, SIGNAL-2 scores were slightly higher at the downstream sites for both edge and riffle habitat (although riffle habitat was not available at upstream site CC5 in either season). Site CC2, located onsite at CVO had SIGNAL-2 scores that were either similar to or higher than the upstream sites. The scores for both upstream and downstream sites along the Cadiangullong Creek were roughly equal to the reference sites and SIGNAL-2 scores were marginally higher in spring than in autumn.

For edge habitat, the sites were spread across quadrant 2, quadrant 3 and quadrant 4 of the SIGNAL-2 family bi-plot (Figure 8). The spread of samples varied between the seasons (Figure 9, Figure 10); In spring, the downstream scores were mostly within quadrant 2 and quadrant 4, whereas in autumn scores were mostly in quadrant 2. Results in quadrant 2 may indicate high salinity or nutrient levels (which may be natural), while results in quadrant 4 may indicate industrial or agricultural pollution or the downstream impacts of dams (Chessman, 2001). One downstream site scored within quadrant 3, which may indicate toxic pollution, harsh physical conditions or inadequate sampling. In spring, scores of the upstream sites mainly located in quadrant 2, while downstream sites were located in quadrants 3 and 4. There was no clear pattern in the autumn results.

The SIGNAL-2 scores for riffle habitat were within quadrant 2 and quadrant 4 and the spread of samples across the two quadrants was not season specific (Figure 11). There was no obvious difference in the distribution between the upstream and downstream sites.

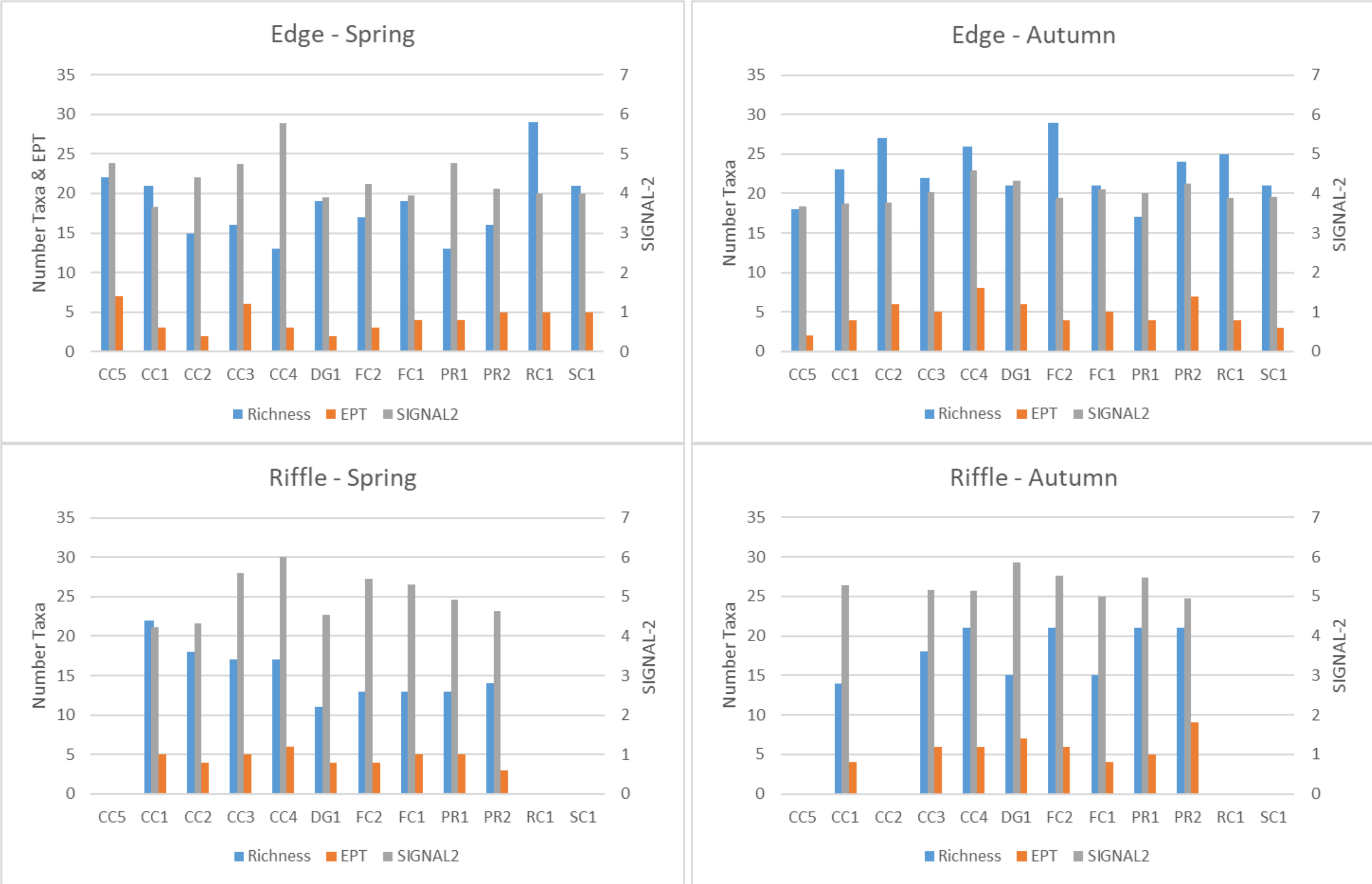

Figure 7 ***Taxa richness, EPT richness and SIGNAL-2 scores during spring 2021 and autumn 2022 for each site***

Table 10 Summary of macroinvertebrate biological indices

Site	Habitat	Season	Taxa Richness	EPT richness	SIGNAL-2 score	AUSRIVAS		
						OE50	Band	Combined Season Band
CC5	Edge	Spring	22	7	4.8	1.13	A	A
		Autumn	18	2	3.7	0.71	B	
	Riffle	Spring	No samples					NA
		Autumn						
CC1	Edge	Spring	21	3	3.7	0.56	B	A
		Autumn	23	4	3.7	OEX	OEX	
	Riffle	Spring	22	5	4.2	0.62	B	B
		Autumn	14	4	5.3	0.81	B	
CC2	Edge	Spring	15	2	4.4	0.85	A	B
		Autumn	27	6	3.8	1.01	A	
	Riffle	Spring	18	4	4.3	0.39	C	NA
		Autumn	No samples					
CC3	Edge	Spring	16	6	4.8	1.02	A	A
		Autumn	22	5	4.0	0.79	B	
	Riffle	Spring	17	5	5.6	0.85	A	A
		Autumn	18	6	5.2	0.90	A	
CC4	Edge	Spring	13	3	5.8	0.36	C	A
		Autumn	26	8	4.6	1.05	A	
	Riffle	Spring	17	6	6.0	0.97	A	A
		Autumn	21	6	5.1	0.82	B	
DG1	Edge	Spring	19	2	3.9	0.91	A	OEX
		Autumn	21	6	4.3	0.81	B	
	Riffle	Spring	11	4	4.5	OEX	OEX	OEX
		Autumn	15	7	5.9	OEX	OEX	

Site	Habitat	Season	Taxa Richness	EPT richness	SIGNAL-2 score	AUSRIVAS		
						OE50	Band	Combined Season Band
FC2	Edge	Spring	17	3	4.2	OEX	OEX	X
		Autumn	29	4	3.9	0.97	A	
	Riffle	Spring	13	4	5.5	0.72	B	B
		Autumn	21	6	5.5	0.75	B	
FC1	Edge	Spring	19	4	3.9	1.18	X	A
		Autumn	21	5	4.1	0.87	A	
	Riffle	Spring	13	5	5.3	0.77	B	B
		Autumn	15	4	5.0	0.45	C	
PR1	Edge	Spring	13	4	4.8	0.55	B	B
		Autumn	17	4	4.0	0.69	B	
	Riffle	Spring	13	5	4.9	0.70	B	B
		Autumn	21	5	5.5	0.82	B	
PR2	Edge	Spring	16	5	4.1	0.82	B	A
		Autumn	24	7	4.3	0.87	A	
	Riffle	Spring	14	3	4.6	0.70	B	B
		Autumn	21	9	5.0	0.82	B	
RC1	Edge	Spring	29	5	4.0	OEX	OEX	OEX
		Autumn	25	4	3.9	OEX	OEX	
	Riffle	Spring	No samples					NA
		Autumn						
SC1	Edge	Spring	21	5	4.0	0.82	B	A
		Autumn	21	3	3.9	0.61	B	
	Riffle	Spring	No samples					NA
		Autumn						

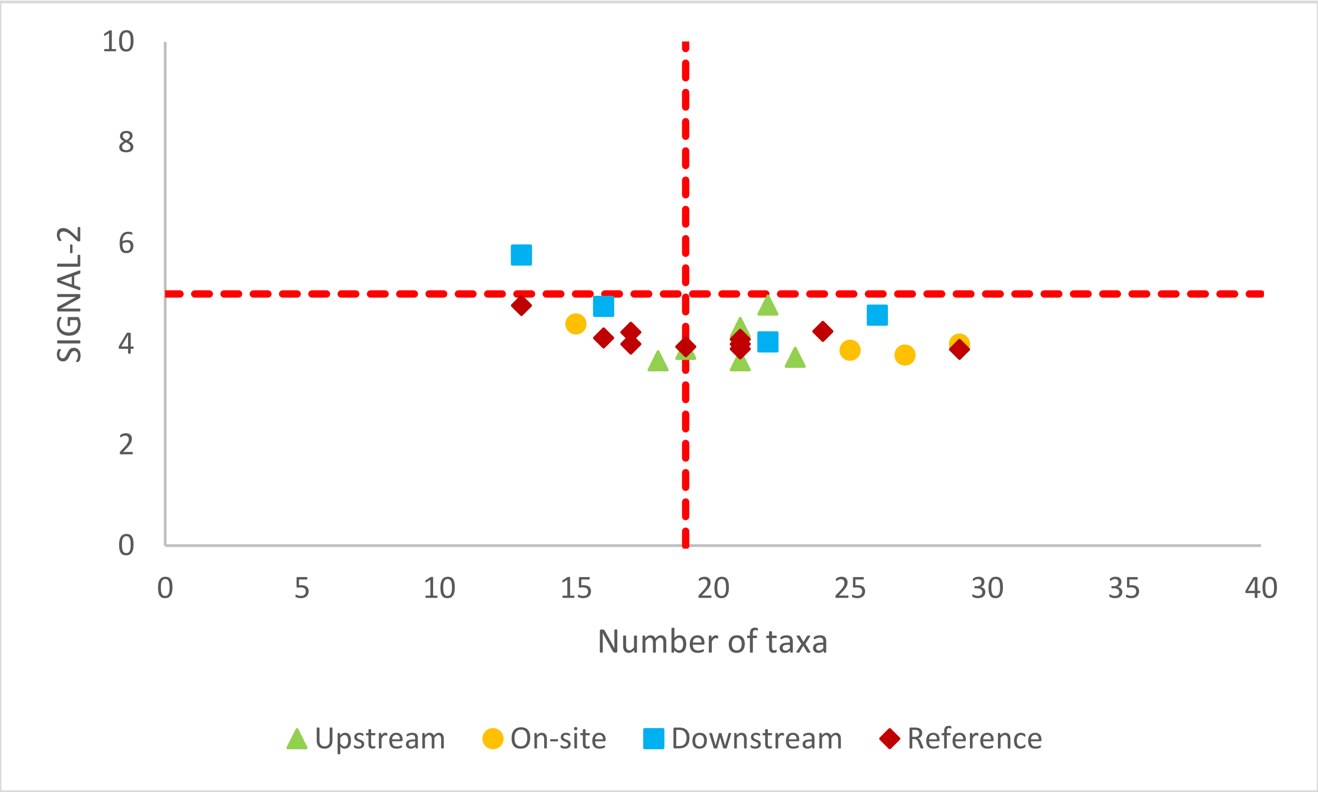

Figure 8 ***SIGNAL-2 bi-plot for spring and autumn edge samples (red lines indicate the NSW interim SIGNAL-2 quadrant boundaries)***

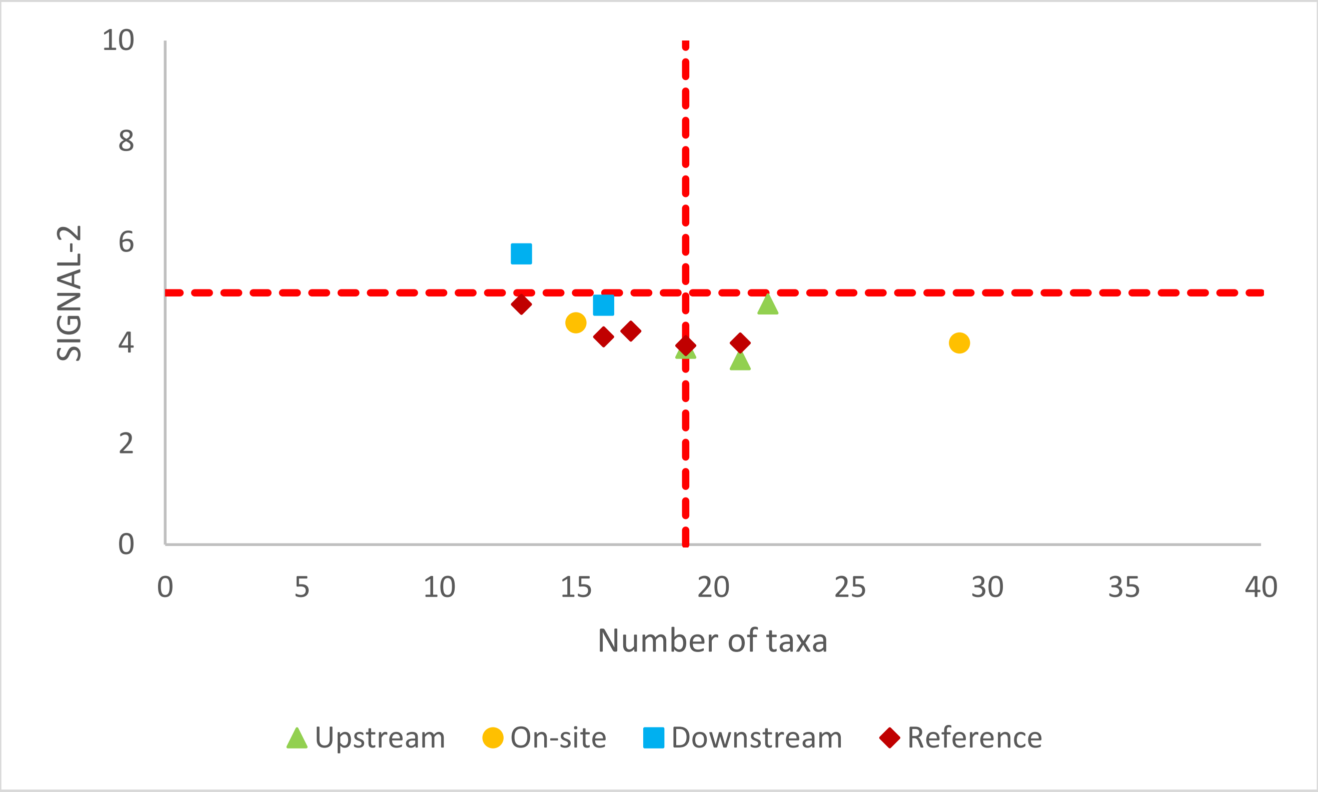

Figure 9 ***SIGNAL-2 bi-plot for spring edge samples (red lines indicate the NSW interim SIGNAL-2 quadrant boundaries)***

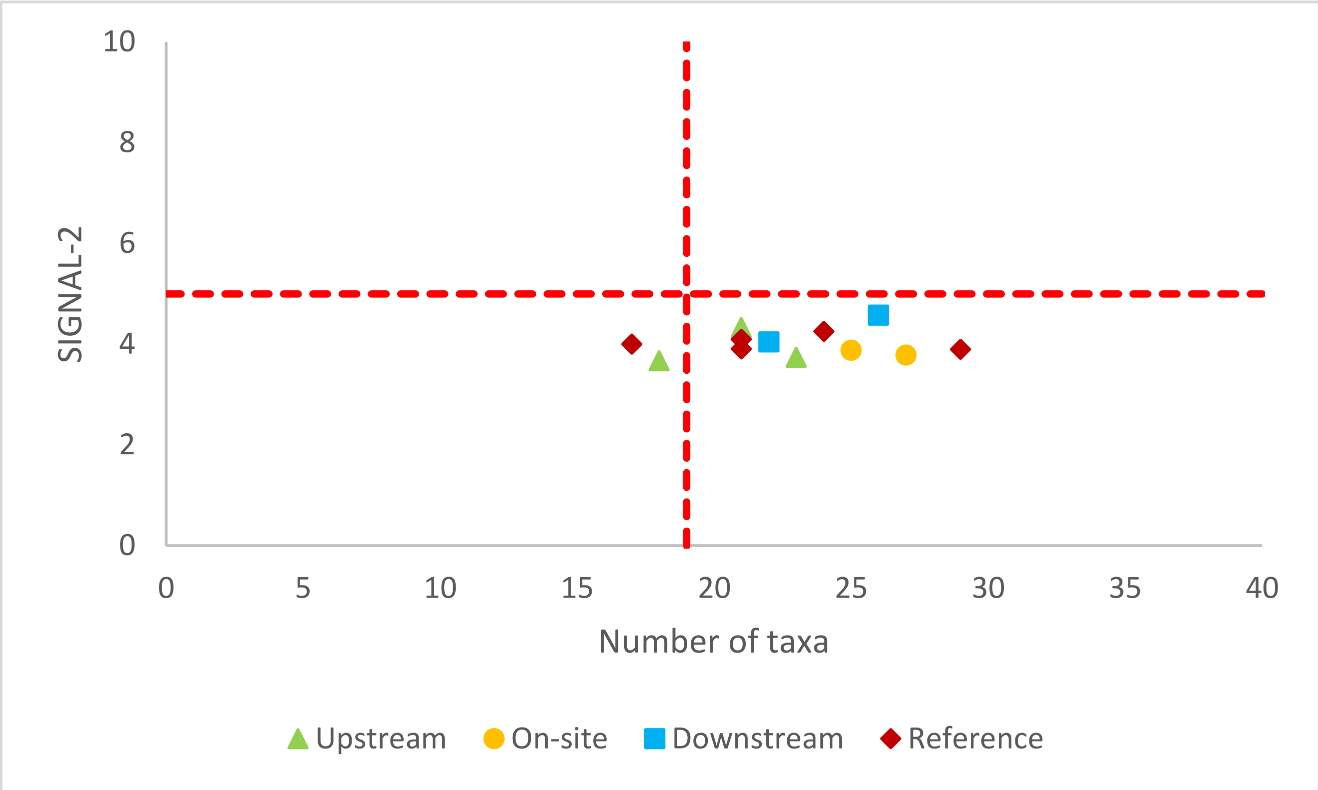

Figure 10 ***SIGNAL-2 bi-plot for autumn edge samples (red lines indicate the NSW interim SIGNAL-2 quadrant boundaries)***

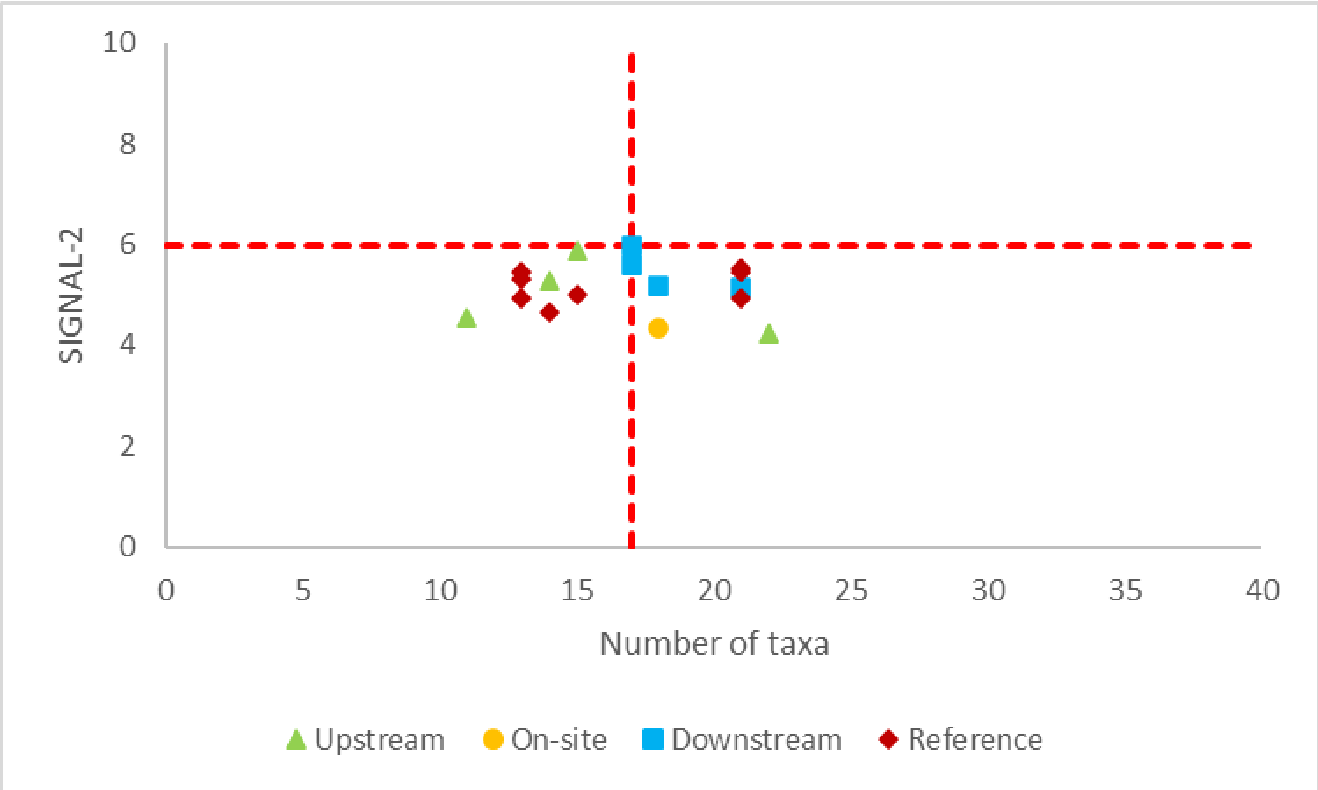

Figure 11 ***SIGNAL-2 bi-plot for spring and autumn riffle samples (red lines indicate the NSW interim SIGNAL-2 quadrant boundaries)***

3.5.4 Multivariate analyses

Riffle habitats

The nMDS (non-metric multidimensional scaling) ordination of spring riffle habitats suggested the downstream sites on Cadiangullong Creek (CC3 and CC4) were more similar to the reference sites on Flyers Creek and the Panuara Rivulet, than the upstream sites (Figure 12). The upstream site CC1 was most similar to CC2, located onsite. The Diggers Creek site (DG1) had a distinct macroinvertebrate community and was not grouped with any other sites. The Analysis of Similarities (ANOSIM) detected a significant difference amongst treatments (R = 0.661; P = 0.003), although pairwise comparison did not detect any differences amongst the site treatments (P > 0.05).

A similar pattern found for the autumn riffle habitats; the downstream sites on Cadiangullong Creek (CC3 and CC4) were more similar to the reference sites on Panuara Rivulet (PR1 and PR2) and one of the Flyer’s Creek sites (FC2) (Figure 13). The upstream site CC1 was separated from the downstream sites. Despite the patterns, there were no significant differences in the riffle macroinvertebrate communities associated with the different treatment types detected by the ANOSIM in autumn (R = 0.238; P = 0.205).

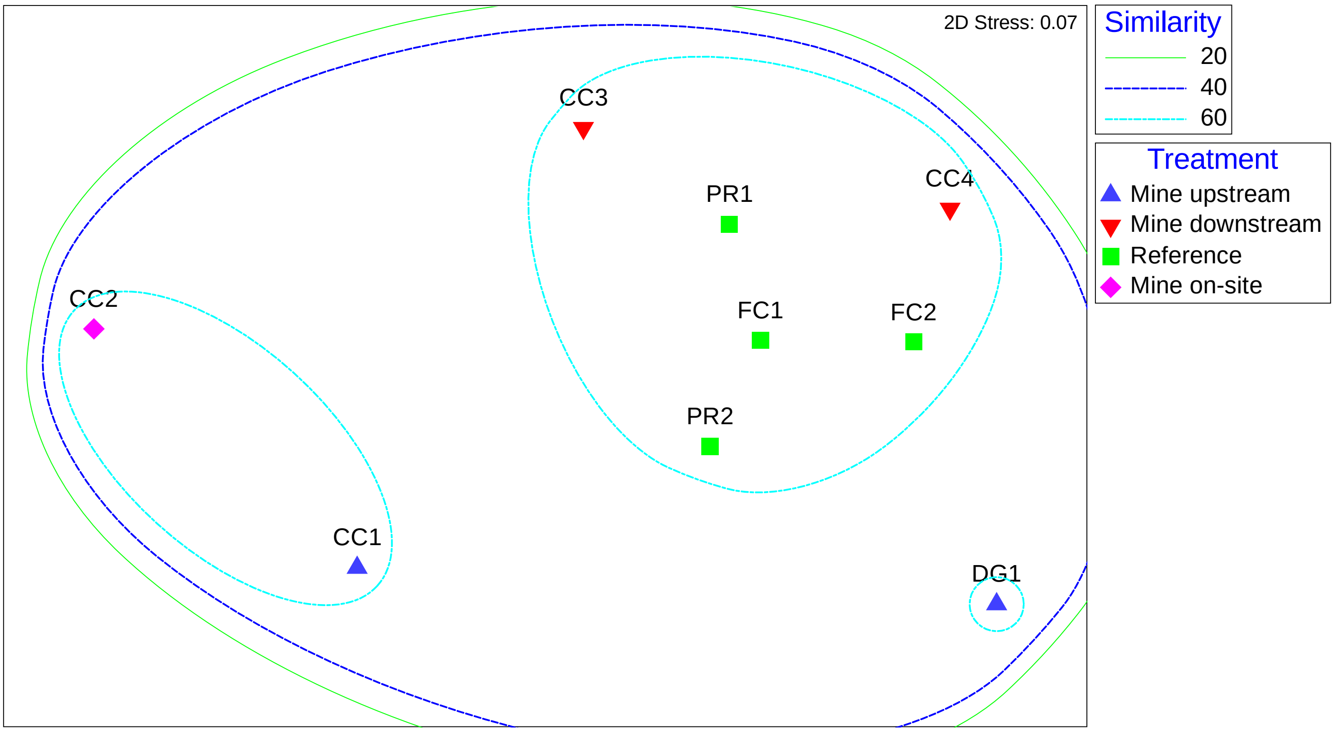

Figure 12 ***nMDS analysis of spring riffle data displaying influence of site treatment on the similarities of macroinvertebrate communities***

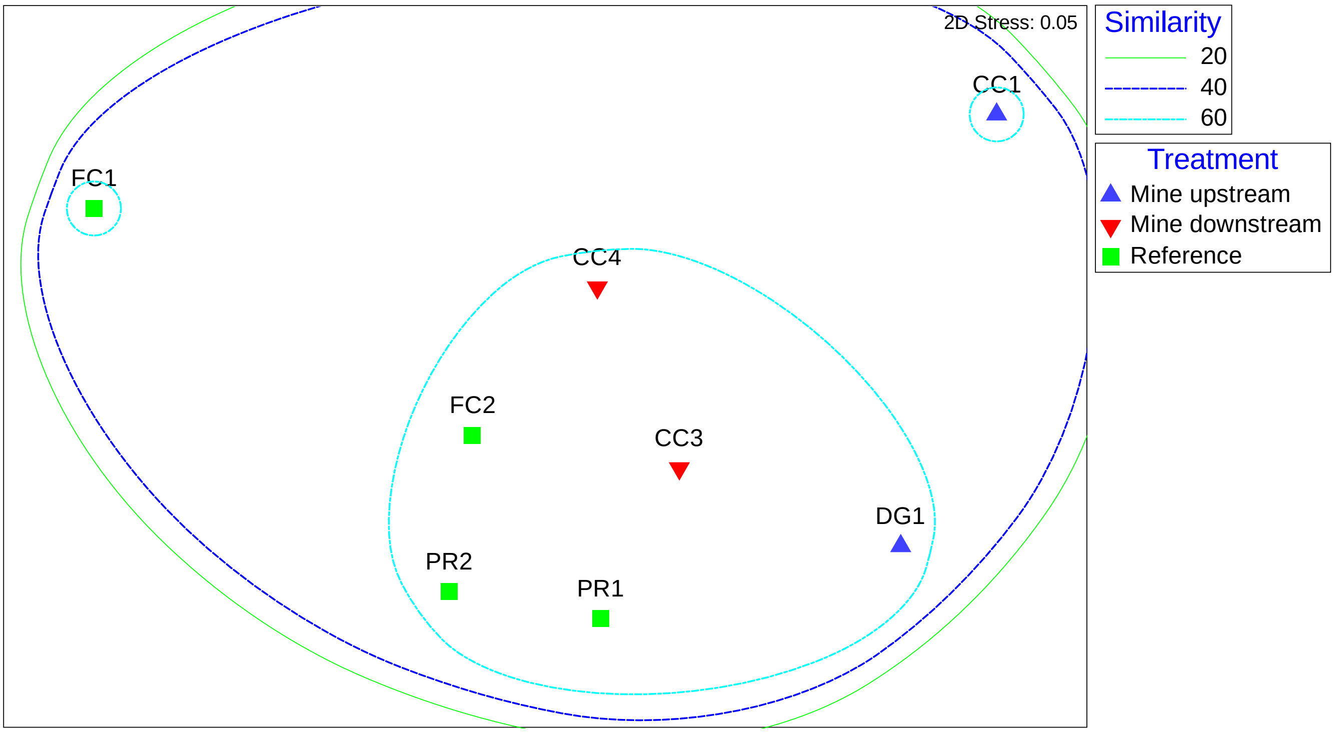

Figure 13 ***nMDS analysis of autumn riffle data displaying influence of site treatment on the similarities of macroinvertebrate communities***

Edge habitats

The nMDS ordination for spring edge habitats did not find clear patterns that divided the upstream, downstream, on-site and reference sites (Figure 14); upstream site CC5 was most similar to downstream site CC4 and one of the Panuara Rivulet reference sites. The other upstream sites, DG1 and CC1, were most similar to on-site location RC1 and the reference sites, PR2 and SC1. The downstream site CC3 and on-site location CC2 were separated from the other sites. The two Flyers Creek reference sites (FC1 and FC2) were separated from the other sites.

For autumn edge habitat, the nMDS ordination also did not show distinct patterns between the upstream, downstream, on-site and reference sites (Figure 15).

Overall, there were no significant differences in the macroinvertebrate communities associated with the different treatment types detected by the ANOSIMs in edge habitat for both spring (R = 0.034; *P* = 0.403) or autumn (R = -0.221; *P* = 0.911).

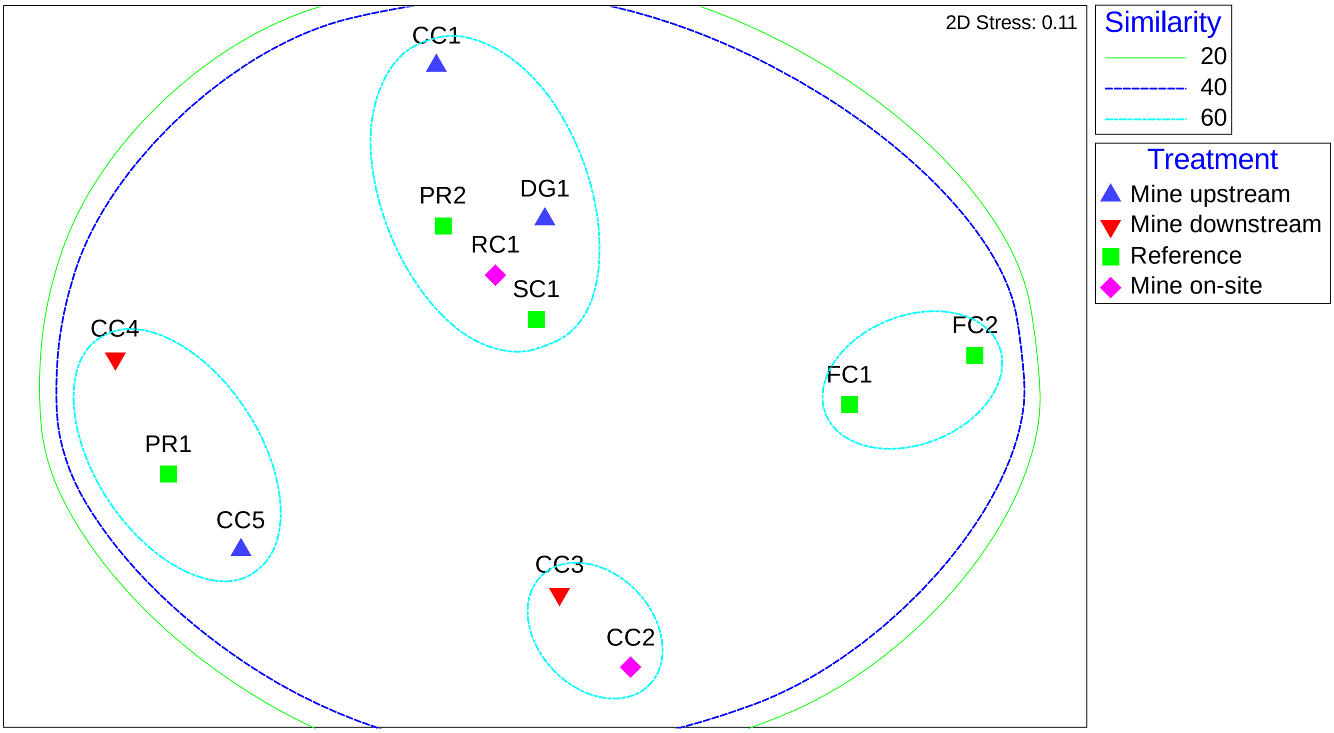

Figure 14 ***nMDS analysis of spring edge data displaying influence of site treatment on the similarities of macroinvertebrate communities***

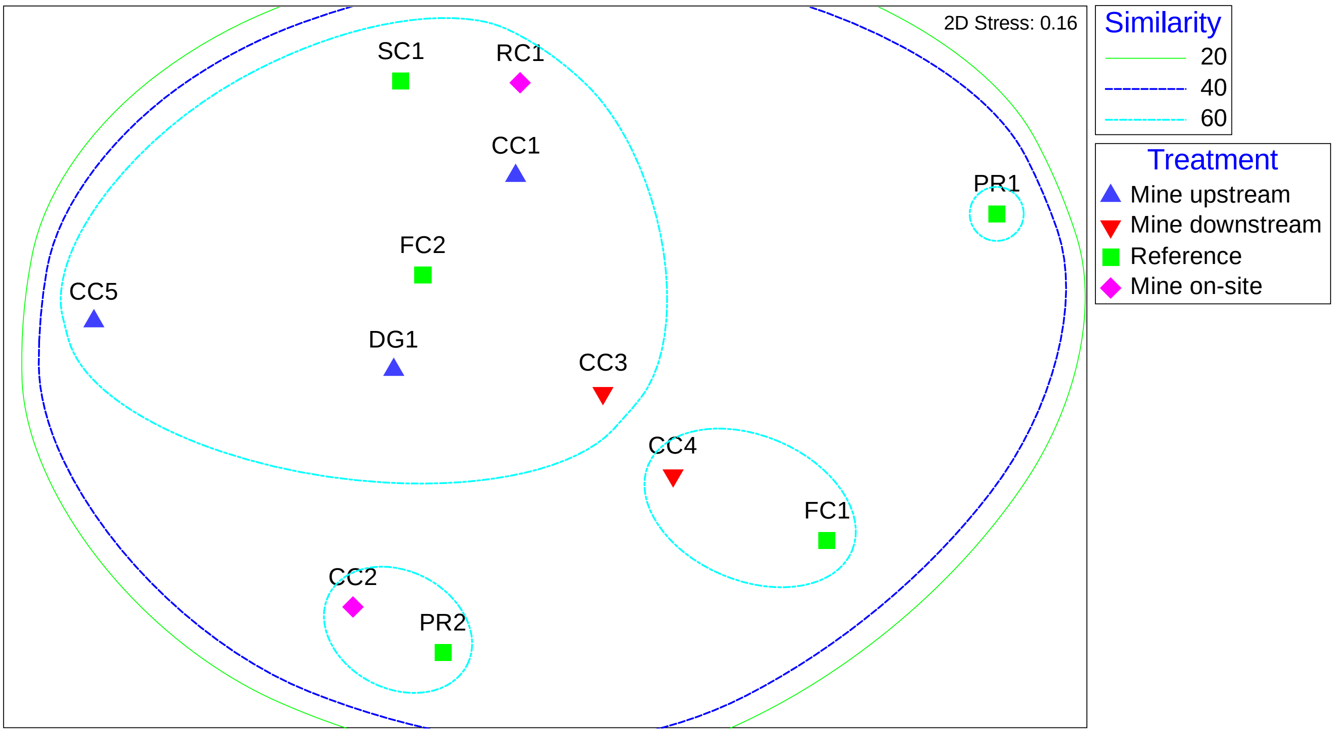

Figure 15 ***nMDS analysis of autumn edge data displaying influence of site treatment on the similarities of macroinvertebrate communities***

3.6 Sediment/macroinvertebrate relationship

The RELATE procedure determined that there was no significant correlation between patterns in the sediment quality and macroinvertebrate communities for edge samples in autumn (Rho 0.021, *P* = 0.465) or riffle samples in either spring (Rho 0.129, *P* = 0.274) or autumn (Rho 0.018, *P* = 0.465). For edge samples, in spring a significant correlation was found (Rho 0.419, *P* = 0.007). The combined season analyses determined that there was close to a significant correlation for both edge samples (Rho 0.202, *P* = 0.077) and riffle samples (Rho 0.310, *P* = 0.108). Overall, the RELATE analyses suggests that sediment quality is not a consistent driver of macroinvertebrate community composition although there was some degree of correlation with sediment quality for edge samples in spring, and the combined seasons edge and riffle samples.

Based on the RELATE analyses, the BEST analyses were undertaken for edge habitats in spring and both edge and riffle samples in the combined seasons. The BEST analyses determined there was some degree of correlation between several sediment metal concentrations and the macroinvertebrate community composition, and that these correlations were significant Table 11.

Table 11 BEST results of associations between macroinvertebrate communities and sediment quality. Bold text indicates a significant correlation

Model	BEST Variables	Correlation	BEST *P*
Spring - Edge	Arsenic, Beryllium, Molybdenum, Nickel, Zinc	0.567	**0.050**
Combined seasons - Edge	Beryllium, Chromium, Iron, Manganese, Molybdenum	0.337	**0.033**
Combined seasons - Riffle	Arsenic, Beryllium, Cobalt, Copper, Manganese	0.859	**0.002**

Those metals that showed significant correlation with the macroinvertebrate community composition (BEST results in Table 11) were subsequently included in the DISTLM analyses (Table 12). The DISTLM results indicate that of the sediment analytes that best correlated to the macroinvertebrate communities from edge habitats in spring, arsenic, nickel and zinc significantly correlated and explained 65% of the variation in the communities. The nMDS ordination plot incorporating the DISTLM results suggest the high concentrations of these analytes may have contributed to the distinct macroinvertebrate community amongst sites, particularly Flyers Creek (Figure 16).

Table 12 DISTLM results of associations between macroinvertebrate communities and sediment quality. Significant results at the P = 0.050 level in red

Model	Variables	DISTLM *P*	Variation explained (%)
Spring edge	Arsenic	0.047	16
	Beryllium	0.435	9
	Molybdenum	0.116	14
	Nickel	0.004	26
	Zinc	0.006	23
Combined seasons edge	Beryllium	0.365	10
	Chromium	0.002	20
	Iron	0.009	19
	Manganese	0.180	12
	Molybdenum	0.094	14
Combined seasons riffle	Arsenic	0.438	11
	Beryllium	0.415	10
	Cobalt	0.057	31
	Copper	0.033	39
	Manganese	0.202	17

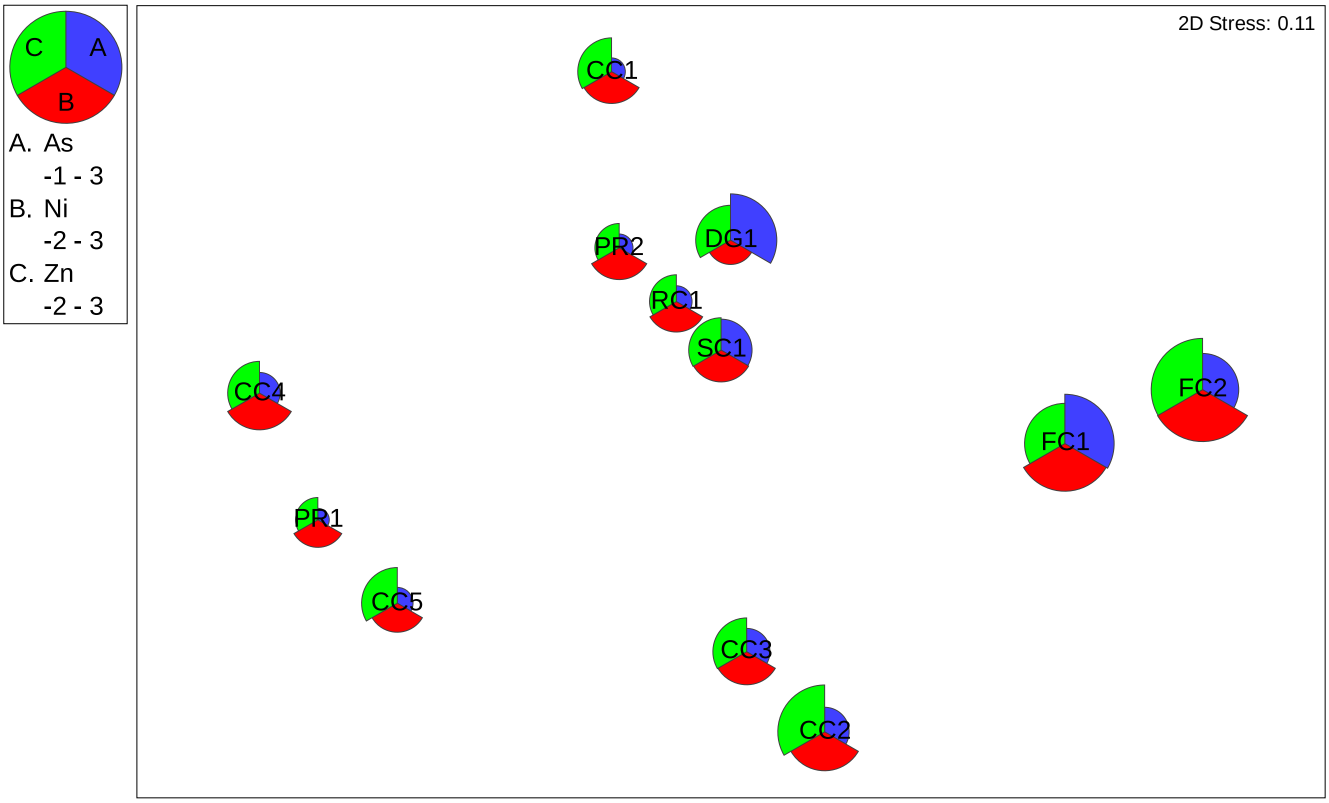

Figure 16 ***nMDS ordination indicating association between sediment analytes and macroinvertebrates from edge habitats across all sites in spring. Bubble plots showing relative concentration of sediment analytes***

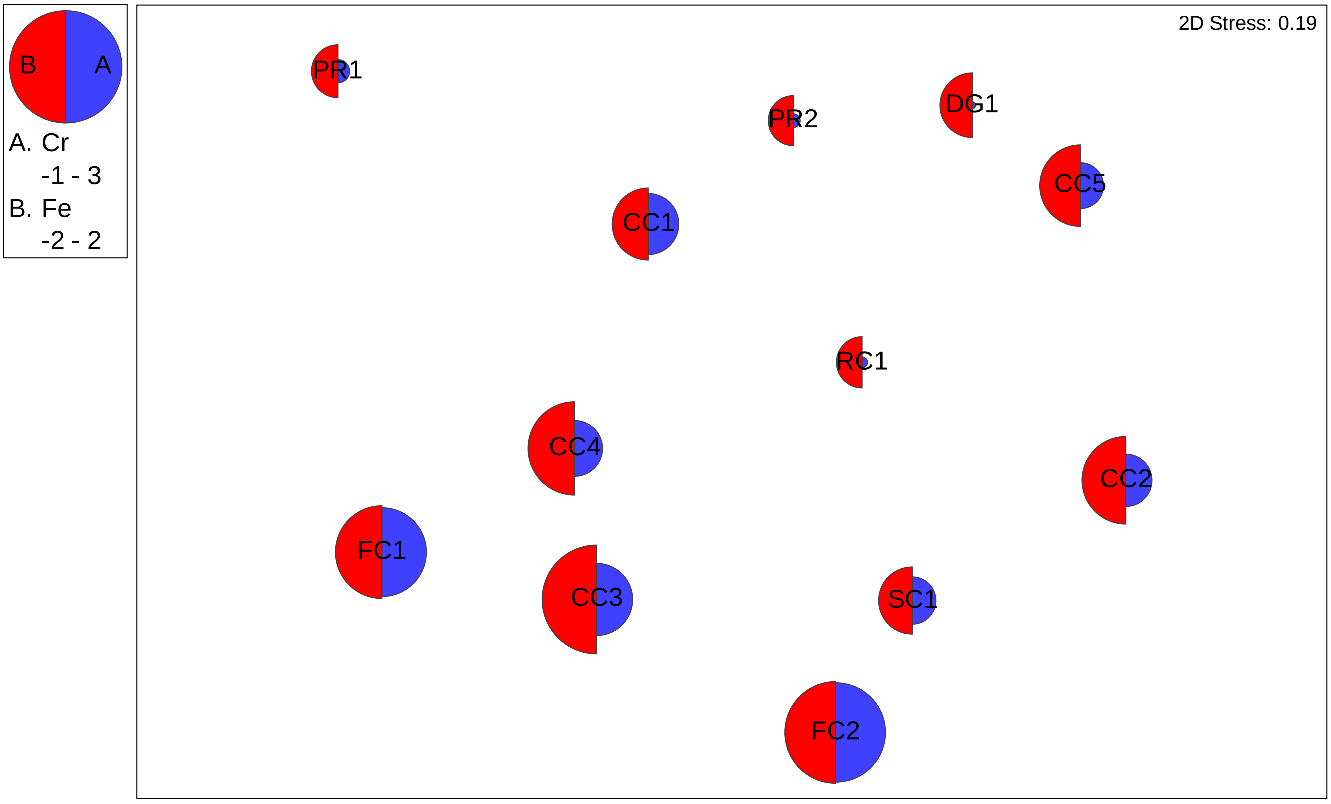

Figure 17 ***nMDS ordination indicating association between sediment analytes and macroinvertebrates from edge habitats across all sites and combined seasons. Bubble plots showing relative concentration of sediment analytes***

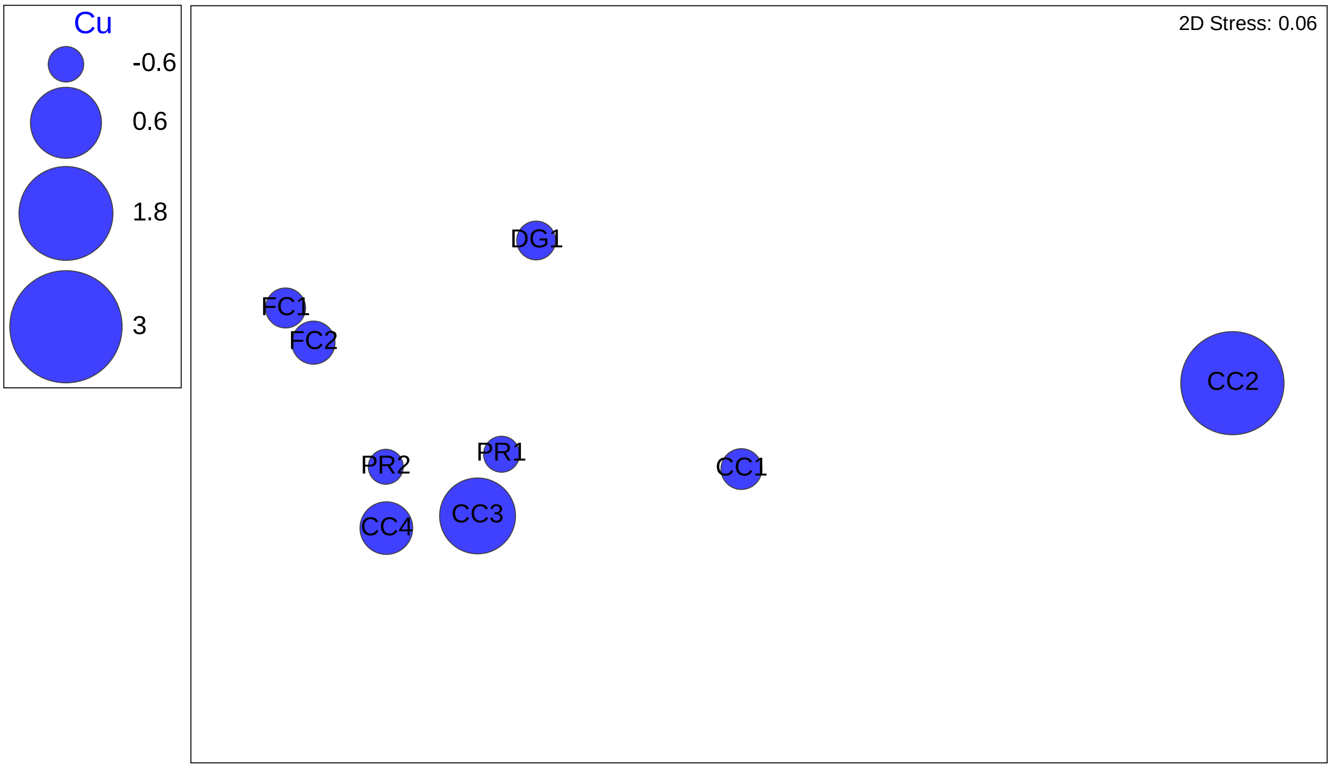

Figure 18 ***nMDS ordination indicating association between sediment analytes and macroinvertebrates from riffle habitats across all sites and combined seasons. Bubble plots showing relative concentration of copper***

3.7 Fish

Four species of fish were collected during the two monitoring seasons and included the native Mountain Galaxias (*Galaxias olidus*) and the non-native Redfin Perch (*Perca fluviatilus*), Rainbow Trout (*Oncorhynchus mykiss*) and Eastern Gambusia (*Gambusia holbrooki*). Mountain Galaxias (Plate 6) was by far the numerically dominant species, followed by Redfin perch. Only a single Rainbow Trout and Eastern Gambusia were collected across the two seasons. In both seasons, Mountain Galaxias were collected from all sites on Cadiangullong Creek except for CC5 during autumn. No fish were observed or collected from Panuara Rivulet in either season.

Table 13 Total fish catch during the CVO AEMP

Site	Season	Mountain Galaxias	Redfin Perch	Rainbow Trout	Eastern Gambusia
CC5	Spring	1	3	1	
CC5	Autumn				
CC1	Spring	167			
CC1	Autumn	60	32		
CC2	Spring	56	1		
CC2	Autumn	37			
CC3	Spring	236			
CC3	Autumn	72			
CC4	Spring	70			
CC4	Autumn	89			
FC2	Spring	82			
FC2	Autumn	98			
FC1	Spring	68			
FC1	Autumn	106			
SC1	Spring	142			
SC1	Autumn	28			1

Of note was the increase in Redfin Perch at CC1 on Cadiangullong Creek during autumn, which included juveniles approximately 15 mm in length and more mature individuals >200 mm (Plate 6). This abundance of Redfin Perch has not been observed at this site in previous seasons. Summary statistics of Mountain Galaxias collected in spring and autumn are presented in Table 14.

Mountain Galaxias

Redfin Perch

Plate 6 Mountain Galaxias and Refin Perch collected from Cadiangullong Creek autumn 2022

Table 14 Total catch and summary statistics of total length (mm) of Mountain Galaxias (G. olidus) caught at each site per season

Site	Season	Count	Mean	Median	Min	Max	10th Percentile	90th Percentile	StdDev
CC5	Spring	1	89	89	89	89	89	89	NA
CC5	Autumn	0	NA	NA	NA	NA	NA	NA	NA
CC1	Spring	167	44	41	31	106	35	63	12
CC1	Autumn	60	84	86	42	120	51	110	22
CC2	Spring	56	37	33	22	67	28	53	11
CC2	Autumn	37	56	50	40	108	42	83	16
CC3	Spring	236	53	55	22	100	31	67	15
CC3	Autumn	72	65	62	42	108	44	92	19
CC4	Spring	70	58	63	21	90	36	75	16
CC4	Autumn	89	75	70	54	108	62	96	14
FC2	Spring	82	53	53	23	114	28	80	21
FC2	Autumn	98	56	53	36	92	45	68	11
FC1	Spring	68	52	43	21	105	29	82	21
FC1	Autumn	106	62	54	46	102	49	86	15
PR1	Spring	No fish collected							
PR1	Autumn								
PR2	Spring	No fish collected							
PR2	Autumn								
SC1	Spring	142	52	47	21	95	38	80	17
SC1	Autumn	28	64	60	42	92	45	87	17

Overall, a similar number of Mountain Galaxias were collected from the upstream sites (CC5 and CC1) the downstream sites (CC3, CC4) and the Flyers Creek (FC1, FC2) and Swallow Creek (SC1) reference sites. There was considerable variation between sites, with 277 Mountain Galaxias collected at CC1 and only one collected at CC5. The highest number collected was at downstream site CC3. It should be noted that no fish surveys are undertaken at Diggers Creek (DG1), the other upstream treatment site, or Rodd's Creek downstream of the tailings dam.

Histograms of total length of Mountain Galaxias indicates all site treatments have a wide distribution of lengths, indicating a combination of recent recruits and older fish (Figure 19). This suggests that sites across all treatments are maintaining self-sustaining populations with adequate recruitment levels.

The Gaussian kernel curves indicate that during spring, smaller Mountain Galaxias were collected. There was also some variation in size amongst the site treatments. During spring, most individuals were in the 40 – 50 mm range upstream of the mine, while downstream of the mine most fish were in the 40 – 80 mm range. During autumn, the size distribution of Mountain Galaxias was similar for the upstream and downstream sites, with most fish being with the 50 – 110 mm range. The distribution of Mountain Galaxias at the reference sites was slightly smaller, with most fish being in the 50 – 90 mm range.

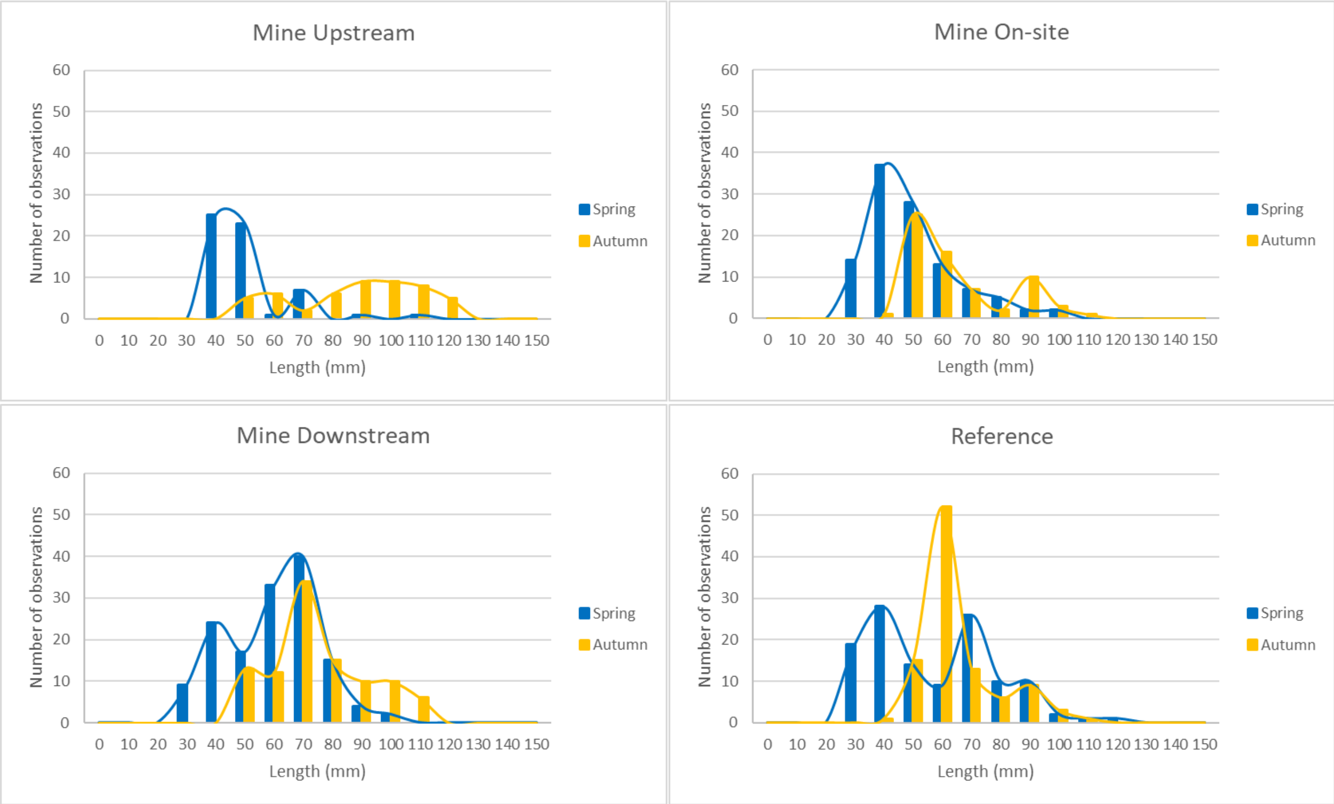

Figure 19 ***Histograms of total length (mm) of Mountain Galaxias categorised by site treatment***

3.8 Platypus

The eDNA monitoring for platypus determined that they have been regularly present in upper reaches of Cadiangullong Creek in Pools 1 and 2 since March 2019, and in Pool 7 approximately 1 km downstream of site CC2 (Table 15). Following the trial environmental flow release, which concluded on 29 July 2019, platypus were detected in Pool 10. Although, they were not recorded in Pool 10 again until April 2020 they have regularly been detected since then, especially in autumn. It is possible that improved flows in April 2020 have allowed platypus to recolonise these pools from upstream locations. The presence of platypus in Pools 17 and 18 has been rare although they were detected in March 2019 and as equivocal results in June 2020 and Dec 2021. The May 2022 eDNA results demonstrate platypus are present throughout Cadiangullong Creek, although results were equivocal in Pool 6/7 and they still appear absent at the most downstream site at Oaky Station (Pools 17/18).

Table 15 Summary of platypus results; green cells indicate presence based on eDNA; green cells with Sighted or Video indicate presence confirmed by chance visual observations or capture on field deployed cameras; orange cells indicate equivocal eDNA results; red cells indicate absence based on eDNA

	Pool 1	Pool 2	Pool 6/7	Pool 9/10/11	Pool 17/18
Mar 2019					
May 2019					
Jun 2019	Sighted				
Jul 2019					
Jul 2019	Not sampled	Photography	Not sampled	Not sampled	Not sampled
Jul 2019		Photography		Photography	
Aug 2019	Photography	Photography	Photography		
Sep 2019					
Nov 2019	Photography				
Dec 2019	Not sampled	Photography	Not sampled	Not sampled	Not sampled
Jan 2020					
Feb 2020					
Apr 2020					
May 2020					
Jun 2020					
Dec 2020					
May 2021					
Dec 2021					
May 2022					

Note Table 15 refers to Pools 9 and 11. These sites were used in previous surveys but were replaced by Pool 10.

4. Discussion

4.1 Rainfall and hydrology

This report presents the results from the spring 2021 and autumn 2022 monitoring for the CVO AEMP. This monitoring period corresponds with a La Niña event and prior to the spring and autumn monitoring, rainfall was substantially higher than for the same period in the previous 12 months. Although rainfall in November 2021 was particularly high, it was slightly below the long-term average prior to spring monitoring in December. Rainfall was higher-than-average prior to autumn monitoring in May.

Flow in Cadiangullong Creek upstream of Cadiangullong Dam (CC5) reflected the pattern in rainfall with an increase in mean daily flow following increased rainfall. Downstream of Cadiangullong Dam at CC1, flows patterns were similar to CC5, although the lower magnitude flows in July 2021 indicate the high flows were captured by Cadiangullong Dam. Flows at sites CC3 and CC4 downstream of the CVO MLA followed rainfall patterns more closely because flow at these sites is due to a combination of surface water and groundwater inputs, and releases from Cadiangullong Dam.

Riparian releases from Cadiangullong Dam are made in accordance with Condition 27 of the Project Approval PA06_0295 to meet the criteria listed in Table 16. Under normal conditions, the CVO riparian releases are approximately 2.8 ML/day and are aimed at achieving 0.9 ML/day at Oaky Creek although this varies depending on storage levels in the dam and inflows upstream of the dam at gauge 412168 (site CC5). Overall, from 1 July 2021 to 30 June 2022 average flow at gauge 412702 (site CC4) was 20.01 ML/day with a minimum of 3.08 ML/day and a maximum of 2683 ML/day. It can therefore be considered that because rainfall and streamflows were high between July 2021 and June 2022, riparian releases would have been a minor influence on connectivity through Cadiangullong Creek. Although there was a short-term high flow event in the month preceding spring monitoring, it is not expected it influenced the results of the AEMP.

Table 16 Cadiangullong flow criteria

Cadiangullong Dam			Inflow	Downstream minimum	Other conditions
RL (masl)	Volume (ML)	Capacity (%)	ML/day @ GS412168	ML/day @ GS412702	
>778.8	420 to 4200	10 to 100	0 to 0.4	0.4	
			0.4 to 3.47	Inflow	
			>3.4	3.4	
773 – 778.8	170 to 420	4 to 10	0 to 0.4	0.4	No water to be extracted
			0.4 to 3.4	Inflow	
			>3.4	3.4	
762.8 – 773	5 to 170	0.1 to 4	0 to 0.4	Inflow*	
			>0.4	0.4*	
<762.8	5	0.1		No release required	

*Measured at the Dam GS412144

There was little runoff in the Swallow Creek reference site (SC1) throughout the year. However, there were peaks associated with high rainfall in August and from November to January. The Flyers Creek reference site (FC1) had more consistent flow from August to January than both Swallow Creek and Cadiangullong Creek. There was a downward trend in baseflow in Flyers Creek from October to March.

4.2 Aquatic habitat

All waterways assessed as part of the AEMP are subject to disturbance from different land use activities. This includes changes to Cadiangullong Creek due to activities within the CVO MLA, and agricultural uses further downstream. The upstream reference site (CC5) is also located in a modified landscape surrounded by pine plantations.

Habitat conditions during spring 2021 and autumn 2022 were consistent with those found in previous years (GHD 2019; 2020; 2021). Conditions of the aquatic habitat upstream of the CVO are slightly higher than downstream sites. However, the levels of disturbance at the downstream sites are similar to the reference sites.

4.3 Water quality

In Cadiangullong Creek, the longitudinal increase in EC was consistent with previous monitoring periods (e.g., GHD 2019; 2020; 2021). There was no consistent seasonal pattern in EC between seasons. Sites CC5, CC1, CC2 and CC3 remained relatively fresh in both seasons while the higher EC further downstream at CC4 regularly exceeded the ANZG (2018) DGV. High EC in Diggers Creek, Panuara Rivulet, Rodd’s Creek and Swallow Creek have also been observed in previous years

High pH was observed in the upstream and downstream on the Cadiangullong Creek as well as the at reference waterways; several sites had pH levels that were slightly higher than the ANZG (2018) DGV. In spring, DO levels were low, which is consistent with monitoring from previous years. However, DO concentrations were high in autumn. This seasonal variation is related to the cooler water temperatures during autumn that allows for a greater amount of oxygen to be dissolved. High DO levels were observed at Panuara Rivulet in both seasons, particularly spring. As noted above there was excessive algal growth observed in Panuara Rivulet that is likely to have contributed to the high pH and DO. That is, during daytime hours photosynthesis by algae can lead to increased DO in the water. However, during the night this reduces DO and increases the proportion of carbon dioxide. Carbon dioxide (CO_2) is acidic and the sequestration of CO_2 in photosynthesis increases the pH of water which is carried over to daytime. However, the increased pH may also be related to changing land use between sites, or a combination of this and photosynthesis.

Increases in EC were not beyond expected levels for the region based on the reference waterways monitored. The high pH and variable DO observed in Cadiangullong Creek also occurred in other waterways. The tailings dam appears to have negligible impact on water quality in Rodd’s Creek (RC1) based on comparisons with the previous monitoring periods and other waterways.

Overall, the results do not suggest that CVO had a detectable influence on the surface water quality during the spring 2021 and autumn 2022 monitoring.

4.4 Sediment quality

Of the metals that have DGVs published, only arsenic, chromium, copper, and nickel were exceeded. Of these, only copper exceeded the ANZG (2018) upper DGV. This occurred at Cadiangullong Creek at the on-site location CC2 and the downstream site CC3.

This pattern was observed in previous monitoring periods, with evidence of increased copper concentrations levels in Cadiangullong Creek downstream of the mine at CC2 and CC3 that dissipates further downstream. Due to the geomorphology of CC2, the pool at this site appears to act as sink for copper and other contaminants. The pool acts as a settlement pond due to dense stands of *Typha* sp. that limits downstream sediment movement during low flows. Sediment transport may occur during higher flow events and the risk of contamination downstream appears to be dependent on a) the connectivity between CC2 and downstream reaches, b) the frequency and size of the high flow events, and c) the size of the sediment particles.

Other than copper, there was no evidence to suggest the CVO MLA is contributing to elevated metals in Cadiangullong Creek when compared to the reference waterways. During previous monitoring (GHD 2021), high concentrations of barium, cobalt, iron, manganese and selenium were recorded at upstream site CC1. This trend was not observed during spring 2021 and autumn 2022.

4.5 Macroinvertebrates

In Cadiangullong Creek, there was some evidence of reduced diversity, including EPT taxa, at CC2 (located on-site at CVO) compared to other sites, although this trend was only noted for edge habitat in spring 2021. Additionally, the SIGNAL-2 scores for CC2 were similar to upstream site and reference sites on Flyers Creek, Panuara Rivulet and Swallow Creek.

There was little indication of impacts downstream of the mine, with taxa richness, EPT and SIGNAL-2 scores at the downstream sites either similar to or higher than the upstream sites. Biological indicators on Cadiangullong Creek were similar to reference sites. The SIGNAL-2 results also suggest that all waterways monitored may be subject to multiple disturbances irrespective of mine operations including high salinity or nutrient levels, agricultural pollution, or the downstream impacts of dams.

The AUSRIVAS results classified riffle habitat for the on-site location as Band C, which suggests a loss of families due to moderate to severe impacts on water and/or habitat quality. In general, the EPA consider SIGNAL to be more sensitive to impacts of pollution while AUSRIVAS is relatively more sensitive to impacts on habitat (EPA, 2000). Consequently, it is likely that habitat conditions are more influential on the macroinvertebrate community health at CC2 than water or sediment quality. Although all sites are subject to disturbance from different land use activities, extensive willows at CC2 have reduced habitat diversity at this site. This is also reflected by the multivariate analyses that did not detect any differences amongst treatments.

Downstream of the mine site, the AUSRIVAS results did not indicate impacts from the mine; many of the sites downstream of CVO were classified as Band A, suggesting they were similar to reference conditions. The sites along the Cadiangullong Creek in general had higher AUSRIVAS scores than the reference sites.

4.6 Sediment/macroinvertebrate relationship

The riffle at the on-site location at CVO (CC2) had elevated copper concentration and macroinvertebrate monitoring found the site has a macroinvertebrate community that is different to other sites. The DISTLM analysis found a significant correlation between copper concentration and the macroinvertebrate community for riffle habitat.

It is likely that the macroinvertebrate community at the CC2 riffle is influenced primarily by habitat quality rather than water quality. The riffle at CC2 received a low AUSRIVAS score – which as outlined in Section 4.5 reflects habitat quality – and a SIGNAL-2 score – which is generally indicative of sediment and water quality – that was similar to other sites on Cadiangullong Creek. Taxa richness and EPT richness at CC2 were similar to the upstream site CC1. The health of the riffle habitat at CC1 was comparable to sites further downstream and other references sites. This again suggests that habitat quality is likely to be the main driver of macroinvertebrate and waterway health.

4.7 Fish

Overall, the results from the 2021-22 fish monitoring indicate a relatively healthy community dominated by the native Mountain Galaxias (*Galaxias olidus*). The species remains distributed throughout Cadiangullong Creek, along with Flyers Creek and Swallow Creek.

The low numbers of fish collected at CC5 and SC1 in autumn 2022 is consistent with previous seasons and may be due to predatory Trout upstream of Cadiangullong Dam and the small size of Swallow Creek. It is reported that the presence of trout has reduced the abundance of Mountain Galaxias in lowland streams and completely eliminated them in some upland streams (Lintermans, 2007). The barrier effect of Cadiangullong Dam may also prevent recruitment and recolonisation of upstream reaches. However, it should be noted electrofishing was not possible at CC5 and SC1 and this may have biased the results.

For all treatments (i.e. upstream, on-site, downstream and reference) there was a range of size classes in the fish community. Furthermore, there was an increase in length during autumn compared to spring. These results are consistent with previous monitoring and may indicate the recruitment of juveniles during spring that had matured by the following autumn, indicating reasonably healthy self-sustaining community with adequate recruitment. On current evidence, the mine does not appear to be negatively impacting populations of Mountain Galaxias.

4.8 Platypus

The eDNA monitoring for platypus determined they have regularly been present in upper reaches of Cadiangullong Creek in Pools 1 and 2 since March 2019, and in Pool 7 approximately 1 km downstream of site CC2. Since April 2020, platypus have also regularly been detected in downstream Pool 10, especially in autumn. Importantly, the autumn 2022 eDNA results demonstrate platypus are present throughout Cadiangullong Creek although they still appear absent at the most downstream site at Oaky Station (Pools 17/18).

5. Conclusion

– High flow events occurred throughout the 12-month period between July 2021 and May 2022 in response to high rainfall and a La Niña event.
– Discharge in Cadiangullong Creek upstream of the dam (CC5) reflected the pattern in rainfall with an increase in mean daily flow following increased rainfall. Downstream of Cadiangullong Dam at CC1, flow patterns were similar to CC5, although the lower magnitude flows in July 2021 indicate the high flows were captured by Cadiangullong Dam. Sites CC3 and CC4 downstream of the CVO MLA followed rainfall patterns more closely than CC1 as they receive additional runoff from tributaries.
– Disturbances to riparian zone vegetation and broader catchment scale land-use which, aside from mining and associated operations, is heavily influenced by grazing in the mid to lower catchment areas, and pine plantations in the upper catchments, are likely to be impacting on aquatic ecosystem health.
– Elevated EC in Cadiangullong Creek is influenced by low flows, increased groundwater contributions, changing land use, or a combination of these factors.
– Variation in DO and pH are likely influenced by photosynthetic activity and land use between sites, or a combination of the two. Overall, the results do not suggest that CVO had a detectable influence on the surface water quality during the spring 2021 and autumn 2022 monitoring. Seepage from the tailings dam also appears to have negligible impact on water quality or sediment quality in Rodd's Creek (RC1).
– There was evidence of increased copper in the sediments of Cadiangullong Creek downstream of the mine at site CC3 and the pool at CC2 appears to act as a sink for copper and other contaminants. Sediment transport may occur during high flow events thereby increasing the risk of contamination downstream of CC2. This risk is dependent on a) the connectivity between CC2 and the reaches downstream, b) the frequency and size of the high flow events, and c) the size of the sediment particles. As found in previous years, copper is dissipated further downstream.
– There was some evidence the macroinvertebrate community as site CC2 was different to other sites on Cadiangullong Creek or the reference sites. Elevated copper concentrations were detected at this site. However, it is likely that habitat conditions are more influential on the macroinvertebrate community health at CC2, rather than water or sediment quality.
– There was little indication of impacts to macroinvertebrate communities downstream of the CVO MLA, biological indicators downstream of the mine similar to or higher than the upstream sites.
– Results suggest that all waterways monitored may be subject to multiple disturbances irrespective of mine operations including high salinity or nutrient levels, agricultural pollution, or the downstream impacts of dams.
– A relatively healthy fish community dominated by the native Mountain Galaxias remains distributed throughout Cadiangullong Creek, along with Flyers Creek and Swallow Creek. There was a range of size classes in the fish community and an increase in length during autumn compared to spring. This may indicate the recruitment of juveniles during spring that had matured by the following autumn, indicating a reasonably healthy self-sustaining community with adequate recruitment.
– Platypus remain distributed throughout Cadiangullong Creek although they still appear absent at the most downstream site at Oaky Station (Pools 17/18).

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Appendices

Appendix A

Site location details for the CVO AEMP

Site Code	Site Name	Position Relative to Potential Impacts and CVO	Latitude	Longitude	Catchment Area (km^2)
CC5	Cadiangullong Creek at Forestry gauging station	Downstream of Canobolas State Forest (pine plantation); upstream of CVO	-33.41563	148.98528	33.44
CC1	Cadiangullong Creek 200 m downstream of Cadiangullong Dam	Downstream of Cadiangullong Dam; upstream of CVO mining facilities	-33.43592	148.99287	40.28
CC2	Cadiangullong Creek at South Portal Road (lower cutting)	Downstream of Cadiangullong Dam; downstream of Cadiangullong Creek diversion; adjacent to Cadia pit (now in care and maintenance phase)	-33.46092	148.98957	58.16
CC3	Cadiangullong Creek at Southern Lease Boundary	Downstream of CVO facilities; upstream of tailings dams; grazing in surrounding lands	-33.49894	148.97604	72.71
CC4	Cadiangullong Creek at Oaky Creek Gauging Station	Downstream of CVO facilities; downstream of tailings dams; grazing in surrounding lands	-33.53951	148.97173	107.36
FC2	Flyers Creek at Extraction Weir	Catchment east and adjacent to Cadiangullong Creek catchment; grazing and pine plantation in surrounding lands; upstream of Flyers Creek Extraction Weir	-33.47829	149.04060	52.36
FC1	Flyers Creek at Martin Road Gauging Station	Catchment east and adjacent to Cadiangullong Creek catchment; grazing and pine plantation in surrounding lands; downstream of Flyers Creek Extraction Weir	-33.48849	149.03539	56.16
SC1	Swallow Creek at Gauging Station No. 412167	Catchment west and adjacent to Cadiangullong Creek catchment; grazing in surrounding lands; downstream of Ridgeway underground mine sinkhole	-33.48234	148.95974	17.97
PR1	Panuara Rivulet upstream of Revegetation Area	Catchment west of CVO; located on leased sheep grazing property; upstream of proposed revegetation area	-33.49671	148.89010	54.04
PR2	Panuara Rivulet downstream of Revegetation Area	Catchment west of CVO; located on leased sheep grazing property; downstream of proposed revegetation area	-33.52097	148.87873	58.72
RC1	Rodd's Creek upstream of Cadiangullong Creek	Downstream of tailing dams on Rodd's Creek; upstream of CVOCC4 confluence with Cadiangullong Creek	-33.53107	148.98513	21.14
DG1	Diggers Creek at Diggers Weir Station No. 412166	Upstream of Panuara Rivulet, catchment adjacent to, but not influenced by mining operations.	-33.43434	148.93373	5.29

Appendix B

Field sheets summarising habitat conditions

	Site	CC5	CC1	CC2	CC3	CC4	FC1	FC2	PR1	PR2	SC1	RC1	DG1
Site Attributes	Topography	Broad Valley	Steep Valley	Steep Valley	Broad Valley	Steep Valley	Steep Valley	Broad Valley	Broad Valley	Broad Valley	Broad Valley	Steep Valley	Broad Valley
	Water Level	Low	Moderate	Low	Low	Low	Low	Moderate	NF	NF	Low	Low	Low
	Shading of River	Moderate	High	Low	Moderate	Moderate	None	Low	Low	Low	None	None	Low
	Trees >10 m	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
	Trees <10 m	60	10	15	15	45	5	5	1	5	15	2	5
	Shrubs / Vines / Rushes	30	30	5	5	10	5	3	0	30	5	5	0
	Grasses / Herbs / Ferns	40	90	40	80	3	80	95	30	15	90	90	90
	Stream Width - Min	1	1	1	0.5	3	0.5	2	0	0	51	1	1
	Stream Width - Max	5	6	5	2	7	2	12	4	3	2	2	1
	Stream Width - Mode	3	3	1.5	1	4	1.5	5	0.5	1.5	1	1	1
Land Use	Left Bank	Forestry	Exotic Grassland (no grazing)	Mining (Open Cut)	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing
	Right Bank	Forestry	Exotic Grassland (no grazing)	Exotic Grassland (no grazing)	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing	Grazing
Riffle	Bedrock	/	10	/	5	0	5	15	30	/	/	/	/
	Boulder	/	20	/	20	2	10	10	40	0	/	/	/
	Cobble	/	40	/	40	30	45	20	20	/	/	/	/
	Pebble	/	5	/	10	35	15	20	5	/	/	/	/
	Gravel	/	5	/	10	20	10	10	1	/	/	/	/
	Sand	/	10	/	5	5	10	10	0	/	/	/	/
	Silt	/	10	/	10	4	5	10	2	/	/	/	/

	Site	CC5	CC1	CC2	CC3	CC4	FC1	FC2	PR1	PR2	SC1	RC1	DG1
	Clay	/	0	/	0	4	0	5	2	/	/	/	/
	Depth - Mode	/	4	12	10	15	9	14	0	/	/	/	/
Edge	Bedrock	15	0	10	0	0	0	0	40	15	0	0	20
	Boulder	10	0	30	0	5	0	0	5	0	0	0	10
	Cobble	10	0	20	30	30	0	0	30	10	15	20	5
	Pebble	20	15	2	0	30	15	5	15	2	10	10	5
	Gravel	15	10	2	0	15	15	5	5	3	10	10	10
	Sand	15	20	1	10	5	40	5	0	5	15	40	20
	Silt	20	50	30	50	8	20	70	3	60	35	10	25
	Clay	5	5	5	10	7	10	15	2	5	15	10	5
	Detritus Cover	30	60	30	60	15	25	65	20	30	40	30	15
	Bank Overhang	20	30	5	40	25	15	5	5	10	20	10	40
	Total Macrophytes	60	80	80	70	20	70	20	0	60	90	80	70
Site Assessment	Water Quality	2	2	2	2	2	2	3	3	2	2	2	2
	Instream	2	2	4	3	3	2	3	4	2	3	2	2
	Riparian Zone	3	1	3	2	3	4	3	4	3	4	4	3
	Catchment Assessment	2	2	3	3	3	3	3	3	3	4	3	3
	Total	9	7	12	10	11	11	12	14	10	13	11	10

Appendix C

Sediment quality analytes schedule and results (spring 2021 and autumn 2022)

CERTIFICATE OF ANALYSIS

Work Order	: **ES2146962**	Page	: 1 of 5
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MS DEMELZA SCOTT	Contact	: Sarah Mathew
Address	: 270 SUMMER STREET ORANGE NSW, AUSTRALIA 2800	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 6393 6400	Telephone	: +61-2-8784 8555
Project	: 12564894	Date Samples Received	: 22-Dec-2021 14:00
Order number	: ----	Date Analysis Commenced	: 23-Dec-2021
C-O-C number	: ----	Issue Date	: 06-Jan-2022 17:40
Sampler	: Grace Rogers		
Site	:		
Quote number	: EN/005		
No. of samples received	: 11		
No. of samples analysed	: 11		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG005T: Poor precision was obtained for Manganese on sample ES214962 # 001. Confirmed by redigestion and reanalysis.
- EG005T: Poor precision was obtained for Iron on sample ES2146741 # 002. Confirmed by redigestion and reanalysis.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	CC1	CC2	CC3	CC4	CC5
			Sampling date / time	16-Dec-2021 00:00	16-Dec-2021 00:00	16-Dec-2021 00:00	15-Dec-2021 00:00	19-Dec-2021 00:00
Compound	CAS Number	LOR	Unit	ES2146962-001	ES2146962-002	ES2146962-003	ES2146962-004	ES2146962-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**40.0**	**61.9**	**60.2**	**33.2**	**33.2**
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**15000**	**18300**	**10400**	**17500**	**9790**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**100**	**130**	**50**	**140**	**80**
Beryllium	7440-41-7	1	mg/kg	**2**	<1	<1	**1**	**2**
Cobalt	7440-48-4	2	mg/kg	**14**	**58**	**18**	**20**	**14**
Iron	7439-89-6	50	mg/kg	**44700**	**47500**	**44400**	**42300**	**46000**
Manganese	7439-96-5	5	mg/kg	**581**	**2720**	**400**	**1540**	**664**
Molybdenum	7439-98-7	2	mg/kg	<2	**4**	**4**	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Arsenic	7440-38-2	5	mg/kg	**7**	**14**	**13**	**11**	**8**
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**40**	**32**	**37**	**34**	**35**
Copper	7440-50-8	5	mg/kg	**30**	**966**	**474**	**133**	**19**
Lead	7439-92-1	5	mg/kg	**11**	**15**	**10**	**9**	**8**
Nickel	7440-02-0	2	mg/kg	**13**	**19**	**14**	**17**	**11**
Zinc	7440-66-6	5	mg/kg	**77**	**134**	**77**	**70**	**84**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	FC1	FC2	PR1	PR2	SC1
			Sampling date / time	15-Dec-2021 00:00	15-Dec-2021 00:00	17-Dec-2021 00:00	17-Dec-2021 00:00	19-Dec-2021 00:00
Compound	CAS Number	LOR	Unit	ES2146962-006	ES2146962-007	ES2146962-008	ES2146962-009	ES2146962-010
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	29.0	23.3	31.9	23.6	30.3
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	11300	18400	10900	8910	14700
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	70	130	110	100	80
Beryllium	7440-41-7	1	mg/kg	1	<1	<1	<1	<1
Cobalt	7440-48-4	2	mg/kg	26	36	8	10	10
Iron	7439-89-6	50	mg/kg	63700	63900	19400	20600	31600
Manganese	7439-96-5	5	mg/kg	1110	1620	634	422	401
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Arsenic	7440-38-2	5	mg/kg	45	26	6	7	20
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	103	93	15	18	31
Copper	7440-50-8	5	mg/kg	67	80	21	21	68
Lead	7439-92-1	5	mg/kg	16	28	13	14	10
Nickel	7440-02-0	2	mg/kg	28	33	10	13	13
Zinc	7440-66-6	5	mg/kg	103	158	42	47	72
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL)**

			Sample ID	DG1	----	----	----	----
			Sampling date / time	15-Dec-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	ES2146962-011	--------	--------	--------	--------
				Result	----	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**64.0**	----	----	----	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**10900**	----	----	----	----
Antimony	7440-36-0	5	mg/kg	<5	----	----	----	----
Barium	7440-39-3	10	mg/kg	**60**	----	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	----	----	----	----
Cobalt	7440-48-4	2	mg/kg	**5**	----	----	----	----
Iron	7439-89-6	50	mg/kg	**26600**	----	----	----	----
Manganese	7439-96-5	5	mg/kg	**154**	----	----	----	----
Molybdenum	7439-98-7	2	mg/kg	**2**	----	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	----	----	----	----
Silver	7440-22-4	2	mg/kg	<2	----	----	----	----
Arsenic	7440-38-2	5	mg/kg	**40**	----	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	----	----	----	----
Chromium	7440-47-3	2	mg/kg	**17**	----	----	----	----
Copper	7440-50-8	5	mg/kg	**41**	----	----	----	----
Lead	7439-92-1	5	mg/kg	**27**	----	----	----	----
Nickel	7440-02-0	2	mg/kg	**8**	----	----	----	----
Zinc	7440-66-6	5	mg/kg	**81**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	----	----	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **ES2217923**	Page	: 1 of 5
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MS DEMELZA SCOTT	Contact	: Sarah Mathew
Address	: 270 SUMMER STREET ORANGE NSW, AUSTRALIA 2800	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 6393 6400	Telephone	: +61-2-8784 8555
Project	: 12564894	Date Samples Received	: 24-May-2022 15:45
Order number	: 12564894	Date Analysis Commenced	: 27-May-2022
C-O-C number	: ----	Issue Date	: 31-May-2022 14:35
Sampler	: Grace Rogers		
Site	:		
Quote number	: EN/005		
No. of samples received	: 12		
No. of samples analysed	: 12		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	CC1	CC2	CC3	CC4	CC5
			Sampling date / time	18-May-2022 00:00	18-May-2022 00:00	18-May-2022 00:00	17-May-2022 00:00	16-May-2022 00:00
				ES2217923-001	ES2217923-002	ES2217923-003	ES2217923-004	ES2217923-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**32.9**	**56.1**	**57.5**	**58.6**	**39.4**
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**10500**	**23000**	**12000**	**30700**	**19500**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**70**	**100**	**60**	**180**	**160**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	**5**
Cobalt	7440-48-4	2	mg/kg	**36**	**30**	**21**	**20**	**16**
Iron	7439-89-6	50	mg/kg	**27900**	**48400**	**90800**	**63500**	**40300**
Manganese	7439-96-5	5	mg/kg	**691**	**884**	**372**	**810**	**1900**
Molybdenum	7439-98-7	2	mg/kg	<2	**6**	**4**	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Arsenic	7440-38-2	5	mg/kg	**15**	**13**	**21**	**14**	**6**
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**46**	**40**	**70**	**43**	**28**
Copper	7440-50-8	5	mg/kg	**94**	**783**	**474**	**214**	**33**
Lead	7439-92-1	5	mg/kg	**8**	**13**	**10**	**9**	**8**
Nickel	7440-02-0	2	mg/kg	**24**	**19**	**17**	**26**	**15**
Zinc	7440-66-6	5	mg/kg	**65**	**119**	**76**	**113**	**136**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	FC1	FC2	PR1	PR2	SC1
			Sampling date / time	16-May-2022 00:00	16-May-2022 00:00	19-May-2022 00:00	19-May-2022 00:00	20-May-2022 00:00
Compound	CAS Number	LOR	Unit	ES2217923-006	ES2217923-007	ES2217923-008	ES2217923-009	ES2217923-010
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**73.2**	**32.3**	**56.4**	**31.5**	**58.5**
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**16200**	**19600**	**16300**	**8400**	**18100**
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	**190**	**130**	**190**	**80**	**180**
Beryllium	7440-41-7	1	mg/kg	<1	<1	<1	<1	<1
Cobalt	7440-48-4	2	mg/kg	**22**	**29**	**11**	**9**	**20**
Iron	7439-89-6	50	mg/kg	**41200**	**57400**	**30600**	**26600**	**34600**
Manganese	7439-96-5	5	mg/kg	**6140**	**1520**	**600**	**530**	**1610**
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	**8**	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Arsenic	7440-38-2	5	mg/kg	**20**	**24**	**10**	**8**	**26**
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	**42**	**80**	**26**	**18**	**34**
Copper	7440-50-8	5	mg/kg	**43**	**83**	**29**	**14**	**67**
Lead	7439-92-1	5	mg/kg	**13**	**23**	**17**	**10**	**11**
Nickel	7440-02-0	2	mg/kg	**17**	**26**	**14**	**11**	**16**
Zinc	7440-66-6	5	mg/kg	**76**	**151**	**72**	**53**	**70**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	**0.1**	<0.1	<0.1	<0.1	<0.1

Analytical Results

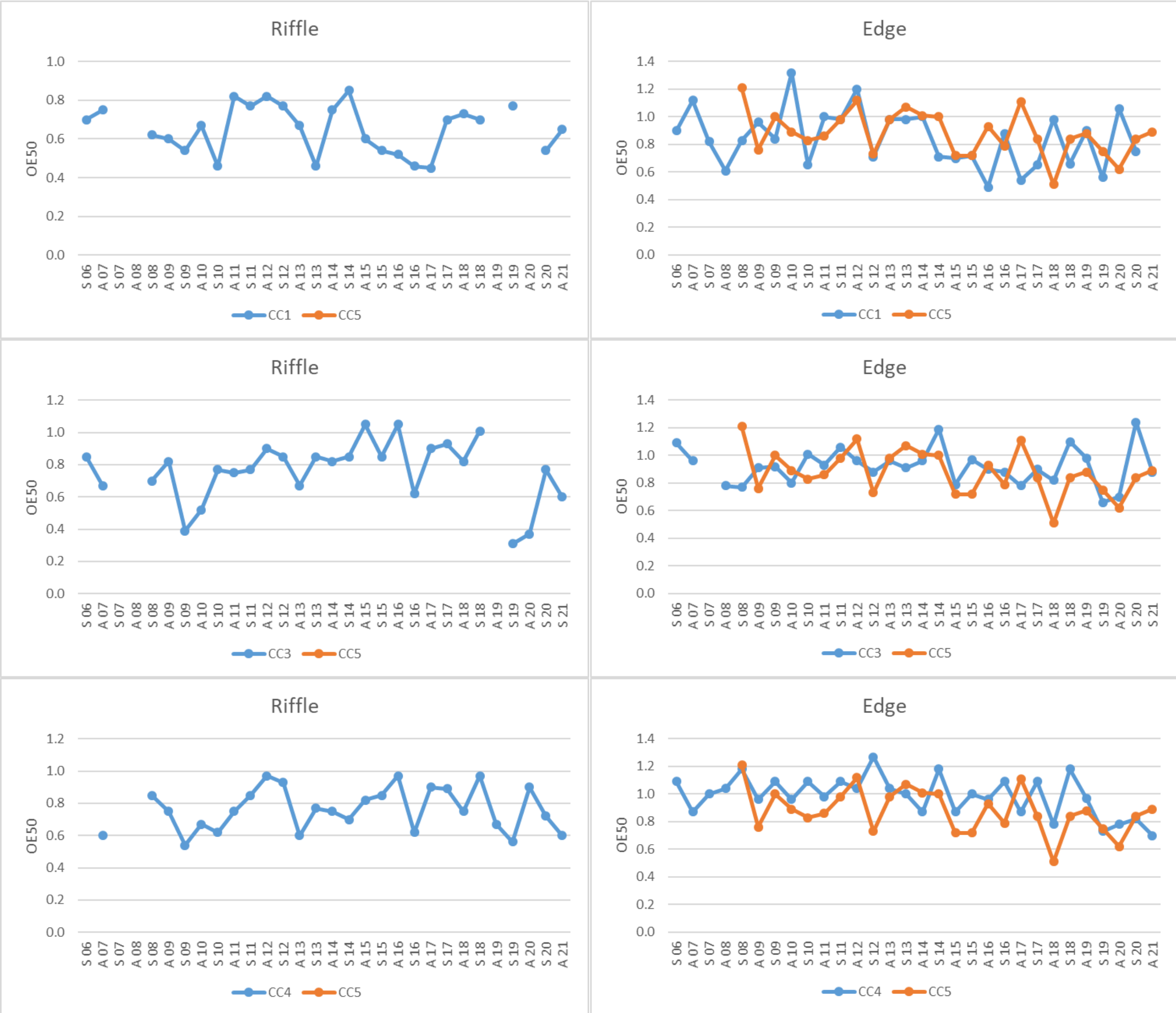
Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	DG1	RC1	----	----	----
			Sampling date / time	17-May-2022 00:00	17-May-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	ES2217923-011	ES2217923-012	--------	--------	--------
				Result	Result	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**46.6**	**53.3**	----	----	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**11800**	**13800**	----	----	----
Antimony	7440-36-0	5	mg/kg	<5	<5	----	----	----
Barium	7440-39-3	10	mg/kg	**120**	**90**	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	----	----	----
Cobalt	7440-48-4	2	mg/kg	**11**	**9**	----	----	----
Iron	7439-89-6	50	mg/kg	**36400**	**21800**	----	----	----
Manganese	7439-96-5	5	mg/kg	**932**	**1320**	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	----	----	----
Silver	7440-22-4	2	mg/kg	<2	<2	----	----	----
Arsenic	7440-38-2	5	mg/kg	**68**	<5	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	----	----	----
Chromium	7440-47-3	2	mg/kg	**17**	**17**	----	----	----
Copper	7440-50-8	5	mg/kg	**51**	**41**	----	----	----
Lead	7439-92-1	5	mg/kg	**22**	<5	----	----	----
Nickel	7440-02-0	2	mg/kg	**13**	**8**	----	----	----
Zinc	7440-66-6	5	mg/kg	**149**	**50**	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	----	----

Appendix D

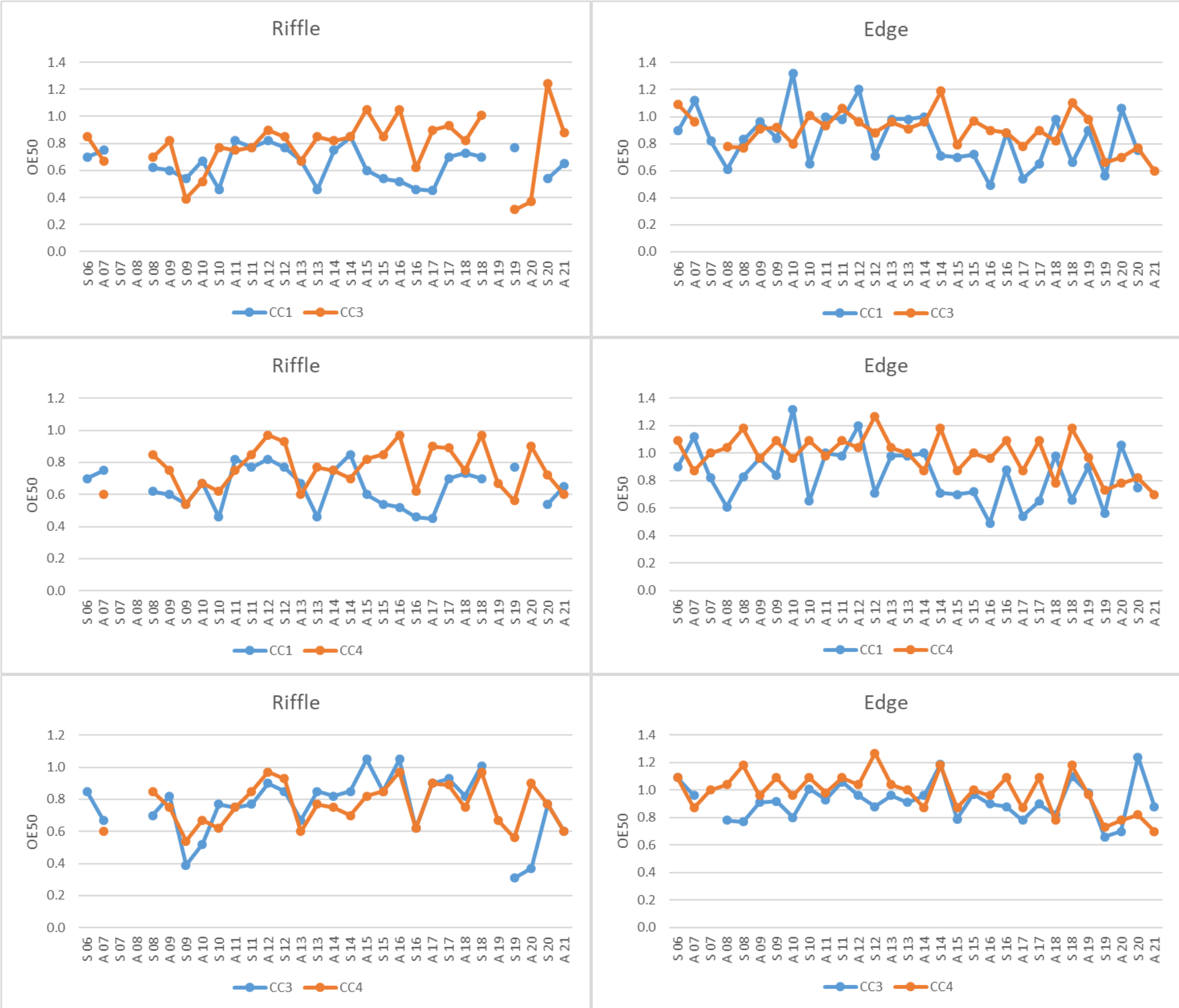
Long term patterns in macroinvertebrate indices

This appendix includes long term plots for the macroinvertebrate indices measured as part of the Cadia Valley Operations AEMP. These graphs include all monitoring sites for the period, spring 2006 – autumn 2022, and are grouped into the sites pairings that were described in the recent 10-year data review. Pairwise comparisons of water quality monitoring sites were investigated to determine the key factors that may influence the water quality and streamflow of Cadiangullong Creek. The site comparisons and rationale are as follows:

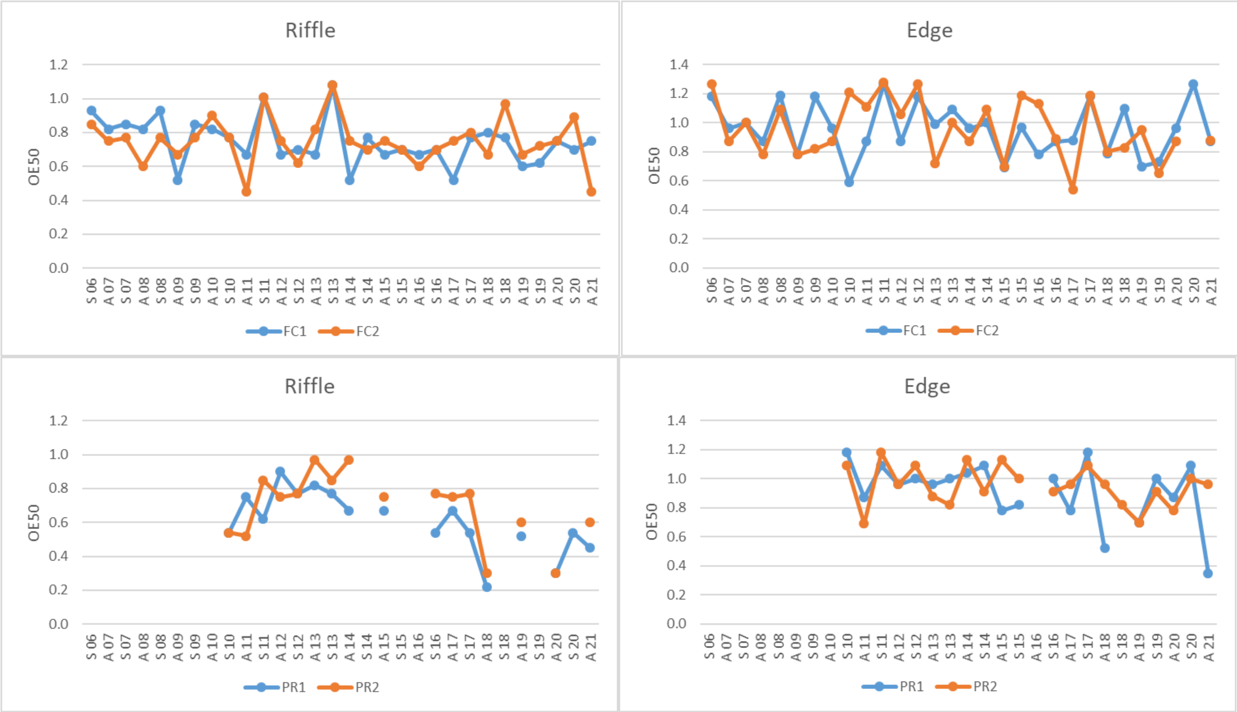
- CC5 vs CC1 - Cadiangullong Creek upstream of Cadiangullong Dam vs downstream of Cadiangullong Dam; investigating the influence of Cadiangullong dam on the water quality and streamflow of the waterway
- CC5 vs CC3 - Cadiangullong Creek upstream of Cadiangullong Dam vs Cadiangullong Creek at Southern Lease Boundary, downstream of the main areas of mining operations; investigating the influence of Cadiangullong Dam and mining operations on the water quality of Cadiangullong Creek
- CC5 vs CC4 - Cadiangullong Creek upstream of Cadiangullong Dam vs Cadiangullong Creek at Oaky Creek gauging station: investigating the influence of all CVO operations including Cadiangullong Dam, CVO facilities and tailing dams on the water quality and stream flow of Cadiangullong Creek
- CC1 vs CC3 – Cadiangullong Creek downstream of Cadiangullong Dam vs Cadiangullong Creek at Southern Lease Boundary; investigating the influence of CVO main area of operations on the water quality of Cadiangullong Creek, separated from the influence of Cadiangullong Dam
- CC1 vs CC4- Cadiangullong Creek downstream of Cadiangullong Dam vs Cadiangullong Creek at Oaky Creek gauging station; investigating the influence of CVO main area of operations and tailing dams on the water quality and stream flow of Cadiangullong Creek without separated from the influence of Cadiangullong Dam
- CC3 vs CC4 - Cadiangullong Creek at Southern Lease Boundary vs Cadiangullong Creek at Oaky Creek gauging station; investigating the influence of land use and tailings dams in the Rodds Creek catchment on Cadiangullong Creek, separated from the influence of CVO main operations, and Cadiangullong Dam upstream
- All of the other sites are grouped by their catchments



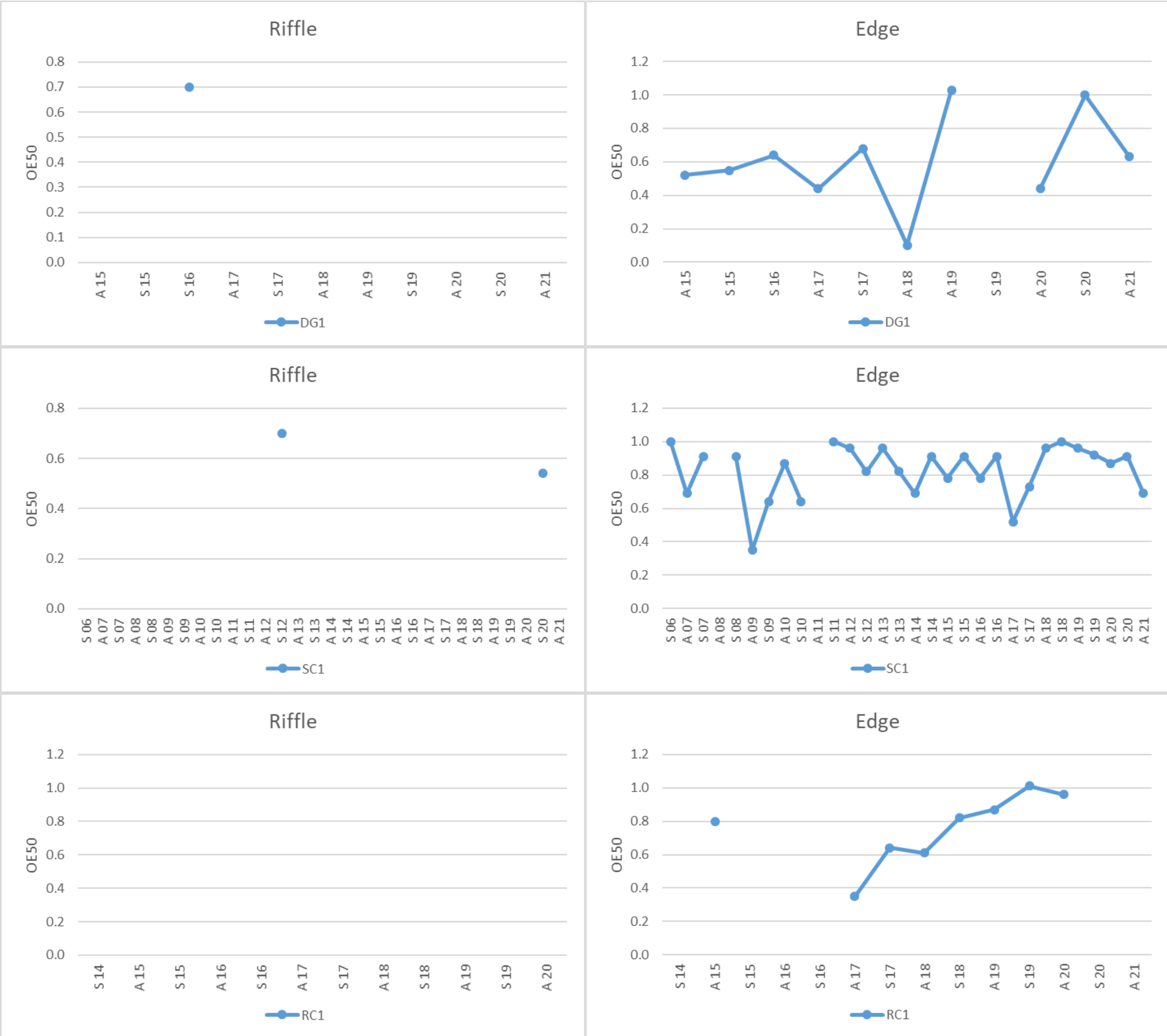
Macroinvertebrate OE50 scores in Cadiangullong Creek between spring 2006 and autumn 2021



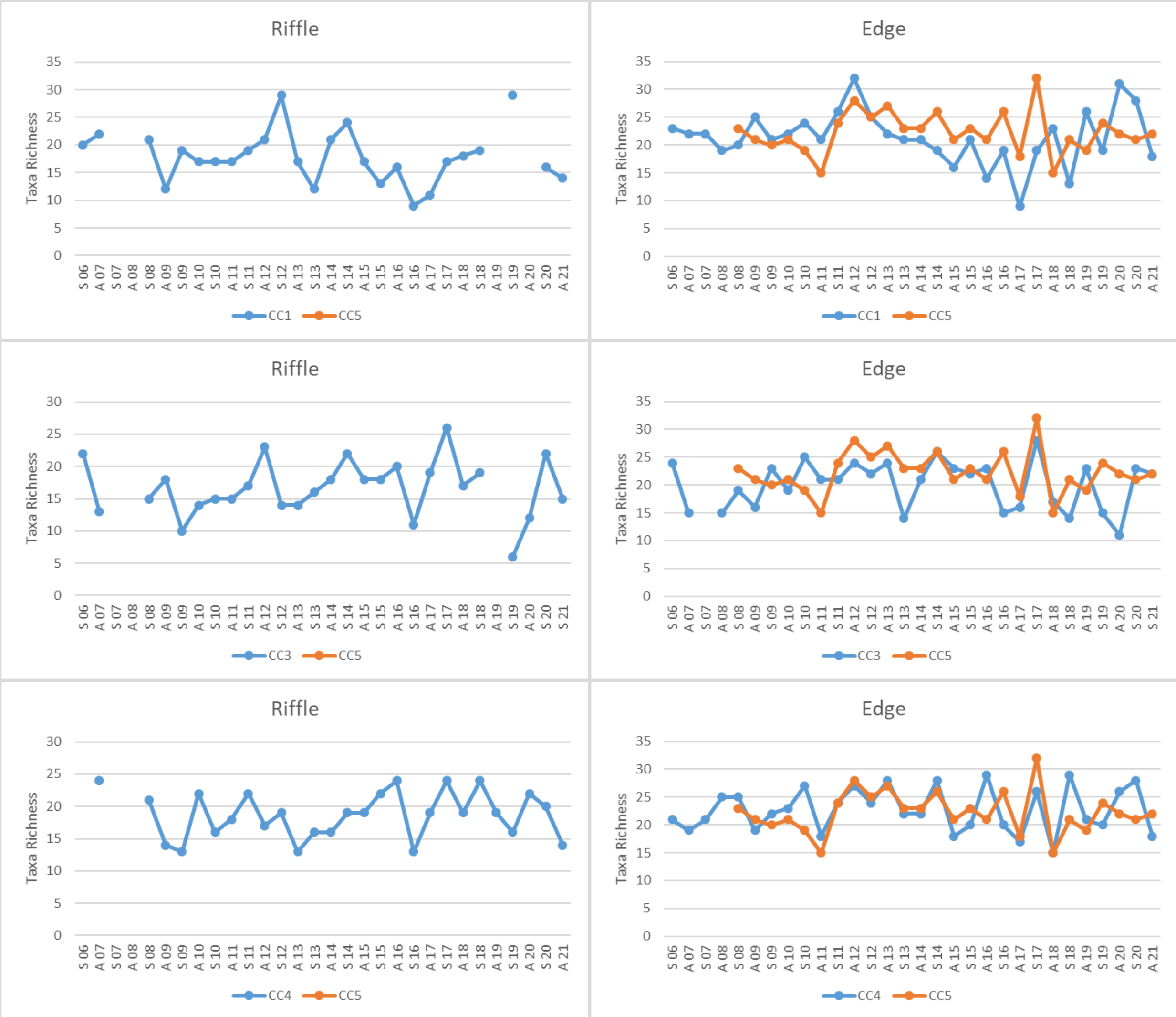
Macroinvertebrate OE50 scores in Cadiangullong Creek between spring 2006 and autumn 2021



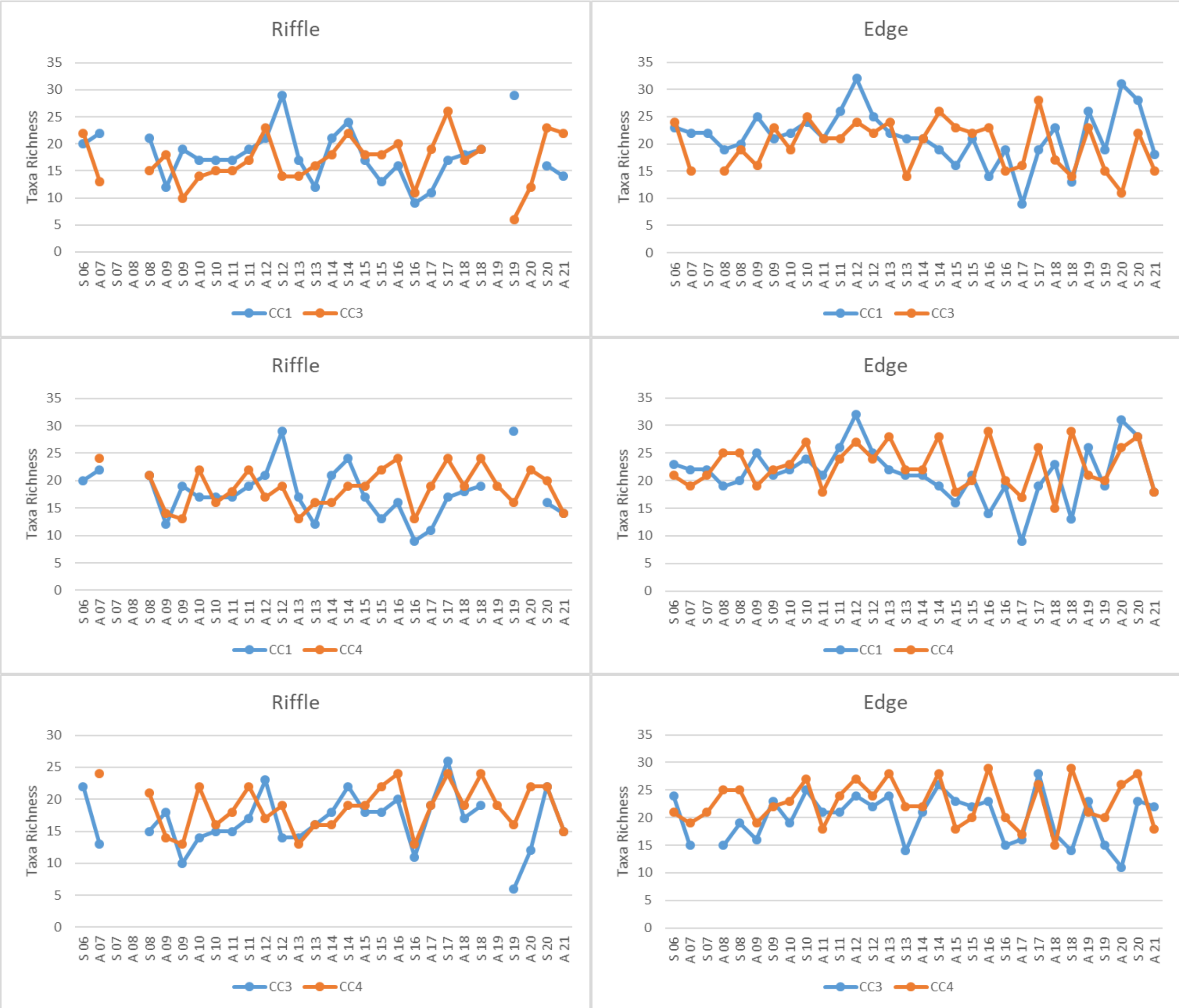
Macroinvertebrate OE50 scores in Flyers Creek (top) and Panuara Rivulet (bottom) between spring 2006 and autumn 2021



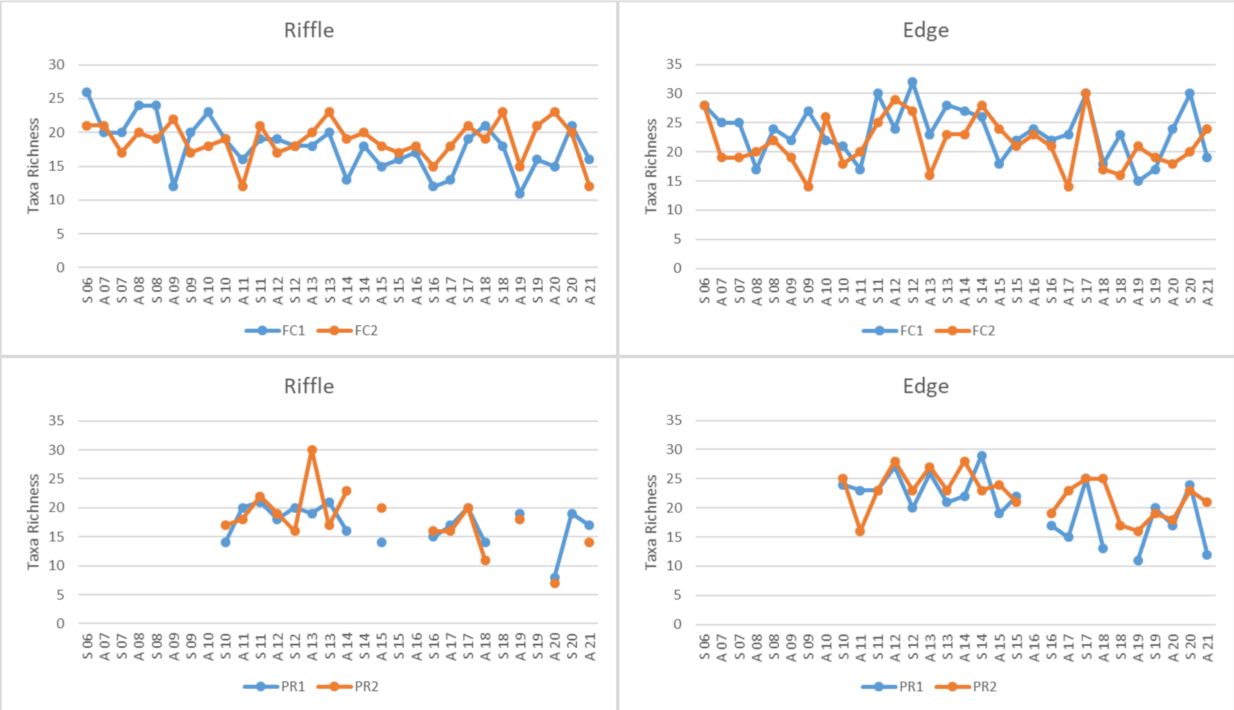
Macroinvertebrate OE50 scores in Diggers Creek (top), Swallow Creek (middle) and Rodd's Creek (bottom) between spring 2006 and autumn 2021



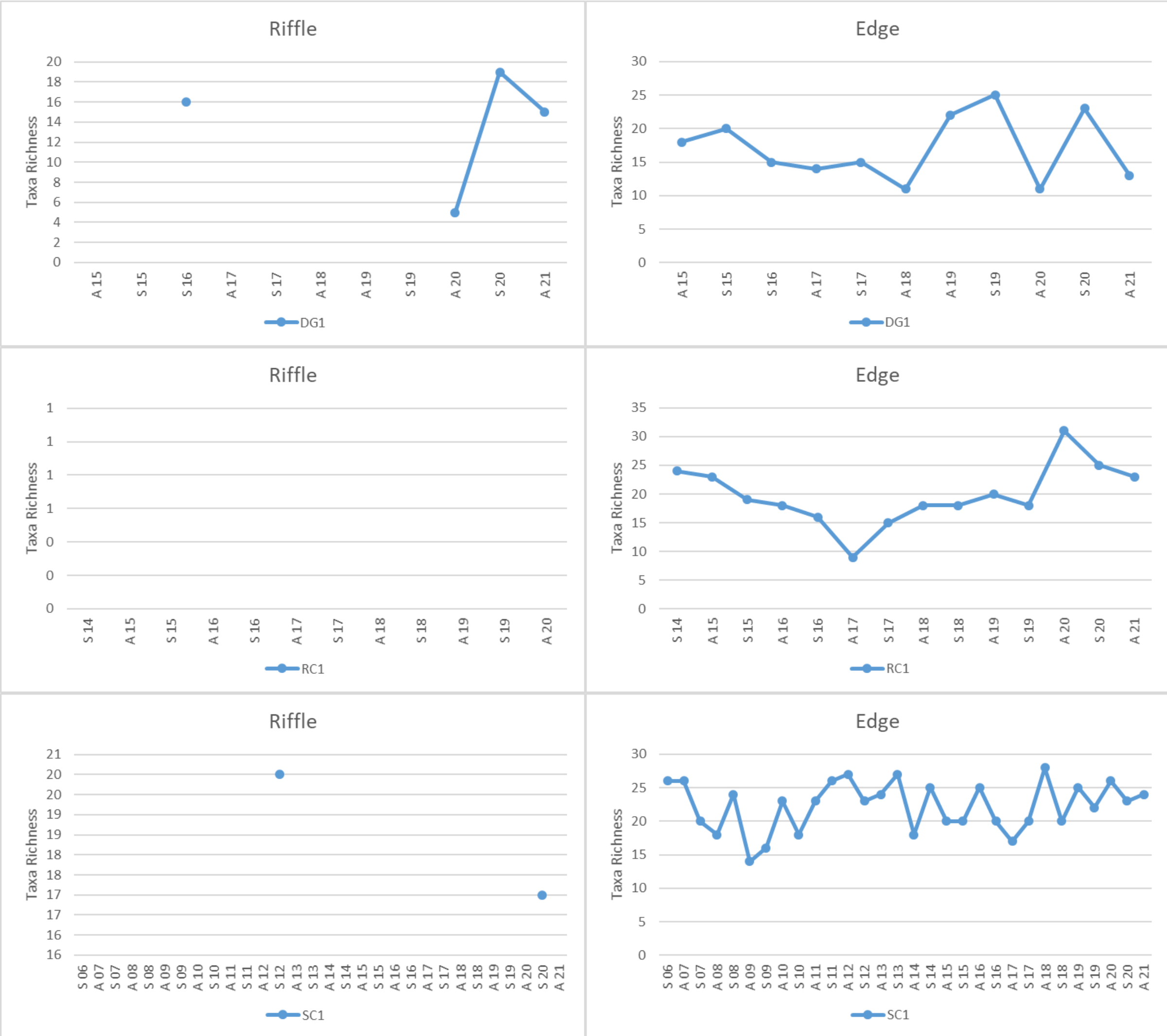
Macroinvertebrate taxa richness in Cadiangullong Creek between spring 2006 and autumn 2021



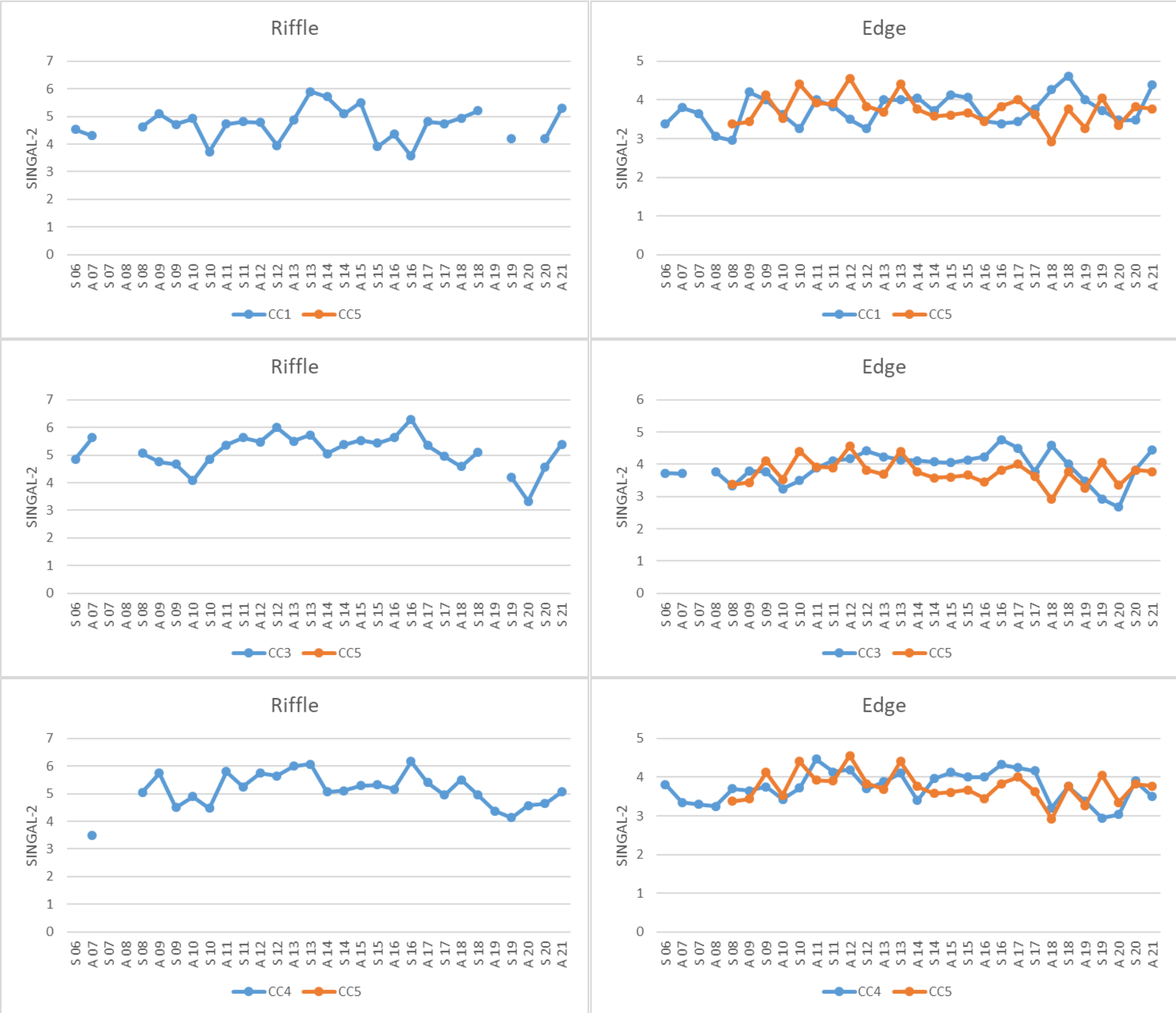
Macroinvertebrate taxa richness in Cadiangullong Creek between spring 2006 and autumn 2021



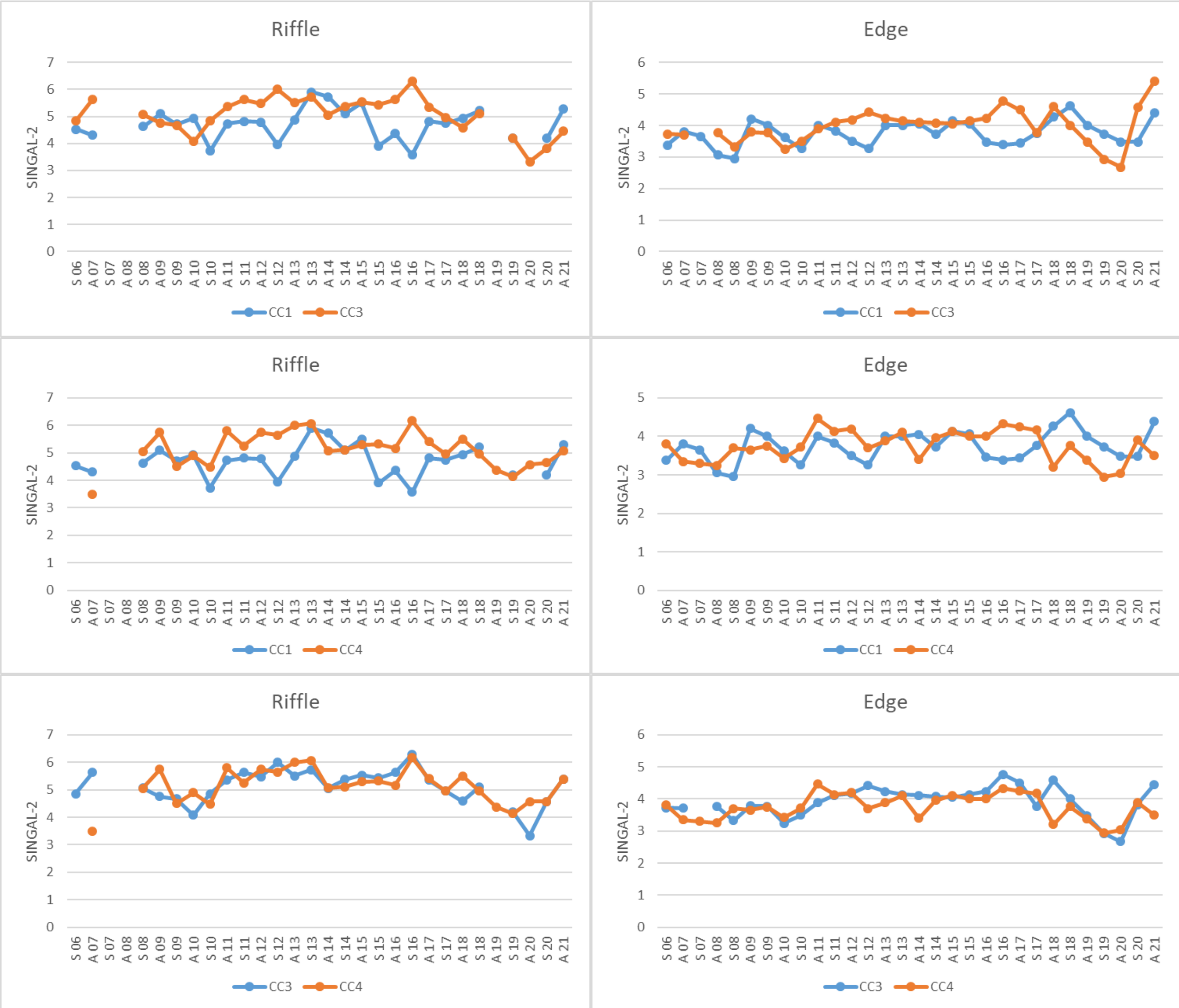
Macroinvertebrate taxa richness in Flyers Creek (top) and Panuara Rivulet (bottom) between spring 2006 and autumn 2021



Macroinvertebrate taxa richness in Diggers Creek (top), Swallow Creek (middle) and Rodd's Creek (bottom) between spring 2006 and autumn 2021

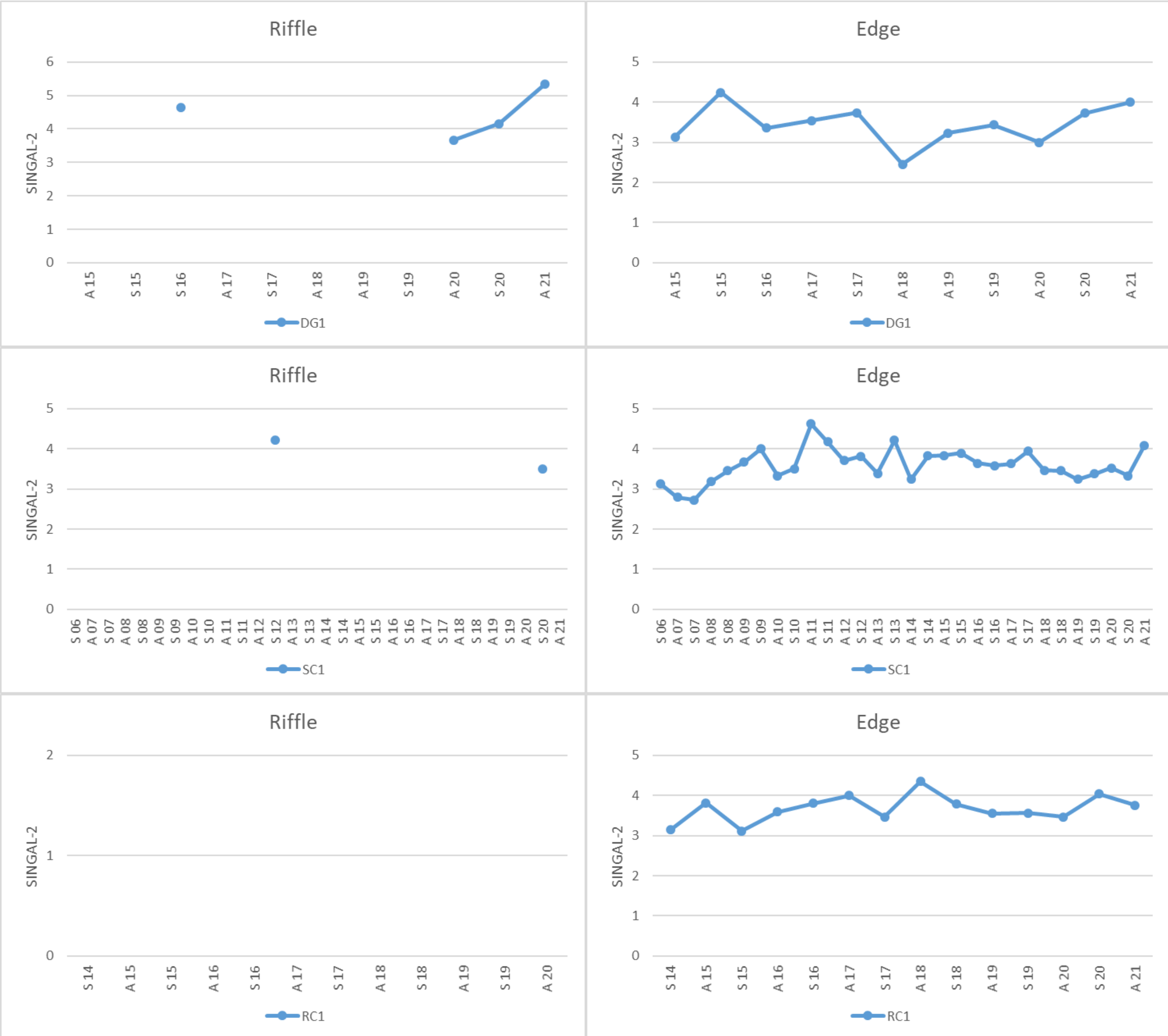


Macroinvertebrate SIGNAL-2 Scores in Cadiangullong Creek between spring 2006 and autumn 2021

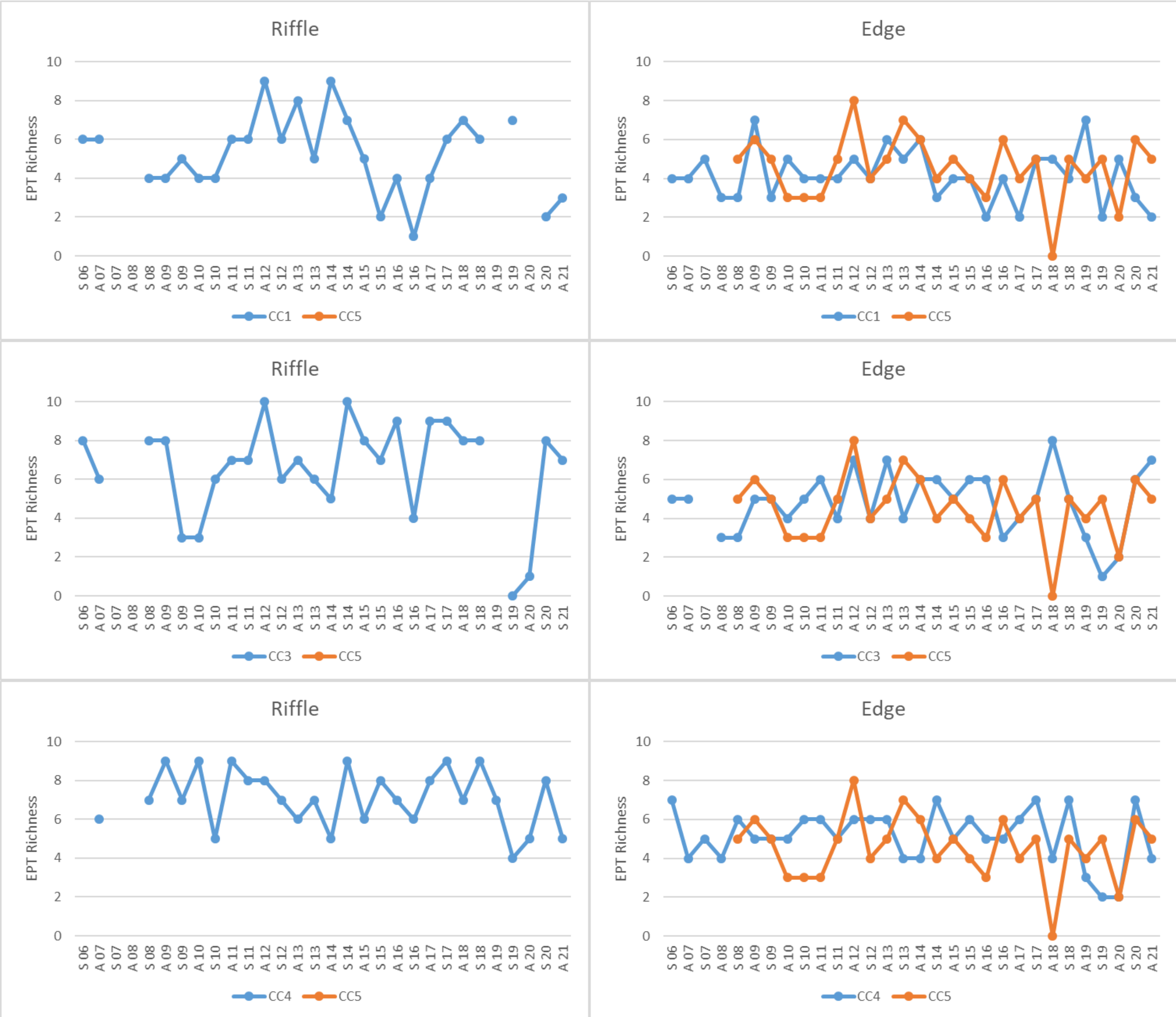


Macroinvertebrate SIGNAL-2 Scores in Cadiangullong Creek between spring 2006 and autumn 2021

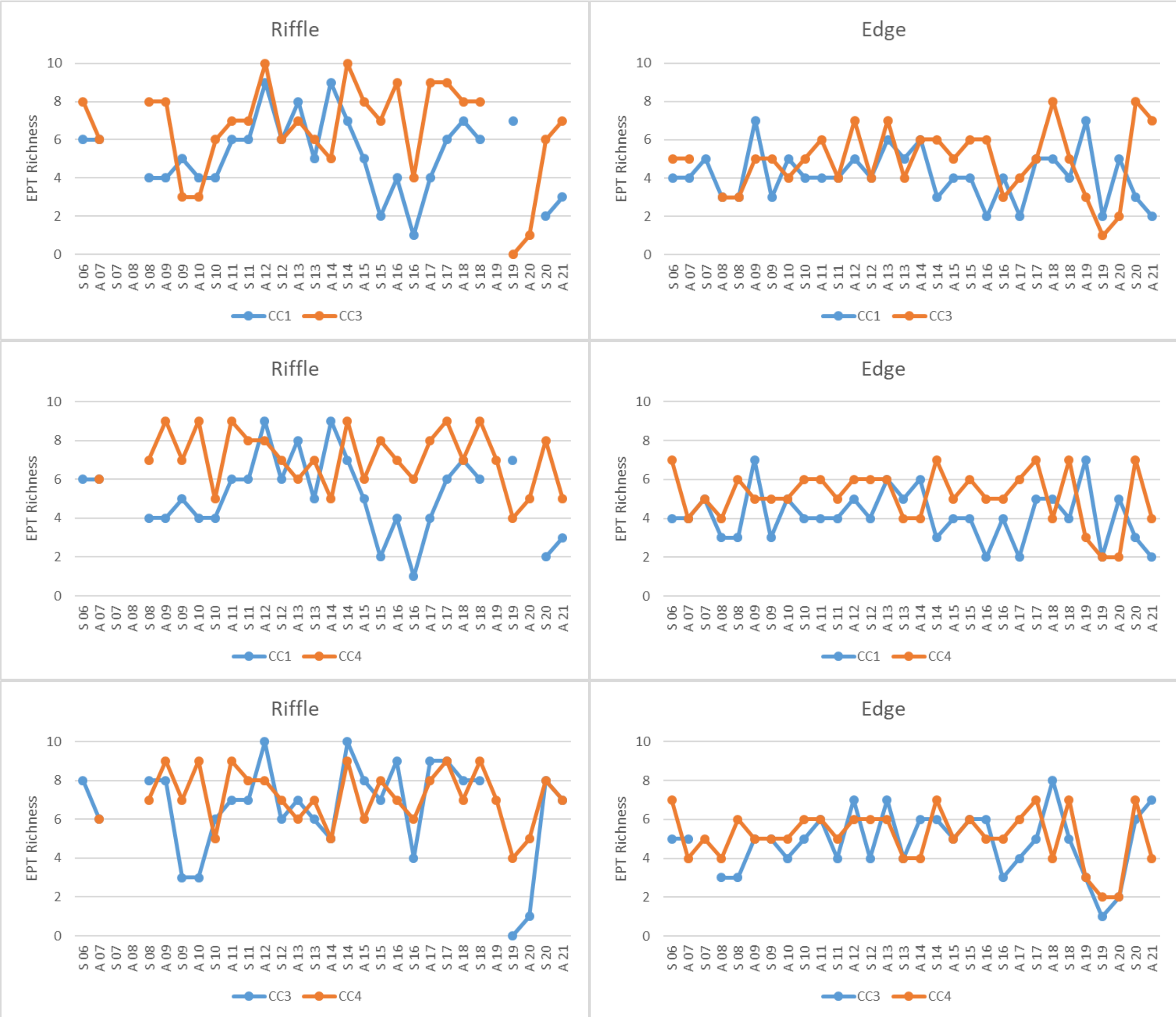
Macroinvertebrate SIGNAL-2 Scores in Flyers Creek (top) and Panuara Rivulet (bottom) between spring 2006 and autumn 2021



Macroinvertebrate SIGNAL-2 Scores in Diggers Creek (top), Swallow Creek (middle) and Rodd's Creek (bottom) between spring 2006 and autumn 2021

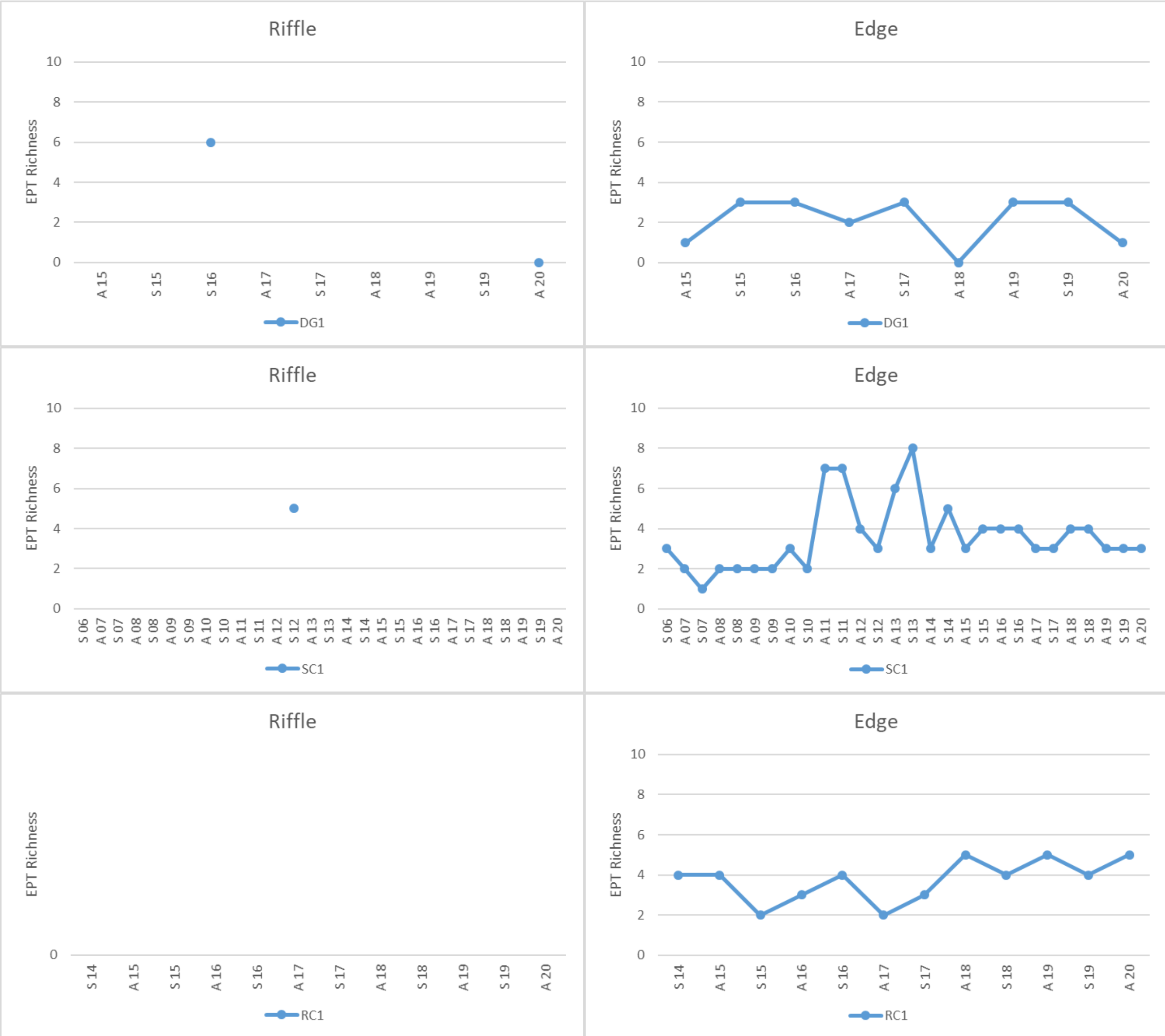


Macroinvertebrate EPT Richness in Cadiangullong Creek between spring 2006 and autumn 2021



Macroinvertebrate EPT Richness in Cadiangullong Creek between spring 2006 and autumn 2021

Macroinvertebrate EPT Richness in Flyers Creek (top) and Panuara Rivulet (bottom) between spring 2006 and autumn 2021



Macroinvertebrate EPT Richness in Diggers Creek (top), Swallow Creek (middle) and Rodd's Creek (bottom) between spring 2006 and autumn 2021 ghd.com

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